Improving research quality on primary cam morphology

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Abstract

Introduction: Primary cam morphology—a cartilage or bony prominence at the head-neck junction of the hip—develops due to high-load sporting activity during maturation. Although prevalent in many athlete populations, this morphology generally occurs without ill-effects; however, some individuals develop femoroacetabular impingement syndrome or hip osteoarthritis. Existing research on primary cam morphology and its natural history is mired in confusion partly because clinicians, athletes, patients, and researchers have not agreed on key primary cam morphology elements or a prioritised research agenda.

Aim and objectives: The overall aim of the programme of research presented in this thesis is to support a transformation of both research and clinical practice related to primary cam morphology and its natural history so that it takes a more pragmatist and patient-centred direction, with specific objectives to: (1) explore the concept of primary cam morphology and its natural history; (2) mobilise and engage a community of athletes, patients, clinicians, and researchers; (3) ensure buy-in and diverse participation to facilitate inclusive co-production partnerships; (4) inform a more rigorous, inclusive, and evidence-based approach to research on primary cam morphology and its natural history by ascertaining the level of agreement among experts on key primary cam morphology elements and a prioritised research agenda; (5) surface and discuss competing perspectives on primary cam morphology and its natural history; (6) explore stakeholders' perspectives on research quality relevant to primary cam morphology and its natural history; and (7) disseminate findings.

Methods: The hybrid mixed methods approach adopted for this programme of research include: (1) a literature review of primary cam morphology using concept analysis method; (2) a consensus exercise (Delphi panel, interacting group process and Essential National Health Research ranking strategy) to ascertain the level of agreement among experts on terminology, taxonomy, definitions, and imaging outcome measures for primary cam morphology and to work collaboratively towards agreement on a set of research priorities on conditions affecting the young person's hip; and (3) a qualitative interview study to explore stakeholders' perspectives on research quality relevant to primary cam morphology and its natural history.

Results: The concept analysis introduced and clarified primary cam morphology. Reported in the Oxford Consensus Study, stakeholders agreed—and surfaced areas of tension and dissent—on: (1) a new conceptual definition for the morphology; (2) more consistent terminology; (3) a taxonomy distinguishing between primary and secondary cam morphology; (4) challenges of operationalising the hip morphology, and (5) a prioritised research agenda for the field. We constructed five action-inviting themes for higher quality research based on stakeholders' perspectives on research quality, which are that research communities in this field should: (1) partner with athletes/patients; (2) collaborate with one another; (3) champion equity, diversity, and inclusion; (4) pursue open science; and (5) nurture young scholars.

Conclusion: The empirical work presented in this thesis could move both research and clinical practice related to primary cam morphology and its natural history in a more pragmatist and patient-centred direction. It serves as a foundation for concrete actions by research communities in the field to pursue high value research and generate less research waste.

Acknowledgements

I thank Professor Mike Clarke, Professor Siôn Glyn-Jones, Dr Jason Oke, Professor Karim Khan, and Professor Trisha Greenhalgh for their academic supervision. They carefully mentored me—especially during challenging Covid-19 times—and I hugely benefitted from their wealth of expertise in different areas relevant to this thesis. These include sports medicine, orthopaedic surgery, research methods and evidence-based medicine, biostatistics, mixed methods research, co-production, dissemination, and academic writing.

I also thank Associate Professor Geoff Wong, my college tutor, for his steadfast support and encouragement throughout this DPhil journey; Professor Greenhalgh for welcoming me to the Interdisciplinary Research In Health Sciences (IRIHS) unit; Nuffield Department of Orthopaedics, Rheumatology, and Musculoskeletal Sciences (NDORMS), specifically Dr Antony Palmer, Ms Sue King, Professor Andy Car, Professor Jonathan Rees, Mr Mat Brock, Ms Jo Silva and other members of the IT and Marketing teams; the Centre for Evidence-based Medicine (CEBM), specifically Ms Ruth Davis and all tutors of the seven MSc in Evidence-Based Health Care modules I completed as part of this DPhil; Kellogg College administrators and fellow students, the Department for Continuing Education, and the Department of Primary Care Health Sciences; Professor Karim Khan for including me in some of the online activities of his meta-research group at the University of British Columbia (UBC) in Vancouver; and Ms Rebecca Stewart and her team at Worcester College.

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Thank you to Aspetar colleagues and friends: all my Medical Education Department team members, Aspetar Sports Medicine Department (specifically Dr Louis Holtzhausen, Dr Juan-Manuel Alonso, Dr Carmen Adamuz, Professor Thor Einar Andersen, and Dr Celeste Geertsema), Aspetar senior management (specifically Professor Nebojsa Popovic, Drs Pieter D'Hooghe, and Abdulaziz Al-Kuwari; also Professor Jan Ekstrand and Dr Scot Gillogly). You have been part of this DPhil journey, many from the very first day! I want to thank Aspetar for their sponsorship as organising partner to the 2022 YAHiR Young Athlete's Hip Symposium and Research Meeting. Thank you to BJSM, in particular Editor-in-Chief Professor Jonathan Drezner, for support and sponsorship of the YAHiR Young Athlete's Hip Symposium and Research Meeting.

Thank you to my parents, Hessel and Annatjie, and father- and mother-in-law, Nardus and Bets (with a combined life experience of 344 years) for all your guidance, love, and support. You have, despite your own very significant Covid-related challenges and traumas, continued to support me and understood when, at times, I became a DPhil-enforced recluse.

Finally, I thank my dear wife, Andrea, for her unwavering love and support—and for paving the way. And my daughters, Elisabet and Anne-Joke for enthusiastically sharing every step of this journey, and for continuing to be amazing and exemplary co-scholars.

Statement of Contributions

This doctoral thesis is independent and original work of which I, Paul Dijkstra, am the sole author. Academic supervisors Professor Mike Clarke (MC), Professor Siôn Glyn-Jones (SGJ), Dr Jason Oke (JO), Professor Trisha Greenhalgh (TG), and Professor Karim Khan (KK) contributed supportive guidance on the overall research strategy, protocol, analyses, publication, and presentation of results.

Here I describe how supervisors and other individuals contributed to the programme of research presented in this thesis:

Chapter 2: I was the lead investigator and first author of a publication in the British Journal of Sports Medicine (BJSM): 'Primary cam morphology; bump, burden or bog-standard? A concept analysis.' This study is my original work. Co-researchers contributed in the following way: Dr Nia Roberts (NR) assisted in developing the systematic review search strategy, search of different databases, and removal of duplicate publications. As described in the methods section of this chapter, Drs Clare Ardern (CLA), Andreas Serner (AS) and Adam Weir (AW) acted as second systematic reviewers, contributing to data extraction and risk-of-bias assessment of (approximately one third each) of the 111 included publications. Dr Andrea Mosler (ABM) arbitrated in unresolved conflicts. Co-researchers CLA, AS, AW, AM and Dr Sean McAuliffe (SMA) contributed to the concept analysis as described in this chapter's methods section (and the statement of contributions in the published paper). Supervisory oversight was provided by MC, SGJ, KK and JO. Figures 2.6, 2.7, 2.8 and 2.12, all published in BJSM, are the work of Ms Vicky Earle.

Chapters 4 and 5: I was the lead investigator and first author of three publications in BJSM:

1. 'Oxford consensus on primary cam morphology and femoroacetabular impingement syndrome: part 1—definitions, terminology, taxonomy and imaging outcomes'

2. ‘Oxford consensus on primary cam morphology and femoroacetabular impingement syndrome: part 2—research priorities on conditions affecting the young person’s hip’
3. ‘Infographic. Oxford consensus on primary cam morphology and femoroacetabular impingement syndrome—natural history of primary cam morphology to inform clinical practice and research priorities on conditions affecting the young person’s hip’

This study is my original work. I proposed the idea of a Delphi consensus study on the topic, planned, and coordinated the study. Supervisors TG, MC, KK, SGJ, and JO provided oversight to this study with other members of the ‘Delphi Study Steering Committee’ led by principal investigator (PI) TG: Dr Sean McAuliffe (SMA), Dr Clare Ardern (CLA), Associate Professor Joanne Kemp (JLK), Dr Andrea Mosler (ABM), Dr Amy Price (AP), Mr Paul Blazey (PB), Dr Andreas Serner (AS). In addition to the steering committee members, five co-researchers and/or Delphi panellists contributed to, and therefore co-authored, the published paper: Dr Dawn Richards (DPR), Dr Abdulaziz Farooq (AF), Dr Eugene McNally (EM), Professor Vasco Mascarenhas (VM), and Professor Richard Willy (RW). I wrote the first draft Delphi statements. Following that, all steering committee members contributed to, revised, and refined the Delphi statements. AP co-led the Patient and Public Involvement Group with me and, with DPR and RW, facilitated an authentic patient’s voice throughout. AF, with oversight by JO, contributed to the statistical analysis of the study. Although EM and VM, both radiologists, contributed to all stages of the Delphi study, their focus was revising the imaging- and research priorities domains. CLA and KK co-chaired with me the online interacting group process while ABM, AP, JLK, SGJ, DPR, SMA, EM, PB, RW, AS and MC acted as group leads for the six multistakeholder groups who met online. I wrote the first and all subsequent drafts of the published manuscripts, including responding to peer reviewers’ comments. All listed authors contributed to reviewing, editing and revising the manuscript, and have read and agreed to the final publication. I convened the *Young Athlete’s Hip Research (YAHiR) Collaborative* listed as ‘collaborators’ in the BJSM publication. They were all Delphi panel members and contributed to the online interacting group process and the Essential National Health Research ranking exercise as described.

Chapter 6: The qualitative study presented in chapter 6 is my original work. As lead investigator, I proposed the idea of a qualitative study to explore stakeholders’ perspectives of research quality, planned and coordinated the study, and conducted all interviews. I coded all interview transcripts (using NVivo® software) and led iterative research team discussions to refine the interview guide, initial coding framework, and final themes. All DPhil supervisors provided oversight to this study but specifically TG as experienced qualitative researcher. Following the University of Oxford Central University Research Ethics Committee (CUREC) policy on DPhil studies, supervisor SGJ acted as lead principal investigator (PI). Dr Sean McAuliffe (SMA) acted as Qatar-based co-PI (complying with Qatar’s Ministry of Public Health PI policy: all PIs must be PhD-graduates). Co-researchers contributed in the following way: SMA assisted in participant recruitment (n=1), observed 14 of 15 online interviews, coded approximately half of the 15 interviews, and contributed to iteratively refining themes and subthemes; Ms Jolanda Boersma, a medical anthropologist with experience in qualitative research (sociology and anthropology), transcribed the audio recordings, independently coded all interview transcripts (using Nvivo®) and contributed to an iterative process to refine final themes and subthemes.

Dissemination: (1) ***Oxford-Aspetar-La Trobe Young Athlete’s Hip Webinar Series*** (November 2020 to September 2021): I chaired the Scientific Planning Committee (SPC) and Organising Committee and developed the Webinar Series programme with oversight from the SPC. Other SPC members were: Professor Siôn Glyn-Jones (Co-Chair), Professor Mike Clarke (Co-Chair), Dr Joanne Kemp (Co-Chair), Professor Karim Khan, Professor Trisha Greenhalgh, Dr Jason Oke, Dr Clare Ardern, Dr Andrea Mosler, Dr Louise Strickland, Dr Sofie Nelis, Ms

Faten Smiley, Ms Sue King, Ms Tiya Muluzi, Mr Matt Brock, Ms Ruth Davis. I organised, recruited faculty, and moderated with Drs Clare Ardern (Journal of Orthopaedic and Sports Physical Therapy Editor-in-Chief) and Joanne Kemp (BJSM Editor) all 11 webinars. (2) ***The Young Athlete's Hip Symposium*** (September 2022): I chaired the Scientific Planning Committee (SPC) developed the scientific programme (with SPC oversight) and organised the hybrid event at Worcester College in Oxford. Other members of the SPC included: Professor Siôn Glyn-Jones (Co-Chair), Dr Joanne Kemp (Co-Chair), Professor Karim Khan (Co-Chair), Dr Clare Ardern (Co-Chair), Professor Mike Clarke, Professor Trisha Greenhalgh, Professor Inger Mechlenburg, Dr Andrea Mosler, Dr Jason Oke, Dr Amy Price and Dr Dawn Richards. Ms Sue King significantly contributed to organising the event. (3) **Oxford Consensus Infographic**, published in BJSM. I designed the infographic. Mr Ivan Stankovic finalised the published version using Photoshop® design software. (4) **Qualitative study Infographic**. I designed the infographic. Ms Jolanda Boersma finalised the published version using Photoshop® design software.

I received group and one-to-one academic writing coaching from Professor Lorelei Lingard, initially as part of a CPD-accredited *Aspetar Academic Writing Workshop and Course* (I chaired the Scientific Planning Committee for these education events), and via individual coaching. I did not submit this thesis to a professional proof-reading/editing company.

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List of Abbreviations

Abbreviation	**Meaning**
3D	Three-dimensional
AA	Alpha Angle
AI	Artificial Intelligence
AP Pelvis	Anterior Posterior pelvis
BJSM	British Journal of Sports Medicine
CEBM	Centre for Evidence-based Medicine
CHARMS	*CHecklist* for critical Appraisal and data extraction for systematic Reviews of prediction Modelling Studies
CISM	International Military Sports Council
COHRED	Council On Health REsearch for Development
COS	Core Outcome Set
CPD	Continuing Professional Development
CT	Computed tomography
CREDES	Conducting and REporting DElphi Studies
DAG	Directed acyclic graphs
DICOM	Digital Imaging and Communications in Medicine
DOHA study	Development of Hip Abnormalities in Athletes
DXA	Dual-Energy X-ray Absorptiometry
EBHC	Evidence-Based Health Care
EBM	Evidence Based Medicine
EDI	Equity, Diversity, and Inclusion
ENHR	Essential National Health Research
FABER	Flexion ABduction External Rotation
FADIR	Flexion ADduction Internal Rotation
FAI	Femoroacetabular impingement
FHR	Femoral Head Ratio
FIMS	International Sports Medicine Federation
FOV	field-of-view
GEE	Generalised Estimating Equations
GOBSAT	Good Old Boys Sat Around a Table
HAGOS	Hip And Groin Outcome Score
ICC	Intraclass Correlation Coefficient
ICD	International Classification of Diseases
iHot	International Hip Outcome Tool
IMHA	Institute for Musculoskeletal Health and Arthritis
INQUIRE	INcreasing QUality In patient-orientated academic clinical REsearch
IHiPRN	International Hip-related Pain Research Network
IPD	Individual participant data

IPR	Interview Protocol Refinement
IQR	InterQuartile Range
IRIHS	Interdisciplinary Research In Health Sciences
JOSPT	Journal of Orthopaedic Sports Physical Therapy
LCEA	Lateral Centre Edge Angle
LGBTQIA2S+	Lesbian, Gay, Bisexual, Transgender, Queer and/or Questioning, Intersex, Asexual, Two-Spirit, and the countless affirmative ways in which people choose to self-identify
LMS	Learning Management System
MDCT	MultiDetector Computed Tomography
MR	Magnetic resonance
MRI	Magnetic resonance imaging
MS IDREC	Medical Sciences Interdivisional Research Ethics Committee, University of Oxford
NDORMS	Nuffield Department of Orthopaedics, Rheumatology, and Musculoskeletal Sciences
OA	Osteoarthritis
OS	Orthopaedic Surgeon
OR	Odds Ratio
PCM	Primary cam morphology
PDFS	Proton Density Fat Saturation
PERSiST	Prisma in Exercise, Rehabilitation, Sport medicine and SporTs science
PI	Principal Investigator
PPI	Patient & public involvement
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PROMs	Patient Reported Outcome Measures
PT	Physical Therapist
UKA	United Kingdom Athletics
QOL	Quality Of Life
QUIPS	Quality in Prognosis Studies
QUAN	Quantitative
QUAL	Qualitative
RCT	Randomized Controlled Trial
REPRISE	REporting guideline for PRIority SEtting of health
REWARD	Reduced Research Waste and Reward Diligence
RoBANS	Risk of Bias tool for Non-randomised Studies
RTS	Return To Sport
SCFE	Slipped Capital Femoral Epiphysis
SCM	Secondary cam morphology
SD	Standard Deviation
SE	Standard Error
SMD	Standardised Mean Difference

SPC	Scientific Planning Committee
UBC	University of British Colombia
UCT	University of Cape Town
UKA	United Kingdom Athletics
WATSf	WATer Selective fluid
YAHiR	Young Athlete's Hip Research

Abbreviation	**Name**
ABM	Andrea Mosler
AF	Abdulaziz Farooq
AP	Amy Price
AS	Andreas Serner
AW	Adam Weir
CLA	Clare Ardern
DPR	Dawn Richards
EM	Eugene McNally
HPD	Hendrik Paulus Dijkstra
JB	Jolanda Boersma
JO	Jason Oke
JLK	Joanne Kemp
KK	Karim Khan
MC	Mike Clarke
NR	Nia Roberts
PB	Paul Blazey
RW	Richard Willy
SGJ	Siôn Glyn-Jones
SMA	Sean McAuliffe
TG	Trisha Greenhalgh
VM	Vasco Mascarenhas

Chapter one

Introduction

Chapter 1: Introduction

1.1 Overview of thesis

The programme of research presented in this thesis explores primary cam morphology and its natural history, including hip disease consequences. Primary cam morphology, or 'cam morphology' before we expanded the morphology's taxonomy to distinguish between primary and secondary cam morphology [1], is prevalent in many athletes. Primary cam morphology is a cartilage or bony prominence that develops at the head-neck junction of the hip in maturing athletes—likely due to high-load sporting activity. Secondary cam morphology is cam morphology due to primary (hip) disease, including Perthes' disease and slipped capital femoral epiphysis (SCFE).

Primary cam morphology lingers in the healthy hips of many athletes but lurks behind debilitating hip osteoarthritis in an unfortunate few. Despite a prevalence of more than 70% in athletes participating in high-load sports like football [2–4], most athletes living with the morphology will never know they have it. In a small proportion of athletes for whom the morphology is not benign, primary cam morphology could cause career-threatening and potentially crippling hip osteoarthritis [5].

The scientific community has accumulated much empirical knowledge on primary cam morphology aetiology and its natural history [6–13] but significant gaps remain. The scientific community does not fully understand the morphology's causal mechanisms and risk factors (aetiology), cannot yet predict who might develop this morphology (prediction), cannot suggest interventions to prevent primary cam morphology from developing (prevention), and cannot confidently predict which athletes will need their hips replaced (prediction/ prognosis). Athletes, patients, clinicians, and researchers will benefit from better understanding of primary cam morphology, including its aetiology and prognosis.

The morphology's aetiology was an important focus of my research when I was beginning to flesh out potential PhD research questions in 2015. I proposed a prospective cohort study to compare how different load exposures in adolescent swimmers and footballers contributed to primary cam morphology. To underpin this cohort study, I performed a systematic review of primary cam morphology risk factors [14], described in chapter 2 as part of a literature review of primary cam morphology. This systematic review had unexpected outcomes.

My systematic review illuminated high risk of bias in the field and exposed at least three major gaps in the knowledge that I was interested in pursuing. The primary cam morphology[1] risk factor research field was distorted by many forms of bias: small sample-, selection-, attrition-, misclassification-, and confounding bias. Existing research on primary cam morphology lacked clarity on conceptual and operational definitions of the morphology, didn't apply a consistent taxonomy of subtypes, and used confusing terminology [1]. There was no agreement on a prioritised research agenda for the field. These gaps compromised the nature and quality of knowledge being 'produced' on primary cam morphology and its natural history. My planned cohort study would have been wasted research. Therefore, in discussion with my supervisors, I modified the focus of my research. Rather than research on risk factors of primary cam morphology, I envisioned a more rigorous, evidence-based, and inclusive approach to research on primary cam morphology and its natural history. I outline the specific goals to achieve that vision here.

1.2 Aim and objectives

In this thesis, I aimed to support a transformation of both research and clinical practice related to primary cam morphology and its natural history so that it takes a more pragmatist and

[1] Although the PROSPERO-registered protocol of my systematic review referred to 'primary cam morphology', most authors used the term 'cam morphology' even though they excluded all 'cam morphology' due to existing or previous hip disease (e.g. Perthes' Disease). Therefore, in Chapter 2, I propose a new taxonomy for 'cam morphology'.

patient-centred direction—early steps towards coproducing knowledge that matters to athletes and patients. Strategic objectives of the programme of mixed methods research were to:

1. explore the concept of primary cam morphology and its natural history, including hip disease;
2. mobilise and engage a community of athletes, patients, clinicians, and researchers;
3. ensure buy-in and diverse participation to facilitate inclusive co-production partnerships;
4. inform a more rigorous, inclusive, and evidence-based approach to research on primary cam morphology and its natural history by:
    a. ascertaining the level of agreement among experts on definitions, terminology, taxonomy, and imaging outcome measures for research on primary cam morphology;
    b. working collaboratively towards agreement and highlighting residual disagreements on a set of research priorities on conditions affecting the young person's hip;
5. surface and discuss competing perspectives on primary cam morphology and its natural history, including hip disease;
6. explore stakeholder (athletes, parents, coaches, patients, clinicians, and researchers) perspectives on research quality relevant to primary cam morphology and its natural history, including hip disease;
7. disseminate findings through education events and otherwise.

Operational objectives were to:

1. perform a **literature review** of primary cam morphology using **concept analysis** method based on the early results of an ongoing **systematic review of risk factors** for primary cam morphology (STUDY 1; CHAPTER 2)
2. describe and discuss the **methodology and methods** for the programme of research (CHAPTER 3)

3. perform an international **consensus study** to inform a more rigorous, inclusive, and evidence-based approach to research on primary cam morphology and its natural history in order to
   - ascertain the level of agreement among experts on **definitions, terminology, taxonomy, and imaging outcome measures for research** on primary cam morphology; (STUDY 2; CHAPTER 4)
   - work towards agreement and highlight residual disagreements on a set of **research priorities** on conditions affecting the young person's hip focussing primarily on primary cam morphology and its natural history; (STUDY 3; CHAPTER 5)
4. develop and deliver the *Oxford-Aspetar-La Trobe Young Athlete's Hip* ***Webinar Series*** and the *Young Athlete's Hip Research (YAHiR) Collaborative* ***Symposium and Research Meeting*** to engage stakeholders, disseminate evidence, and stimulate debate (DISSEMINATION; CHAPTER 5)
5. describe stakeholders' perspectives on factors contributing to high quality research on primary cam morphology and its natural history through a **qualitative interview study** and thematic analysis (STUDY 4; CHAPTER 6)

In sum, the operational objectives were vehicles to realise, or work towards realising, the strategic objectives. This work is not done. Nor were the strategic and operational objectives set in stone at the beginning of my DPhil journey. They constantly evolved. Before discussing the structure of the thesis, I reflect on the influence of my personal history and positionality on the programme of research described in this thesis.

1.3 Personal history and positionality

The different stages of my life and career—the people, circumstances, challenges, opportunities, and strokes of luck—informed the context that led me to pursuing this DPhil, and the seven MSc Evidence-Based Health Care Modules I completed in the early stages of the DPhil.

I was born in the semi-desert Karoo[2] of South Africa on 3 December 1967 while Christiaan Barnard (also from a small rural town in the Karoo) was performing the first heart transplant at Groote Schuur Hospital in Cape Town. My parents had just returned to South Africa after seven years in Europe where my father completed his doctorate in Theology as an Alexander von Humboldt Scholar at Heidelberg University in Germany. I think my father was a pragmatist, not only in the lay sense but also philosophically. He *had no choice* but to live pragmatism (what works or what is useful is true), embracing and valuing the practical knowledge and lived experiences of those he worked with. He was a liberal academic who, at the time, led a Christian congregation in a small very non-academic Karoo town (and later in a conservative farming community two hours' drive from Johannesburg). My mother, a secondary school music teacher, instilled in me a love for classical music and the performing arts.

Academically ambitious, I grew up in Apartheid South Africa and later graduated from 'whites-only' University of Pretoria Medical School in November 1991. It was a time of fast-paced substantial change in the world order. The Berlin wall fell on 9 November 1989 and by October 1990 Germany was reunified. Soon after Solidarity's Lech Walesa was elected President of Poland (in December 1990), the Union of Soviet Socialist Republics dissolved.

South Africa was also experiencing rapid change. Apartheid was crumbling. Many young white South Africans developed a careful curiosity about social justice and change. The communal zeal of the vast majority of South Africans, however, was to vigorously—often violently—challenge and change the status quo.

Change, and a craving for the associated excitement and discomfort, gradually became a way of life for me too. I had a rebellious streak and ruffled a few feathers in 1989 as Editor in Chief

[2] Karoo, from the !Orakobab word !'Aukarob, meaning 'Hard Field' (From *Dreaming the Karoo. A people called the /Xam* by Julia Blackburn, ISBN 9781787332171)

of *Die Perdeby* ('The Wasp'), South Africa's largest university newspaper, when I 'illegally' re-published a banned silhouette of Nelson Mandela on the newspaper's front page. On 11 February 1990, after 27 years in prison, Nelson Mandela walked free. As a result, the 24-year South African Border War ended in March 1990, and enforced military conscription for all white male South Africans was abolished in 1993. I completed my medical internship in Windhoek, Namibia, in 1992. Professor Tim Noakes, who co-founded the Cape Town-based Sports Science Institute of South Africa in 1994, visited Windhoek to lecture on sports injuries—this sparked an interest as my first introduction to the field of sports medicine. I joined the Permanent Force of the South African National Defence Force in January 1993 and got involved in military sports injury clinics in Pretoria (1993) and Potchefstroom (1994-1995). On 10 May 1994 Mr Nelson Mandela became South Africa's first democratically elected president. I was one of six Military Medical Officers on duty at the Union Buildings in Pretoria on that day. These tectonic shifts in South Africa meant that our nation was back in global sporting competitions and very new sports medicine service opportunities arose for my generation.

I was not immune to the euphoria surrounding South Africa's 1995 Rugby World Cup victory and a few months after that I was chosen as team doctor for the South African Armed Forces Team to the 1st CISM[3] Military World Summer Games in September 1995 in Rome [15]. This was my first experience as a team physician, my first visit to Europe (which included an audience with Pope John Paul II), and my first experience of a major global sporting event. Sports medicine hooked me—but I had no training!

As sports medicine was not recognised as an official medical specialty, those of us interested in the field creatively pursued pathways to gain knowledge and skills. Following my 3-year military career, and while practicing as a family physician, I enrolled for a part-time MPhil in

[3] The worldwide International Military Sporting Organisation - https://www.milsport.one/cism/what-is-cism

Sports Medicine at the University of Cape Town (UCT) in 1996 with Professors Tim Noakes, Martin Schewellnus and Wayne Derman as mentors. They were sports medicine pioneers—in South Africa and on the international stage. In 1996, Professor Tim Noakes, leading the Sports Medicine Department at UCT, delivered his ground-breaking Joseph B. Wolffe Memorial Lecture[4]—'Challenging beliefs: *ex Africa semper aliquid novi*' [16]. Looking back over the past 26 years, I see my MPhil at UCT as one of four major actions I have taken in my postgraduate medical career to date to develop academically.

In the early 2000s, I was combining family medicine and general sports medicine in a South African university town, Potchefstroom—the altitude and warm weather training base for many international Olympic athletes. I managed elite and recreational athletes with a variety of sports injuries, including several with hip and groin pain. One of them was a recreational ultramarathon athlete in his early forties who presented in 2003 with hip pain while preparing for his 8th Comrades Marathon.[5] He had end-stage hip osteoarthritis and underwent hip replacement surgery before winning another two Comrades medals to earn a place on the prestigious Comrades Marathon Green Number Roll of Honour. I presented his case at the 2005 World Track and Field Conference in Newcastle, England.

At the time, however, I didn't make the connection between hip morphology, hip pain and osteoarthritis despite the publication of three seminal papers by Professor Reinhold Ganz and his group in Bern, Switzerland: 'Anterior Femoroacetabular Impingement After Periacetabular Osteotomy' [17], coining the term 'femoroacetabular impingement' in 1999; 'Femoroacetabular impingement and the cam-effect' [18] in 2001; and 'Femoroacetabular Impingement. A Cause for Osteoarthritis of the Hip' [19] in December 2003. I, like many other sports physicians in the Global South, had limited access to journal publications and relied on

[4] A prestigious named lecture since 1972 at the annual meeting of the American College of Sports Medicine

[5] The world's largest and oldest ultramarathon race of approximately 89 kilometres run annually between the cities of Durban and Pietermaritzburg in South Africa's KwaZulu-Natal province.

Brukner and Khan's *Clinical Sports Medicine* [20] as my main reference—'femoroacetabular impingement' was not mentioned yet in the 2001 second edition of this popular sports medicine textbook (Figure 1.1). It was not until a few years later, between 2006 and 2008, that 'cam deformity', 'pincer deformity', and 'femoroacetabular impingement' of the hip became familiar terms to me. This is when I revisited the Comrades marathoner's hip radiographs and I realised that his osteoarthritis was likely caused by cam morphology and femoroacetabular impingement syndrome.

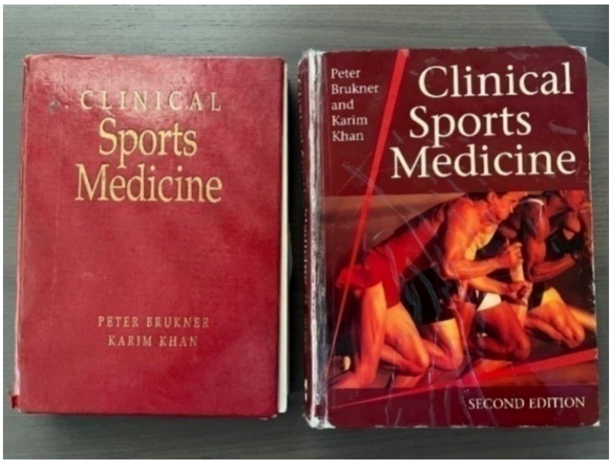

Figure 1.1. My copies of the first and second editions of *Clinical Sports Medicine*.

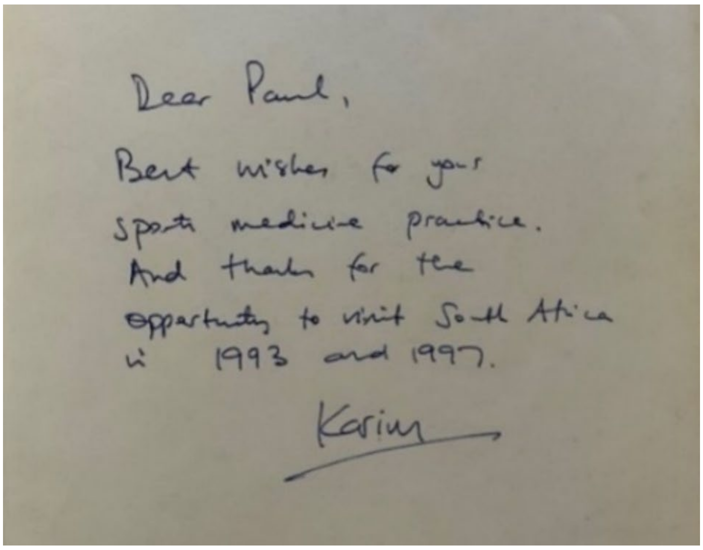

Figure 1.2. A personal message by Professor Khan in my copy of the first print run of *Clinical Sports Medicine*.

The second radical career action for me was in 2006. I was offered and accepted a clinical sports medicine job in London. I managed several elite athletes, mainly sprinters, with hip pain and 'femoroacetabular impingement' in my first fulltime sports medicine role as London Medical Officer for United Kingdom Athletics (UKA) and the English Institute of Sport (and later UKA Chief Medical Officer to the Beijing and London Olympic Games and many World and European Athletics Championships, including the 2010 World Indoor Athletics Championships in Doha, Qatar). This was excellent career timing—a stroke of luck: in 2007, as a London 2012 Olympic Games bid commitment, Sport and Exercise Medicine became the first new medical specialty in the UK for more than 25 years [21]. I successfully applied for direct entry to the General Medical Council (UK) Specialist Register via a Certificate Confirming Eligibility for Specialist Registration [22] in November 2011, twenty years after qualifying as a doctor. At the same time, my wife Andrea, a pharmacist, completed a master's degree in Experimental Therapeutics at Kellogg College in Oxford; she introduced me to Oxford's Centre for Evidence Based Medicine and Professor Mike Clarke.

The third major career action came after the London Olympics when, in February 2013, I accepted a consultant position at Aspetar Orthopaedic and Sports Medicine Hospital in Doha, Qatar. I worked (and became friends) with world leaders in sports medicine, including Professors Karim Khan (Editor-in-Chief of the *British Journal of Sports Medicine*, the 'Khan' of Brukner and Khan, my new neighbour at the time, and ultimately one of my five DPhil supervisors), Roald Bahr and Per Hölmich. Professor Per Hölmich led Aspetar's Groin Pain Centre with sports physician Dr Adam Weir. They organised the *First World Conference on Groin Pain in Athletes* in November 2014 in Doha [23]. A one-day agreement meeting on terminology and definitions in groin pain in athletes followed on 4 November 2014, resulting in the seminal 'Doha Agreement' paper by Adam Weir and Per Hölmich [24]. I was keen to develop as a scholar in Sport and Exercise Medicine. Dr Weir, who shared an office with me at Aspetar, proposed the Development of Hip Abnormalities in Athletes (or 'DOHA' study), focussing on 'cam deformity' and femoroacetabular impingement as a possible research project. I realised that a systematic review on the topic would be essential and that I needed further training. The MSc module on systematic reviews at the University of Oxford's Centre for Evidence Based Medicine (CEBM) was a high-quality option. I completed this module in February 2015 with Professor Mike Clarke as Module Coordinator.

This inspirational course provided the catalyst for my fourth foray into further academic development—the DPhil. Professor Clarke offered to be my primary supervisor for a DPhil in Evidence Based Health Care (EBHC). I was accepted to the programme in June 2015, a week after commencing a new role as Aspetar's Director of Medical Education. I completed six more MSc EBHC modules and describe in chapter 7 how the final module ('Knowledge into Action') had four important consequences[6]. My journey from Apartheid South Africa to London and finally to Doha prepared me for the ultimate scholarly journey of a DPhil at Oxford. I was essentially a *bricoleur* without knowing it.

This thesis aimed to explore and transform a field, and in the process, accelerated by Covid-19-related challenges, changed me from a sports medicine physician and scholar with a predominantly positivist world view to adopting pragmatism with elements of, what Levi-Strauss described as, a *bricoleur* [25–27]. *Bricoleurs* 'examine phenomena not as detached things-in-themselves, but as connected things-in-the-world' [28]. I will explore this concept further in chapter 3.

I broadened my predominantly positivist[7] and monological research horizon, to also embrace research pursuits that appreciate the complexity of the lived world. I began to creatively combine quantitative and qualitative methods. A mixed methods approach to this thesis' programme of research complemented my scholarly and personal transformation. I will reflect

[6] Section 7.1, p231
[7] I describe the theoretical approach to the programme of research presented in this thesis in section 3.2, p71

on my scholarly journey and transformation in the final chapter of this thesis. An extract on positionality from my research diary adds nuance:

> I am a cisgender white male, married with two daughters, and first-generation South-African—my father and his family were post-World War II Dutch refugees. My mother was born in South Africa. Being part of a socio-political system that institutionally delivered racism until the official end of Apartheid in 1994 (the year I turned 27), I attended 'whites-only' schools and universities, and experienced huge privilege. Although living and working in multicultural environments in post-apartheid South-Africa, the UK since 2006, and Qatar since 2013, I've continued to bathe in the privileges of these societies' Whiteness and Eurocentrism, amplified by the power of being a bilingual Afrikaans-English male physician. The Covid-19-fueled social and academic debates, including Black Lives Matter, #MeToo and 'traditional' vs 'contemporary' Evidence-Based Medicine, ignited further transformation—a personal journey from being 'non-racial' and 'non-sexist' to being more sensitive to an 'anti-racist' and 'anti-sexist' agenda; a scholarly journey from aligning with quantitative 'positivism' to aligning with pragmatist-underpinned codesign. Far from arrived, this transformative 'walk' is a lifelong journey and incomparable to Nelson Mandela's *Long Walk to Freedom*.

This illustrates how people, circumstances, challenges, opportunities, and strokes of luck shaped the context for pursuing this DPhil that not only changed me but also the patients involved. I reflect on my DPhil journey of change and growth in the final Chapter of this thesis.

1.4 Structure of thesis

The programme of research presented in this thesis explores primary cam morphology and its natural history, including its hip disease consequences.

Chapter 2 describes a literature review using concept analysis method (informed by a systematic review of primary cam morphology risk factors [14]), and exposes confusion on key elements related to 'cam morphology', contributing to overall high risk of bias and compromised research quality [1]. Small sample bias, selection-, attrition-, misclassification-, and confounding bias contribute to an overall high risk of bias in the field. There is a need to improve the rigour and evidence-base of research on primary cam morphology and its natural history to achieve meaningful progress on the aetiology, prognosis and treatment of the morphology and its potential consequences in athletes. Applying concept analysis method, chapter 2 identifies four key areas for further attention: it (i) proposes a new conceptual definition for the morphology based on five defining attributes; (ii) spotlights inconsistent and troublesome terminology; (iii) introduces taxonomy distinguishing between primary and secondary cam morphology; and (iv) exposes the challenges of operationalising the morphology [1]. I reflect in this chapter's commentary section on my intellectual journey, focussing on how I adopted a broader definition of rigour to 'evidence.'

Chapter 3 introduces the pragmatist-informed co-production methodology and mixed methods underpinning the programme of research following the systematic review. As part of my DPhil growth, I assembled the Young Athlete's Hip Research (YAHiR) Collaborative, an international grouping of multi-profession stakeholders, including athletes and patients, to increase research value and reduce research waste through higher quality research on the aetiology, treatment and prognosis of bony morphologies and conditions affecting the young athlete's hip [1]. 'Yahir' is an Arabic name and means 'they will enlighten' [1,29]. The YAHiR Collaborative aims to 'enlighten' clinical decision-making through higher quality research on primary cam morphology aetiology and prognosis.

Building on chapter 2 and early results of a qualitative study on research quality (chapter 6), chapters 4 and 5 describe a multi-method (but predominantly Delphi method) consensus study with the overarching aim to inform a more rigorous, inclusive, and evidence-based approach to research on primary cam morphology and its natural history with three specific objectives: to

(i) ascertain the level of agreement among experts on definitions, terminology, taxonomy, and imaging outcome measures for research primary cam morphology; (chapter 4)

(ii) work towards agreement and highlight residual disagreements on a set of research priorities on conditions affecting the young person's hip focussing primarily on primary cam morphology and its natural history; (chapter 5) and

(iii) hold two education events to engage stakeholders, disseminate the latest evidence, and stimulate debate (chapter 5)

a. *Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series*, and

b. *Young Athlete's Hip Research Collaborative Symposium*.

The final section of chapter 5 describes how I used the revised Bloom's Taxonomy [30] to develop these two education events [31]. The *Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series* of 11 webinars was a collaborative education event between the University of Oxford's Centre for Evidence-Based Medicine, three University of Oxford's Departments (Continuing Education, Primary Health Care, and Nuffield Department of Orthopaedics, Rheumatology, and Musculoskeletal Science), Aspetar Orthopaedic and Sports Medicine Hospital, and the La Trobe University Centre for Sport and Exercise Medicine. This webinar series, delivered by the YAHiR Collaborative between November 2020 and September 2021, was endorsed by the *British Journal of Sports Medicine* (BJSM) and the *Journal for Orthopaedic Sports Physical Therapy* (JOSPT), and Institute for Musculoskeletal Health and Arthritis (IMHA), part of the *Canadian Institutes of Health Research*. I based evaluation of quality and short-term impact of the Webinar series on Kirkpatrick's Framework [32].

Chapter 6, focusing on improving future research quality, and applying qualitative methods, explores stakeholders' perspectives on factors contributing to high quality research in the field of primary cam morphology and its natural history. To investigate stakeholder perspectives, I purposively recruited a heterogenous sample of participants representing a wide range of expertise and experience including, clinician-researchers, parents of young adolescent athletes (potential future patients with primary cam morphology), sports coaches and adult patients with a history of hip disease related to primary cam morphology. I performed 15 semi-structured individual interviews. The framework for INcreasing QUality In patient-orientated academic clinical REsearch (INQUIRE) [33] informed the interview guide and analysis. This method inductively draws descriptive and/or explanatory conclusions specific to primary cam morphology research quality, clustered around broad research quality themes based on the INQUIRE framework.

Chapter 7 summarises the key findings and methodological contribution of the programme of research presented in this thesis. I address the strengths and limitations of this research programme and reflect on the impact of the Covid-19 pandemic. Finally, I describe my personal growth before ending with the implications of this research and my future plans—post-doctoral work to cement the aim of the YAHiR Collaborative to enlighten clinical decision making through higher quality research in the field.

In sum, the empirical work presented in this thesis aimed to support transformation of both research and clinical practice on primary cam morphology and its natural history so that it takes a more pragmatist and patient-centred direction. Primary cam morphology is a distinct and important hip morphology that is not only observed, measured, and quantified, but also owned, experienced, and perceived in a unique way. This duality informs a new approach to primary cam morphology and its natural history—co-producing, with athletes, patients, clinicians and researchers, knowledge that matters.

Chapter two

Primary cam morphology: bump, burden or bog-standard? A literature review using concept analysis method

Key publications and conference presentations relevant to this chapter

Publication
Dijkstra HP, Ardern CL, Serner A, *et al.* Primary cam morphology; bump, burden or bog-standard? A concept analysis. *Br J Sports Med* 2021;**55**:1212–21. doi:10.1136/bjsports-2020-103308 [1]. My role in study and publication: I (HPD) was the lead investigator and first author. Co-researchers contributed in various ways: Dr Nia Roberts assisted in developing the systematic review search strategy, search of different databases, and removal of duplicate articles. Drs Clare Ardern (CLA), Andreas Serner (AS) and Adam Weir (AW) acted as second systematic reviewers, contributing to the data extraction and risk-of-bias assessment of (approximately one third each) of the 111 included articles as described in the methods section of this chapter. Dr Andrea Mosler (AM) arbitrated in unresolved conflicts. Co-researchers CLA, AS, AW, AM and Dr Sean McAuliffe (SMA) contributed to the concept analysis as described in this chapter's methods section (and the statement of contributions in the published paper). Supervisory oversight was provided by Professors Mike Clarke, Siôn Glyn-Jones, and Karim Khan, and Dr Jason Oke. Relevance to this chapter: Significant sections from the BJSM publication are reproduced in this chapter. As lead investigator, I planned, managed, and delivered the study. Co-researchers contributed to the systematic review and concept analysis as declared. I wrote the draft paper. All co-authors, including my DPhil supervisors, provided feedback, suggested edits, and signed-off on the final version submitted to and published in BJSM. Sections of this chapter are updated since publication in 2021 and expand accordingly.
Conference presentations
I presented sections of this chapter (1) at the Swiss Sports Medicine Conference in November 2018[8] and (2) at the La Trobe Sport and Exercise Medicine Research Centre's Hip and groin pain symposium[9] in June 2022 (the agenda is included as supplementary material); (3) as part of Webinar 1 of the *Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series* in November 2021, described in more detail in chapter 5; (4) as Symposium 44, International Olympic Committee's World Conference on Prevention of Injury and Illness in Sport in November 2021. I developed and co-chaired (and presented a paper) 'Preventing primary cam morphology and femoroacetabular impingement syndrome in the young athlete: Is the 'hop' really the hip's demise?' (See section 7.1, p231, and supplemental file G.1)

[8] https://www.youtube.com/playlist?list=PLEyFKL_-aBmwfMC6F9VUQG8w2cTA6O6lL&app=desktop
[9] http://semrc.blogs.latrobe.edu.au/events/hip-groin-symposium/

Chapter 2: Primary cam morphology: bump, burden or bog-standard? A literature review using concept analysis method

Significant sections of this chapter have been published in British Journal of Sport Medicine:

Dijkstra HP, Ardern CL, Serner A, *et al.* Primary cam morphology; bump, burden or bog-standard? A concept analysis. *Br J Sports Med* 2021;**55**:1212–21. doi:10.1136/bjsports-2020-103308 [1].

2.1 Introduction

Femoroacetabular impingement (FAI) syndrome and hip osteoarthritis (OA) are common causes of hip-related pain and strongly associated with cam morphology of the hip [12,34–37]. Secondary cam morphology, due to pre-existing hip disease or acute trauma including Perthes' disease, slipped capital femoral epiphysis, healed proximal femoral fractures or acute fractures, is well-described [35,37]. Cam morphology not associated with a primary disease is a challenging concept for clinicians, scientists, and patients. I propose that this morphology, which likely develops during skeletal maturation as a physiological response to skeletal loading patterns at the hip, should be referred to as *primary* cam morphology [1].

A primary medical condition is one that arises spontaneously and is not associated with, or caused by a previous disease, injury, or an acute event [38]. For example, primary osteoporosis, bone loss due to aging or the loss of sex steroids at menopause, differs from secondary osteoporosis which is due to conditions such as thyroid hormone imbalance or renal disease [39,40]. Thus, primary cam morphology is cam morphology that is not caused by previous disease, injury, or an acute event.

The programme of research presented in this thesis explores primary cam morphology and its natural history. Primary cam morphology matters; the community of sports medicine clinicians, researchers and patients interested in hip-related pain needs to clearly delineate what they mean when using terms such as ‘cam morphology’, ‘cam lesions’, ‘cam-type impingement’ or ‘cam deformity’ [3,41,42]. Clarifying the taxonomy, terminology, and definition of primary cam morphology are key steps to assist the community to distinguish between a normal variant (‘bog-standard’) and a pathology (‘burden’) in athletes with primary cam morphology.

2.2 Aim and objectives

The aim of this study is to introduce and clarify the concept of *primary cam morphology* using Walker and Avant’s formal concept analysis method and a systematic review of risk factors dataset. The objectives are to:

- describe the taxonomy and classification of primary cam morphology
- synthesise how terminology is currently being used
- list the defining attributes of primary cam morphology and how they are being operationalised (their ‘empirical referents’)
- identify the antecedents and consequences of primary cam morphology, and
- propose a conceptual and operational definition for primary cam morphology.

2.3 Methods

This study applies Walker and Avant’s concept analysis method to critically review primary cam morphology and its natural history, including hip-disease consequences. To add rigour, I used the dataset from a systematic review of risk factors for the concept analysis.

2.3.1 Concept analysis

Walker and Avant’s concept analysis method is a rigorous 8-step process to examine the basic elements of a concept [43]. The results are precise conceptual and operational definitions, and clear communication as a basis for research and clinical practice [43]. Concept analysis has been used in other healthcare disciplines, especially nursing, to clarify the characteristics and attributes of abstract concepts such as chronic fatigue [43–46].

A scoping review of concept analyses identified 43 distinct concept analysis methods—Walker and Avant's method (adapted from Wilson) was the most popular one [47]. Other concept analysis methods used included Evolutionary Method, Principle-based Method, Hybrid Method, Concept Clarification, and Dimensional Analysis [47].

Concept analysis has not been previously applied in the field of sports and exercise medicine and may establish a foundation for higher quality research and clinical decision making [43]. The concept analysis method is an intellectual exercise and a strategy to construct theory; it is not a mere summary of the concept. Walker and Avant (2019; p167) stressed the importance of 'describing phenomena in measurable or at least communicable ways' to demonstrate the evidence base for our practice [43].

> Concept analysis allows the theorist, researcher, or clinician to come to grips with the various possibilities within the concept of interest—to 'get inside' the concept and see how it works. It is a challenging activity but provides an enormous insight into the phenomenon of interest. ([43] p167)

I argue that the concept analysis method is rigorous—especially when underpinned by a systematic review dataset—and appropriate for a primary cam morphology literature review. Concept analysis guides a discipline and links research, theory, and practice by providing clear conceptual foundations. Without these foundations, research quality and theory construction of any discipline is weakened, and its maturity compromised [43,48].

I applied Walker and Avant's 8-step concept analysis process to the concept of primary cam morphology (Figure 2.1.).

Step 1: Select a concept

Consensus statements from experts on hip-related pain, the 'Warwick consensus statement on FAI syndrome' [36] and the 'International Hip-related Pain Research Network (IHiPRN) consensus', reported in four publications [49–52], recommended further research on cam morphology. I contributed to these consensus statements as co-author (Warwick Consensus and three IHiPRN statements) and senior author ('Zurich IHiPRN consensus on the classification, definition, and diagnostic criteria on hip-related pain in young and middle-aged active adults') [49]. Soon after the Zurich consensus, I established the **Y**oung **A**thlete's **Hi**p **R**esearch (YAHiR) Collaborative as part of my DPhil research. YAHiR is an international grouping of multi-profession stakeholders aiming to increase value and reduce waste through higher quality research on the aetiology, treatment and prognosis of conditions that affect the young person's hip, including bony morphologies.

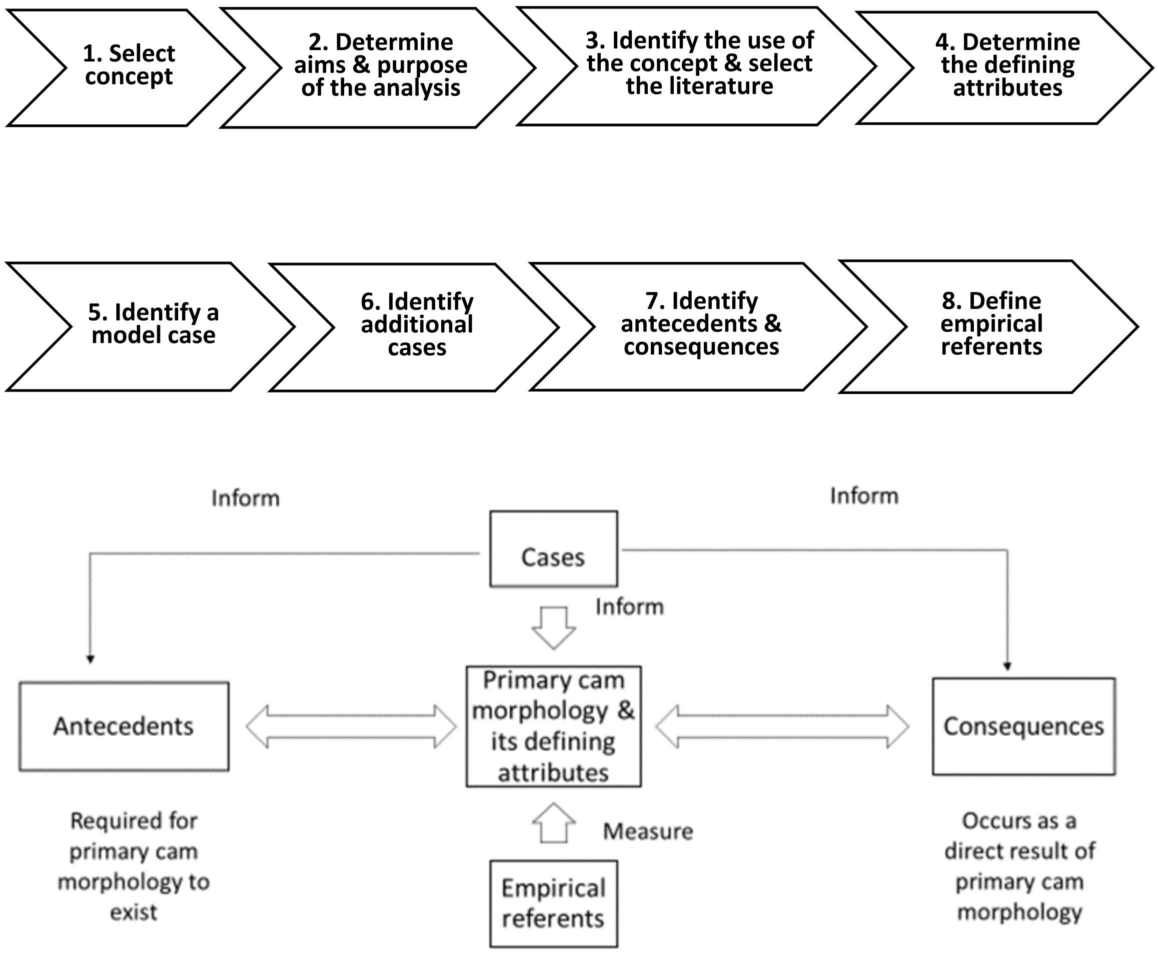

Figure 2.1. Primary cam morphology: a concept analysis process following Walker and Avant's 8-step method (adapted from Walker and Avant) [43]

As described in chapter 1, 'Yahir' is an Arabic name and means 'they will enlighten'; the YAHiR Collaborative aims to 'enlighten' better clinical decisions for patients through higher quality research. The systematic review and concept analysis co-researchers (and authors of the concept analysis manuscript) are all members of the YAHiR Collaborative.

Primary cam morphology is a distinct but often confusing concept. It is important—for clinical practice, education, and research—to distinguish between primary and secondary cam morphology because, although they are related concepts, they have distinctly different aetiology and clinical management. Primary cam morphology likely develops during maturation as a physiological response to specific, but, to date, unclear physical loading patterns. This morphology is therefore important for many athletes. Clarity on primary cam morphology terminology, taxonomy, and definitions are key for long-term research on its aetiology, clinical management, and prognosis.

Step 2: Determine the aims and purpose of the analysis

Members of the YAHiR Collaborative agreed that primary cam morphology, as a distinct and important concept, needed further clarity to underpin more rigorous and evidence-based research on the morphology and its natural history. The aim of this study was, therefore, to perform an in-depth concept analysis of the concept of primary cam morphology. We describe its taxonomy, synthesise how terminology is currently being used, list the defining attributes, identify its antecedents and consequences, and propose a conceptual and operational definition for primary cam morphology.

An 'enlightened' community of clinicians, researchers, athletes, and patients are empowered to manage challenging situations better. Such a challenging situation, for example, could arise when discussing the morphology and its natural history with an athlete who trains and competes with a healthy hip. Clear, consistent, and non-threatening language will invite the athlete-patient to co-manage the risk of future hip conditions related to the morphology, including hip-related pain, femoroacetabular impingement syndrome and osteoarthritis of the hip.

Step 3: Identify all the uses of the concept and select the literature

The concept of cam morphology is normally used in the context of bony morphologies of the hip, FAI, and FAI syndrome, and osteoarthritis of the hip. Any risk factor study (aetiological or prognostic) relies on clear conceptual and operational definitions for the specific condition/ disease to avoid, amongst other biases, measurement, and misclassification bias. The scope of this study was to introduce and understand *primary* cam morphology—cam morphology that develops spontaneously, likely as a normal physiological response to load—in the context of its risk factors.

For a concept analysis of rapid implementation, the authors combined concept analysis with a systematic integrative review [53]. The resulted triangulation of methods made their concept analysis process more rigorous and enlightened research challenges from multiple perspectives [53]. My approach to this primary cam morphology concept analysis study was similar.

Publications (n=111) identified for an ongoing systematic review of risk factors for primary cam morphology served as the dataset foundation of this concept analysis (Table 2.2). Investigator triangulation was an additional strength—the concept analysis and systematic review research team brought extensive hip-related knowledge and experience to the table [54], p35. The systematic review methods were published in BJSM as Data supplement 3[10] of the concept analysis paper [1], including: study eligibility criteria, search strategy, study selection, data extraction (domains adapted from the CHARMS[11] Checklist [55]), quality and risk of bias assessment (combining the Quality in Prognosis Studies (QUIPS) tool [56,57], and Risk of Bias tool for Non-randomised Studies (RoBANS) [58]), and data synthesis and analysis. The systematic review was reported in accordance with the Preferred Reporting Items for

[10] Data supplement 3: https://bjsm.bmj.com/content/55/21/1212.info
[11] CHecklist for critical Appraisal and data extraction for systematic Reviews of prediction Modelling Studies

Systematic Reviews and Meta-Analyses (PRISMA) guidelines [59] and registered a priori with the International Prospective Register of Systematic Reviews (CRD42016033635) [14].

Step 4: Determine the defining attributes

Primary cam morphology conceptual definitions (how authors conceptually defined cam morphology) and operational definitions (how the different attributes were measured) were extracted from the publications included in the systematic review. We then took a systematic and purposeful approach to discover the defining conceptual and operational attributes, antecedents, and consequences. We did this by: (1) reading the included articles (HPD read all the included articles and three co-authors (CLA, AS, AW) each read one third of them); (2) identifying and extracting the different conceptual and operational characteristics of primary cam morphology. (HPD developed the initial conceptual and operational framework, antecedents and consequences, and refined this with the co-authors CLA, AS, AW, AM, SMA and SGJ through iterative discussions); (3) placing the frequently occurring characteristics into a coding scheme (using Atlas.ti® software); (4) grouping the characteristics and classifying them into categories and subcategories; (5) discussing the categories and subcategories, and underlying characteristics in the author team and with other experts; (6) renaming the categories as attributes; (7) randomly assigning two papers to co-researchers (AS, SMA, and AM) for coding using the attribute framework and Excel®; and (8) further refining the attribute framework after co-author coding and feedback. I present examples from included studies to explain each attribute as part of the results.

Step 5: Identify a model case

Based on real-life experiences working with patients with primary cam morphology and/or FAI syndrome, I crafted, in discussion with the co-researchers AS, SMA, and AM, a model case. We refined and developed this case as a narrative to illustrate conceptual and operational definitions for primary cam morphology.

Step 6: Identify additional cases

I wrote, and iteratively refined with co-researchers, corresponding narratives for additional borderline and contrary cases to further illustrate the concept of primary cam morphology. Additional cases describe borderline cases, related cases, contrary cases, and invented cases, refined by the research team through an iterative process of feedback and discussion. This is an important step as it may be difficult to determine the defining attributes that most closely represent primary cam morphology. Additional cases therefore helped us to refine the best fit defining attributes [43].

Step 7: Identify antecedents and consequences

Antecedents and consequences illuminate a concept's context. According to Walker and Avant (2019), a defining attribute can neither be an antecedent nor a consequence. Antecedents—or risk factors in the context of primary cam morphology—are 'events' that must arise or be in place prior to a concept's occurrence. For instance, if a tibial stress fracture is the concept under investigation, an antecedent could be prior high-volume training on a hard surface. Consequences are 'events' or 'incidents' that can arise as a result of the concept, and are therefore relevant to prognosis of a morphology or disease. Chronic non-union might be a consequence of an anterior cortical tibial stress fracture. Primary cam morphology antecedents and consequences—enlightening the defining attributes—were extracted from risk factor publications, and iteratively refined by the research team. The final list of antecedents and consequences are described in the results section of this chapter.

Step 8: Define empirical referents

Empirical referents are 'the means by which the defining characteristics or attributes of a concept are recognised or measured' [43]. In what follows, I describe how various authors observed and measured the different conceptual attributes for primary cam morphology, which could relate to patient history, clinical examination and/or imaging findings.

2.4 Results

The results are presented according to Walker and Avant's eight steps (Figure 2.1) [43]. Steps 1 and 2 (selecting the concept and determining the aims and purpose of the analysis) were discussed in the methods section. Here I discuss the results from step 3 (the literature used for the concept analysis, including types of studies and risk of bias assessment), step 4 (attributes), steps 5 and 6 (model and additional cases), and step 7 (antecedents and consequences). I combine step 4 and 8, empirical referents, describing how each attribute is recognised or measured (operationalised).

2.4.1 Step 3: Identify all the uses of the concept and select the literature

Primary cam morphology is a distinct and important concept for clinical practice and research, mostly in the context of sport, femoroacetabular impingement (FAI) syndrome and hip osteoarthritis. For the systematic review, the database search identified 3656 unique publications for screening after applying a causation search filter and removing duplicates and animal studies (Figure 2.2). Of 266 full-text publications screened, 111 met the risk factor systematic review eligibility criteria.

Two systematic reviewers (HPD and CLA) read all full text publications, excluded 155 and agreed to include 111 eligible for evaluation (Figure 2.2). Four publications reported prospective cohort studies, 60 reported cross-sectional studies (including 23 cross-sectional comparative), and 46 reported case-control studies. The PRISMA flow diagram (Figure 2.2) summarise the publication selection process. I included all 111 publications in this concept analysis. However, for the Discussion section for this chapter, I cast the net wider. Important consensus statements, systematic reviews, case studies, and animal and cadaver studies informed this chapter and DPhil thesis. In the discussion section of this chapter, I reflect on the exclusion of such papers from the risk factor systematic review and how important animal model publications, investigating the aetiology of bony morphologies, for example, could be missed when only relying on a systematic review method for reviewing the literature.

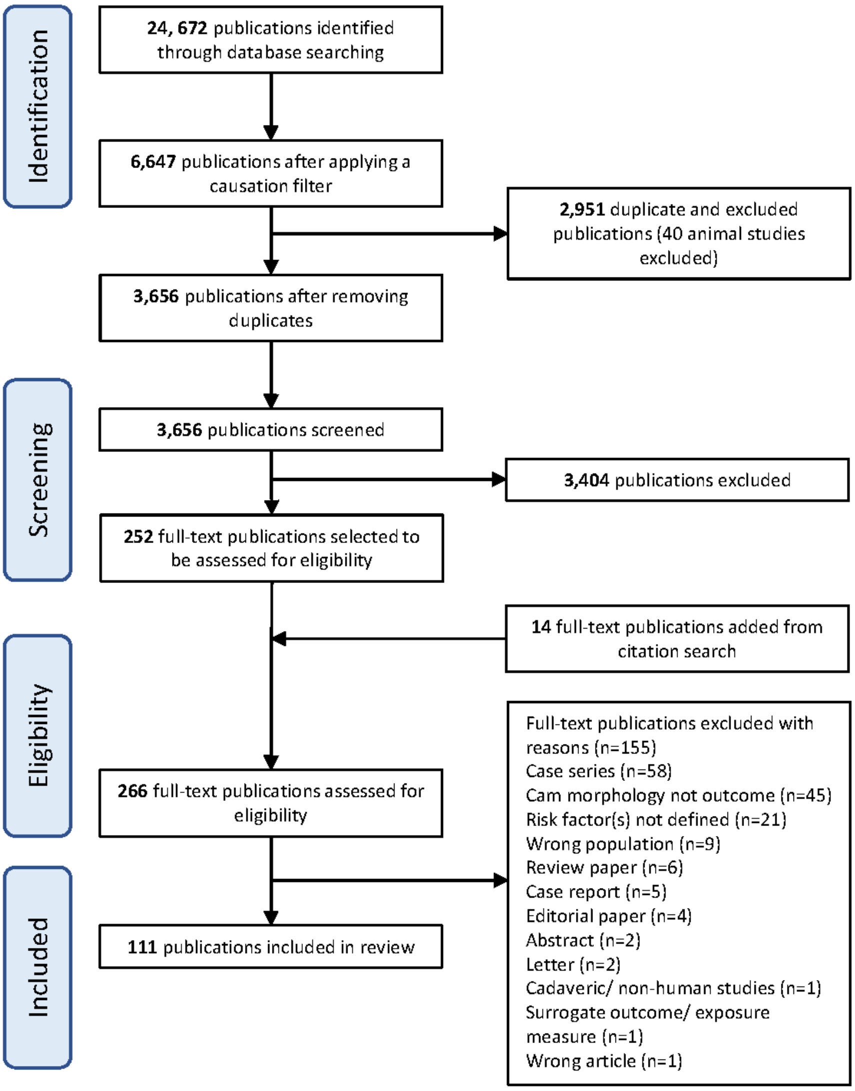

Figure 2.2. PRISMA* flow diagram of publication selection process (21st May 2018).

***Preferred Reporting Items for Systematic Reviews and Meta-Analyses**

Risk of bias assessment

The systematic review research team used a combination of QUIPS and RoBANS tools to assess risk of bias of the 111 publications included in the systematic review. The majority of publications (*n*=84) were rated as high risk of bias in three or more of the six domains (Table 2.1 and 2.2; Figure 2.4).

- Domain 1: Selection bias. The risk of selection bias was high in 82 of 111 publications. Authors, for example, did not adequately describe the population of interest resulting in sampling bias. Most studies did not use random selection or consecutive inclusion. Participants were often not representative of a normal or at-risk population and small samples were used (leading to small sample bias).

Table 2.1. Risk of bias of included publications

Domain	Risk of bias (number of publications)		
	High	Unclear	Low
1. Selection bias	82	24	5
2. Confounding bias	85	24	2
3. Measurement bias (exposure)	47	32	32
4. Measurement bias (outcome)	65	28	18
5. Attrition bias	53	56	2
6. Bias in statistical analysis and reporting	92	17	2

- Domain 2: Confounding bias. The risk of confounding bias was high in 85 of 111 publications because all the confounders were not clearly defined, measured (e.g. measurement not valid or reliable), or accounted for in design or analysis.
- Domain 3: Measurement bias (exposure). The risk of measurement bias (exposure) was high in 47 of 111 publications. Authors, for example, did not describe a clear risk factor definition and/or measurement, and the setting of risk factor measurement was not the same for all study populations.
- Domain 4: Measurement bias (outcome). The risk of measurement (or detection bias) was high in 65 of 111 publications. Reasons include: no clear outcome definition; methods to measure outcomes were not adequately valid or reliable to limit misclassification bias (Figure 2.3). Studies rated as high risk of bias in domain 4 used a range of arbitrary cut-off values to dichotomise continuous outcome variables (mostly alpha angles), used an outcome measurement not adequately valid or reliable to limit misclassification bias, or

failed to use similar methods and settings of outcome measurements for all study participants.

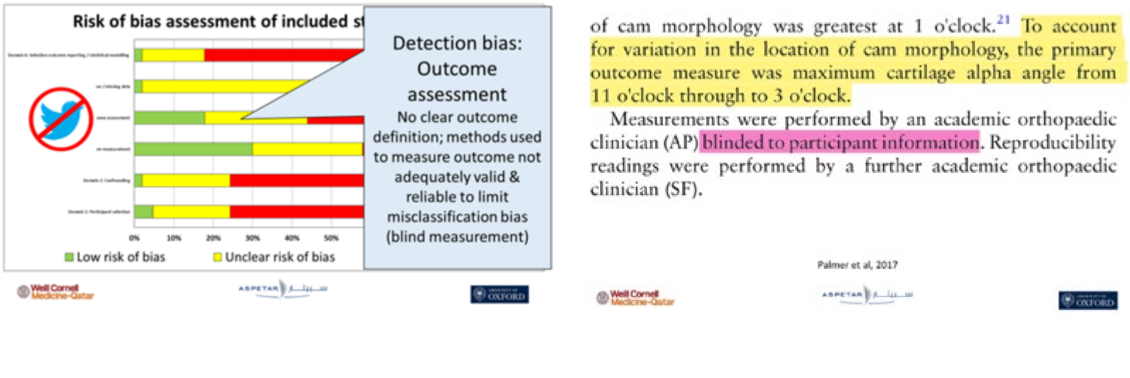

Figure 2.3. Slides from my presentation at the Swiss Sports Medicine Conference in 2018 explaining high risk measurement bias (outcome) contributing to detection bias (A) and an example of a study with low risk of bias in this domain (B) [60].

- Domain 5: Attrition bias. The risk of attrition bias was high in 54 of 111 publications. Attrition seems to be a problem in elite athlete cohort studies [13].
- Domain 6: Bias in statistical analysis and reporting. The risk of bias in this domain was high in 92 of 111 publications. Most of the publications in this systematic review are based on studies with no available a priori or registered protocol pre-defining primary/secondary outcomes and statistical analysis. Reasons include insufficient presentation of data to assess adequacy of analysis, selective reporting of results, an invalid statistical model, or an inadequate strategy for model building.

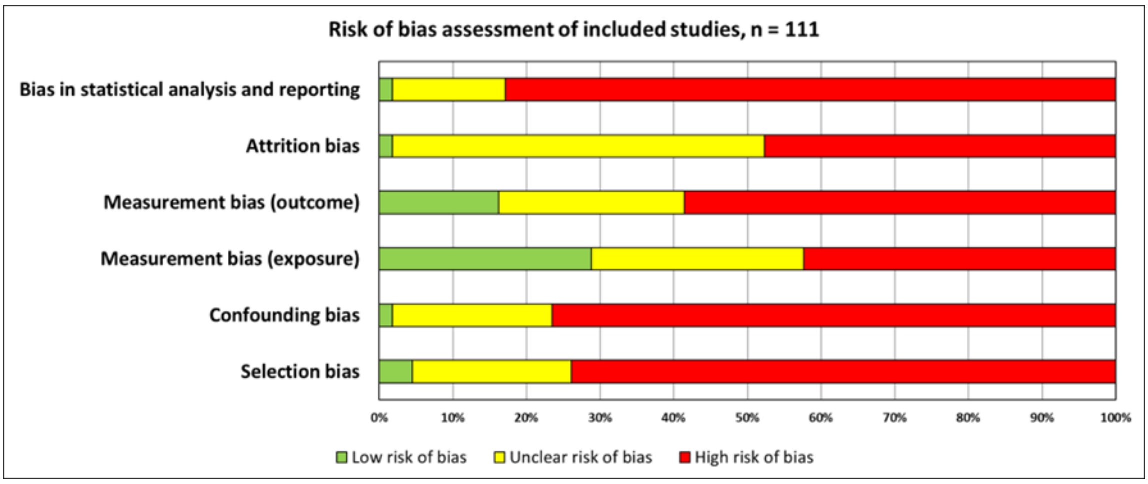

Figure 2.4. Risk of bias of included publications (*n*=111)

Table 2.2. Summary of risk of bias assessment (adapted from RoBANS and QUIPS)

Study	Selection bias	Confounding bias	Measurement bias (exposure)	Measurement bias (outcome)	Attrition bias	Bias in statistical analysis & reporting
Agnvall 2017 [61]	high	high	low	low	unclear	unclear
Agricola 2012 [62]	unclear	high	unclear	unclear	unclear	high
Agricola 2014 [13]	high	high	high	high	high	unclear
Ahn 2016 [63]	unclear	high	unclear	high	high	high
Anderson 2016 [64]	high	high	high	high	unclear	high
Anwander 2015 [65]	high	high	unclear	high	high	high
Anwander 2017 [66]	high	high	unclear	high	high	high
Audenaert 2012 [67]	high	high	unclear	unclear	low	low
Ayeni 2014 [68]	high	high	high	unclear	high	high
Azevedo 2016 [69]	high	high	low	high	unclear	high
Bagherifard 2018 [70]	high	high	high	high	unclear	high
Bagwell 2016 [71]	unclear	unclear	high	high	high	high
Barrientos 2016 [72]	High	High	High	High	High	High
Beaule 2005 [73]	High	high	low	unclear	high	high
Bittersohl 2009 [74]	high	high	unclear	unclear	unclear	high
Carsen 2014 [75]	high	high	high	low	unclear	high
Charbonnier 2010 [76]	high	high	high	low	high	high
Cobb 2010 [77]	high	high	low	high	high	high
Cooke 2013 [78]	high	high	high	high	high	high
Cooper 2017 [79]	high	high	high	high	high	high
de Boer 2013 [80]	high	high	unclear	high	unclear	high
Diamond 2015 [81]	high	unclear	low	high	high	high
Diamond 2016 [82]	high	unclear	low	high	unclear	high
Diamond 2017 [83]	high	high	unclear	high	unclear	high
Diamond 2017 [84]	high	unclear	high	high	high	high
Diamond 2018 [85]	high	unclear	high	high	high	high
Dickenson 2016 [86]	high	high	unclear	high	unclear	high
Diesel 2015 [87]	high	unclear	low	unclear	unclear	unclear
Dudda 2011 [88]	high	unclear	unclear	high	unclear	unclear
Duthon 2013 [89]	high	high	high	low	unclear	high
Ehrmann 2015 [90]	high	high	unclear	high	unclear	high
Espie 2016 [91]	unclear	high	high	high	high	high
Farkas 2016 [92]	high	high	low	high	high	high
Farrell 2016 [93]	high	unclear	unclear	unclear	unclear	high
Ferro 2015 [94]	high	high	low	high	unclear	high
Fukushima 2016 [95]	high	high	high	high	high	high
Gerhardt 2012 [96]	unclear	high	unclear	unclear	unclear	high
Golfam 2017 [97]	unclear	unclear	high	low	unclear	high
Gosvig 2008 [98]	unclear	high	unclear	high	unclear	unclear
Gosvig 2010 [99]	low	high	low	high	unclear	unclear
Grammatopoulos 2018 [100]	high	high	low	low	unclear	high
Guo 2017 [101]	high	unclear	low	high	high	high
Hack 2010 [102]	high	high	high	high	unclear	high
Harris 2016 [103]	high	high	high	high	high	high
Ito 2001 [18]	high	high	low	unclear	high	high
Johnson 2012 [104]	high	high	high	unclear	high	high
Kapron 2011 [105]	unclear	unclear	high	unclear	unclear	unclear
Kapron 2012 [106]	high	high	unclear	high	unclear	high
Kapron 2015 [107]	high	unclear	unclear	unclear	unclear	unclear
Kennedy 2009 [108]	high	unclear	low	high	high	high
Kienle 2012 [109]	high	high	low	low	high	high
Kohno 2016 [110]	high	high	low	low	high	high
Kolo 2013 [111]	high	high	high	low	high	high
Kopec 2017 [112]	unclear	high	high	high	high	high
Laborie 2011 [113]	unclear	high	low	high	high	high
Laborie 2014 [114]	unclear	high	low	unclear	unclear	unclear

Lahner (1) 2014 [115]	high	high	high	high	high	high
Lahner (2) 2014 [116]	high	unclear	high	low	unclear	unclear
Lahner (3) 2014 [117]	high	low	high	high	unclear	high
Larson 2017 [118]	unclear	unclear	unclear	unclear	unclear	high
Lerebours 2016 [119]	unclear	high	high	high	high	high
Leunig 2013 [120]	high	unclear	unclear	unclear	high	unclear
Mantovani 2016 [121]	high	high	high	unclear	unclear	high
Masjedi 2013 [122]	high	high	unclear	high	high	high
Mayer 2016 [123]	high	high	high	unclear	unclear	high
Mayes 2017 [124]	high	high	high	low	unclear	high
Miguel 2012 [125]	high	high	high	high	unclear	high
Mosler 2016 [126]	low	high	unclear	unclear	high	high
Mosler (1) 2018 [127]	low	high	low	high	high	high
Murray 1971 [128]	high	high	high	high	unclear	high
Muthuri 2017 [129]	high	high	unclear	high	unclear	high
Nelson 2016 [130]	high	high	unclear	high	high	high
Ng 2015 [131]	high	high	low	low	unclear	high
Ng 2018 [132]	high	high	high	low	unclear	high
Nicholls 2011 [133]	high	high	high	high	high	high
Notzli 2002 [134]	high	high	high	high	unclear	high
Palmer 2017 [135]	unclear	high	low	unclear	unclear	high
Palmer 2017 [136]	unclear	high	unclear	high	high	high
Palmer 2018 [60]	unclear	low	unclear	low	low	low
Philippon 2013 [137]	high	high	high	high	high	high
Phillips 2016 [138]	high	high	high	high	high	high
Pollard 2010 [139]	high	high	low	high	high	high
Pollard 2010 [140]	unclear	high	low	high	high	unclear
Pollard 2010 [141]	unclear	high	high	unclear	high	high
Pollard 2013 [142]	unclear	unclear	unclear	unclear	unclear	unclear
Raveendran 2018 [143]	low	unclear	low	high	unclear	high
Register 2012 [144]	high	high	high	high	high	high
Reichenbach 2010 [145]	low	high	low	unclear	unclear	unclear
Reichenbach 2011 [146]	unclear	high	low	unclear	unclear	high
Schaeffeler 2012 [147]	high	high	low	unclear	high	high
Scheidt 2014 [148]	high	high	unclear	high	high	high
Siebenrock 2004 [149]	high	high	unclear	high	high	high
Siebenrock 2011 [150]	high	unclear	high	unclear	unclear	unclear
Siebenrock (1) 2013 [151]	unclear	high	high	unclear	unclear	high
Siebenrock (2) 2013 [152]	high	high	unclear	unclear	unclear	high
Silvis 2011 [153]	high	high	high	high	unclear	high
Speirs 2013 [154]	high	high	high	high	high	unclear
Speirs 2013 [155]	high	high	high	high	high	high
Sutter (1) 2012 [156]	unclear	high	low	low	unclear	high
Sutter (2) 2012 [157]	high	high	high	unclear	unclear	high
Tak 2015 [158]	high	unclear	high	high	unclear	high
Tak 2016 [159]	high	unclear	low	high	unclear	high
Todd 2016 [160]	high	high	unclear	high	high	high
Valera 2018 [161]	unclear	unclear	unclear	low	unclear	high
VanHoucke 2014 [162]	high	unclear	low	high	unclear	unclear
vanSpil 2015 [163]	unclear	unclear	low	high	high	high
Weinberg 2016 [164]	high	high	high	high	high	high
Wyles 2017 [165]	high	high	high	low	high	high
Yamauchi 2017 [166]	high	high	unclear	high	unclear	high
Yuan 2013 [167]	high	high	unclear	low	high	high
Zilkens 2013 [168]	high	high	low	high	unclear	high

Primary cam morphology taxonomy and terminology

Authors used at least 206 different terms related to cam morphology and FAI (syndrome) in the 111 included publications, which can be divided into three categories: (1) cam morphology as it relates to FAI (syndrome), (2) 'morphology' and its related terms, and (3) 'lesion', 'deformity', 'abnormality' and related terms (See section 1 of supplemental file B.1). Most of the included publications referred to cam morphology in the context of FAI (78% of the 111 included publications) and FAI syndrome (6%). 'Cam FAI' and 'cam-type FAI' were used in 19% and 21% of the included publications, while 23% used 'cam impingement' and 14% used 'cam-type impingement'. 'Cam lesion', 'cam deformity', and 'cam-type deformity' were used in 9%, 41% and 22% of the included publications, respectively. Many publications used more than one term (some up to 5, [77]) for the same concept.

I compared the most-used terms in all publications from 2016 and earlier (n=88) and those published in 2017/18 (*n*=23) (i.e. published at least 2 months after the Warwick consensus paper recommended to use 'cam morphology' and avoid 'lesion' and 'deformity') (Figure 2.5) [36]. There was greater use of 'cam morphology' in the 2017/18 publications compared to publications from 2016 and earlier (43% vs 11%), and also greater use of 'femoroacetabular impingement (FAI) syndrome' (26% vs 1%), 'cam deformity' (70% vs 33%), 'cam lesion' (26% vs 5%), and 'cam FAI' (35% vs 15%) (Figure 2.5).

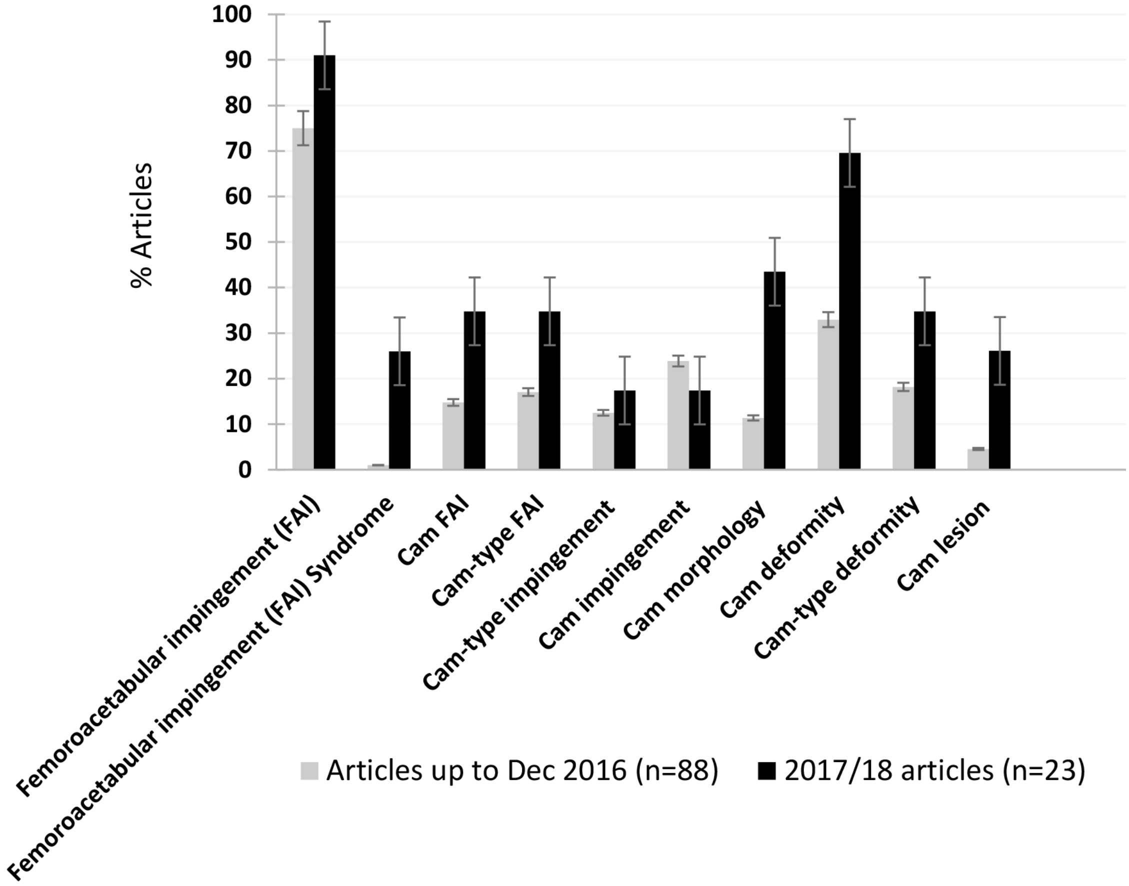

Figure 2.5. Time trend for 10 most-used terms relating to primary cam morphology - all publications from 2016 and earlier (grey bars, n=88) compared with 2017/18 publications (dark bars, n=23); many publications used more than one term. Error bars = standard errors. Reproduced from Dijkstra *et al* (2021), published CC-BY-NC [1]

Due to the high overall risk of bias in the primary cam morphology risk factor literature, amplified by inconsistent terminology, confusing conceptual and operational definitions, and no taxonomy of types for the morphology, I had to rethink the risk factor-related aim of my research programme. My DPhil focus changed. Rather than primary cam morphology risk factor and prediction model-focussed research, I decided to pursue a programme of research to improve research quality in the field. This was a pragmatic decision taken in consultation with DPhil supervisors (and the systematic review research team as we had to postpone working on the risk factor systematic review). I invested significant effort mobilising a 'learning community' to grapple with several areas that needed urgent attention and improvement. While continuing exploratory work on risk factors, I developed and completed three studies described in this thesis: a Delphi consensus study on primary cam morphology and femoroacetabular impingement syndrome terminology, taxonomy, definitions and imaging outcomes for research (chapter 4); a Delphi consensus study on research priorities for the field (chapter 5); and a qualitative study to explore stakeholders' perspectives on research quality in the field of primary cam morphology and its natural history (chapter 6). In addition, I completed seven MSc in Evidence-Based Health Care modules at the University of Oxford to equip me to develop and lead these studies (Section 7.4, p256).

2.4.2 Step 4: Attributes

In this section, I describe 5 attributes and combine step 8, empirical referents, with each attribute to describe how it was recognised or measured (operationalised) (Table 2.3 and sections 2-7 of supplemental file B.1): attribute 1 – tissue types involved in primary cam morphology; attribute 2 – size of primary cam morphology; attribute 3 – site (location) of primary cam morphology; attribute 4 – shape of primary cam morphology; attribute 5 – ownership of primary cam morphology.

Table 2.3. Primary cam morphology, its defining attributes, and empirical referents; quotations from selected publications are in italics.

Attribute	Description	Empirical Referent
Attribute 1: Tissue types involved in primary cam morphology	Distinguish between bone and soft tissue (cartilage) on MR imaging	Cartilage: 3T MR imaging Bone: Radiographs, CT scan, MR imaging
'Cam morphology was quantified using the alpha angle for bone and cartilage, which was treated as a continuous variable given there is no agreed diagnostic threshold (figure 1). Radiographic epidemiological studies suggest alpha angles above 60 degrees are elevated and potentially diagnostic. Cartilage alpha angle was chosen as the primary outcome measure because in the skeletally immature hip the secondary ossification centre does not accurately reflect overall hip shape. Furthermore, it is non-ossified structures that impact in femoroacetabular impingement.' [60]		
Attribute 2: The size of primary cam morphology	Small; moderate; large; pathologic; significant; severe	Alpha angle (degrees), impingement angle (degrees), offset measure (millimetres), offset ratio, femoral head ratio (FHR) of Murray, triangular index, relationship between the width of the femoral neck and

		diameter of the femoral head. Outcome variables are continuous and/or dichotomous using different cut-off values: alpha angle (≥50°, >50°, ≥50.5°, >50.5°, >51°, >55°, ≥55°, >57°, >60°, >62°, >62.5°, >65°, >78°, >83°), head-neck offset <8mm, anterior offset ratio <0.135, FHR >1.35, triangular index ≥0mm.
‘3D multiplanar reconstructions were performed using OsiriX Software (V.6.0.2, Pixmeo). Radial images were acquired around the axis of the femoral neck at 30° intervals. Alpha angle and epiphyseal extension were measured using custom-developed software on the radial slices at 11 o'clock, 12 o'clock, 1 o'clock, 2 o'clock and 3 o'clock. These positions were selected as they include the most frequent locations of cam morphology and pilot data suggested the magnitude of cam morphology was greatest at 1 o’clock. To account for variation in the location of cam morphology, the primary outcome measure was maximum cartilage alpha angle from 11 o’clock through to 3 o’clock.’ [60]		
Attribute 3: The site (location) of primary cam morphology	Femur; femoral head-neck; Superior; anterior; inferior; posterior; lateral-lateral; 12 to 11 o’clock positions	Radiographs; CT scans or MR imaging CT scan or MR imaging
‘the morphology of the femoral head-neck junction is such that the alpha angle measurements are significantly higher at the anterosuperior femoral head-neck position (1:30 radial position) compared with the anterior position (3:00 radial position)’ [75]*; ‘the circumference of the deformity clearly extended from anterior to anterolateral quadrants’* [75]*; ‘males anterolateral quadrant; females anterior quadrant’* [75]. *‘We used a clock face system to record the localization of cam-type deformities on radial sequences, with 12 o’clock denoting a superior location, 3 o’clock an anterior, 6 o’clock an inferior, and 9 o’clock a posterior location’;* [146] *‘clockface system on the radial cuts at 7 defined points ranging from 9 o’clock (posterior head-neck junction) to the 3-o’clock position (anterior head-neck junction). The analysis was simplified by converting left sided images into right-sided joints’* [152]*; seven measurements from 9 o'clock to 3 o'clock positions - superior half of the femoral head)* [61]. *‘To account for variation in the location of cam morphology, the primary outcome measure was maximum cartilage alpha angle from 11 o'clock through to 3 o'clock’* [60].		
Attribute 4: The shape of primary cam morphology	Cam-shape; pistol-grip deformity; bump; hump; flattening; aspherical; oval-shaped;	Qualitative judgement or quantified on radiographs, CT scans or MR imaging
‘The α angle is an indicator for head asphericity’ [152]. *‘Shape defined by a set of landmark pints that are positioned along the contour of the bone’* [62].		

Attribute 5: Ownership of primary cam morphology	More common in asymptomatic males (vs females)	Qualitative judgement or quantified on radiographs, CT scans or MR imaging
	More common in asymptomatic athletes/sporting cohorts (vs non-athletes)	'*Cam-type deformities were seen in 868 male and 1192 female participants, respectively, as follows: pistol grip deformity, 187 (21.5%) and 39 (3.3%)'* [113].
	Reported: males vs females; athletes vs non-athletes	*'Males participating in competitive sport are at particularly elevated risk of developing cam morphology…'* [60]. *'…CAM impingement is more common in the elite ice hockey athlete in comparison with non-athletes'* [68].
	One hip (unilateral); both hips (bilateral); left and right hips; Reported: Per hip; per person; both per hip and per person	'*when a cam deformity was present in either view in either hip'* [159]. *'flattening or prominence in at least one hip in either AP or frog-leg lateral view';* [62] *'randomly assigned one hip to be evaluated for each athlete';* [152] *'To investigate the differences between ethnicities in the continuous measures, a univariate linear regression model with generalized estimating equations (GEE) was used to account for the correlation between the left and right hips of each individual.'* [126]

2.4.2.1 Attribute 1: tissue types – cartilage or bone

All but one of the included articles described cam morphology as a bony entity. The article describing cartilage *and* bony cam morphology used 3 Tesla (3T) Magnetic resonance (MR) imaging to distinguish between cartilage and bone [60]. They showed that the cartilage alpha angle increased as early as age 10 years, qualitatively representing soft-tissue hypertrophy at the head-neck junction, that preceded extension of the ossified epiphysis. Cartilage alpha angle might therefore reflect the hip shape better than the secondary ossification centre in skeletally immature individuals. It is likely non-ossified structures that impact in femoroacetabular impingement in these young hips, but more research is needed to confirm this. Bony primary cam morphology is described and measured on radiographs, CT scans and MR imaging at the time of and after femoral head physeal closure.

2.4.2.2 Attribute 2: Size

Primary cam morphology is a three-dimensional entity of variable size. It was described in the included articles as ‘small’, ‘moderate’, ‘large’, ‘pathologic’, ‘significant’, ‘severe’ or ‘definite’. Assigning these categories can be a qualitative judgement (subjective impression of shape and size on imaging) or quantified on imaging through various measures such as the alpha angle (Figures 2.6 A and 2.7 C). See section 3 of supplemental file B.1 for references.

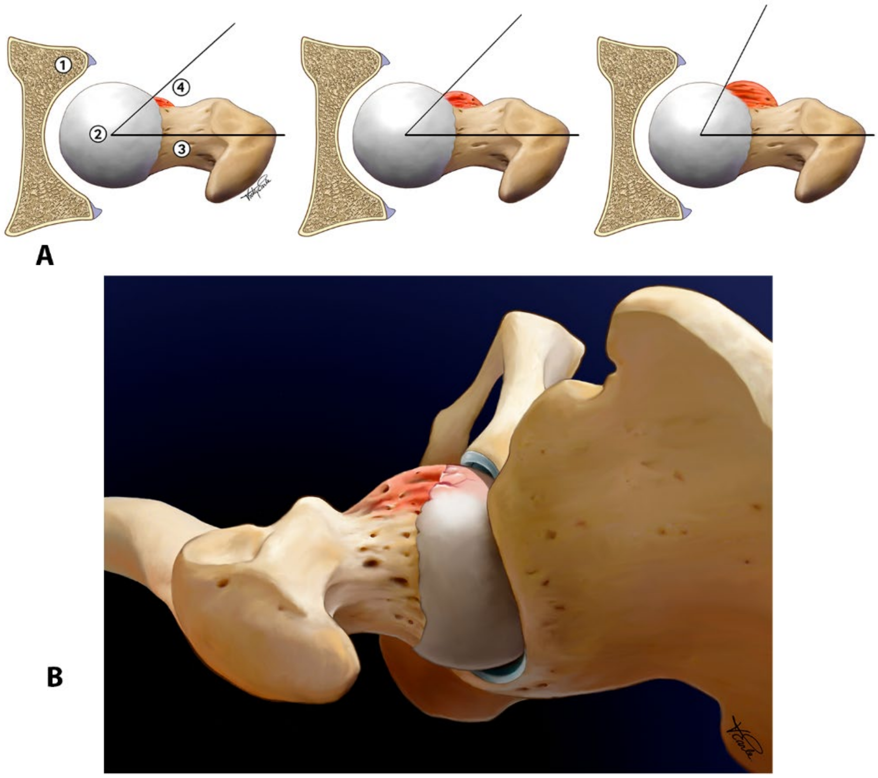

Figure 2.6. A - Increasing size of cam morphology (anterior cam morphology in a sagittal oblique or transverse plane; left hip; superior cam morphology in coronal (frontal) plane; left hip); 1 = acetabulum; 2 = femur head; 3 = femur neck; 4 = cam morphology; B - Anterior cam morphology. Reproduced from Dijkstra *et al* (2021), published CC-BY-NC [1].

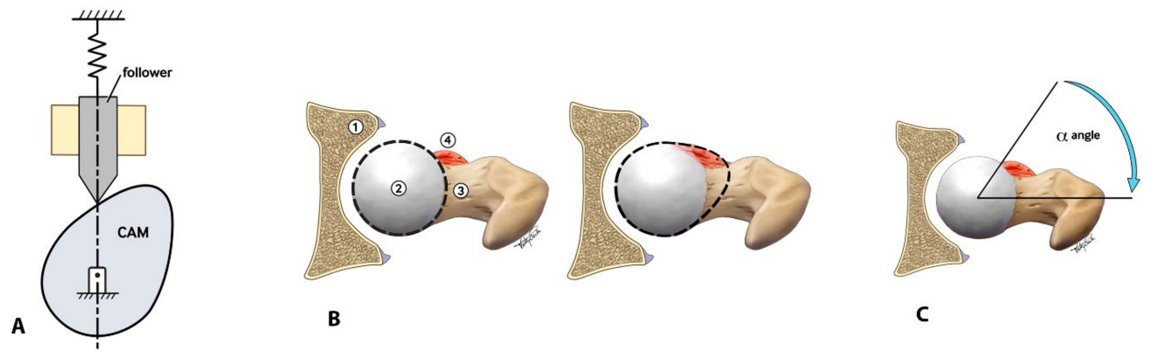

Figure 2.7. A - Cam disc/saft: ‘Cam’ is a rotating piece, such as an eccentric wheel or cylinder with an irregular (oval) shape in a mechanical linkage used to transform rotary motion into linear motion or vice versa. Adapted from [169]; B - Cam morphology—changing the shape of the femoral head from spherical to aspherical; (this can be an anterior or superior position; left hip); 1 = acetabulum; 2 = femur head; 3 = femur neck; 4 = cam morphology; C - The alpha angle: angle between a line joining the centre of the femoral head with the centre of the neck at its narrowest point, and a line from the centre of the femoral head to a point where the distance from the centre of the head exceeds its radius. Reproduced from Dijkstra *et al* (2021), published CC-BY-NC [1,134].

2.4.2.3 Attribute 3: Location (site)

Primary cam morphology location refers to the general anatomical area (femoral head-neck junction; attribute 3.1), and the specific anatomical location (attribute 3.2 and 3.3), depending on the type of imaging used to operationalise the morphology (2- or 3-dimensional) (Figures 2.6A and B; Figures 2.8A and B). See section 4 of supplemental file B.1 for references.

Attribute 3.1: femoral head-neck junction: Primary cam morphology develops at the femoral head-neck junction. The location is also described as ‘proximal femur’ [86,103,123,152,153], ‘femoral’, ‘femoral head’, ‘femoral head-neck transition’, and ‘femoral head-neck type’.

Attribute 3.2: anterior, anterolateral, lateral, inferior, posterior, superior, anterior-superior, superior-anterior: Primary cam morphology is a 3-dimensional entity usually located on the anterosuperior aspect of the femoral neck [114]. Anterior and lateral primary cam morphology are visible and measured on true lateral- and AP-pelvis radiographs respectively (two-dimensional imaging) while cam morphology in any femoral head-neck position is visible and measured on three-dimensional imaging (CT scan or MR imaging) (Figure 2.8A).

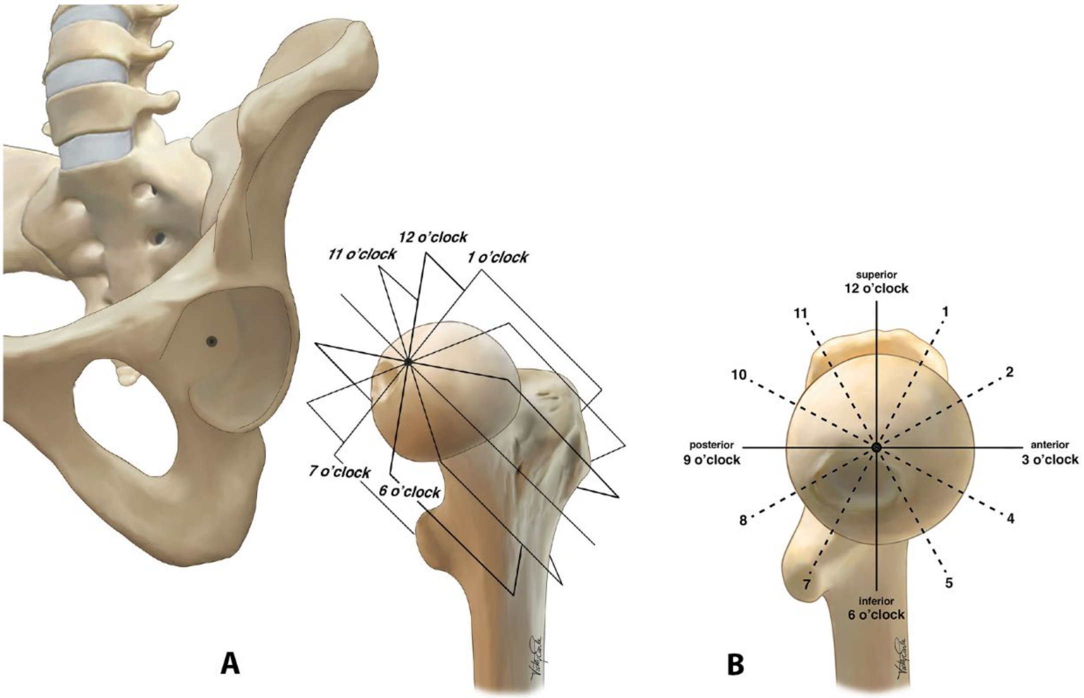

Figure 2.8. A - Schematic representation of radial images around the axis of the femoral neck. The radial magnetic resonance imaging (MRI) planes are perpendicular to the femoral head-neck axis (sagittal oblique MRI localizer). B - The radial cuts rotate clockwise in 30° intervals around the femoral head-neck axis. The coronal plane (12 o'clock) is parallel to the axis of the proximal femur diaphysis. Reproduced from Dijkstra *et al* (2021), published CC-BY-NC [1]. Adapted from Reichenbach *et al*, Siebenrock, *et al*, Dudda *et al*. [146,150,170].

Several lateral views exist to visualize other parts of the head-neck junction (for example corresponding to the anterolateral region). Despite being a two-dimensional image, radiographs can still capture the presence of cam morphology quite accurately. However, it doesn't always capture 'peak' cam morphology. The size and position of the bony prominence may vary. One paper suggests it is more superior in males and more anterior in females [79].

Attribute 3.3: different o'clock positions of the femoral head (12 o'clock to 11 o'clock): Many authors (approximately 40% of the total included articles) used a clock face system (Figure 2.8A and B) to describe the location of cam morphology on radial MR imaging or CT scan sequences around the axis of the femoral neck, normally 30° intervals with 12 o'clock as the superior location, and 3 o'clock, 6 o'clock and 9 o'clock as the anterior, inferior and posterior locations, respectively [60,61,65,75,86,123,137,146,152,160,167]. The most frequent positions used are 12 to 3 o'clock.

2.4.2.4 Attribute 4: Shape

The included articles used a variety of terms to describe or refer to the 'cam shape'. These terms include 'cam morphology', 'FAI morphology', 'morphologic variation', 'pathomorphology', 'pistol-grip deformity', 'tilt deformity', 'bump', 'hump', 'prominence', 'reduced (less; diminished) femoral head-neck junction concavity', 'incongruity', 'convex', 'flattening', 'asphericity (aspherical; nonspherical)', 'oval-shape', 'decreased offset', 'decrease in hip clearance' and 'extra bone formation'. See section 5 of supplemental file B.1 for references.

The normal anatomy and morphology of the femoral head (caput femoris) and neck (collum femoris) are well documented [171,172]. In mechanical engineering, 'cam' refers to an irregular aspherical rotating or sliding piece (Figure 2.7A) [169]. Cam morphology in orthopaedics refers to an aspherical or cam-shaped femoral head (Figure 2.7B).

2.4.2.5 Attribute 5: Ownership

Primary cam morphology is more common in male athletes and occurs in one, but more often in both hips. It is reported per hip and/or per person in the included articles. See section 6 of supplemental file B.1 for references.

Attribute 5.1: sex/gender: Primary cam morphology is more prevalent in males compared to females [96,113]. More research in female cohorts is needed.

Attribute 5.2: athletes: Primary cam morphology is more prevalent in athletes compared to non-athletes. There is strong evidence that high activity levels during adolescence promote cam morphology development with a dose-response relationship [60,75,158].

Attribute 5.3: one or both hips (per hip; per person): Some included articles analysed and reported cam morphology in both hips for each research participant as a dichotomous outcome variable (using a range of different cut-off values), a continuous outcome variable or both (Table 2.3). Some included articles analysed and reported cam morphology in one hip ('per person') for each research participant: either the 'right or the left hip', the 'dominant hip', the 'kicking leg', a 'random hip' or a 'symptomatic hip' (Table 2.3).

Attribute 5.4: symptoms: The majority of individuals with primary cam morphology are symptom free [2,127]. In a 2-year prospective cohort study of professional adult male soccer players, bony morphology, including cam morphology, was not associated with the risk of groin injuries. Despite the high prevalence of cam morphology (71% of players), only 1 of 113 index hip/groin injuries recorded was hip-related [2].

2.4.3 Step 8: Empirical referents

Primary cam morphology is only visible on imaging or during open or arthroscopic hip joint surgery. The included articles used imaging to observe or measure (operationalise) primary cam morphology, qualitatively (visual) and/or quantitatively (measuring a specific imaging outcome variable). See section 7 of supplemental B.1 for references.

2.4.3.1 Imaging used for primary cam morphology

Primary cam morphology was measured on radiographs, Dual-Energy X-ray Absorptiometry (DXA), CT scans and MR imaging.

Radiographs: The following radiographs were used to operationalise cam morphology applying a range of different outcome measures: AP Pelvis, Dunn 45, Frog-leg lateral, cross table lateral [139–142], Sugioka view [63], standing false profile hip [103], Von Rosen view [165,167], and Lauenstein radiograph [168].

Dual-energy X-ray absorptiometry (DXA): One of the included articles used posterior-anterior dual-energy X-ray absorptiometry bone mineral density images to quantify bony morphology of the hip [129].

CT scan: CT scans were used in 18 of the 111 included articles to operationalise cam morphology [65,72,73,77–79,91,100,110,121–123,131,132,154,155,161,164]. Ng et al (2015) describe axial alpha angles measured on oblique-axial plane of the longitudinal femoral neck axis (cam deformity in the anterior aspect of the femoral head), and radial alpha angles obtained through a 1:30 clockface rotation about the longitudinal femoral head neck axis (anterosuperior quadrant). Axial alpha angle >50.5˚ or radial alpha angle >60˚ were considered as cam deformity [131]. Speirs et al (2013) measured the Alpha angle on two images to evaluate the femoral head-neck junction anteriorly and anterosuperiorly in the traditional axial oblique (3:00) and radial 1:30 planes, respectively. They classified asymptomatic subjects with an alpha angle ≥50.5° measured in the 3:00 plane or >60° in the 1:30 plane as 'bump' [154].

MR imaging: MR imaging of different magnetic field strengths, 0.5-Tesla, 1-Tesla, 1.5-Tesla, and 3-Tesla were used to operationalise cam morphology and the important associate structures (e.g. physeal growth plate, labrum, and joint cartilage). The authors describe coils, 'body coil for signal transmission and a flexible four channel surface coil for signal reception' [65], relaxation time: T1ρ, Turbo spin echo (TSE) [65], and planes: sagittal [60], sagittal-oblique [65], radial [60,89], 'axial angled on the femoral neck' [61], axial-oblique [68], 'transverse oblique with radial images reformatted by using the femoral neck long axis as a rotation axis' [90], 'axial-oblique sagittal and coronal' [93], and coronal-oblique [149].

Ultrasound: Ultrasound was used to measure alpha angles in a publication included after the January 2021 update search (Section 2.5.6) [173]. The authors used a previously validated ultrasound technique [174].

Imaging outcome measures: The included articles used different imaging outcome measures to report the shape and size of cam morphology (Figure 2.9 and supplemental file B.2). These include alpha angle (degrees) (Figure 2.7 C), impingement angle (degrees), offset measure (millimetres), offset ratio, femoral head ratio (FHR) of Murray, triangular index, and the relationship between the width of the femoral neck and diameter of the femoral head.

The included articles reported these outcome variables as continuous and/or dichotomous using different cut-off values. There was no consensus on an operational definition for cam morphology based on any of the outcome variables in the literature (Figure 2.9).

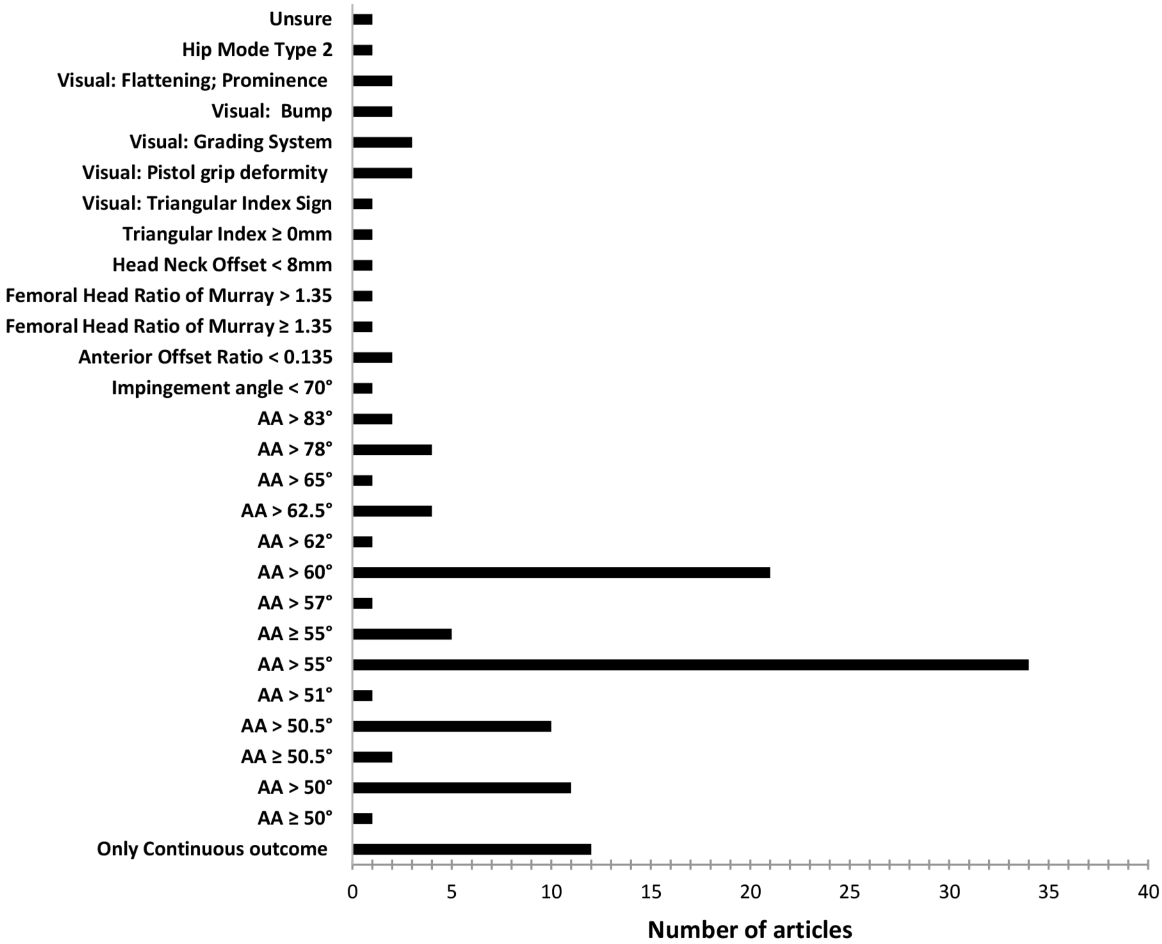

Figure 2.9. Cam morphology outcome measures and prevalence definitions based on a dichotomous outcome measure. AA, alpha angle. Reproduced from Dijkstra *et al* (2021), published CC-BY-NC [1].

2.4.4 Steps 5 and 6: Model and additional cases

All co-researchers, many with extensive clinical experience in the field, contributed to crafting the model and additional cases to inform the concept. I describe a model case of primary cam morphology in a 15-year-old male football player (Table 2.4 A) and wrote corresponding narratives for additional cases. Additional cases describe ‘borderline cases’, ‘related cases’, and ‘contrary cases’ to further illustrate the concept of primary cam morphology. This is an important step as it may be difficult to determine the defining attributes that most closely represent primary cam morphology. I therefore describe 3 additional cases to help refine the best fit defining attributes: (1) primary mixed morphology, (2) hip dysplasia, and (3) secondary cam morphology due to slipped capital femoral epiphysis (Table 2.4 B to D).

Table 2.4. Model and additional cases to illustrate the concept of primary cam morphology

Clinical case	Description
A: Model case Primary cam morphology	Jason, a 15-year-old male academy-level football player reports a 1-month history of occasional left groin (anterior hip) stiffness associated with high-intensity football practice or match play. He also reports a feeling of restricted ‘hip’ movement but cannot explain exactly what he feels. He is a striker who prefers to kick with his right foot and has played competitive football at his London-based football club academy since age 9. He denies any previous hip or groin injuries. Hip and groin examination findings are unremarkable apart from lower left hip internal rotation (20°) compared to 35° on the right side. He agrees to further special investigations: anterior posterior pelvis (AP-pelvis) and lateral radiographs of both hips. The radiologist reports a left hip cam morphology visible on both AP-pelvis and lateral radiographs, measuring the alpha angles in both views (65° and 58° respectively). The player, his parents and the club’s physician are all keen to know more about the current joint status and agree to a 3 Tesla MR imaging of the player’s left hip. (The radiologist asked for two morphological sequences: three-dimensional (3D) water selective fluid (WATSf) to image joint cartilage and bone, and 3D proton density fat saturation (PDFS) to image the physeal scar. The radiologist also performed 3D multiplanar reconstructions and acquired radial images around the femoral neck at 30° intervals [60]). The alpha angle (63°), epiphyseal hypertrophy and extension are maximal at the 1 o’clock position
B: Additional case – border line: Primary mixed morphology	Lynn, a 19-year-old female rugby player reports occasional left anterior groin stiffness associated with high-intensity practice or games. She also reports a feeling of restricted ‘hip’ movement but cannot explain exactly what she feels. She is a fly-half and kicks with her right foot and has played competitive rugby at her club’s rugby academy since age 9. She denies any previous significant hip or groin injuries. Hip and groin examination findings are unremarkable apart from slightly lower hip internal rotation of 25° on the left compared to 35° on the right side. She agrees to further special investigations: anterior posterior pelvis (AP-pelvis) and lateral radiographs of both hips. The radiologist reports left hip mixed cam and pincer morphologies visible on both AP-pelvis and lateral radiographs and measured the alpha angles in both views (67° and 63° respectively). The player and the club’s physician are all keen to know more about the current joint status and agree to a 3 Tesla MR imaging of her left hip. (The radiologist asked

	for a morphological sequence: three-dimensional (3D) water selective fluid (WATSf) to image joint cartilage and bone. The radiologist also performed 3D multiplanar reconstructions and acquired radial images around the femoral neck at 30° intervals [60].)
C: Additional case – contrary: Hip dysplasia	Carlos, a 15-year-old male ballet dancer reports occasional left groin stiffness associated with high-intensity practice or performance. He also reports an occasional feeling of restricted 'hip' movement but cannot explain exactly what he feels. He joined the ballet school, practicing and performing more than 10 hours per week since age 9. He denies any previous significant hip or groin injuries. Hip and groin examination findings are unremarkable, including normal bilateral hip range of motion tests (internal rotation of 40°). The flexion adduction internal rotation (FADIR) and flexion abduction external rotation (FABER) special tests are both normal. He agrees to further special investigations: AP-pelvis and lateral radiographs of both hips. The radiologist reports normal head-neck femoral morphology on both AP-pelvis and lateral radiographs with signs of left hip dysplasia; she measured normal alpha angles in both views (48° and 49° respectively); Lateral center-edge angles (LCEAs) were 19° and 23° for the left and right hips respectively. The dancer, his parents and the ballet school's sports physician are all keen to know more about the current joint status and agree to a 3 Tesla MR imaging of his left hip. (The radiologist asked for two morphological sequences: three-dimensional (3D) water selective fluid (WATSf) to image joint cartilage and bone, and 3D proton density fat saturation (PDFS) to image the physeal scar. The radiologist also performed 3D multiplanar reconstructions and acquired radial images around the femoral neck at 30° intervals [60]). MR imaging confirmed a small anterior labral tear.
D: Additional case – contrary: Secondary cam morphology	Ahmad, a 13-year-old male presents with a two-month history of intermittent left groin and knee pain and an associated limp made worse by playing sports. He also reports an occasional feeling of restricted 'hip' movement but cannot tell exactly what he feels. He kicks with his right foot and plays occasional football with his friends, no more than 1 hour per week since age 11. He denies any previous significant hip and groin injuries. He is overweight; his knee examination is normal. The left hip has reduced hip flexion and rotation range of motion (internal and external rotation) compared to the right hip. The FADIR test is painful on the left but the FABER special test on the left is normal. His left leg is 2.5 cm shorter compared to the right leg. He and his parents agree to further special investigations: anterior posterior pelvis (AP-pelvis) and lateral radiographs of both hips. The radiologist reports a posterior slipped capital femoral epiphysis.

2.4.5 Step 7: Antecedents and consequences

The science concerning primary cam morphology, including its aetiology and prognosis, is not settled. No high-quality prospective studies with an adequate follow up time exist on primary cam morphology aetiology or prognosis.

This concept analysis could inform higher quality research, amplified by the consensus exercise on taxonomy, terminology, definitions, and imaging outcome measures reported in chapter 4. A collaborative approach to multi-cohort prospective aetiology and prognosis studies provides the opportunity to share higher quality, and more uniform research data.

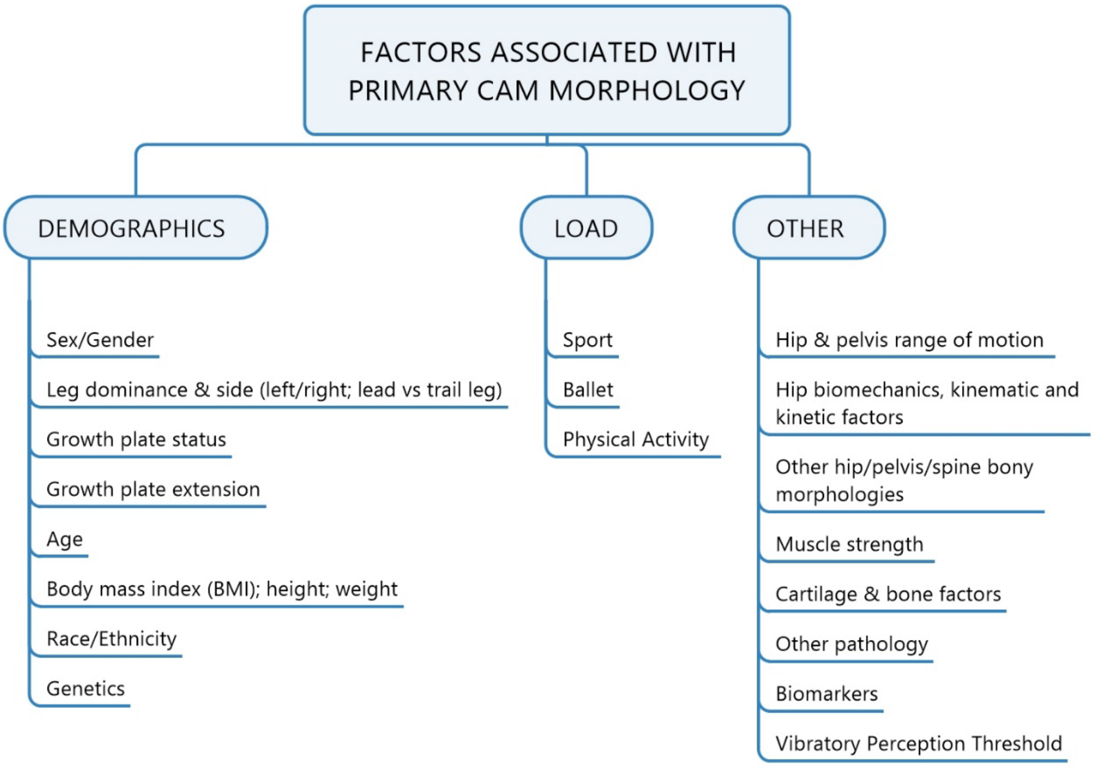

Figure 2.10. Factors associated with primary cam morphology

In the following sections, I report the important primary cam morphology antecedents—factors most likely causally linked to primary cam morphology—and the morphology's hip disease consequences. See supplemental file B.3 for references.

2.4.5.1 Antecedents

Three important antecedents were identified in this concept analysis: (1) young adolescents with no other disorders of the hip (absence of conditions associated with secondary cam morphology), (2) an open femoral capital physis with epiphyseal hypertrophy and/or extension as a result of (3) high-load physical activity (shear-type load) as the likely causative risk factor (volume and type of load are not well understood; probably external rotation with flexion—axial and rotational forces combined), and other unconfirmed risk factors.

Young adolescents with no other disorders of the hip or any co-occurring hip impingement/pathology (absence of conditions associated with secondary cam morphology): Primary cam morphology is cam morphology that develops in the absence of other hip pathology, and we excluded all articles on secondary primary cam morphology from the primary cam morphology risk factor systematic review and this concept analysis. Secondary cam morphology is caused by pre-existing hip disease or trauma including, Perthes' disease, slipped capital femoral epiphysis (SCFE), healed proximal femoral fractures, avascular necrosis, or osteophytes.

An open femoral capital growth plate (when does primary cam morphology develop?): It is still unclear exactly when and how primary cam morphology develops. We conclude from cross sectional studies and a small number of prospective cohort studies that primary cam morphology likely develops during skeletal maturation when the femoral capital physis is still open. The included articles refer to (early) adolescence [13], childhood [150], skeletal maturation [13], and young adulthood [150].

High-load physical activity (shear-type) as the likely causative risk factor (volume and type of load are not well understood; probably external rotation with flexion—axial and rotational forces combined), and other unconfirmed risk factors: Primary cam morphology develops gradually during skeletal maturation as a result of physiological skeletal response to physical load (athletic activity) on the femoral capital physis, hence the term 'primary' (including 'idiopathic') cam morphology. The exact mechanism of primary cam morphology development is unknown. Our systematic review of risk factors for primary cam morphology has identified several factors associated with primary cam morphology. These include demographic risk factors, environmental/lifestyle risk factors (sport, physical activity, and dance) and a variety of other risk factors. The science of its causal inference—understanding why primary cam morphology occurs—is unclear.

2.4.5.2 Consequences

A consequence of primary cam morphology could be motion dependant abutment against the acetabular rim, described as femoroacetabular impingement (FAI). However, in large population-based prospective studies, end-stage osteoarthritis was the sequalae in <11% of hips with cam morphology [35,175]. Furthermore, in two smaller prospective studies, >84% of hips defined as having cam morphology did not develop hip pain [2,176]. A combination of risk factors, including primary cam morphology, may cause hip disease in some individuals, including: (1) tissue damage, including labral, and cartilage; (2) femoroacetabular impingement syndrome (combination of symptoms, including pain, stiffness, reduced range of motion, signs, and hip morphology changes on imaging); and (3) early hip joint osteoarthritis (Figure 2.11) [49].

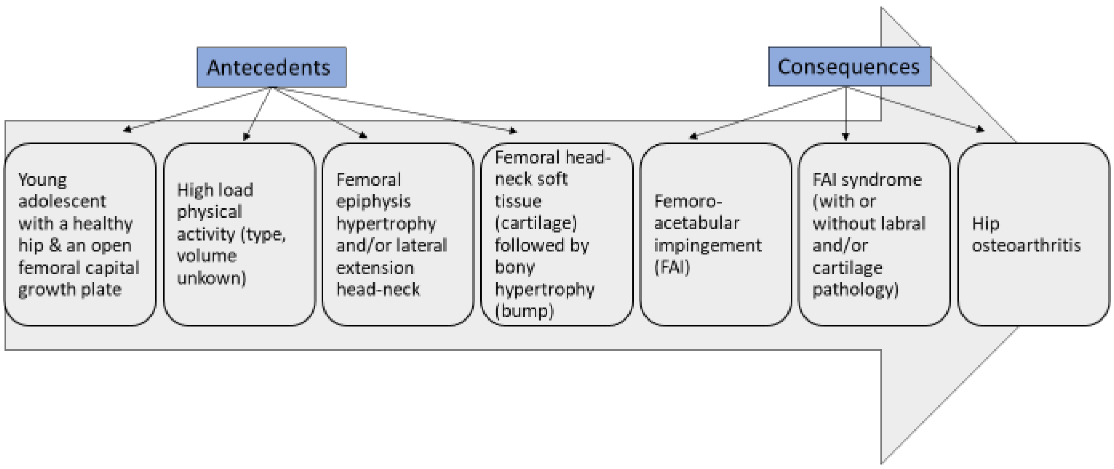

Figure 2.11. Pathogenesis (antecedents and consequences) of primary cam morphology. Reproduced from Dijkstra *et al* (2021), published CC-BY-NC [1].

Femoroacetabular impingement (FAI) was originally described by Ganz et al (2003) as a condition of 'abnormal contact that may arise as a result of either abnormal morphological features… or as a result of subjecting the hip to excessive and supraphysiological range of motion' [19]. Although some clinicians and researchers still use the term 'femoroacetabular impingement' to refer to the (unwanted) compression of soft tissue (labrum; cartilage; joint capsule) between the femur (head; head-neck junction; neck) and the acetabulum (usually the acetabular rim), this term creates confusion and should be avoided [36].

Soft tissue damage: labral; chondral: Cam morphology has been associated with hip joint soft tissue damage, including labral and chondral tissue using normal MRI [146], MRI T1ρ relaxation time [65,65,74,135,140], and T2-mapping [94].

FAI syndrome (symptoms: pain, with or without other symptoms like stiffness, clicking or catching): FAI syndrome is a triad of symptoms (most often motion-related or position-related pain in the hip or groin), clinical signs (most commonly a positive flexion adduction internal rotation – FADIR test) and imaging findings (cam and/or pincer morphology) [36,49,177].

Hip osteoarthritis: Patients with cam deformity and decreased internal rotation were at significantly higher risk of developing end stage hip osteoarthritis (odds ratio 25.21) in a large cohort of individuals with early onset hip pain with osteoarthritis [12].

Other consequences: Other possible consequences of primary cam morphology include limited hip range of motion, changes in hip mechanics and biomechanics and muscle recruitment patterns [51]. The data are equivocal and mostly cross sectional [71], and a detailed analysis of primary cam morphology consequences is beyond the scope of this chapter.

In summary, several causal and prognostic factors have been associated with primary cam morphology—as antecedents to the morphology and its hip disease consequences. The International Hip-related Pain Network (HiPRN) recommended more large scale and interdisciplinary research

> on aetiology and prognosis for each of the listed hip-related pain conditions. (For example, the relationship between bony morphology and other factors related to

> these conditions or movement-related factors relative to each hip-related pain condition.) [49]

Such research is key—but the research and clinical community need to agree on a uniform conceptual and operational definition for primary cam morphology.

2.4.6 Conceptual and operational definition for primary cam morphology

Based on this concept analysis, I propose the following conceptual and operational definition for primary cam morphology:

> Primary cam morphology is a cartilage or bony prominence (bump) of varying size at any location around the femoral head-neck junction, which changes the shape of the femoral head from spherical to aspherical. It often occurs in asymptomatic male athletes in both hips. The most common outcome measure is a cartilage or bone alpha angle as a dichotomised or continuous variable on radiographs, CT scans or MR imaging, reported per hip, per person or both. Primary cam morphology likely develops during skeletal maturation in young adolescents (with no current or previous hip disease), as a normal physiological response to high-load sporting activity and other unconfirmed risk factors [1].

This definition is based on the defining attributes and empirical referents for primary cam morphology, informed by clinical cases, antecedents, and consequences (Table 2.5).

Table 2.5. Primary cam morphology conceptual definition statements based on its attributes, empirical referents, antecedents, and consequences

Conceptual definition with examples of heterogenous empirical referents (operationalising)	Attribute/ empirical referent/ antecedents/ consequences
Primary cam morphology	Concept and terminology
is a cartilage or bony prominence (bump)	Attribute 1 (tissue type) Antecedent (acquired during maturation)
of varying size	Attribute 2 (size)
at any location around the femoral head-neck junction of the hip	Attribute 3 (site)
which changes the shape of the femoral head from spherical to aspherical.	Attribute 4 (shape)
It often occurs in asymptomatic male athletes in both hips, and is reported per hip, per person or both.	Attribute 5 (ownership)
We distinguish between cartilage and bone on MR imaging. We see primary cam morphology and measure its size, site, and shape on two-dimensional imaging (AP pelvis and lateral radiographs) and/or three-dimensional imaging (CT scan/MR imaging). The size and shape are measured in individual hips as a continuous or dichotomous outcome	Empirical referents for attributes 1 to 5

measure. The most common outcome measure is the alpha angle as a continuous variable (mean, SD degrees or median; IQR) or a dichotomous variable (primary cam morphology is present when the alpha angle is above a certain cut-off value) on two-dimensional radiographs (AP pelvis or lateral hip) or three-dimensional imaging. The location (site) depends on the imaging and how it is reported: e.g., femoral head-neck junction, anterosuperior, 1.30 o'clock position (e.g. *'3 Tesla MRI: 3D multiplanar reconstructions producing radial images around the axis of the femoral neck at 30° intervals; using the primary outcome measure as the maximum cartilage alpha angle from 11 o'clock through to 3 o'clock to account for variation in the location of cam morphology at the femoral head-neck junction of the hip'*) [60]. Regression models (with, for example, Generalised Estimating Equations, GEE) would allow data from both hips to be included in the same data set to account for potentially related observations between hips from the same person, and to assess changes in morphology over time, to account for correlation between measurements from the same research participant at different stages [126] (attribute 5).	
Primary cam morphology likely* develops during skeletal maturation in young adolescents (with no history of current or previous hip disease), as a normal physiological skeletal response to high-load sporting activity and other unconfirmed risk factors that affects the growth plate (capital physis) resulting in epiphyseal hypertrophy and/or extension. Epiphyseal extension is measured on 3 Tesla MR imaging as the distance the epiphysis extends along the femoral neck expressed as a ratio of femoral head diameter using custom-developed software on the radial slices at 11 o'clock, 12 o'clock, 1 o'clock, 2 o'clock and 3 o'clock or the physeal tilt quantified as the ratio of epiphyseal extension on either side of the physis at the different o'clock positions.	Antecedents (risk factors and pathogenesis)
When developed, primary cam morphology has likely* no hip disease consequence in the majority of individuals [2]. Long term prospective research on prognosis is needed to confirm this. tissue damage: labral, cartilage, and other pathology; In some individuals, however, the regular abutment of primary cam morphology against the hip socket (acetabular rim) may cause symptoms: pain and/or stiffness (femoroacetabular impingement syndrome); early-onset hip joint osteoarthritis. We define these hip diseases as a consequence of primary cam morphology based on clinical history and examination as well as imaging findings.	Consequences

*supported by current—albeit limited—prospective research evidence

2.5 Discussion

In this first concept analysis of primary cam morphology in the disciplines of sports medicine, orthopaedics, radiology, and physiotherapy, I introduce *primary* cam morphology and propose five defining attributes—tissue type, size, site, shape, and ownership—in a new conceptual and operational definition. Concept analysis has been described as a rigorous method to clarify a concept [43]. Here I highlight that taxonomy for the morphology is inconsistent, and terminology and how the morphology is described (imaging) are equally variable. I outline the clinically important findings related to primary cam morphology—a distinct concept in many (male) athletes, inconsequential ('bog standard') in most, but an important risk factor for early hip disease in some.

2.5.1 Primary cam morphology taxonomy (classification) and terminology

Taxonomy: There is no agreed taxonomy for primary cam morphology. Primary cam morphology is an important concept—a normal physiological response to load, hence 'bog-standard' in most athletes. Yet, in some athletes, this morphology can be associated with burdensome hip disease such as FAI syndrome and osteoarthritis. Disease taxonomy (naming, describing, and classifying disease into domains and subcategories), underpins communication and research [178–181]. The International Classification of Diseases (ICD) has no detailed taxonomy for femoroacetabular impingement syndrome, a hip disease with described clinical and imaging characteristics, including cam morphology [36,182]. The ICD-11 code, FA34.5, refers only to 'Impingement syndrome of the hip' without detailing the associated bony morphology [182]. This is vague and a problem for clinicians and researchers in sports medicine, orthopaedics, radiology, and physiotherapy.

Primary cam morphology is more common in male athletes. An athlete with hip-related pain, who participated in regular impact sports during maturation and has no previous hip disease, a positive Flexion Adduction Internal Rotation (FADIR) test, and cam morphology on imaging, has FAI syndrome and *primary* cam morphology. Clinicians should reason differently when they manage these patients compared to a patient with FAI syndrome and *secondary* cam morphology [183].

Terminology: The terminology for cam morphology is only consistent in its inconsistency. The 2016 Warwick consensus on FAI syndrome, endorsed by 25 clinical societies, recommended the term 'cam morphology'. The authors recommended eschewing terms such as 'deformity', 'abnormality' or 'lesion'—to avoid attributing 'pathology' to an anatomical feature [36]. The concept analysis presented in this chapter indicates that the Warwick nomenclature has not yet been widely adopted among cam morphology researchers. One reason might be that there is no consensus on terminology, definitions, and imaging outcome measures specific to cam morphology—when anatomy flips to pathology. Overall, 11% of the 88 publications from 2016 and earlier, included in our concept analysis data set, used the term 'cam morphology', and this increased to 43% of the 23 publications from 2017/2018.

A pragmatic FAI syndrome and cam morphology taxonomy and terminology, to include primary and secondary cam morphology, provides a conceptual framework that will allow clinicians, researchers, and patients to dance and deliberate around the same fire—common ground to communicate more precisely, apply informed clinical decisions, and perform better research.

2.5.2 Primary cam morphology definition

I propose a new definition for primary cam morphology (Figure 2.12 and Table 2.5). This definition is based on the 5 defining attributes of primary cam morphology: tissue type, size, site, shape, and ownership. This concept analysis confirmed inconsistent operational definitions for primary cam morphology; many different imaging modalities and outcome measures were used to report the shape, size, and location of cam morphology. The included articles in our concept analysis used different dichotomous and continuous imaging outcome measures to operationalise primary cam morphology on radiographs, DXA scans, CT scans, MR imaging and Ultrasound. Primary cam morphology is a 3-dimensional entity with as yet no agreed diagnostic threshold [184].

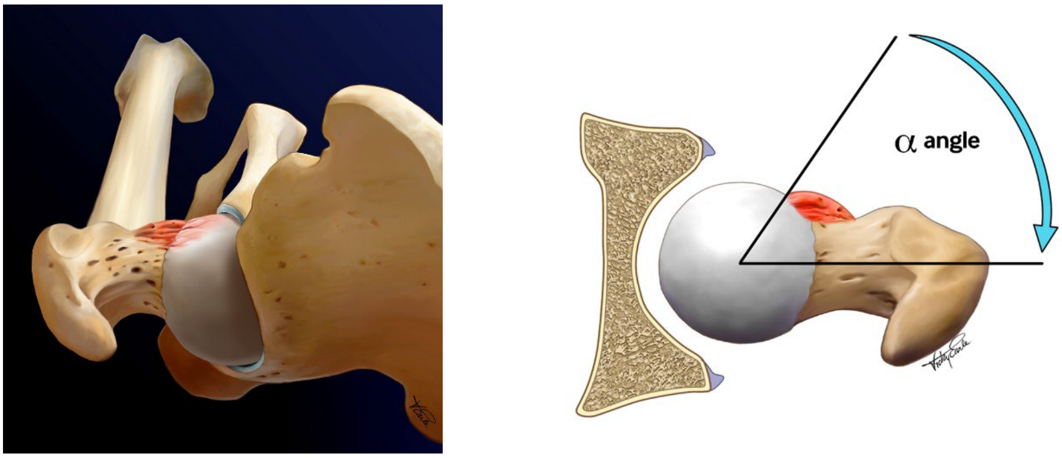

Figure 2.12. Primary cam morphology definition.

Primary cam morphology is a cartilage or bony prominence (bump) of varying size at any location around the femoral head-neck junction, which changes the shape of the femoral head from spherical to aspherical. It often occurs in asymptomatic male athletes in both hips. The most common outcome measure is a cartilage or bone alpha angle as a dichotomised or continuous variable on radiographs, CT scans or MR imaging, reported per hip, per person or both. Primary cam morphology likely develops during skeletal maturation in young adolescents (with no current or previous hip disease), as a normal physiological response to high-load sporting activity and other unconfirmed risk factors. Reproduced from Dijkstra *et al* (2021), published CC-BY-NC [1].

The alpha angle is the most common outcome measure reported in the risk factor literature and, despite its limitations, is widely accepted as the best way to operationalise the different primary cam morphology attributes. However, to date, no agreement exists on a diagnostic alpha angle cut-off value, and we doubt a specific alpha angle cut-off value will benefit clinical practice or research [60,184]. A systematic review by Van Klij et al (2020) suggested a 'diagnostic' Alpha angle cut-off value of $\geq 60°$ [184]. Significant methodological and clinical heterogeneity compromised this systematic review outcome and the authors recommended further research to evaluate whether this threshold is applicable for all imaging modalities and/or views before introducing diagnostic criteria.

Researchers should not dichotomise continuous outcome variables in regression models to investigate aetiology or prognosis—it leads to serious flaws [185,186]. We agree that alpha angle—as a continuous variable on MR imaging—should be the gold standard empirical referent in prospective research on how primary cam morphology develops (aetiology), taking into account the radiation risk associated with CT scans and regular radiographs, especially in children [60]. Alpha angles on AP Pelvis and lateral radiographs are an acceptable alternative for long-term research on prognosis and in clinical practice.

Vague concepts confuse patients, clinicians, and researchers. Our proposed definition and the inconsistent empirical referents for primary cam morphology, highlight the value of applying the 'rigorous intellectual exercise' ([43], p180) of concept analysis method in sports medicine. It lays the foundation for higher quality further research in the field, including a consensus exercise on terminology, definitions, and imaging outcome measures for primary cam morphology.

2.5.3 Primary cam morphology antecedents

Our concept analysis identified three antecedents for primary cam morphology: (1) young adolescents with no other disorders of the hip, (2) an open femoral capital physis, and (3) high-load sporting activity. Primary cam morphology likely develops during skeletal maturation as a normal physiological response to load. Physeal stress during maturation (e.g. due to intense sporting activity) is associated with epiphyseal hypertrophy and extension along the anterosuperior femoral neck with a dose-response relationship—the salient mechanism of primary cam morphology development [5,60]. Two aspects relevant to future research on primary cam morphology are important: causal reasoning and statistical heterogeneity. Grappling with the ocean of heterogenous 'risk factor' systematic review data, I include some of my explorative work in these two areas in the sections below. These could be further explored as post-doctoral work.

2.5.3.1 Causal reasoning: aetiology of primary cam morphology

To date, no studies in the primary cam morphology research field have used an intervention to modify exposure (load) with the intent of modifying outcome (e.g. incidence and/or size of primary cam morphology). There are two approaches to the study of primary cam morphology development/aetiology: causation or prognosis. Causation studies are concerned with the mechanisms that cause primary cam morphology; prognosis studies investigate factors that might predict the development of primary cam morphology or its natural history (including hip disease). A pre-requisite for both causation and prognosis studies is to identify associations between exposures and outcomes [187]. These associations must be causal in aetiology, whereas any association, causal or non-causal, might predict the development of primary cam morphology (prognosis) [187].

How should exposure variables for primary cam morphology be chosen? The slogan 'no causation without manipulation', coined by pioneers on causation research methods Paul Holland and Donald Rubin [188], applies to primary cam morphology too. This slogan implies that it is not possible to meaningfully talk about the causal effects (for primary cam morphology) unless 'it is clear how that variable could be manipulated' [187]. Load is the key causal factor for primary cam morphology development. When planning causation research, directed acyclic graphs (DAGs) could be useful.

Consisting of measured and unmeasured variables and arrows, DAGs integrate statistical and subject-matter information. They are useful to illustrate causal structures: arrows are interpreted as causal effects of one variable on another. DAGs are queried to produce mathematical expressions for causal effects based on observed distributions or to 'suggest additional observation or auxiliary experiments from which the desired inferences can be obtained' [189]. Intense sporting activity (load) during youth is associated with the development of cam morphology (Figure 2.13).

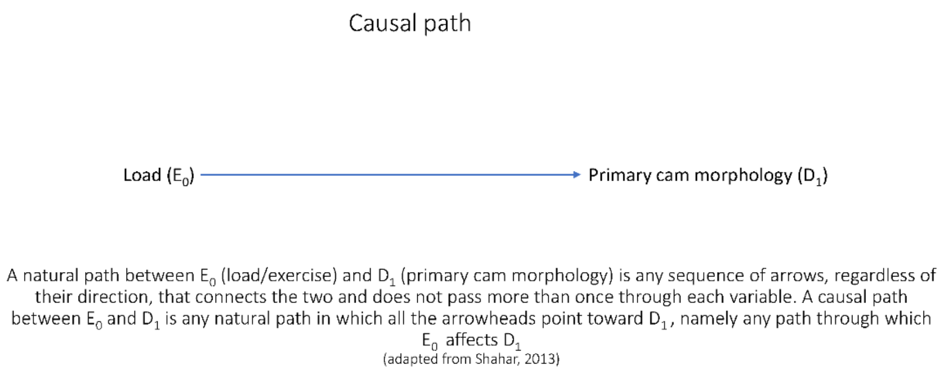

Figure 2.13. The natural path between load and primary cam morphology (adapted from [190].)

However, for load to cause primary cam morphology, an open femoral capital physis is key; primary cam morphology formation likely happens secondary to epiphyseal hypertrophy and extension along the anterosuperior femoral neck [60]. I illustrate in Figure 2.14 how DAGs could be used to hypothesise on the cause(s) of primary cam morphology.

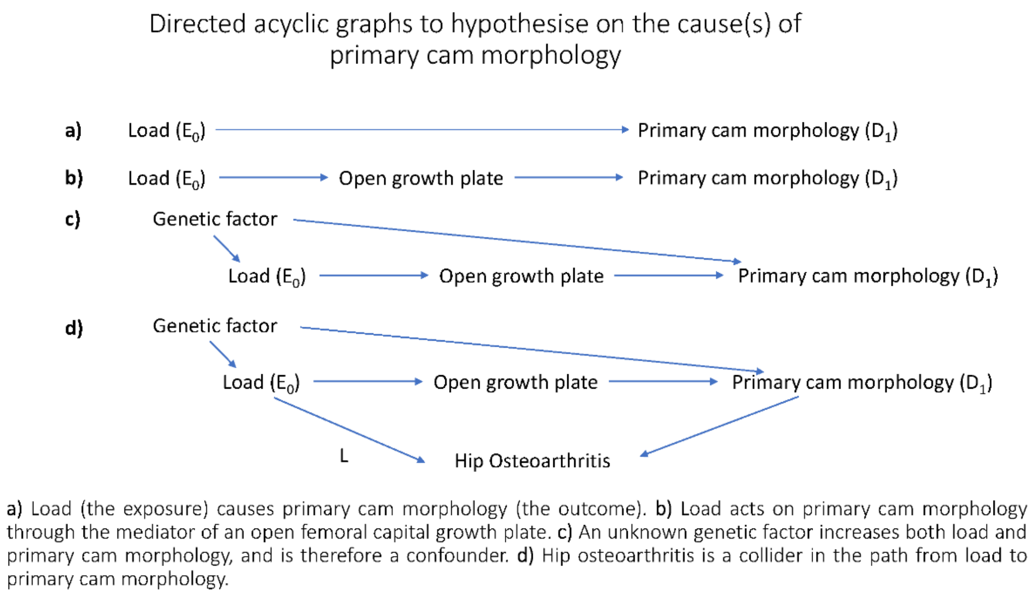

Figure 2.14. Directed acyclic graphs (DAGs) to hypothesise on the cause(s) of primary cam morphology

In sum, DAGs integrate statistical and subject-matter information and could be useful when studying primary cam morphology causation.

2.5.3.2 Statistical heterogeneity

Studies investigating risk factors for primary cam morphology in the systematic review that informed this concept analysis were all observational. When evaluating the results of observational studies, it is important to judge whether the observed association between the exposure or possible risk factor and the morphology/ disease is causal or induced by a systematic error, a random error, or influenced by a confounding variable [191]. This judgment can be difficult thus creating a challenge to the application of formal meta-analytic methods. Careful examining of the possible sources of heterogeneity among the results of the observational studies may therefore be of more value [192].

Statistical heterogeneity in meta-analysis refers to the variation other than that which arises by chance and may reflect methodological or clinical differences among studies [193]. Potential sources of clinical and methodological heterogeneity should be considered when registering and publishing the review protocol [59,194]. Possible subgroup analyses should be pre-specified rather than trying to explain statistical heterogeneity after the analysis. Sources of bias and heterogeneity can then be hypothesized prior to analysis and subsequently confirmed [195]. This was done in our PROSPERO-registered protocol [14].

There are several reasons for clinical and methodological heterogeneity in cam morphology and FAI syndrome research resulting in statistical meta-analysis heterogeneity. These reasons are summarized in Table 2.6.

Table 2.6. Reasons for clinical and methodological heterogeneity in primary cam morphology and FAI research

Clinical diversity (clinical heterogeneity)
• Research participant characteristics (differences in age, gender, ethnicity) • Difference in exposure (type of sport; duration of sport exposure - total or weekly) • Inaccuracies in assessment of exposure (recall bias in case control studies) • The same person should interview/assess cases and controls, using the same interview/assessment techniques, at the same place. If possible interviewers/assessors should not know the disease status of the participants • Use the same data sources for cases and controls

- Inconsistency in the diagnostic criteria of cam morphology and FAI
- Measurement errors of alpha angles
- Difference in accuracy – x-ray vs MRI
- Baseline disease severity

Methodological diversity (methodological heterogeneity)

- High risk of bias (e.g. in patient selection/ publication bias)
- Lack of quality trial design (e.g. no randomization; low number of prospective studies)
- Small sample sizes
- Accuracy of outcome measures
- Statistical analysis: didn't state the overall strategy for analysing as intended; no clear distinction between planned and ad hoc analysis given in paper; is the analysis adjusted for relevant confounders?
- Are confounders mentioned and how are they defined as being relevant? How was adjusting done – e.g. by matching, multivariate modelling or stratification? Confidence intervals given for all estimations; exact tests in small numbers

Ideally, all studies included in a systematic review and meta-analysis will have used the same methods. However, in practice, and in this review, studies will differ in many ways with potentially greater sources of heterogeneity existing for observational than for randomized controlled trials (RCTs) [195]. Some variation arises by chance alone, as no study is ever large enough to fully eliminate random error. In general, meta-analysis should only be considered when a group of studies is sufficiently homogenous in terms of participants, interventions/ exposure, methods of measurement and outcome measures to provide a meaningful summary [196]. However, determining what is 'sufficiently homogenous' can be difficult and subjective.

The decision to calculate a summary estimate in a meta-analysis should be based on clinical judgment, the number of studies and the degree of variation between studies [197]. Variation between studies is not necessarily a weakness of a systematic review. Results are probably robust and transferable if consistent across many studies, despite variation in populations and methodology. Any variability among the studies in a systematic review is termed heterogeneity. If heterogeneity exists between studies, however, we must be wary of generalizing the results of the meta-analysis [198].

Is heterogeneity necessarily bad and should this be a reason not to do a meta-analysis in observational research like primary cam morphology risk factors? Meta-analysis may help us to understand and quantify the sources of heterogeneity between the results of studies. Following further training (in statistics and meta-analysis, including Stata), I did explorative meta-analyses on primary cam morphology risk factors and created forest plots [199–201].

In the three forest plots and their corresponding Stata code presented here (Figures 2.15, 2.16, and 2.17), I illustrate six areas of possible statistical heterogeneity and how a forest plot, including sensitivity analysis, could help to explain the heterogeneity.

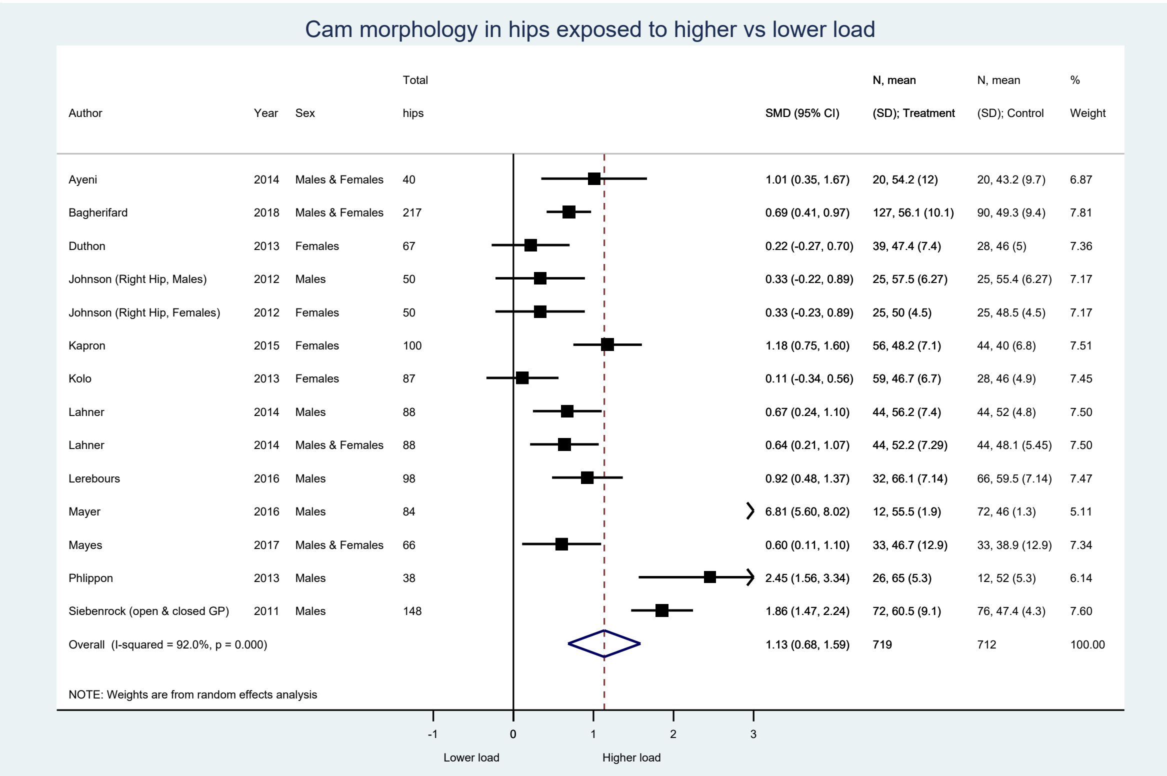

Figure 2.15. Forest plot displaying a random-effects meta-analysis of the effect of load on cam morphology (standardised mean difference (SMD) of alpha angle). (Without the Dickenson et al study on trail vs front hip; Johnson LEFT hip in males; Johnson LEFT hip in females). I include the Stata code below.

```
STATA code:
metan total_hips_exp expaa expaa_sd total_hips_con conaa conaa_sd, classic counts ///
lcols(author year sex total_hips) textsize(160) title("Cam morphology in hips exposed to higher vs lower load", size(small))
favours(Lower load#Higher load) force ///
cohen random xlabel(-1,0,1,2,3) astext(70), if covidence_id != 888 & covidence_id != 13902 & covidence_id != 13904
```

The forest plots provide a summary estimate (SMD and representing 95% CI) of the effect of load on primary cam morphology. The outcome variable is continuous, here reported as a mean alpha angle. I stratified results by sex (Figures 2.16 and 2.17) and used I^2 to quantify heterogeneity. I^2 measures the percentage of total variability across studies due to between-study heterogeneity rather than chance [202]. Several factors could explain the high, and different, I^2-values (92%, p=0.0000 in Figure 2.15; 90.7%, p=0.000 in Figure 2.16; and 0%, p=0.802 for studies that investigated males and females together in Figures 2.16 and 2.17). First, studies involved heterogenous populations—different sports and sex/ genders. Some authors compared 'sport' vs 'no sport', others 'sport' vs 'ballet', and others 'sport' vs 'sport'. Second, alpha angles were measured using different types of imaging (MR imaging, CT and radiographs) and in different locations (o'clock positions) around the femoral head-neck junction.

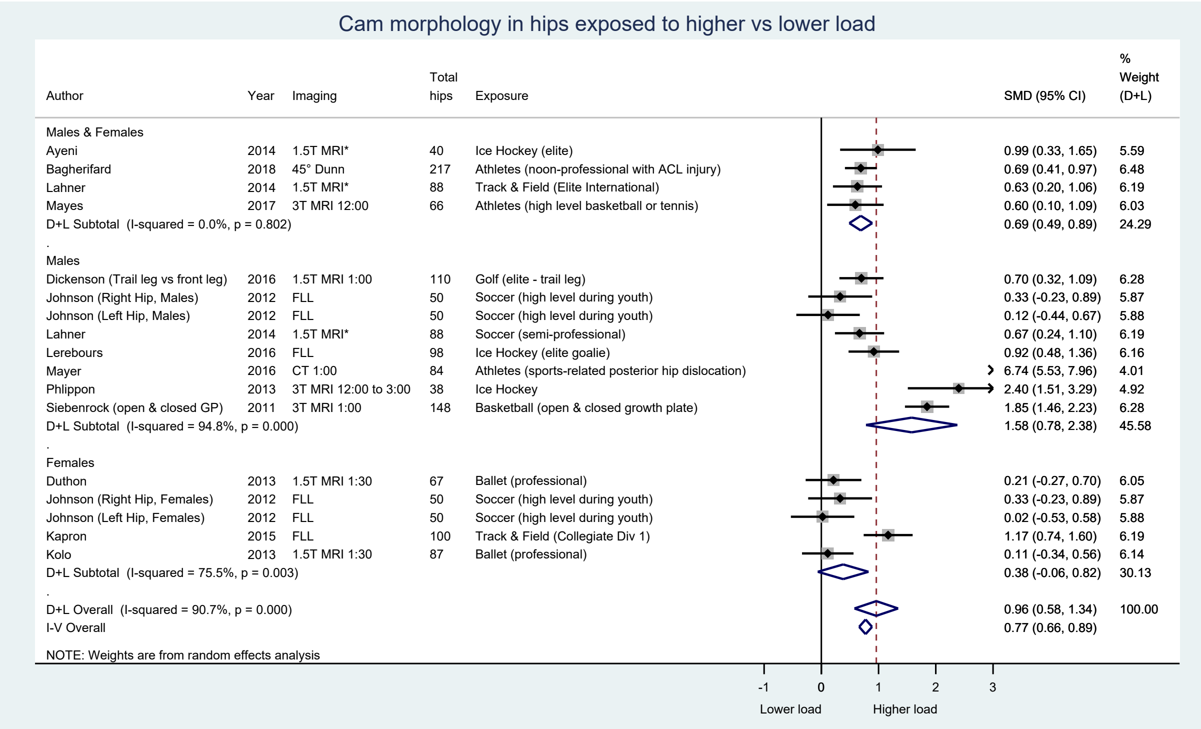

Figure 2.16. Forest plot displaying a random-effects meta-analysis of the effect of load on primary cam morphology (standardised mean difference (SMD) of alpha angle). Results are stratified by gender, and the inverse-variance weighted fixed-effects estimate is also displayed. I include the Stata code below.

```
STATA code:
metan total_hips_exp expaa expaa_sd total_hips_con conaa conaa_sd, ///
lcols(author year imaging total_hips exposure_group) textsize(140) title("Cam morphology in hips exposed to higher vs lower load", size(small)) ///
hedges random second(fixed) nosecsub xlabel(-1,0,1,2,3) xsize(11) ysize(7) ///
astext(80) favours(Lower load#Higher load) force by(sex)
```

Third, Philippon *et al* (2013) reported the range of mean alpha angles, and not standard deviation (SD) [137]. I mistakenly used range (Figures 2.15 and 2.16) and corrected this mistake (Figure 2.17) after calculating and using estimated SD (0.25 of typical range of data values) ([203], p176). Fourth, Mayer *et al* (2016) reported the IQR of median alpha angles. I made the same mistake and included median, IQR values for Mayer *et al* in the first two forest plots (Figures 2.15 and 2.16). I corrected this mistake in the third forest plot (Figure 2.17) after assuming median equals mean and calculating SD ([203], p176).

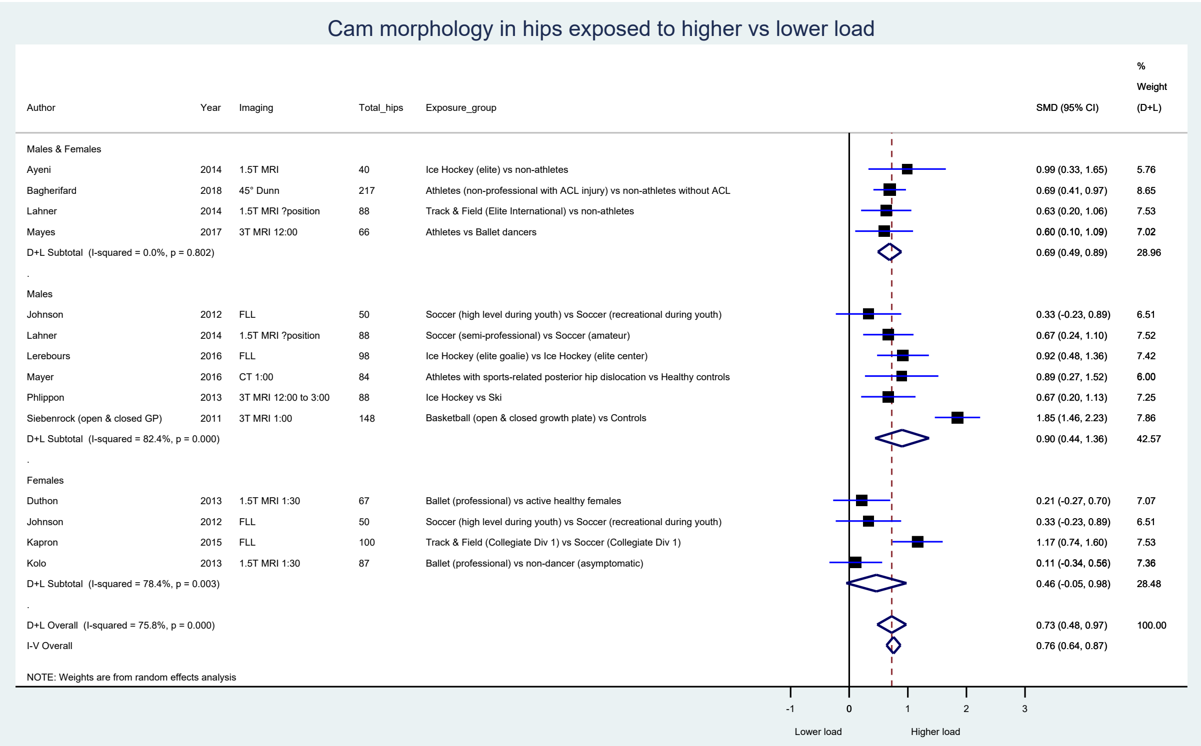

Figure 2.17. Forest plot displaying a random-effects meta-analysis of the effect of load on cam morphology (standardised mean difference (SMD) of alpha angle). Results are stratified by sex, and the inverse-variance weighted fixed-effects estimate is also displayed. (Without the Dickenson et al study on trail vs front hip; Johnson LEFT hip in males; Johnson LEFT hip in females). I include the STATA code used below.

STATA code:

```
metan total_hips_exp expaa expaa_sd total_hips_con conaa conaa_sd, ///
lcols(author year imaging total_hips exposure_group) textsize(140) title("Cam morphology in hips exposed to higher vs lower load", size(small)) ///
hedges random second(fixed) nosecsub xlabel(-1,0,1,2,3) xsize(11) ysize(7) ///
astext(80) favours(Lower load#Higher load) force by(sex), if covidence_id != 888 & covidence_id != 13902 & covidence_id != 13904
```

Fifth, authors reported mean alpha angles in these studies 'per hip'. However, Johnson *et al* (2012) [104] reported left and right hips in the same individual, and Dickenson *et al* (2016) [86] lead and trail legs in the same individual golfers (Figure 2.16). In a sensitivity analysis, I excluded these two studies (Figure 2.17). Finally, and not reported here, different study types are pooled in one meta-analysis: cross sectional comparative and case-control.

There are many reasons for considering not doing meta-analysis in observational studies [192,195], including: (1) potential misleading calculation of a single summary estimate of the effect of exposure (due to potential biases in the original studies, e.g. selection and recall bias in case-control studies—a potentially significant problem in the primary cam morphology field); (2) significant heterogeneity caused by the effects of confounding factors. These factors may be related to both exposure and the disease/ morphology being studied and is the most important threat to the validity of results from cohort studies; (3) diversity of study designs and populations in epidemiology; and (4) methodological issues related to meta-analysis, such as publication bias. Both the diversity of study designs and populations, and methodological issues related to meta-analysis could have an impact on heterogeneity when combining the results of observational studies. These potential sources of heterogeneity and bias all require consideration when determining whether to conduct a meta-analysis of data from observational studies.

In sum, I have illustrated that heterogeneity should not necessarily be a reason not to do a meta-analysis in observational research like primary cam morphology risk factors. Meta-analysis may help us to understand and quantify the sources of heterogeneity between the results of studies. Careful examining of the possible sources of heterogeneity among the results of observational studies—although potentially complicated as demonstrated in the examples above—could be of value when researchers and clinicians need to judge whether the observed association between an exposure (or possible risk factor) and outcome (e.g. morphology or disease) is causal or induced by a systematic error, a random error, or influenced by a confounding variable.

2.5.4 Primary cam morphology consequences

A possible consequence of primary cam morphology could be motion-dependant abutment against the acetabular rim. In large prospective population-based studies, fewer than 11% of hips with cam morphology developed features of end-stage osteoarthritis [35,175]. Furthermore, in two smaller prospective studies, >84% of hips defined as having cam morphology did not become painful [2,176]. A combination of risk factors, including primary cam morphology, may cause hip disease in some individuals, including: (1) tissue damage (e.g. labral and cartilage); (2) femoroacetabular impingement syndrome, and (3) early hip joint osteoarthritis [49].

Cam morphology is more prevalent in adult athlete cohorts than in non-athlete cohorts [204], and a cause of early hip degeneration [5]. This might explain the greater rates of hip OA in retired football players than in controls [205–207]. The association between cam morphology and hip OA varied in retrospective and cross-sectional studies with odds ratios (OR) from 2.2 (95% CI 1.7 to 2.8) to 20.6 (95% CI 3.4 to 34.8) [99,208,209]. Baseline cam morphology in one study was strongly associated with total hip arthroplasty (adjusted OR of 1.5 for every degree increase in α angle; P=0.001) [133]. A moderate or severe 'cam abnormality' at baseline was associated with 4-5 times the odds of end-stage hip OA within 5 years in a large prospective cohort study [12]. Cam morphology is important and confers a substantially increased causal risk of hip OA [5]. Prospective research is needed to clarify aetiological- and potential prognostic factors (e.g. the type or volume of physical load) [49].

2.5.5 Concept analysis

I introduced Walker and Avant's 8-step concept analysis method to sports medicine as a rigorous exercise to refine and clarify ambiguous or vague concepts in theory [1]. A strong concept clearly names the thing to which it refers (taxonomy and terminology), is well defined (provides structure) and enlightens theory (explains function). The result of concept analysis is uniform terminology and a more accurate definition that increases the validity of the construct at that point in time. However, concepts can evolve over time—what is 'true' of a concept like primary cam morphology today may be proven incomplete or wrong in the future [43].

2.5.6 Update searches (systematic review)

The systematic review applied to this concept analysis is ongoing. Sections have been published and presented at conferences. Following a January 2021 update search, we (HPD and CLA) screened 72 additional full-text publications and included 38 (Table 2.7). Reasons for additional exclusions (*n*=34) were: case series (*n*=12); cam morphology not outcome (*n*=3); risk factors not defined (*n*=1); wrong population (*n*=13); editorial paper (*n*=1); cadaveric/non-human studies (*n*=2); duplicate (*n*=2).

Table 2.7. Included publications following the January 2021 update search

Study	Study type	Risk factor
Abdelazeem 2020 [210]	Cross-sectional	Demographic: Race/ ethnicity – Egyptian
Abrahamson 2019 [211]	Prospective cohort (2 years)	Load: Sport – elite ski; hip range of motion
Abrahamson 2020 [212]	Prospective cohort (5 years)	Load: Sport – elite ski
Akgun 2019 [213]	Cross-sectional	Other pathology – osteitis pubis
Aminoff 2020 [214]	Cross-sectional comparative	Sport – Alpine and Mogul ski
Bagwell 2019 [215]	Case-control	Other – biomechanics, kinematics and kinetic factors
Beiri 2019 [216]	Cross-sectional	Demographic: Race/ ethnicity – Swiss; Other – cartilage and bone factors (subchondral bone thickness)
Biernacki 2020 [173]	Cross-sectional	Demographic: Sex/ gender – female Load: Ballet
Carter 2020 [217]	Cross-sectional	Demographic: Sex/ gender – female; Load: Sport – professional ice hockey
Catelli 2019 [218]	Case-control (prospective, matched)	Other: hip range of motion; muscle strength
Catelli 2018 [219]	Case-control	Other: lower limb biomechanics, kinematics; muscle strength
Catelli 2020 [220]	Case-control	Other: biomechanics, kinematics and kinetics
Catelli 2019 [221]	Case-control	Other: biomechanics, kinematics and kinetics
Diamond 2019 [222]	Case-control	Other: biomechanics, kinematics and kinetics; muscle activation patterns
Dickenson 2019 [223]	Cross-sectional	Demographic: race/ ethnicity – British (general population sample)
Edwards 2020 [224]	Cross-sectional	Demographic: race/ethnicity and sex
Fader 2018 [225]	Case-control	Other: biomechanics, kinematics and kinetics
Falotico 2019 [226]	Cross-sectional comparative	Load: Sport – professional soccer

Fischer 2018 [227]	Cross-sectional	Demographic: race/ ethnicity – German; sex/ gender; side (left/ right)
Hancke 2021 [228]	Prospective cohort	Load: Sport – ice hockey
Hasegawa 2020 [229]	Cross-sectional	Demographic: race/ ethnicity – Japanese;
Hodgdon 2020 [230]	Case-control	Other: cartilage and bone factors
Kopec 2020 [231]	Cross-sectional	Demographic: sex/ gender; race/ ethnicity – Canadian
Kopec 2019 [232]	Cross-sectional	Demographic: side (left/ right); Other: other bony morphologies; hip-related patient-reported outcomes (HAGOS)
Langner 2020 [233]	Cross-sectional	Load: Sport – aquatic athletes
Mahan 2020 [234]	Cross-sectional	Demographic: sex/ gender (women cohort); Other: hip range of motion;
Marquez 2019 [235]	Cross-sectional	Load: Sport – elite soccer; Other: other pathology (chondral, labral)
Ng 2018 [236]	Case-control	Other: biomechanics, kinematics and kinetics
Pachore 2018 [237]	Cross-sectional	Demographic: sex/ gender; race/ ethnicity – Indian
Polat 2019 [238]	Cross-sectional	Load: Sport – paediatric male soccer; side (left/ right) Other: other bony morphologies;
Rodriguez 2019 [239]	Cross-sectional	Demographic: sex/ gender; Load: Ballet; Other: hip and pelvis range of motion; other pathology (labral tear)
Samaan 2020 [240]	Case-control	Other: biomechanics, kinematics and kinetics
Savage 2021 [241]	Cross-sectional comparative	Other: biomechanics, kinematics and kinetics
Sveen 2019 [242]	Cross-sectional comparative	Demographic: side (left/ right); open vs closed physes; Load: Sport – cross country ski; Other: hip and pelvis range of motion;
Van Klij 2020 [243]	Prospective cohort	Demographic: growth plate extension; Other: hip and pelvis range of motion; other bony morphologies
Van Klij 2020 [244]	Cross-sectional	Load: Sport – football; Other: hip range of motion
Van Klij 2019 [245]	Prospective cohort	Demographic: age; growth plate status
Varada 2020 [246]	Case-control	Demographic: age; sex/ gender; Load: Sport – history of sports participation; Other: other pathology (significant association with adductor tendinosis and osteitis pubis)

These articles are not yet included in the ongoing risk factor systematic review. This was a pragmatic decision taken in consultation with my DPhil supervisors and the systematic review team. As described earlier, I redirected the focus of my DPhil following the early results of this systematic review. The decision to postpone work on the systematic review was amplified by

Covid-19-related personal and research team challenges, including illness, family trauma and several key research team members relocating countries to new work environments. The plan is to re-assemble the systematic review research team (and invite new members to join), to perform a formal risk of bias assessment and data extraction of the 38 included publications following the January 2021 search, and abstract and full-text screen of another update search performed in February 2023[12].

2.5.7 Strengths and limitations

This concept analysis was based on 111 publications identified for a systematic review of risk factors for primary cam morphology—a large and appropriate dataset for concept analysis. The quality of studies—especially risk factor studies—for a specific health condition relies on consistent terminology and a clear operational definition for the relevant condition. Introducing primary cam morphology, this concept analysis clarified and refined a taxonomy of cam morphology types, illuminated confusing terminology, and proposed conceptual attributes of primary cam morphology in a new definition. These outcomes, when agreed upon and implemented, could help patients, researchers, and clinicians to communicate better, develop strong theory, and higher quality research on primary cam morphology and its natural history.

Concept analysis, although a structured and systematic analysis method, is time-dependent and based on current knowledge and insights that might change. It has been described as a rigorous intellectual exercise that requires the author to interpret the evidence, integrate their opinions, draw conclusions, and make recommendations—amplified in this empirical study by a systematic review approach. Concept analysis outcomes depend on the dataset used. Although the systematic review added rigour, it is possible that a different dataset (e.g. including more papers specific to cam morphology imaging) might influence some of the outcomes. Several elements of the concept of primary cam morphology, including taxonomy

[12] See section 7.5, p259: Implications and future work.

and operational definition, remain contested. The findings of this concept analysis could serve as an opportunity for experts, including patient-partner experts, to work towards agreement on these.

My decision to exclude certain types of publications brings limitations. The systematic review team only included human studies. Excluding all publications reporting animal and cadaver studies from the systematic review applied to this concept analysis might mean that important publications were not available for the analysis. Especially publications exploring causality. Two studies by Jónasson et al (2014 and 2015) [247,248], for example, explored the role of loading patterns and the porcine proximal femoral epiphyseal plate to propose a possible cause of the development of ‘cam deformity in young athletes’ [248]. In a novel immature rabbit model study, a surgically created epiphyseal injury of the medial femoral head led to growth arrest at the proximal femoral physis. This resulted in ‘femoral head-neck deformity similar to human FAI’ [249].

Morris et al (2021), examining 962 cadaveric hips, concluded that subtle slipped capital femoral epiphysis (SCFE) was not associated with ‘idiopathic cam morphology’ [250]. This is an important finding signalling that more research is needed to explain primary cam morphology aetiology. These examples illustrate the importance of animal and cadaver studies to explain primary cam morphology development—as are case studies and case series.

We excluded case reports, case series and incidental case series from this systematic review. An excluded case report by Cho et al (2016) described a patient with ‘cam-type femoroacetabular impingement’ with ‘delayed epiphyseal closure at the sight of the cam lesion’ as a possible aetiology for ‘primary cam-type deformity’ [251]. We excluded a publication by Bixby et al (2013) as an incidental case series [252]. This study provided important plane- and sex-specific imaging reference values for cam morphology (α-angle, femoral head-neck offset), and epiphyseal extension in asymptomatic adolescent patients. The authors included 132 asymptomatic adolescent patients who underwent pelvic multidetector computed tomography (MDCT) scans for abdominal pain to define the morphological characteristics of the femoral head-neck junction.

Systematic reviews to evaluate causation [253,254], prediction [255,256], and prognosis [56,257] are distinctly different. The scope for a risk factor systematic review could be overwhelming and its quality compromised when the research question is vague or too broad. When systematic reviewers cast a wide net—when not explicit about the type of risk factor they are interested in (causal, predictive, or prognostic)—they and their systematic review could suffer.

2.6 Conclusion and chapter summary

In this chapter, presenting a first concept analysis of primary cam morphology, I propose five defining attributes—tissue type, size, site, shape, and ownership—in a new conceptual and operational definition. I introduce and clarify primary cam morphology as a distinct concept. It has a unique aetiology that is likely related to a normal physiological skeletal response to physical loading patterns during maturation and important to be distinguished from secondary cam morphology. Primary cam morphology is an important 'bump' in some athletes, associated with the burden of future hip disease, particularly FAI syndrome and osteoarthritis. However, several elements of the concept of primary cam morphology remain unclear and contested. Proposing consistent terminology and a new conceptual definition and a taxonomy of types, this chapter sets the stage for addressing these areas of confusion. An important next step is a consensus exercise on the proposed new taxonomy, terminology, and definition that better reflect the primary cam morphology landscape—a bog-standard bump in most athletic hips, and a possible hip disease burden in an unfortunate few.

I describe the overall methodology and methods for the programme of research presented in this thesis in chapter 3. Study-specific methodology and methods are described in chapter 4 (for the Oxford Consensus Study) and chapter 6 (for the qualitative interview study of stakeholders’ perspectives on research quality).

Chapter three

Methodology and methods

Chapter 3: Methodology and methods

3.1 Outline of the chapter

In chapter two, I presented a primary cam morphology literature review using Walker and Avant's concept analysis method informed by an ongoing systematic review. I described how this systematic review approach to synthesising evidence on the morphology's risk factors had unexpected outcomes. It illuminated high overall risk of bias in the field and exposed more urgent gaps to pursue. Existing research on primary cam morphology is mired in confusion partly because researchers lacked clarity on conceptual and operational definitions of the morphology, do not apply a consistent taxonomy of subtypes, and used confusing terminology [1]. Included in this gap is no agreement on a prioritised research agenda for the field. These represented more serious gaps compromising the nature and quality of knowledge 'produced'. My planned cohort study to explore load and the development of primary cam morphology would have been wasted research. I therefore realigned my research focus to a programme that mobilised a community of athletes, patients, clinicians, and researchers to co-produce knowledge on primary cam morphology and its consequences with a view to transforming both research and practice.

In this chapter, I review pragmatist-informed co-production—the philosophical paradigm underpinning my mixed methods approach to the programme of research presented in this thesis.

3.2 Theoretical approach

I use the term 'methodology' to refer to the abstract theoretical assumptions and principles that underpin a particular research approach [258], and frame the main research question of this programme of research—*How can research and clinical practice on primary cam morphology and its natural history be transformed in a more pragmatist and patient-centred direction?* I use the term ‘methods’ to describe the practical means and the tools for collecting and analysing the data: ‘…methods are the tools of the trade. Methodology is the philosophy that guides how and when you deploy those tools’ ([259], p27).

My draft methodological plan in 2015 was firmly situated in the positivist paradigm [260], involving a programme of empirical research aiming to investigate primary cam morphology risk factors. However, as I have indicated above, the results of my systematic review-informed concept analysis changed that. In what follows, I discuss how pragmatism as the philosophical paradigm, along with theories of knowledge co-production and transformation, and my own positionality, framed the mixed methods approach to the programme of research presented in this thesis.

3.2.1 Pragmatism

Paradigms have been defined as ‘world views that signal distinctive ontological (view of reality), epistemological (view of knowing and relationship between knower and to-be known), methodological (view of inquiry), and axiological (view of what is valuable) positions’ [261]. Guba and Lincoln (1998, p200) clarify a paradigm as a world view that defines for its holders ‘…the nature of the “world”, the individual’s place in it, and the range of possible relationships to that world and its parts…’ [262]. Paradigms, according to Morgan (2007, p49) are ‘systems of beliefs and practices that influence how researchers select both the questions they study and methods that they use to study them’ [263]. Healthcare research tends to be positioned in one of two major paradigms—‘positivist’ and ‘interpretive’—each of which assumes different things about the nature of reality and how that reality should be studied [264]. I explain these terms below.

Whilst my ideas were firmly rooted in a positivist paradigm at the start of this DPhil, I gradually came to adopt a more pluralist approach to evidence, broadly aligned with the philosophical approach known as pragmatism (explained below). Within this problem-focused orientation I embraced 'positivist' research designs (such as cohort studies and clinical trials), but I also came to value a wide range of other designs which are more interpretivist in their assumptions. The programme of research presented in the next three chapters illuminates this journey.

This is not a thesis on the philosophy of pragmatism, but I wish to briefly highlight the distinction between the term 'pragmatic' used in the lay sense (roughly, common-sense, and problem-orientated) and pragmatism as a *philosophy*. Whereas positivists assume, broadly speaking, that there is a universal truth 'out there' which scientists may be able to ascertain, pragmatists are more interested in *working truths*, defined as the best way of meeting the future that current science can provide. For pragmatists, truth is in some sense provisional (i.e. what we assume to be 'true' may change in the light of new data). To progressively refine understanding of a problem, the pragmatist-informed researcher may draw on a wide range of data and evidence, some of which makes positivist assumptions and some of which is sited in a more interpretivist tradition.

A key tenet of pragmatism is that all evidence should be brought to the table and all should deliberate on its significance and findings. This is important for research on primary cam morphology and its natural history. Pragmatists hold that truth is that which is 'indefeasible'—that is, the 'truth' that guides our approach to a concrete problem consists of both research evidence (of various kinds) and also other (non-research) evidence, which cannot be disproved or dismissed as collective deliberation occurs.

This research applies the pragmatic philosophical paradigm as a dynamic and changing guide. I acknowledge the potential of paradigms to marginalise other beliefs or force researchers to buy into a set of beliefs and agree with Maxwell (2011) that 'mutually productive dialogue' brings us together [265]. Although primary cam morphology is a concept with five specific and measurable conceptual attributes—tissue type, shape, size, location, and ownership—this morphology is also a social construct [1]. Its fifth attribute, 'ownership', not only informs prevalence and incidence of the morphology and its consequences, but also the 'lived-with' experiences and perspectives. Research on primary cam morphology and its consequences, and by implication communication and clinical practice, is therefore more than operationalising the morphology on imaging, or studying factors predicting its aetiology or prognosis. It should also prioritise research on experiences and perspectives of living with the morphology and its hip disease consequences, and managing and researching it *with* athletes and patients. I strongly believe such a journey of inquiry should embrace what Green (2007) calls a 'mixed methods way of thinking' based on

> a stance or an orientation toward social research and evaluation that is rooted in a multiplistic mental model and that actively invites readers to participate in dialogue… multiple ways of seeing and hearing, multiple ways of making sense of the social world, and multiple standpoints on what is important and to be valued and cherished ([266], p20).

Although primary cam morphology and its natural history is centre stage in the programme of research presented in this thesis, my research is not about a piece of anatomy only; crucially, people develop and live with the morphology, and do research about it, in the social world. Agreeing with Greene's (2007) 'multiple ways of seeing' perspective on mixed methods research, I argue that research on primary cam morphology should co-create knowledge based on dialogue between diverse perspectives to deepen, rather than simply extend or triangulate, new understandings [266]. My chosen approach rejects the way knowledge production is assumed to occur in a positivist paradigm through 'singular methods and mono-disciplinary approaches that refuse to account for alternative rationalities, multiple knowledges, or complexities inherent on the inquiry process' ([28] p8). This monological research, according to Kincheloe (as cited by Rogers 2015, p9), has (at least) two problems: it overlooks dynamics of power, and it puts constraints around knowledge production [28].

Research to date on primary cam morphology has been sited predominantly in the positivist paradigm and hence likely compromised by imbalances in power between different staff groups and also patients. To address this deficiency, and reflecting my pragmatist stance, I have sought to strengthen my methodology by applying knowledge co-production and transformation, both key elements of a more inclusive approach to research.

3.2.2 Knowledge co-production (through 'engaged scholarship' in a 'learning community' operating in a 'field of scientific capital')

As described earlier, primary cam morphology is not only a scientific concept with objective attributes, but it also has an important subjective component; it is acquired, owned, lived with and experienced. This subjectivity frames inclusive knowledge co-production in 'engaged scholarship' and 'learning communities' [267], involving athletes, patients, clinicians and researchers. A strategic objective of the programme of research presented in this thesis is to surface and discuss competing perspectives on primary cam morphology, for example. Three philosophical questions are therefore relevant: what is knowledge? why is knowledge important? and, how is knowledge co-produced and exchanged?

First, *what* is knowledge? At its core, distinguishing it from data and information, knowledge is 'judgement of the significance of events or items, which comes from a particular context and/or theory' [268]. My approach to knowledge in this research takes the perspective that knowledge is collectively built and shared among people in particular communities (such as sports coaches, university researchers and athletes). Knowledge, as 'the capacity to exercise judgement', requires the ability to draw distinctions, and a location within a domain of action that is collectively generated and sustained [268,269]. Therefore, knowledge of the significance of primary cam morphology and its consequences is grounded in context (e.g. a maturing football player in a well-known academy developing primary cam morphology as a consequence of playing football), and theory (e.g. what scientists at a university orthopaedic department know about the causal mechanisms and prognosis of primary cam morphology; and, importantly, how this knowledge is described and communicated to stakeholders). The shared knowledge and 'domains of action' relevant to primary cam morphology will be different in (say) a football academy and a university research lab, but there will be some overlap. My qualitative study on research quality, presented in chapter 6, will illuminate these domains of action more.

Second, *why* is knowledge important? Knowledge empowers individuals to exercise judgement within a particular context or 'domain of action' [269]. Football coaches acquire—and collectively refine—knowledge about how to manage athletes with this condition; radiologists acquire and refine knowledge about how to interpret radiographs and scans. Central to this process of improving one's domain knowledge is completing a period of socialisation to allow practitioners to appreciate and consider contextual subtleties when making distinctions [269]. Primary cam morphology knowledge is embedded in these various domains of action; it cannot be abstracted from these domains. The football coach's knowledge emerges from, and is operationalised within, the practice of football coaching; the radiologist's knowledge is tied to the practice of visual imaging of the body. Central to a person's *knowledge* (the ability to exercise judgement) is *meaning*: What does a particular piece of data or evidence mean to this practitioner in this context? And given that meaning, how should he or she therefore act?

'Meanings' according to Pansiri (2009) citing Burnier (2005, pp501-502) are '…the definitions that individuals attach to the full range of objects (i.e. physical, social, cultural, political) that comprise their lifeworld' and 'emerge through social interaction with others and the self, and ultimately become the basis of human and collective action' [264]. One aspect of this perspective on meaning is how 'facts' are value-laden and different knowledge communities view different findings as more or less important, personally salient, reassuring, frightening and so on. The meaning of primary cam morphology and its consequences to the different stakeholders, is negotiated through their social interaction. The surgeon, for example, discovers through these interactions what is 'at stake' for the professional athlete who is told to skip a season.

Athletes, patients, clinicians, and researchers (and those close to them including parents, coaches, funders, policy makers etc) co-produce knowledge. The goal was not necessarily to reach a bland consensus on every aspect of the topic, but to create a rich and vibrant picture of the topic from multiple perspectives. Knowledge, including scientific knowledge, is not produced, debated, reported, acted upon, and revisited in a vacuum. This point is illustrated by an athlete-patient research participant in the qualitative study on research quality (chapter 6). She describes how her knowledge and understanding of primary cam morphology and femoroacetabular impingement (FAI) syndrome has been framed by the somewhat alarming words and actions of an orthopaedic surgeon she consulted years ago: '…it really just led me down that spiral of catastrophising' (Participant 8, page 203).

Third, *how* is knowledge co-produced? Knowledge co-production is highly dependent on context; it requires trust, authentic power sharing, and respect for the different forms of stakeholders' expertise, and an approach to funding that supports the complex partnerships necessary for co-production [270]. Redman *et al* (2021, p1) defined co-production as a

> collaborative model of research that includes stakeholders such as patients, the public, donors, clinicians, service providers, and policy makers. It is a sharing of power, with stakeholders and researchers working together to develop the agenda, design and implement the research, and interpret, disseminate, and implement the findings [270].

Gibbons *et al* (1994, pp4-8) referred to this collaborative approach as 'Mode 2 knowledge production' [271]. Mode 2 knowledge production is (1) produced in the context of its application; (2) shaped by a dynamic transdisciplinary approach to consensus; (3) diverse and heterogenous with a flexible approach to 'less firmly institutionalised research groups'; (4) permeated by social accountability with 'sensitivity to the impact of the research built in from the start' by reflexive participants; (5) novel in its approach to quality control 'determined by a wider set of criteria which reflects the broadening social composition of the review system'

[271]. In this research, I suggest that Mode 2 knowledge co-production is key to move the primary cam morphology research field forward. These attributes are contrasted with Mode 1 knowledge production in table 3.1 [272].

Table 3.1. Attributes of Mode 1 and Mode 2 knowledge production [272]

Mode 1	Mode 2
Academic context	Context of application
Disciplinarity	Transdisciplinary
Homogeneity	Heterogeneity
Autonomy	Reflexivity/ social accountability
Traditional quality control (peer review)	Novel quality control

Knowledge co-production therefore pivots on the relationship between theory and practice; specifically, how the gap between theory and practice is framed. Van de Ven and Johnson (2006) distinguish three broad ways of conceptualising the relationship between theory and practice [267]. The first formulates the gap as a knowledge transfer problem; in this view, practical knowledge is viewed as derived from research knowledge. The second views theory and practice as distinct forms of knowledge that provides complementary insights for understanding reality. The third view, and key to my research, holds that the theory-practice dialectic culminates in practice-based scientific knowledge co-produced by learning communities (e.g. patients, clinicians, researchers, coaches and so on). This happens through what Van de Ven has called 'engaged scholarship' and 'intellectual arbitrage' (Figure 3.1 - an infographic for primary cam morphology knowledge co-production based on Van de Ven and Johnson's co-production of knowledge (2006) [267]). The term 'communities of practice' was first used in 1991 by theorists Jean Lave and Etienne Wenger in the context of 'legitimate peripheral participation' [273].

Engaged scholarship implies relationships of negotiation and collaboration to co-produce knowledge that can both advance science and enlighten practice [267]. Intellectual arbitrage—a common objective of interdisciplinary research—is a dialectical form of inquiry where participants confront and grapple with divergent views and approaches to better understand a complex problem [267]. This approach is especially relevant to the Oxford Consensus Study, and specifically its interacting group process stage presented in chapters 4 and 5.

Figure 3.1. Primary cam morphology knowledge co-production through engaged scholarship and examples of stakeholder roles and the questions that matter to them – informed by Van de Ven and Johnson (2006) [267], and Boyer (1996) [274].

A strategic objective of the programme of research presented in this thesis is to inform inclusive co-production partnerships; partnerships focussed on relationships, sharing of power, and respecting and valuing the knowledge of everyone. Albeit a different community, this resonated with the National Institute of Health and Care Research's principles of co-production and how they align with the UNICEF[13] 'minimum standards for community engagement' (Figure 3.2) [275]. The key elements of this approach could inform a learning community relevant to the programme of research presented in this thesis. A community of (1) athletes/patients at risk of developing the morphology or living and competing with the hip disease consequences of the morphology; (2) parents and coaches of young athletes/patients; (3) clinicians co-managing with athletes/patients the clinical challenges of, for example, hip-related pain; and (4) researchers grappling with the pertinent questions of primary cam morphology and its natural history—ideally in partnership with athletes/patients, coaches, parents and clinicians.

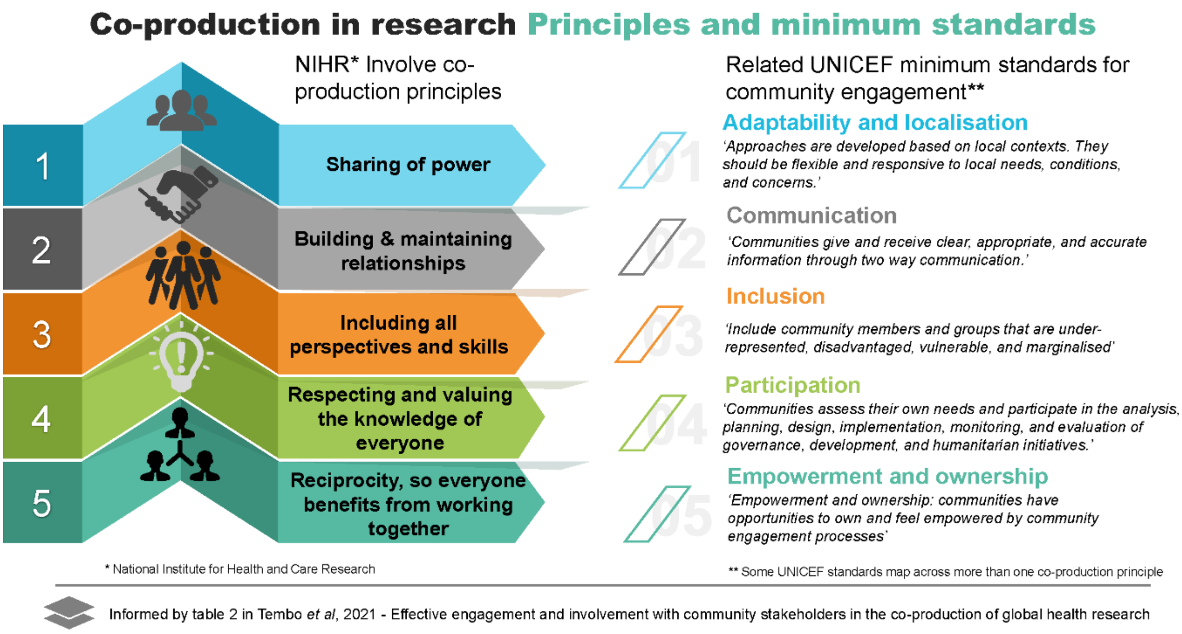

Figure 3.2. Principles and minimum standards of co-production in research adapted from Table 2 in Tembo *et al* [275]

[13] United Nations Children's Fund

Authentic sharing of power in knowledge co-production, including respect for each other's perspectives, is easier said than done. The power dynamics of knowledge and how knowledge is co-produced (or not) and acted upon in the field, are important aspects to consider. Illuminating how new knowledge is produced, and the importance of patients' experiential voices as 'valid and equal epistemes', Renedo (2017, p791) highlighted the importance of 'encounters with transformative potential' [276]. Patients and clinicians/researchers are equal partners in transformative encounters [277]. Their respect of each other's perspectives as different but equally legitimate types of knowledge result in novel, co-produced knowledge [276,277].

It is beyond the scope of this thesis to conduct an in-depth theoretical analysis of power, but my ideas have been influenced by Foucault's ideas on the close link between knowledge and power. Foucault believed that *epistemes* (i.e. the grammatological foundations of truth), are tied to the dominant power relationships—that is, the powerful are able, to some extent at least, to define what knowledge *is* and whose knowledge *counts* [28]. His views differ from positivist traditions which hold that truth will be discovered if researchers use the 'correct' methods to collect information and observe the world [28]. Powerful groups get to define the rules of knowledge production [28], which could include

> who is sanctioned to be a knowledge producer (e.g., experts, scientists, the able-bodied, men); what methods must be followed to produce truth (e.g., scientific, quantitative or qualitative); or, what institutions are sanctioned as knowledge producers (e.g., church, governments, schools, business). For Foucault, powerful groups maintain their knowledge construction legitimacy by continuously undermining alternative knowledges. In this way, discursive rules lead to the exclusion of the knowledges of those who are not in positions of power. As such, power shapes and constrains knowledge—limiting what can be said, and thought, in a given context (Rogers, 2015, p11) [28].

One cannot dissociate Foucault's powerful (knowledge) individuals and groups (agents), and their views on truth, from the field(s) they operate in and influence; in the context of my research, the orthopaedic and sports medicine field and hip-and-groin sub-field. Another author whose work has sensitised my approach is the sociologist Bourdieu, who defined science

(1991, p3) as 'a social field of forces, struggles, and relationships that is defined at every moment by the relations of power among the protagonists' [278]. My example earlier of the athlete-patient's clinical encounter with her orthopaedic surgeon[14] resonates: the surgeon acted, in that context, from a position of power. A field (equivalent to Tsoukas and Vladimiros's 'domains of action' mentioned earlier [268]), has been defined as 'an area or sphere of action, enquiry, or interest; a (wider or narrower) range of opportunities, or of objects, for activity or consideration; a theme, a subject' [279]. Fields are the fundamental sociological units of science [280].

A strategic objective of the programme of research presented in this thesis is, what has been termed, 'field building' [281] – that is, to develop the primary cam morphology clinical and research field so that it takes a more pragmatist and athlete/patient-centred direction. Field-building in complex topic areas such as hip-related pain requires an ecological approach where interdisciplinary and multi-stakeholder teams apply systems thinking to 'produce sufficient collective high-quality evidence' that are recognised and valued by their peers ([281], p232).

Building and working towards consensus within a scientific field, as described in this thesis, involves mobilising individuals and institutions. Therefore, Bourdieu's view of a scientific field as a relational construct 'involving social agents occupying different positions in a structured network' (Albert 2003, p149) [282], is important. Bourdieu's scientific field is also 'a field of forces' and struggles or competition where agents or institutions work at 'valorising their own capital' (Bourdieu 1991, p6) [278].

Finally, I have been sensitised by the notion of 'science capital', a Bourdieusian concept used by Archer *et al* (2014) [283] as a conceptual tool for understanding the production of 'classed patterns in the formation and production of children's science aspirations'. Science capital provides a lens to co-production and how it relates to power and different views on

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[14] See chapter 6, section 6.4.1, page 201.

'science capital'. Science capital refers to 'knowledge, education, intellect, insight, skills, and understanding that an individual could deploy to shape their status and power in a particular field' [284]. According to Greenhalgh *et al* (2021, p4) 'inter-field struggles for status and prestige could warp how certain forms of science capital may be recognised and valued while other forms are marginalised' [284]. Relevant here is the physiotherapy vs arthroscopic hip surgery approach to FAI syndrome intervention research; it could signal struggle, status, and prestige. How 'scientific capital' is viewed is therefore not only important for authentic primary cam morphology knowledge co-production; it could be a transformational cornerstone of the hip-and-groin scientific field giving voice to minoritised and marginalised individuals and groups (and their knowledge). The inclusive aim and objective of this thesis.

3.2.3 Transformative perspective: addressing power and social relationships

Pragmatism supports a transformative perspective—indeed, pragmatism has its roots in the civil rights movement and campaigns for social justice [285]. Whilst transformative pragmatist research has traditionally been used to help disadvantaged and underserved communities (such as the homeless or refugees), it can also be applied in less extreme power imbalances such as any doctor-patient or researcher-participant-patient relationship. Moving away from the requirement of 'normative consensus or collective vision(s)' as prerequisites for engaging a diverse group in transformation, Doerr *et al* (2021, p246) state 'pragmatist perspectives suggest perceiving of an initiative's transformative effect not as its effect on a regime or an abstract social field, but as the expansion or reduction of a community's capability to bring forth other initiatives' [286]. Therefore, 'transformative pragmatist research assists communities' collective problem-solving capabilities rejecting normative prefixes like (counter-)hegemonic, (de-)growth, or (anti-)capitalist' [286].

The transformative paradigm or perspective, according to Mertens (2003, cited by Tashakkori, Johnson, and Teddle, 2020, p3), prioritises

> the lives and experiences of marginalised groups such as women, ethnic/racial minorities, members of gay and lesbian communities, people with disabilities, and those who are poor. The researcher who works within this paradigm consciously analyses asymmetric power relationships, seeks ways to link results of social inquiry to action, and links the results of the inquiry to wider questions of social inequality and social justice. (p62) [54]

My research aims to inform research quality and inclusivity in the field of primary cam morphology by supporting a community of athletes, patients, clinicians and researchers to co-transform, amongst other key elements, power positions related to professional status, class, sex/ gender and race/ ethnicity, disability, framing language, and knowledge 'status'.

3.3 Methods

I use the term 'methods' to describe the practical means and the tools for collecting and analysing my data—'the tools of the trade' [259].

3.3.1 Mixed methods research design

Mixed methods research has been described as 'a type of inquiry that is philosophically grounded where an intentional mixture of both qualitative and quantitative approaches is used in a single research study' with the purpose of providing 'a more complex understanding of a phenomenon that would otherwise not have been accessible by using one approach alone' [287]. Mixed methods research

> is the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g. use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breadth and depth of understanding and corroboration ([288], p123).

Four 'families' of mixed methods designs have been proposed: parallel, sequential, conversion and hybrid (Table 3.2).

Table 3.2. Four families of mixed methods research (reproduced from [54], p128)

Mixed methods design family	Description of key features
Parallel mixed methods design	Mixture of *QUAN and **QUAL data collection across two or more parallel strands
Sequential mixed methods design	Mixture of QUAN and QUAL data collection occurs across two or more chronological strands of the study
Conversion mixed methods design	Mixing occurs when one type of data (QUAN or QUAL) is transformed and analysed accordingly to answer related aspects of the same research question
Hybrid mixed methods design	Three or more strands; combine features of two or more of the three basic families of designs. Integration occurs at multiple stages and across strands of the study in which one approach affects the formulation and implementation of the other

*quantitative; **qualitative

I adopted a hybrid mixed methods approach combining features of parallel and sequential families of mixed methods design. Integration of quantitative (QUAN) methods and qualitative (QUAL) methods occurred at multiple stages and across strands of the programme of research presented in this thesis (Figure 3.3).

3.3.2 Strands of research design presented in this thesis

The programme of research presented in this thesis has multiple strands. Strands represent the components or phases of a mixed methods study, and include initiation, implementation, analysis, and inference stages [54]. These often operate in an iterative or interactive manner. Here I list strands relevant to the programme of research presented in this thesis (Figure 3.3) and their QUAN/QUAL methods. I will discuss ontological and epistemological orientation, and detailed methods in the relevant chapters.

- Literature review: concept analysis method informed by a risk factor systematic review (Chapter 2; QUAN + QUAL;).
- Oxford Consensus, part 1—terminology, taxonomy, definitions, and outcome measures: Delphi method, interacting group process (Chapter 4; QUAN + QUAL).

- Oxford Consensus, part 2—research priorities: Delphi method, interacting group process, and Essential National Health Research ranking strategy (Chapter 5; QUAN + QUAL).
- Qualitative study on research quality: semi-structured individual interviews and thematic analysis (Chapter 6; QUAL)
- Dissemination: Webinar Series; Symposium; other (Infographic; Website; Podcast) (Chapter 5 and 7; QUAN + QUAL).

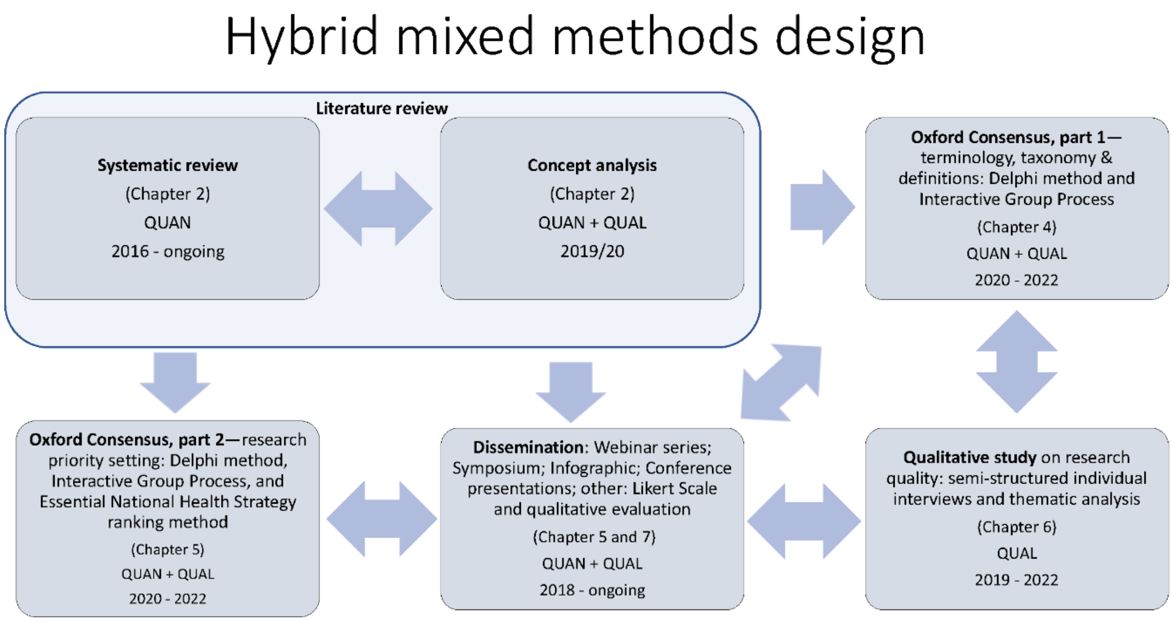


Figure 3.3. Hybrid mixed methods design: (QUAN + QUAL) → (QUAL + QUAL) ↔ QUAL

3.3.3 Ethical considerations

It is important to consider ethical issues and experiences relevant to mixed methods research. I drew, with examples relevant to my programme of research, on the findings of Stadnick *et al* (2021) [289], who identified several potential ethical issues in mixed methods health services research, including: (1) informed consent (e.g. use simple language and ensure participants understand research activities, expectations and their rights); (2) confidentiality (e.g. implement strategies to ensure ethical adherence to ensure participant confidentiality); (3) data management (e.g. who have access to data and using specialised data management software to ensure data protection); (4) safety (e.g. participant safety and well-being, relevant to, for example, qualitative study where athlete-patients shared their experiences—'struggles'—of hip disease and treatment); (5) burden (e.g. time commitment to complete long surveys, be interviewed, attend online meetings, and contribute as athlete/patient research partner); (6) equitable recruitment (e.g. ensure a diverse and representative Delphi panel in a 'level' research playing field—mentoring, for example, patient partners—and a positive, supportive research participant experience); (7) communication (e.g. ensure effective and efficient communication within the collaborating research team, with research participants, and patient partners); and (8) dissemination (e.g. consider strategies for ethical dissemination of research findings, including co-authorship, member checking, co-producing dissemination products with patient partners, non-technical language, open access publication). I will reflect on these in the final chapter of this thesis.

3.3.4 Positionality: bricolage

I alluded in chapter one how the research presented in this thesis—striving to transform a clinical and research field—changed me too. I changed from a scholar with a predominantly positivist worldview to a pragmatist with elements of, what Levi-Strauss described as, a 'bricoleur' [27]. Bricoleurs 'examine phenomena not as detached things-in-themselves, but as connected things-in-the-world' [28]. I identify with Kincheloe's critical bricolage. Kincheloe adopted and extended Denzin and Lincoln's (1999) multi-methodological five types of *bricoleurs* (interpretative, methodological, theoretical, political, and narrative) [28]. Over time, I became more and more comfortable to spontaneously adapt to the unique and often challenging circumstances of the situation. The Covid-19 pandemic had a significant influence on my research plans; I described in chapter two how the findings of my primary cam morphology risk factor systematic review radically changed the original aim of this thesis.

Through the empirical work of this doctorate, I experimented and creatively employed—usually when needed, but often because I was curious—the available diverse tools, material, and philosophical lenses to inform unique solutions to a (research) problem. Following Kincheloe, I broadened my predominantly positivist and monological research horizon, to also embrace research pursuits that appreciate the complexity of the lived world, and creatively combined quantitative and qualitative methods. A mixed methods approach to the aims and objectives of this thesis reflected my scholarly and personal transformation.

3.3.5 Conclusion and chapter summary

In sum, the programme of mixed methods research presented in this thesis is underpinned by a pragmatist-informed co-production paradigm intended to support a transformation of both research and clinical practice related to primary cam morphology and its natural history so that it takes a more patient-centred direction. I discussed the importance of learning communities applying engaged scholarship and intellectual arbitrage to grapple with, not only the science, but also real-life experiences of athletes and patients living with primary cam morphology and its hip disease consequences. Such an approach will facilitate collective problem solving where all types of knowledge matter, setting the scene for the Oxford Consensus Study presented in chapters 4 and 5.

Chapter four

Oxford consensus on primary cam morphology and femoroacetabular impingement: part 1—definitions, terminology, taxonomy, and imaging outcomes

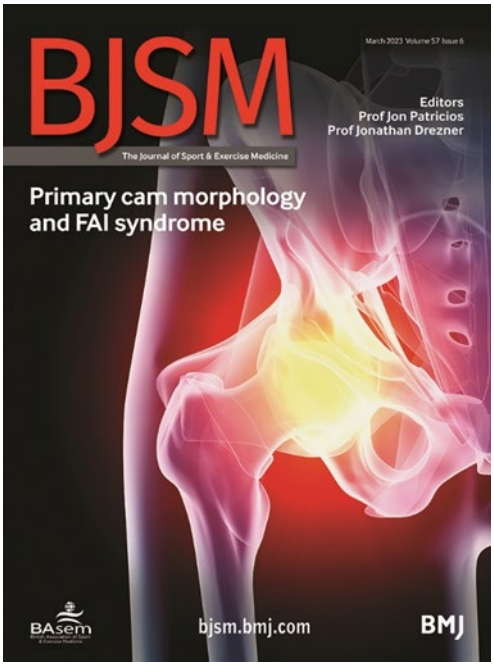
Key publications and conference presentations relevant to this chapter

Publication

Dijkstra HP, Mc Auliffe S, Ardern CL*, et al* Oxford consensus on primary cam morphology and femoroacetabular impingement syndrome: part 1—definitions, terminology, taxonomy and imaging outcomes. Br J Sports Med 2022;57:325–41. doi:10.1136/bjsports-2022-106085 [290].

<u>My role in study and publication</u>: I (HPD) was the lead investigator and first author.

This study is my original work. I proposed the idea of a Delphi consensus study on the topic, planned and coordinated the study as part of my DPhil Evidence-Based Health Care studies. Professors Trish Greenhalgh (TG), Mike Clarke (MC), Karim Khan (KK), and Sion Glyn-Jones (SGJ), and Dr Jason Oke (JO), as supervisors of my DPhil programme of research, provided oversight to this study with other members of the Delphi Study Steering Committee led by principal investigator TG: Dr Sean McAuliffe (SMA), Dr Clare Ardern (CLA), Associate Professor Joanne Kemp (JLK), Dr Andrea Mosler (ABM), Dr Amy Price (AP), Mr Paul Blazey (PB), Dr Andreas Serner (AS). In addition to the steering committee members, 5 co-researchers and/or Delphi panellists contributed, and therefore co-authored, the published paper. They were: Dr Dawn Richards (DPR), Dr Abdulaziz Farooq (AF), Dr Eugene McNally (EM), Professor Vasco Mascarenhas (VM), and Professor Richard Willy (RW). I wrote the first draft Delphi statements. Following that, all Steering Committee members contributed to, revised, and refined the list of Delphi statements. AP co-led the Patient and Public Involvement Group with HPD and, with DPR and RW, facilitated an authentic patient's voice throughout. AF, with oversight by JO, contributed to the statistical analysis of the study. Although EM and VM contributed to all stages of the Delphi study, their focus was revising the imaging- and research priorities domains. CLA and KK co-chaired with HPD the online interacting group process while ABM, AP, JLK, SGJ, DPR, SMA, EM, PB, RW, AS and MC acted as group leads for the 6 small multistakeholder groups.



HPD wrote the first and all subsequent drafts of the published manuscript, including responding to peer reviewers' comments. All listed authors contributed to reviewing, editing, and revising the manuscript, and have read and agreed to the final publication. I convened the *Young Athlete's Hip Research (YAHiR) Collaborative* listed as 'collaborators' in the publication. They were all Delphi panel members and contributed to the online interacting group process and the ENHR ranking exercise. Relevance to this chapter: Significant sections from the BJSM publication are reproduced in this chapter. As lead investigator, I planned, managed, and delivered the study. Co-researchers contributed as stated above.
Conference presentations
I presented sections of this chapter: (1) as a keynote lecture at the Canadian Arthritis Research Conference (February 2022) – I include the invitation letter as supplementary material (Appendix D2); (2) as an invited speaker, La Trobe Sport and Exercise Medicine Research Centre's Hip and groin pain symposium, June 2022 – the agenda is included as supplementary material (appendix D2); (3) in Webinar 10 of the Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series: 'Consensus definition for primary cam morphology and femoroacetabular impingement syndrome' – described in more detail in chapter 5.

Chapter 4: Oxford consensus on primary cam morphology and femoroacetabular impingement: part 1—definitions, terminology, taxonomy, and imaging outcomes

Significant sections of this chapter have been published in British Journal of Sports Medicine:

Dijkstra HP, Auliffe SM, Ardern CL, *et al.* Oxford consensus on primary cam morphology and femoroacetabular impingement syndrome: part 1—definitions, terminology, taxonomy and imaging outcomes. *Br J Sports Med* 2022;**57**:325–41. doi:10.1136/bjsports-2022-106085

Table 4.1. Supplementary material relevant to chapter 4 published in BJSM

Link to Article info:	https://bjsm.bmj.com/content/early/2022/12/06/bjsports-2022-106085.info
Data supplement 1	Oxford consensus on primary cam morphology and femoroacetabular impingement syndrome. Part 1 and 2 methods https://bjsm.bmj.com/content/bjsports/suppl/2022/12/06/bjsports-2022-106085.DC1/bjsports-2022-106085supp001_data_supplement.pdf
Data supplement 2	Recommendations for the Conducting and REporting of DElphi Studies (CREDES) https://bjsm.bmj.com/content/bjsports/suppl/2022/12/06/bjsports-2022-106085.DC1/bjsports-2022-106085supp002_data_supplement.pdf
Data supplement 3	Primary cam morphology steering committee terms of reference https://bjsm.bmj.com/content/bjsports/suppl/2022/12/06/bjsports-2022-106085.DC1/bjsports-2022-106085supp003_data_supplement.pdf
Data supplement 4	Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series agenda https://bjsm.bmj.com/content/bjsports/suppl/2022/12/06/bjsports-2022-106085.DC1/bjsports-2022-106085supp004_data_supplement.pdf
Data supplement 5	Comprehensive Delphi Round results (quantitative and qualitative) and analyses: statement 1 to 47 https://bjsm.bmj.com/content/bjsports/suppl/2022/12/06/bjsports-2022-106085.DC1/bjsports-2022-106085supp005_data_supplement.pdf
Data supplement 6	Interacting group process – Delphi exercise domain 1 to 4. Mixed stakeholder group online Zoom meeting: 22 September 2021 https://bjsm.bmj.com/content/bjsports/suppl/2022/12/06/bjsports-2022-106085.DC1/bjsports-2022-106085supp008_data_supplement.pdf
Data supplement 7	Qualitative analysis of individual panellists' feedback – Delphi domain 1 to 4: definitions, terminology, taxonomy, and imaging outcomes https://bjsm.bmj.com/content/bjsports/suppl/2022/12/06/bjsports-2022-106085.DC1/bjsports-2022-106085supp006_data_supplement.pdf
Data supplement 8	Primary cam morphology Delphi study: dissent analysis Delphi domain 1 to 4 https://bjsm.bmj.com/content/bjsports/suppl/2022/12/06/bjsports-2022-106085.DC1/bjsports-2022-106085supp007_data_supplement.pdf

4.1 Introduction

As explained in previous chapters, primary cam morphology is mostly an inconsequential bony prominence that develops at the femoral head-neck junction of the hip; it is highly prevalent in many athlete populations [3,4,291]. In those few athletes for whom it is not benign, the resulting hip osteoarthritis can be debilitating [5]. This predominantly benign morphology thus places athletes/patients at risk of future hip disease.

Clinicians and researchers cannot currently predict with accuracy whose primary cam morphology will be inconsequential and who will end up with a total hip replacement, hence the need for research to determine the risk factors for poor outcome. I concluded in chapter 2 that existing research is mired in confusion partly because clinicians, athlete-patients, and researchers have not yet agreed on a conceptual or operational definition of primary cam morphology, key terminology, or a taxonomy of subtypes [1].

I introduced the **Y**oung **A**thlete's **Hi**p **R**esearch (YAHiR) Collaborative in chapter 2 (section 2.3.1) as an international multi-professional stakeholder group that aims to add research value and reduce research waste on conditions affecting the young athlete's hip. Some have defined 'natural history' as the 'uninterrupted progression' [292] of a person's condition, including being asymptomatic for life. It is important to recognise that 'progression' for a person with primary cam morphology might also include the curtailment of hip disease by treatment. Therefore, I have included a broader range of outcomes in my use of the term 'natural history' in this study. A concept analysis study described in chapter 2 [1], identified four key areas for further attention: it (i) proposed a new conceptual definition for the morphology based on five defining attributes; (ii) spotlighted inconsistent and troublesome terminology, while also commending the important Warwick Agreement from a small and selective expert panel [36]; (iii) introduced taxonomy distinguishing between primary and secondary cam morphology; and (iv) exposed the challenges of operationalising the hip morphology.

However, publication of a concept paper in isolation does not guarantee dissemination, clinical uptake, impact on research, or benefit to patients. The urgent need is for clinicians, athlete-patients, and researchers to engage with, challenge and improve the above-mentioned four key elements and prioritise a research agenda for this field. If not, communication will remain imprecise, clinical decision-making will be compromised, and research waste will continue.

4.2 Aim and objectives

This study aims to inform a more rigorous, inclusive, and evidence-based approach to research on primary cam morphology and its natural history. The specific objectives of the research are to:

(1) ascertain the level of agreement among experts on definitions, terminology, taxonomy, and imaging outcome measures for research on primary cam morphology;

(2) work towards agreement and highlight residual disagreements on a set of research priorities on conditions affecting the young person's hip focussing primarily on primary cam morphology and its natural history;

(3) hold two education events to engage stakeholders, disseminate the latest evidence, and stimulate debate

   a. *Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series*, and
   b. *Young Athlete's Hip Research Collaborative Symposium*.

I report the results of objective one in this chapter, and objectives two and three in chapter 5.

4.3 Methods

In this methods section, I will describe and discuss the comprehensive methods for the Oxford Consensus Study.

A sequential two-round online Delphi survey and two synchronous online mixed stakeholder group meetings (interacting group process) were held to explore the level of agreement amongst a panel of experts, on primary cam morphology definitions, terminology, taxonomy, and imaging outcome measures for research, and work towards agreement on a set of research priorities on conditions affecting the young person's hip (Figure 4.1).

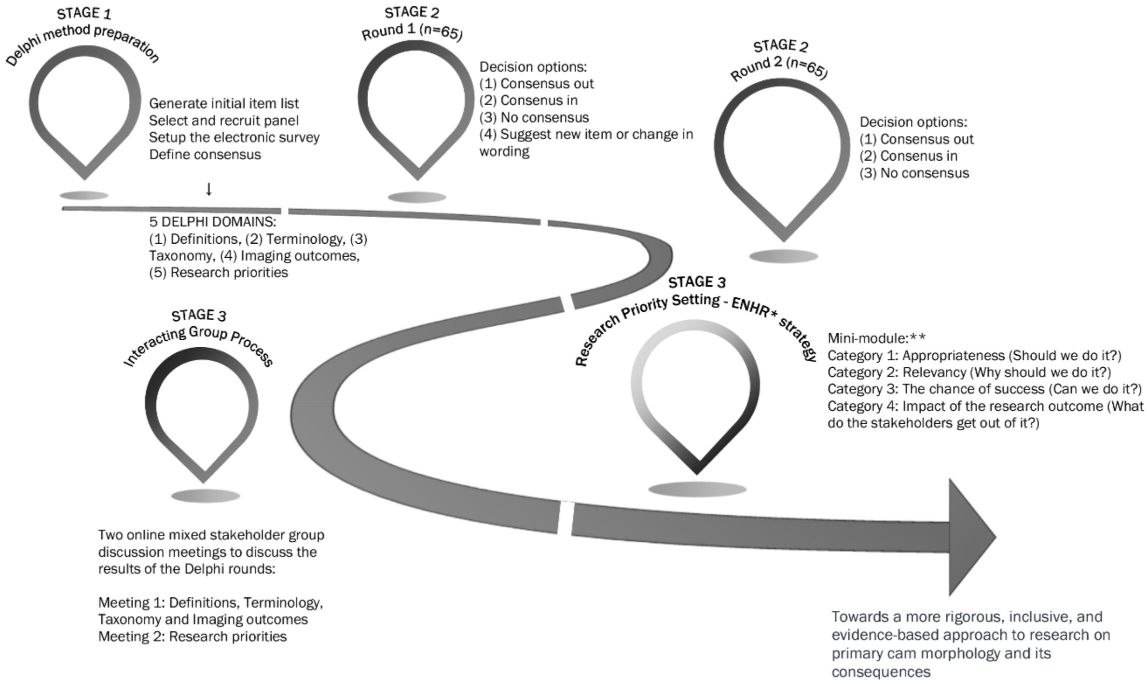


Figure 4.1. Oxford Consensus Study flow chart. Stage 1: prepare for Delphi method; Stage 2: Delphi method online rounds; Stage 3: virtual discussion meetings and ENHR strategy for research priority setting. *Essential National Health Research; **Mini-module adapted from [293]

The prioritised research statements were further ranked according to the Council on Health Research for Development's Essential National Health Research (ENHR) ranking method [293]. The Delphi and ENHR exercises allowed panel members to participate anonymously to reduce the influence of dominant individuals [294]. Reporting followed Conducting and REporting DElphi Studies (CREDES) (Data supplement 2, Table 4.1) [295], and for the research priority setting study, the 31-item REporting guideline for PRIority SEtting of health (REPRISE) (Data supplement 6, Table 5.1) [296].

4.3.1 Methodology

The Delphi method, including its qualitative elements, explicitly uses the group process to shape individual and group opinion [297]. The research team shares information with the group members (Delphi panel), get individual views, and then feed back to the individuals how far or near they are to the group average. This requires them to either change their extreme opinion or justify it. This is important, alongside other sources of empirical data, when exploring the nature of reality or informing decision making [298]. The Delphi method provides a less hierarchical and more ethical approach to conducting research, combined, in the context of this study, with transformative and knowledge co-production lenses underpinned by pragmatism as the philosophical paradigm [298]. As a pragmatic tool, the Delphi method is flexible, favouring diversity over statistical representativeness in sampling, relatively low-resource, and user-friendly [298,299]. Given the focus on (research) transformation and knowledge co-production, it is important to reflect on the positionality and identities (racial/ethnic, sex/gender) of the research group. The steering committee members (HPD, SMA, CLA, JLK, ABM, AP, PB, AS, JO, KK, SGJ, MK, TG; Data supplement 3, Table 4.1), five women and eight men, were English-speaking white academics (11 with PhDs); four physicians, six allied healthcare practitioners, and three health researchers. AP represented the YAHiR Collaborative's Patient and Public Involvement (PPI) Group. One resided in the Global South.

To accomplish the aim of this study, I combined multiple methodologies and research methods, including reflexive quantitative and qualitative analyses. Combining multiple methodologies and methods is not new; qualitative scholars use the term 'methodological bricolage'—an 'eclectic critical, multi-perspectival, multi-theoretical and multi-methodological approach to enquiry' [28,300]. This study combined the online Delphi method, interacting group process for mixed stakeholder group discussions [301], Essential National Health Research (ENHR) research strategy to rank the prioritised research statements [293], and revised Bloom's Taxonomy [30], a tool to create education that encourages critical thinking, to develop two education events aimed at early dissemination and implementation.

4.3.2 Study design – Delphi method and research priority setting process

4.3.2.1 Delphi method

For this 3-stage Oxford Consensus Study (Figure 4.1), I modified the classical Delphi method slightly by replacing an open qualitative first round with a pre-selected list of statements based on a review of existing literature, and a synthesis of the knowledge of steering group members [302–304]. The Delphi method assesses consensus through an iterative multistage process of controlled online questionnaires, feedback, reflection, and discussion, documenting both agreements and the nature and extent of residual disagreement [305–307]. Multiple rounds allow panel members to work towards consensus as members are invited to amend their response in the light of the group average [308,309]. The Delphi method allows panel members to participate anonymously to reduce the influence of dominant individuals [294]. Reporting followed CREDES ('Conducting and REporting DElphi Studies') [295]. Chapter 5 reports the research priority setting, including how the Delphi-prioritised research statements were further ranked according to the Council on Health Research for Development's ENHR ranking method [293].

The essence of the Delphi method, initially developed by the Rand Corporation for technological forecasting and named after the famous oracle at Delphi, is to generate discussion on a topic of interest amongst experts [310,305]. The Delphi method has four important methodological features: (1) a panel made up of various kinds of experts, (2) an anonymous process, (3) iterative rounds of enquiry, (4) subsequent rounds informed by a summary of the group response of the previous round [295,302,311]. While celebrating the Delphi method's strengths, it is important to acknowledge and deal with its challenges.

This Delphi method was delivered online. Although challenging, an online consensus development process is more likely to improve than jeopardise the process and outcome, especially during Covid-19-related restrictions on travel and indoor face-to-face meetings. There are many empirical examples of successful online Delphi studies in health care involving geographically dispersed panel members [312–314]. The online consensus development process is reliable [315], while asynchronous online communication has well-established benefits in promoting reflection and knowledge construction [316]. Therefore, the quality of any Delphi study depends on the underlying design and rigour, and not the medium of the research process [304]. However, ensuring a high-quality Delphi study is easier said than done as no standard quality parameters exist to evaluate Delphi studies in healthcare [317]. This will change. The ACCORD (Accurate Consensus Reporting Document) guideline, providing a set of minimum items that should be reported about methods used to achieve consensus, will likely be published later in 2023 [318].

Many Delphi method quality criteria have been proposed. Nine criteria were used to assess the quality of 52 Delphi studies on Covid-19 [317]. In sum, this study assessed how Delphi studies (1) documented the process followed to identify the problem area; (2) selected panel members based on objective and predefined criteria; (3) maintained strict anonymity of panel members and their responses; (4) provided controlled feedback between rounds; (5) managed iterative rounds of discussions and feedback; (6) defined consensus criteria a priori; (7) analysed consensus in a transparent way; (8) identified criteria for stopping the Delphi rounds; (9) analysed stability of responses. Although comprehensive, this list is arguably not complete. How Delphi researchers performed and reported qualitative analysis of panellists' responses, and treated dissent and ambiguity, for example, are equally important quality criteria [306,319,320].

4.3.2.2 Research priority setting – Essential National Health Research (ENHR) strategy

The problem of largely investigator-driven health research agendas, marginalising the voices of key stakeholders including athletes/patients, caregivers, and the community, has fuelled a mismatch between the interests of patients and researchers, and a possible misdirected allocation of limited resources [296,321,322]. This spotlighted the need for transparent research priority setting with stakeholders [296,323–330]. Research priority setting—a range of interpersonal activities amongst stakeholders to identify, prioritise, and achieve consensus on the key questions or research topics—can be small or broad. Small research priority setting projects, often the scope of a specific group or organization, focus on a health condition, while broader priority setting projects inform national or international health research strategies [296,331–333]. Ensuring transparency of the research priority setting process, and to strengthen legitimacy and credibility for influencing the research agenda, I applied the 31-item REporting guideline for PRIority SEtting of health (REPRISE) [296]. Furthermore, to add rigour and transparency, this research priority setting project has been registered on the Ludwig Biltzmann Gesellschaft Open Innovation in Science Center's worldwide Priority Setting Database of research priority setting projects. This database inspires future priority setting projects and serves as a research tool for unanswered research questions and under-researched topics [334]. The *Early Hip and Knee Osteoarthritis Priority Setting Partnership* and *Too Fit To Fracture: a consensus on future research priorities in osteoporosis and exercise*, are examples of priority setting projects registered on this database [335,336].

We slightly adapted the ENHR 'mini-module' [293], asking the Delphi panel to apply a 0 to 3 Likert Scale score to category 1 criteria, and 1 to 3 Likert Scale for the remaining six criteria. For the two category 1 questions, panellists were asked to score '0' if the planned research is ethically and morally unacceptable or if an abundance of adequate research-based information is available on the topic. A maximum 3 points per criterium resulted in an equal weighting of 6 points for each of the four categories (Figure 4.2).

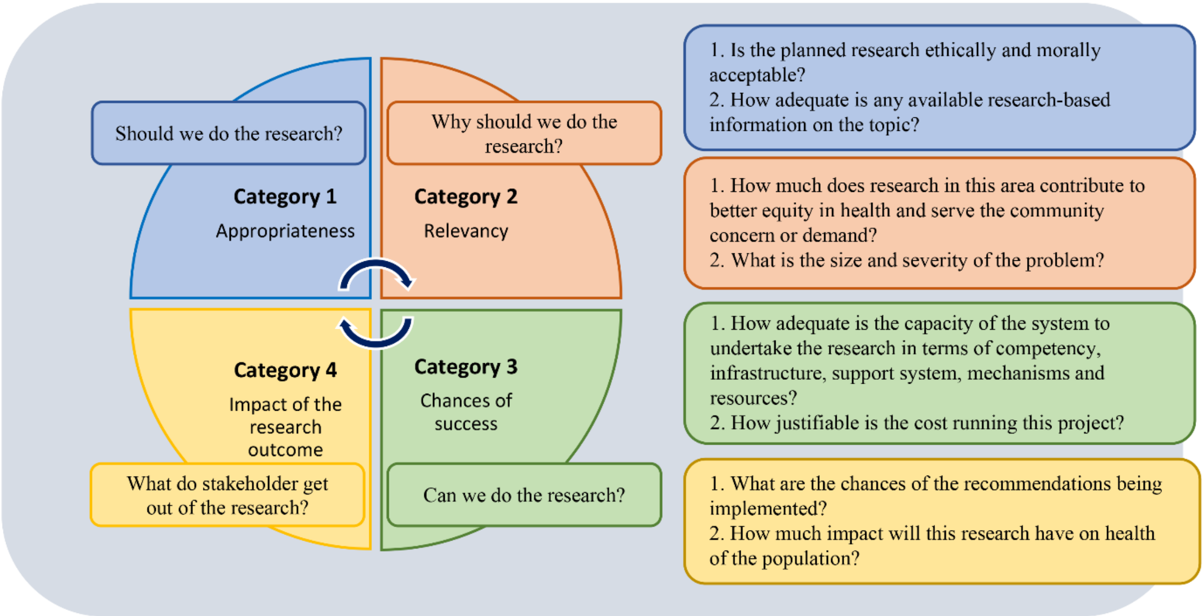


Figure 4.2. Four categories (and two criteria for each) of the Essential National Health Research ranking strategy [293]

We shared and discussed the ENHR ranking strategy results with Delphi panel members during optional online meetings.

4.3.2.3 Stage 1: Planning

Steering committee: The study steering committee included members of the YAHiR Collaborative. Avoiding the 'GOBSAT' ('good old boys sat around a table') approach [337], the steering committee ensured a representative Delphi panel, and a robust Delphi method and ENHR ranking process. Interpreting 'diversity' as more than representation of certain demographic groups, the steering committee ensured a diverse and informed Delphi panel, representing six multi-profession stakeholder groups, including previously minoritised groups relevant to this research field (e.g. women, athletes, patients and the community, participants from the Global South). The online Delphi method for our study, with a specific focus on anonymity and access to adequate topic-specific resources, supported a more equitable and inclusive process.

The online Delphi method was arguable more equitable (as opposed to an in-person meeting) as traditionally underrepresented groups had similar opportunities to participate – they did not need to travel and could share their opinion in a safe space. This study's efforts to promote a more inclusive Delphi study (referring to a positive and supportive experience) included online meetings to share and discuss study resources and topic-specific information, and giving patient and public involvement partners leading roles in all aspects of the study (including steering committee membership, active involvement in study design, leading roles in online discussions, and co-authorship of study reports, including peer reviewed papers). I published the study steering committee terms of reference in BJSM as Data supplement 3 to Oxford consensus, part 1 (Table 4.1).

Delphi and ENHR ranking panel: The concept of 'expert' is contested. According to Christiansen-Ruffman and Stuart (1978), cited by Needham and de Loë (1990, p136) expertise is restricted 'to people with specialized training, such as architects, academics, medical doctors and scientists.' [338]. Cantril et al (1996, p69) argued that an 'expert' is 'any individual with relevant knowledge and experience of a particular topic.' [339]. However, a narrow definition of expertise is unfortunate and could exclude individuals who derived their expertise, not from specialised training, but real or first-hand experience, or familiarity, and more recognition must be given to a variety of experts who exist along a 'closeness continuum' [338].

The closeness continuum represents a more inclusive expert population of individuals with subjective, mandated, and objective closeness to the topic of interest. Experts with subjective closeness have deep experiential knowledge or real-life experiences. Experts with mandated closeness are those with professional and/or legal (ethical) responsibility while experts with objective closeness are those who study the topic, exploring and inquiring without preconceived bias [338,340].

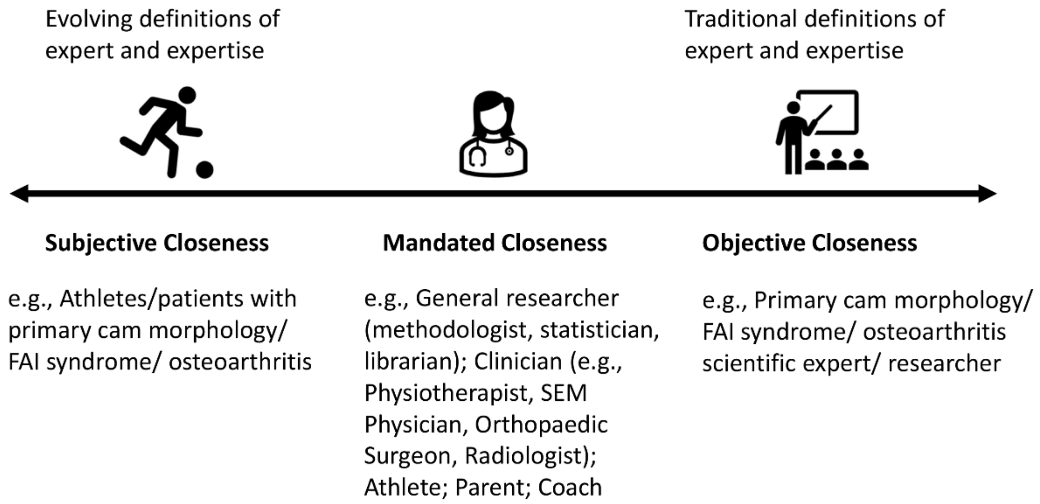


Figure 4.3. Adapted closeness continuum of experts applied to the Oxford Consensus Study [338]

This study adapted and applied the closeness continuum to purposively recruit 73 experts representing six stakeholder groups with relevant (and diverse) experience and expertise (Figure 4.3 and Table 4.2). Participants were not reimbursed.

Table 4.2. Delphi and ENHR panel recruitment criteria

Identification of Delphi panel and sample size	Panel members were identified through (1) expert knowledge of the steering committee and colleagues; (2) International Olympic Committee's 11 research centres for the prevention of injury and protection of athlete health; (3) International Hip Pain Research Network Consensus Group; (4) a list of authors (lead/corresponding authors) with a track record of peer-review publications in sports medicine and science, preferably in the field of cam morphology/FAI syndrome over the past 15-20 years (2000 to 2021). We oversampled to compensate for possible attrition at a rate of 25% per round.
Researchers	Statisticians, methodologists, librarians, and sport scientists
Clinicians and clinician-researchers	Clinicians who treat patients with hip-related conditions and clinician-researchers with a peer reviewed publication record in the field (cam morphology and/or femoroacetabular impingement aetiology, prognosis, treatment), including orthopaedic surgeons, physicians (including sports medicine physicians, physical medicine and rehabilitation physician, rheumatologist, family medicine), radiologists, physical therapists
Patient and Public Involvement (PPI) representatives	• adult patients: a purposive sample of adults diagnosed with femoroacetabular impingement syndrome and cam morphology or hip osteoarthritis and cam morphology or hip arthroplasty and cam morphology or any other joint condition (e.g. inflammatory arthritis or osteoarthritis), or have a history of recreational or competitive high-load sports participation during adolescence or later

	• parents of young adolescents regularly participating in competitive high-load sport, irrespective of a personal history of cam morphology or FAI syndrome • sports coaches (defined as coaches of early adolescents regularly participating in high-load sports) or • athletes (competitive, recreational, or retired), irrespective of a personal history of cam morphology or FAI syndrome • individuals with experience in patient and public involvement, or unique perspectives on, health equity, health ethics, racial, ethnic, and minority groups in sports medicine (e.g. healthcare professionals involved in adolescent sports medicine screening (periodic health assessment) and patient/ athlete education)
Journal editors, representatives of research funding bodies and policymakers	Journal editors (e.g. BJSM and JOSPT); Sports organisations/federations e.g. FIFA, IOC, IAAF

Sample size: We oversampled to compensate for possible attrition over rounds (at a rate of 25% per round). Consensus is normally achieved in an average of three rounds [341]; the steering committee, therefore, aimed to recruit a starting sample of 50 to 100 panel members. The study was fully anonymised, and, during the Delphi survey rounds, panel members did not know who the other panel members were.

Patient and public involvement (PPI): This study involved patient and public partners in the planning, delivery, and dissemination phases of the Delphi study through the YAHiR Collaborative's PPI group. The latter group was represented in the Delphi study steering committee by Dr Amy Price. We supplied all members of the PPI group with a glossary, mentored them on definition use and content (during online individual and PPI Group meetings), and invited them to weigh in on each Delphi round [342]. They had access to the recordings of the *Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series,* providing a good knowledge base including the current evidence, and issues, allowing an informed assessment. Members of the PPI Group led and actively participated in the mixed stakeholder group discussions following the Delphi rounds (Stage 3 below).

Delphi software: For the Delphi rounds, we used DelphiManager®, a web-based system designed to facilitate the building and management of Delphi surveys, and Microsoft Forms for the ENHR research ranking exercise [343].

Ethical considerations: Research participants provided informed online consent for the study as part of the DelphiManager® surveys and did not meet face-to-face during the online Delphi rounds. The University of Oxford's Medical Sciences Interdivisional Research Ethics Committee (MS IDREC) provided ethics approval for the study - R73576/RE001 (Appendix D, supplementary file D.1).

Statement preparation: In close collaboration with the Delphi study steering committee, I created an extensive list of statements and conceptual framework of all the potential definitions, terminology, taxonomy, and a set of research priorities on conditions affecting the young person's hip focussing on primary cam morphology and its natural history. We based the initial statement list on a concept analysis of primary cam morphology [1], the early results of a qualitative study to explore stakeholder perspectives on factors contributing to high-quality research in the primary cam morphology research field, and the Lisbon Agreement on Femoroacetabular Imaging [344–346]. In addition, the list of possible research recommendations was informed by consensus recommendations on research in the field since January 2016 [36,49–52,344–346]. Members of the steering committee independently reviewed the statements, followed by an iterative, asynchronous online process to review, discuss, modify, and approve the final statements. I provided additional descriptive information ('Help Text') where appropriate, and asked stakeholders, including members of the PPI group, to provide feedback on the draft Delphi survey. Stakeholders examined the survey's face validity (e.g. comprehensibility and acceptability) and refined language, formatting, and layout.

Panel information pack: All panel members had access from the outset of the project and throughout the Delphi process, to the course material, including recorded presentations, of the first 9 Webinars of the *Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series* (Data supplement 4, Table 4.1; Chapter 5, section 5.3.6 and figure 5.4; Appendix E). (Webinar 1: *What is primary cam morphology? Taxonomy, terminology, and definitions,* and Webinar 2: *Imaging strategies for primary cam morphology and FAI syndrome*, were particularly relevant to this Delphi study). To support scoring Domain 5 of the Delphi study (on research priorities), panel members had full-text access to five consensus statements [49–52], and a summary of their research recommendations. Completion of the webinars and/or reading of the consensus statements was not required.

Consensus definition: The steering committee agreed on a consensus definition prior to the Delphi rounds (Table 4.3).

Table 4.3. Definition of consensus

Category	Definition	Action
Consensus in (high agreement)	Scored as very important (7 to 9) by ≥70% of panel members *and* not important (1 to 3) by <15% of panel members	Item retained for the next survey round/consensus meeting
Consensus out (low agreement)	Scored as not important (1 to 3) by ≥70% of panel members *and* very important (7 to 9) by <15% of panel members	Item discarded after round 2 (to be ratified at the face-to-face consensus meeting)
No consensus	Neither criteria above are met	Item retained for the next survey round/consensus meeting
Suggest rewording	Scored as important but must be reworded.	Provide the opportunity for panel members to suggest rewording. The study steering committee will consider retaining a reworded item for the next survey round.

4.3.2.4 Stage 2: Online Delphi Rounds

The consensus process involved a sequential, two-round Delphi survey and synchronous online consensus meetings to establish multi-stakeholder agreement and surface disagreement.

Round 1: Participants provided informed consent and registered for the Delphi study in one of six stakeholder groups. The statements were presented in a sensible and logical order in five questionnaire domains (definitions, terminology, taxonomy, imaging outcomes, and research priorities).

Panel members scored each statement using a 9-point Likert scale ranging from 1 ('not important/ disagree') to 9 ('critical/ agree'), based on the Grading of Recommendations Assessment, Development and Evaluation scale for scoring the importance of including the item in the final list of statements [347]. Round 1 survey included free text sections to allow participants to propose new or modified statements and provide general feedback. The steering committee reviewed the proposed new statements or statement modifications suggested by participants in round 1, discussed and considered all the agreed new or modified survey statements for a subsequent round(s), and resolved any uncertainties.

Round 2: Participants had access to the distribution of round 1 scores for each statement stratified by stakeholder group. Judgements after feedback, including aggregated group feedback, are less exposed to cognitive and personal biases, and panellists are more confident in their decisions [348–350]. Panel members saw their score and then re-scored each statement on a scale of 1 to 9 (or not if they chose to defend their outlying score) based on the average scores of the group. We documented changes in scores from round to round. Defending their outlying score(s), panel members could provide reasons when their score boundaries changed between rounds 1 and 2.

The steering committee and Delphi panellists explored and discussed reasons for outlying scores, disagreement, and dissent (including statements with overall consensus) during the online interacting group process (stage 3 of the Delphi study) (Agenda: Data supplement 6, Table 4.1). Multiple rounds can cause 'group-think' among participants via pressure to comply [351]. We did not wish to force agreement among participants and chose to limit the Delphi process to a maximum of 3 rounds. However, two Delphi rounds resulted in high consensus and surfaced important disagreements and areas of dissent to focus on during online discussions. A third voting round was therefore not required. Following Delphi round 2, we included all statements voted ‘consensus in/ agree’ and ‘consensus out/ disagree’ in the final list of consensus statements [352,353].

4.3.2.5 Stage 3: Online interacting group process and research priority setting using the ENHR ranking exercise

Interacting group process - online mixed stakeholder group discussion meetings: Based on the interacting group process, Delphi panellists discussed all discordant items as well as areas of tension and dissent during two online mixed stakeholder group meetings. Interacting group processes stimulate participants to look at problems and solutions from different perspectives [301,354]. While nominal group processes are better for generating ideas or solutions, interacting groups are better for sharing and evaluating information [301]. Acknowledging the importance of areas of dissensus or disagreement, substantial time and effort were allocated to exploring these. To create a safe space for panellists to share their views, the steering committee facilitated discussions in small zoom breakout rooms (6-8 panellists representing different stakeholder groups). The discussions were not recorded but group leads summarised the discussions in field diaries and maintained speaker anonymity.

The first meeting discussed the results of the Delphi rounds, including ongoing areas of disagreement and dissent, and ratified the primary cam morphology definitions, terminology, taxonomy, and imaging outcome measures (Agenda: Data supplement 6, Table 4.1). The second meeting discussed the prioritised (but not yet ranked) list of research statements on conditions affecting the young person’s hip (Agenda: Data supplement 16, Table 5.1).

Research Priority Setting – ENHR strategy: An online Microsoft Forms survey process followed to further rank the prioritised statements according to the ENHR strategy for research priority setting as described earlier [293]. (Data supplement 2 to 4, Table 5.1)

Feedback: Following the ENHR ranking exercise, panellists were able to attend any of six optional and online (time-zone friendly) feedback-and-discuss-meetings. Although these were not recorded, the lead investigator took field notes that provided an additional context for analysis. Field notes aided in constructing thick, rich descriptions of the context and discussions of these (and other) encounters [355].

4.3.2.6 Data analysis

I entered and stored all data using the DelphiManager® electronic software tool and created Excel spreadsheets [343]. Descriptive statistics for each statement and stakeholder group were calculated, e.g. summary scores, ranges, percentage scoring for each statement 'not important/ disagree' (score 1 to 3), 'important but not critical/ neutral' (score 4 to 6) and 'critical/ agree' (score 7 to 9). Specifically, I reported, per stakeholder group, the median and interquartile range (IQR) for each statement between each round. This central tendency and measure of distribution served to estimate the consistency of responses between successive rounds of the Delphi study. Stability of response is an indication of whether agreement (or continuous dissensus or disagreement) is present throughout and whether it develops between rounds [356,357]. The stability of group response between rounds 1 and 2 was calculated using the Intraclass Correlation Coefficient (ICC) type A, and an absolute agreement definition [358,359]. ICC estimates and their 95% confidence intervals were calculated using SPSS statistical package version 23 (SPSS Inc, Chicago, IL) based on 2-way mixed-effects model [360]. The lower bound 95% confidence interval of the ICC estimate was used as the basis to evaluate the level of reliability using the following general guideline: ICC values <0.5 (poor stability), ICC values 0.5 to 0.75 (moderate stability), 0.75 to 0.9 indicated (good stability) and ICC values >0.9 (excellent stability) [360].

Table 4.3 represents the prior consensus definition for categorising the statements in all five Delphi domains. The Delphi study steering committee retained all statements between rounds 1 and 2 to enable participants to re-score every statement after considering feedback from round 1. This likely reduced participant burden in potential subsequent rounds and at the consensus discussion meetings [294]. Acknowledging that certain statements might be more relevant to some panel members than others, stakeholders were given the choice not to score a specific statement. We did, however, analyse the data of different stakeholder groups separately in each round [352].

In addition to the quantitative consensus definition, I (with oversight by the steering committee) reflected carefully on the findings, drawing on clinical wisdom and experience, encouraging, facilitating, and documenting further deliberation during two synchronous online discussion meetings.

Dissent analysis: Although the main aim of the Delphi method is to structure a group communication process that might lead to consensus, we were also interested in panel dissent. To explore possible dissent, we applied *dissent analysis* including outlier analysis, bipolarity analysis, and stakeholder group analysis [361,362].

- Outlier analysis: Outliers can have a substantial effect on variables[15] and statistical consensus. The existence of outliers is therefore an important potential explanation for dissent. Low outliers (data points that fall more than 1.5 times the Interquartile range below the first quartile) and high outliers (data points that fall more than 1.5 times the Interquartile range above the third quartile) were identified. In addition, I visually inspected histograms

[15] This is less true for measures such as the median, quantiles and IQR – they are fairly resistant to outliers (up to a point). The mean and standard deviation can be strongly affected by a single point.

of round 2 stakeholder group scoring for outliers. Consensus was re-analysed after eliminating outliers for all statements with marginal non-consensus to test if these had an impact on the group's consensus.

- Bipolarity analysis: Opposing groups of experts with an important and insoluble cleft of opinion, might result in non-consensus. Bimodal data distribution is therefore a possible explanation for dissent. To test for bipolarity, I investigated potential bimodal distribution (two or more answer options had the same mode frequency) and visually inspected histograms for round 2 scores of each statement [361].
- Stakeholder group analysis: Stakeholder group analysis, a classical dissent analysis, is important to identify opposing stakeholder goup views. To compare round 2 score between the six stakeholder groups, Kruskal-Wallis tests were performed. In addition, to account for multiple post hoc comparisons, the statistical significance threshold p-value was adjusted to 0.0033 according to Bonferroni method. Statistical significance has its limitations [363]; therefore, to understand substantial stakeholder group differences ($p<0.0033$) better, I scrutinised individual- and group opinions for a specific statement with apparent opposing views.

Qualitative analysis: As the lead investigator, I immersed myself in the details of participants' comments provided during Delphi rounds, interacting group process, and ENHR ranking exercise [364]. After developing a framework based on recurrent and important themes, free text comments were grouped into categories and iteratively discussed between me as lead investigator and co-researcher SMA. We then undertook thematic analysis to identify, group and agree on common threads within these categories, further refining themes and subthemes [365,366]. We provided summarised feedback of quantitative and qualitative open responses to panel members during Webinars 10 and 11 of the *Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series* (Webinar Series agenda: Data supplement 4, Table 4.1). The webinars preceded the online synchronous mixed stakeholder group discussions (interacting group process) on 22 and 23 September 2021 (Stage 3).

4.3.2.7 Dissemination

Considerable time lags exist in the health research (knowledge) translation process [367–369]. On the other hand, rapid knowledge translation and implementation into policy and practice, evident in the early Covid-19 pandemic days, served and savaged scientific-, health and care-, and patient communities [370–372]. We created opportunities for the community of researchers, clinicians, athletes, and athlete-patients, to responsibly disseminate and effectively implement the findings of this study, not only to amplify the ethical conduct of future research, but also to foster authentic co-production of new knowledge [373]. Dissemination of new knowledge, an active process of spreading or sharing evidence to a target population, is most effective 'when it starts early, galvanizes support, uses champions and brokers, considers contextual factors, is timely, relevant, and accessible, and knows the players and process.' [374,375].

To fulfil objective 3 of the Oxford consensus, I applied the revised Bloom's taxonomy (Figure 4.4). [30], a tool to create education that encourages critical thinking, to develop two education events aimed at early dissemination and implementation: *Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series* (Chapter 5), and *YAHiR Collaborative's Young Athlete's Hip Symposium and Research Meeting* (22-23 September 2022, Worcester College, Oxford).

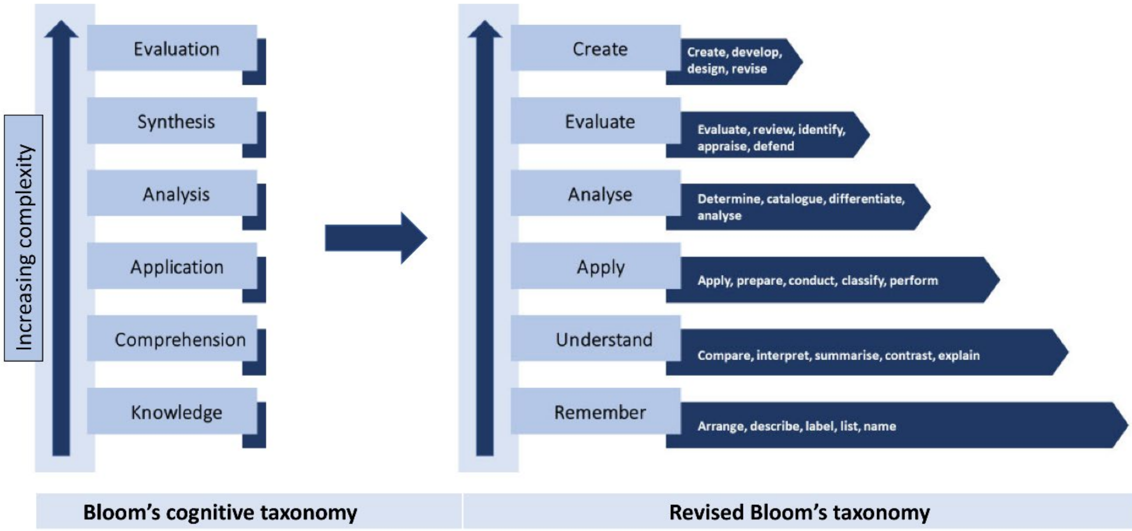


Figure 4.4. Bloom's revised taxonomy of cognitive process action verbs

Bloom and co-workers developed a taxonomy of three learning domains: (1) cognitive (knowledge and mental skills), (2) psychomotor (physical movement, coordination, and use of motor skills), and (3) affective (how individuals deal with things emotionally – feelings, values, attitudes). While the original Taxonomy provided a hierarchy of six different levels of objectives in the cognitive domain, each entailing more intricate thinking than the previous one, the revised Bloom's taxonomy emphasised verbs— the basis of the cognitive process: 'what is to be done with or to the subject matter content.' (Figure 4.4) [30].

Education evaluation: Kirkpatrick's four-level training evaluation model informed the evaluation of the two education events. Kirkpatrick's hierarchy, focussing on four levels to evaluate the effectiveness of training, is one of the most widely applied evaluation approaches in medical education [376]. These levels are: (1) response to training—are participants satisfied with the teaching and learning? (2) learning—do participants acquire the intended knowledge, skills, and attitudes? (3) behavioural change—do participants apply (or intend to apply) what they have learned? (4) results—what is the impact on society, a community or organisation?

Focussing on the first two Kirkpatrick levels and intension to change behaviour, I developed 13 evaluation surveys: a pre-webinar series survey, a post-webinar series survey, and surveys following each webinar (n=11). Participants were asked to score various statements based on a 5-point Likert scale, including a question on the overall quality of the Webinar. To evaluate the effect of the Webinar series on participants' learning (Kirkpatrick level two), I used pre- and post-test surveys, and included open ended questions inviting participants to give additional feedback in their own words.

I report the quantitative (frequencies and percentages of Likert scale responses) for relevant statements, and qualitative results of open-ended questions of surveys. In order to compare the change in experience, knowledge, impact, and beliefs in participants who completed both pre- and post-webinar series surveys, we performed a paired sample t-test of Likert scale responses to the relevant statements. All 'I don't know'-responses were classified as missing and not scored. The paired difference in means along with standard errors were reported. A p-value <0.05 was considered statistically significant. The analysis were repeated using non-parametric Wilcoxon Signed Rank tests since the change in outcome parameters were not normally distributed on a Shapiro Wilk test for normality. However, Norman (2010) demonsrated that parametric statistics can be used with Likert data with 'no fear of coming to the wrong conclusion.' [377].

4.4 Results

Of the 73 experts invited to participate in this study, 65 completed rounds 1 and 2 of the Delphi exercise. The Delphi panel (from 18 countries) represented six stakeholder groups—26 participants were female (Table 4.4). The Delphi panel scored 85 statements (12 definition-, 19 terminology-, 4 taxonomy-, 12 imaging outcome-, and 38 research statements), and reached consensus on 43 of 85 statements in round 1, and 53 of 85 statements in round 2 (Table 4.5: statements 1 to 47; Table 5.2 and 5.3: research priority statements 48 to 85). I published detailed quantitative and qualitative results and analyses for statements 1 to 47 as Data supplement 5 in BJSM; Table 4.1). This data supplement also lists the reasons for score boundary changes between rounds 1 and 2 for each statement. Twelve statements did not reach stability (Table 4.5). There were four marginally non-consensus statements after round 2 (Figure 4.5).

In this section, I report the quantitative results, analysis of qualitative feedback, and dissent analysis of the Delphi rounds for definition-, terminology-, taxonomy, and imaging outcomes statements. An online interacting group process followed the Delphi exercise; six mixed stakeholder groups of 5 to 8 panellists (*n=43*), discussed the Delphi exercise results on 22 September 2021 (Agenda: Data supplement 6, Table 4.1). I summarise these discussions in Tables 4.6, 4.7, 4.8 and 4.9.

Table 4.4. Demographic characteristics of Delphi panel and Essential National Health Research (ENHR) ranking exercise participants

	Delphi exercise	**ENHR ranking exercise - Delphi consensus, Part 2**		
	Round 1 & round 2 (*n* = 65)	Survey 1* (*n* = 49)	Survey 2** (*n* = 44)	Survey 3*** (*n* = 42)
Sex				
Male (*n* = 39)	39	No sex data collected for ENHR ranking exercise		
Female (*n* = 26)	26			
Stakeholder Group: n				
Orthopaedic Surgeons	11	7	4	4
Patient and Public Involvement Group	10	7	6	6
Physical Therapists	17	17	16	16
Physicians	13	8	8	7
Radiologists	6	4	4	4
Researchers	8	6	6	5
Country of residence				
Australia	8	No country of residence data collected		
Belgium	1			
Brazil	1			
Canada	5			
Denmark	4			
Germany	1			
Ireland	2			
Netherlands	5			
Norway	2			
Portugal	1			
Qatar	7			
South Africa	3			
Spain	1			
Sweden	1			
Switzerland	2			
Turkey	1			
UK	7			
USA	8			

*Survey 1: Statement 48 to 54; **Survey 2: Statement 55 to 59; ***Survey 3: Statement 64 to 69

Table 4.5. Results of two survey rounds showing the level of agreement with primary cam morphology definition, terminology, taxonomy, and imaging outcomes statements

		Round 1		Round 2		ICC*	ICC 95% CI	
STATMENTS		**Not important/ disagree**	**Critical/ Agree**	**Not important/ disagree**	**Critical/ Agree**		**Lower bound**	**Upper bound**
No	**DEFINITIONS**							
1	Primary cam morphology develops during skeletal maturation as a normal physiological response to load	**3.3%**	**80.3%**	**1.6%**	**85.9%**	0.69	0.53	0.80
2	Primary cam morphology is not caused by previous disease, injury or an acute event; it represents a normal physiological response of the maturing skeleton to load	**3.3%**	**72.1%**	**1.6%**	**81.3%**	0.79	0.68	0.87
3	Secondary cam morphology develops due to existing hip disease or acute trauma, including Perthes' disease, slipped capital femoral epiphysis, healed proximal femoral fractures or acute fractures	**0%**	**73.8%**	**1.6%**	**81.0%**	0.54	**0.34**	0.70
4	Primary cam morphology develops in young and active individuals, including athletes, likely due to load (e.g. sporting activity) during prepubertal and pubertal skeletal maturation (load during growth) and its (physiological) effect on the proximal femoral growth plate	**0%**	**87.1%**	**0%**	**96.9%**	0.69	0.53	0.80
5	Primary cam morphology is common in young and active males, including athletes, likely due to sporting activity during prepubertal and pubertal skeletal maturation (load during growth) and its (physiological) effect on the proximal femoral growth plate	**4.9%**	**73.8%**	**0%**	**79.4%**	0.80	0.68	0.88
6	Primary cam morphology includes cam morphology of unknown origin	8.8%	49.1%	9.5%	52.4%	0.52	**0.30**	0.69
7	Cam morphology that develops in young and active individuals without any symptoms (e.g. hip-related pain, stiffness) or history of previous/existing hip disease, is primary cam morphology until proven otherwise	3.4%	55.9%	4.7%	53.1%	0.83	0.73	0.90
8	Cam morphology is a cartilage or bony prominence (bump) of varying size at any location around the femoral head-neck junction, which changes the shape of the femoral head from spherical to aspherical	**1.6%**	**90.5%**	**1.5%**	**92.3%**	0.47	**0.26**	0.64
9	Primary cam morphology often occurs in male athletes in both hips	5.1%	50.8%	3.2%	45.2%	0.89	0.83	0.94
10	The most common outcome measure for cam morphology is a cartilage or bone alpha angle as a dichotomised or continuous variable on radiographs, computed tomogram (CT) scans or magnetic resonance (MR) imaging, reported per hip, per person or both	**0%**	**72.6%**	**0%**	**74.6%**	0.72	0.58	0.82
11	Primary cam morphology likely develops during maturation in young adolescents (with no current or previous hip disease), possibly due to high-load sporting activity and other unconfirmed risk factors	**1.6%**	**82.3%**	**0%**	**93.8%**	0.60	0.41	0.74
12	A comprehensive definition for primary cam morphology would be: Primary cam morphology is a cartilage or bony prominence (bump) of varying size at any location around the femoral head-neck junction, which changes the shape of the femoral head from spherical to aspherical. It often occurs in male athletes in both hips. The most common outcome measure is a cartilage or bone alpha angle as a dichotomised or continuous variable on radiographs, CT scans or MR imaging, reported per hip, per person or both. Primary cam morphology likely develops during maturation in young	**0%**	**93.7%**	**1.6%**	**96.9%**	0.44	**0.21**	0.62

	adolescents (with no current or previous hip disease), possibly due to high-load sporting activity and other unconfirmed risk factors.							
	TERMINOLOGY							
13	Cam morphology is the preferred term to use for a bone/ cartilage bump at any location around the femoral head-neck junction	**1.6%**	**87.5%**	**1.5%**	**87.7%**	0.56	**0.36**	0.71
14	Cam lesion is the preferred term to use for a bone/ cartilage bump at any location around the femoral head-neck junction	**75.8%**	**6.5%**	**83.1%**	**4.6%**	0.84	0.69	0.91
15	Cam deformity is the preferred term to use for a bone/ cartilage bump at any location around the femoral head-neck junction	71.0%	12.9%	**81.5%**	**7.7%**	0.67	0.50	0.79
16	Cam abnormality is the preferred term to use for a bone/ cartilage bump at any location around the femoral head-neck junction	**80.6%**	**4.8%**	**86.2%**	**4.6%**	0.70	0.54	0.81
17	Cam-type deformity is the preferred term to use for a bone/ cartilage bump at any location around the femoral head-neck junction	**79.0%**	**3.2%**	**84.6%**	**4.6%**	0.8	0.69	0.87
18	Cam-type abnormality is the preferred term to use for a bone/ cartilage bump at any location around the femoral head-neck junction	**79.0%**	**6.5%**	**87.7%**	**3.1%**	0.64	**0.45**	0.77
19	Cam-type lesion is the preferred term to use for a bone/ cartilage bump at any location around the femoral head-neck junction	**77.4%**	**3.2%**	**89.2%**	**1.5%**	0.69	**0.48**	0.82
20	Pistol grip deformity is the preferred term to use for a bone/ cartilage bump at any location around the femoral head-neck junction	**85.2%**	**1.6%**	**92.2%**	**0.0%**	0.64	**0.40**	0.78
21	Pistol grip lesion is the preferred term to use for a bone/ cartilage bump at any location around the femoral head-neck junction	**85.2%**	**3.3%**	**92.2%**	**1.6%**	0.59	**0.37**	0.74
22	Pistol grip abnormality is the preferred term to use for a bone/ cartilage bump at any location around the femoral head-neck junction	**85.2%**	**4.9%**	**92.2%**	**1.6%**	0.44	**0.22**	0.63
23	Cam-type impingement is the preferred term to use for hip-related pain due to a bony bump at any location around the femoral head-neck junction	56.5%	16.1%	56.3%	10.9%	0.78	0.65	0.86
24	Cam femoroacetabular impingement (FAI) is the preferred term to use for hip-related pain due to a bony bump at any location around the femoral head-neck junction	53.2%	27.4%	51.6%	20.3%	0.83	0.74	0.90
25	Cam-type femoroacetabular impingement (FAI) is the preferred term to use for hip-related pain due to a bony bump at any location around the femoral head-neck junction	59.7%	19.4%	51.6%	20.3%	0.82	0.72	0.89
26	Femoroacetabular impingement (FAI) Syndrome with cam morphology is the preferred term to use for hip-related pain due to a bony bump at any location around the femoral head-neck junction	7.9%	69.8%	**7.8%**	**75.0%**	0.65	**0.47**	0.77
27	Femoroacetabular impingement (FAI) Syndrome with cam deformity is the preferred term to use for hip-related pain due to a bony bump at any location around the femoral head-neck junction	**71.0%**	**6.5%**	**81.5%**	**4.6%**	0.81	0.66	0.89
28	Femoroacetabular impingement (FAI) Syndrome with cam abnormality is the preferred term to use for hip-related pain due to a bony bump at any location around the femoral head-neck junction	**74.2%**	**4.8%**	**81.5%**	**4.6%**	0.82	0.70	0.89
29	Femoroacetabular impingement (FAI) Syndrome with cam lesion is the preferred term to use for hip-related pain due to a bony bump at any location around the femoral head-neck junction	**71.0%**	**4.8%**	**83.1%**	**4.6%**	0.72	0.52	0.84
30	Femoroacetabular impingement (FAI) Syndrome with cam-type abnormality is the preferred term to use for hip-related pain due to a bony bump at any location around the femoral head-neck junction	**74.2%**	**6.5%**	**84.6%**	**1.5%**	0.72	0.55	.83

31	Femoroacetabular impingement (FAI) Syndrome with cam-type deformity is the preferred term to use for hip-related pain due to a bony bump at any location around the femoral head-neck junction	69.4%	9.7%	**81.5%**	**4.6%**	0.75	0.56	0.85
	TAXONOMY							
32	We should distinguish between primary and secondary cam morphology in clinical practice	**6.5%**	**74.2%**	**6.2%**	**83.1%**	0.87	0.79	0.92
33	We should distinguish between primary and secondary cam morphology in research	**4.6%**	**90.8%**	**4.6%**	**92.3%**	0.71	0.57	.815
34	We should distinguish between primary and secondary cam morphology in patients with femoroacetabular impingement syndrome	6.5%	66.1%	4.7%	68.8%	0.82	0.72	0.89
35	We should distinguish between primary and secondary cam morphology in research participants with femoroacetabular impingement syndrome	**4.7%**	**84.4%**	**4.6%**	**90.8%**	0.69	0.53	0.80
	IMAGING OUTCOMES							
36	The main imaging modality for research on how primary cam morphology develops should be magnetic resonance (MR) with radial imaging (1.5T or 3T)	**1.9%**	**75.9%**	**1.8%**	**89.3%**	0.81	0.59	0.90
37	The minimum acceptable number of radial sequence magnetic resonance (MR) imaging slices for research on how primary cam morphology develops should be 12 slices (30° intervals in all 12 clock face positions from 12 o'clock to 11 o'clock positions)	0%	60.0%	**0%**	**81.6%**	0.7	0.49	0.83
38	Referring to precisely quantifying the asphericity of the femoral head-neck junction on radial sequence magnetic resonance (MR) imaging: use either radial sequences along the axis of the femoral neck (providing higher resolution images) or radial reconstructions from 3-dimensional acquisitions	**0%**	**75.0%**	**0%**	**87.0%**	0.84	0.70	0.92
39	The magnetic resonance (MR) imaging protocol for research on how primary cam morphology develops should include: (i) unilateral small field-of-view (FOV) sequences and radial images of a randomly selected or both hips; as well as (ii) femoral torsion assessment (fast axial sequences of the distal knee—femoral condyles—and proximal femoral neck); and (iii) a fluid sensitive sequence covering the whole pelvis (in axial or coronal planes; to screen for soft-tissue and bone marrow edema beyond the hip)	5.9%	64.7%	**0%**	**78.4%**	0.71	**0.47**	0.85
40	The magnetic resonance (MR) imaging for prospective research on how primary cam morphology develops should be repeated every 18 to 24 months	11.3%	56.6%	7.3%	56.4%	0.86	0.78	0.92
41	In primary cam morphology epidemiological research (e.g. when regression is being used in aetiology or prognosis research) continuous imaging outcome measures (variables) like the alpha angle should be kept continuous	**3.6%**	**72.7%**	**0%**	**89.3%**	0.77	0.58	0.87
42	The cam morphology magnetic resonance (MR) imaging outcome measure for research on how primary cam morphology develops (aetiology) should be the alpha angle for bone and cartilage as a continuous variable reported for all the o'clock locations around the femoral head-neck junction regardless of the symptomatic state of the research participant.	5.4%	66.1%	**0%**	**80.7%**	0.81	0.68	0.89
43	For research on how primary cam morphology develops it is important to quantify the epiphyseal morphology magnetic resonance (MR) imaging outcome measure using epiphyseal extension	4.8%	57.1%	0%	65.9%	0.83	0.68	0.91
44	For research on how primary cam morphology develops the epiphyseal morphology magnetic resonance (MR) imaging outcome measure should also be quantified using epiphyseal tilt	5.1%	43.6%	0%	44.2%	0.81	0.67	0.90
45	The main imaging modality for longitudinal primary cam morphology prognosis research should be anteroposterior (AP) pelvis and Dunn 45° view radiographs repeated at least every 5 years	20.4%	44.9%	15.4%	42.3%	0.91	0.84	0.95

46	The radiographic imaging outcome measure for research on primary cam morphology prognosis should be the alpha angle as a continuous variable reported for anteroposterior (AP) pelvis and Dunn 45° view radiographs	15.7%	56.9%	11.3%	67.9%	0.90	0.83	0.94
47	In addition to reporting alpha angles as continuous in studies on aetiology or prognosis the following quantitative and qualitative imaging outcome measures to categorise cam morphology can be useful in research or clinical practice: (i) Alpha angle ≥ 60° (preferred) (ii) Head-neck offset < 8mm AND head-neck offset ratio ≤ 0.15 usually at the anterior (3 o'clock) location around the femoral head-neck junction (in addition to (i)); Osseous or cartilage convexity of the femoral head neck junction at any location (in addition to (i) and (ii))	2.1%	52.1%	**0%**	**72.5%**	0.81	0.68	0.89

Green (high agreement on 'consensus in'): Statement scored as critical (7 to 9) by ≥70% of panel members and not important (1 to 3) by <15% of panel members
Red (high agreement on 'consensus out'): Scored as not important (1 to 3) by ≥70% of panel members and critical (7 to 9) by <15% of panel members
Yellow (non-consensus): Neither of the 'consensus in' or 'consensus out' criteria were met
*ICC: Intraclass Correlation Coefficient; Type A ICC coefficients using an absolute agreement definition; Two-way mixed effects model where people effects are random and measures effects are fixed
ICC is an indication of the level of agreement (within-subject variation and between-subject variance of individual statement scores between Round 1 and Round 2.) We used the lower bound 95% confidence interval of the ICC estimate as the basis to evaluate the level of reliability using the following general guideline: values <0.5 were classified as poor reliability ICC values 0.5 to 0.75 moderate reliability and 0.75 to 0.9 indicated good reliability and ICC values >0.9 indicated excellent reliability.

4.4.1 Definitions – Delphi domain 1

The Delphi panel reached consensus on nine of 12 definition statements in round 1 and 2 (Table 4.5; Data supplement 5, Table 4.1). The panel agreed on a comprehensive definition for primary cam morphology, based on its five proposed conceptual attributes (Figure 4.4; Statements 1, 2, 4, 5, 8, 10-12). The panel also agreed that secondary cam morphology develops due to existing and/or pre-existing hip disease (Statement 3).

Qualitative analysis: Qualitative analysis identified 12 themes (Data supplement 7, Table 4.1). The first four themes illuminated tension and dissent related to three non-consensus definition statements (Statements 6, 7 and 9). First, some Delphi panel members commented that primary cam morphology's origin is not entirely 'unknown' but likely due to variable loading demands (Statement 6). However, at an individual level not all primary cam morphology has a clear cause. Second, the Delphi panel did not agree that 'all cam morphology in young and active adults without any symptoms or history of previous hip disease is primary cam morphology until proven otherwise' (Statement 7). Some found the concept of primary- and secondary cam morphology challenging. Third, the statement 'primary cam morphology is more common in male athletes in both hips' (Statement 9) created the impression that this morphology was a male-only problem while the reality is that females are largely left out of research. Last, while the Delphi panel agreed that primary cam morphology usually occurs bilaterally, representing a defining element for primary vs secondary cam morphology and important for patients, some athletes might have unilateral primary cam morphology.

Dissent analysis: (Data supplement 8, Table 4.1). *Outlier analysis:* Although outliers were identified for 10 of 12 definition statements in round 2, they did not influence group consensus or non-consensus. None of the outliers provided qualitative comments. One physical therapist did not agree that the concept of primary and secondary CAM is commonly agreed and established and chose 'Unable to score' for most of the definition statements in rounds 1 and

2. *Bipolarity analysis:* There was no evidence of bimodal distribution in the overall scoring of definition statements. *Stakeholder group analysis:* There was no significant difference in how stakeholder groups scored definition statements in rounds 1 and 2.

Interacting group process: I summarise the results of the interacting group process in Table 4.6. In sum, panellists agreed that (1) primary cam morphology is an important concept but contended that more work is needed to engage a small group that is not yet convinced; (2) more research is needed in female cohorts; (3) primary cam morphology mostly, but not always, occurs in both hips; (4) primary cam morphology also includes the group where no clear aetiology exists; (5) primary cam morphology develops during skeletal maturation as a normal physiological response to load.

Table 4.6. Interacting group process discussion summary - definition domain

Topic	Discussion summary
Primary cam morphology (PCM) as a concept	Mixed stakeholder groups agreed on the importance of **primary cam morphology as a concept.** This taxonomy, differentiating between primary and secondary cam morphology, offers several advantages that offset its drawbacks—'their origins are important to distinguish', and 'it has utility in research, prognosis, and treatment.' In research the taxonomy is 'important for classification', while the prognosis is often worse for secondary cam morphology. Treatment maybe distinctly different as most individuals with primary cam morphology will never present with any symptoms. The panel contended more work is needed to authentically engage a small group that is not yet convinced that primary cam morphology is an important concept.
Higher prevalence in males	Although there is agreement, albeit 'based on the (limited) available literature', that primary cam morphology is more common in **males** and mostly asymptomatic, **female** athletes also develop this morphology and 'longer term consequences of PCM seem to affect women as much as men.' More inclusive research is needed involving minoritised female cohorts.
PCM often occurs in both hips	Although there is agreement that primary cam morphology, unlike secondary cam morphology, often **occurs bilaterally**, and this distinction 'is the defining element for PCM vs SCM, and important for patients', this is not always the case. Some patients might have unilateral primary cam morphology while others might present with a combination of primary- and secondary cam morphology.
PCM also include the group where no clear aetiology exists	The mixed stakeholder groups agreed that primary cam morphology **also include the group where no clear aetiology** 'at an individual level' exists. It is likely that a 'complex relationship' between primary

	cam morphology and 'a genetic susceptibility' exists. Genetics as risk factor, and 'the interplay between genetic risk and load relationship' should therefore be considered and researched.
PCM develops during skeletal maturation 'as a normal physiological response to load'	Despite strong consensus that primary cam morphology develops during skeletal maturation 'as a **normal physiological response to load'** (Statement 1) further qualified as 'high-load sporting activity' (Statement 11), some panellists, during the online discussions, felt 'normal' is 'potentially problematic.' However, the high prevalence of primary cam morphology in largely asymptomatic professional athletes—'several studies showed >80% prevalence'—begs the question: 'when does it [physiological response] become abnormal? …when it's very painful?' Furthermore, high-load sporting activity for one athlete might be normal-load sporting activity for another; load type ('torsion, varus/valgus') and skeletal maturation status are both important variables to consider in clinical practice and research.

4.4.2 Terminology – Delphi domain 2

The Delphi panel reached consensus on 14 of 19 terminology statements in round 1 and 16 in round 2—consensus on two statements to include ('consensus in/agree'), and consensus on 14 statements to exclude ('consensus out/disagree') certain terms (Table 4.5). The panel agreed that 'cam morphology' is the preferred term to use for a bone/cartilage bump at any location around the femoral head-neck junction (Statement 13), and 'Femoroacetabular impingement (FAI) syndrome with cam morphology' (Statement 26) for hip-related pain due to a bony bump at any location around the femoral head-neck junction. The Delphi panel agreed to avoid ('consensus out') terms 'lesion', 'deformity', and 'abnormality' (Statements 14 to 22, and 27 to 31).

Three statements related to the terms proposed for hip-related pain due to a bony bump at any location around the femoral head-neck junction, did not reach consensus: 'cam-type impingement' (Statement 23), 'cam femoroacetabular impingement (FAI)' (Statement 24), and 'cam-type femoroacetabular impingement (FAI)' (Statement 25).

Qualitative analysis: Qualitative analysis identified 4 themes (Data supplement 7, Table 4.1). First, warning that 'abnormality' is not a very optimistic term, panellists preferred the term 'morphology'. Second, one panellist suggested replacing 'bump' with 'prominence' as not every cam morphology has a 'bump': it might only be decreased offset and that 'certainly' does not constitute a 'bump'. Third, although 'FAI syndrome' is the agreed term for hip-related pain due to a bony bump at any location around the femoral head-neck junction, one panellist warned that other causes for hip-related pain exist, and that FAI syndrome is one type of pathology in the hip. Last, one panellist disagreed with the term 'any location' as they felt 'an inferior bony bump may not lead to FAI.'

Dissent analysis: (Data supplement 8, Table 4.1). *Outlier analysis:* Outliers (present in 16 of the 19 terminology statements) in round 2, did not influence group consensus or non-consensus. The orthopaedic surgeon outlier for statements 13 and 26 did not agree that primary cam morphology refers to a bump 'at any location' around the femoral head-neck junction. One physician chose 'Unable to score' for most of the terminology statements in round 1 as they misinterpreted the statement wording. Feedback after round 1 clarified the misunderstanding. *Bipolarity analysis:* There was no evidence of bimodal distribution in the overall scoring of terminology statements. *Stakeholder group analysis:* The average terminology statement scores were significantly different for the physical therapist stakeholder group compared to the researcher stakeholder group (Statement 23, round 1; Statement 24, rounds 1 and 2), and for the radiologist stakeholder group compared to the researcher stakeholder group (Statement 24, round 2).

Interacting group process: I summarise the results of the interacting group process in Table 4.7. In sum, panellists agreed that (1) the research community and clinicians should abandon 'lesion', 'deformity' and 'abnormality' when referring to primary cam morphology; (2) primary cam morphology is likely more complex than 'bump'; (3) language should be tailored to the individual; in FAI syndrome, 'syndrome' might be 'too serious' for some.

Table 4.7. Interacting group process discussion summary - terminology domain

Topic	Discussion summary
Abandon 'lesion', 'deformity' and 'abnormality' when referring to primary cam morphology (PCM)	The Delphi panel achieved strong consensus on using the term 'morphology' and to **abandon 'lesion', 'deformity' and 'abnormality'**: 'large foreign words set the tone for fear, unknown, not in control, especially about [the] outcome.' Although the majority agreed, some felt that 'language didn't necessarily change things for patients', and that the consequences ('the pathology part') of primary cam morphology 'is the bigger problem and needs to be part of the file, but the patient doesn't necessarily need to know about this [wording].' Others thought that 'morphology should be avoided in patient consultations as it's unfriendly, not well understood and likely medical "jargon".' A further problem is that 'morphology' doesn't always translate well into other languages.
PCM is 'likely more complex than "bump".'	Although '**bump' is easy for patients to understand** and visualise ('I use "bump" to make it easy for patients'), some felt primary cam morphology is 'likely more complex than "bump".' 'Morphology and syndrome sound more scientific. Bump totally not.' Another group warned about the possible 'nociceptive response in patients' caused by associating the term 'bump' with 'bumping bones', or of 'things hitting'; 'Therefore we may need to take care with using this term [bump] too.' One mixed stakeholder group concluded that the 'language we use in patient-facing consultations should be tailored to the person' and mentioned alternatives like 'bumpy-shape' and 'egg-shape.' There was agreement to use 'less threatening' language supported by visual aids 'images/ figures.' While it might be appropriate to 'tailor terms to three different target audiences: researchers, clinicians and patients and public', stakeholder groups suggested that Patient and Public Involvement group should inform further research on this.
In FAI syndrome, '**syndrome'** sounds 'too serious'.	Validating the Warwick Agreement, the Delphi panel achieved strong consensus on using the 'much preferred scientifically' term, 'Femoroacetabular Impingement (FAI) Syndrome' for FAI in patients with symptoms (pain/ stiffness etc). However, some felt that '**syndrome'** sounds 'too serious.' Arguing that 'words matter' panellists discussed the importance to 'tailor language to the individual' and distinguish between a 'research discussion vs talking with patients.' Commenting on the 2016 Warwick Agreement, a member of that panel mentioned 'we considered whether "syndrome" might apply a negative label to patients, but the expert patient member of the panel did not feel this would be the case but could be good to bounce this off more patients too.' We therefore need 'further patient-orientated research to assess whether it [syndrome] has negative consequences and whether femoroacetabular impingement (FAI) used in isolation may be a better term when communicating with patients.'

4.4.3 Taxonomy – Delphi domain 3

The Delphi panel reached consensus in round 1 and 2 on three of four statements in the taxonomy domain (Table 4.5). There is consensus that we should distinguish between primary and secondary cam morphology in clinical practice and in research (Statements 32 and 33), and in research participants with femoroacetabular impingement syndrome (Statement 35). However, there was marginal non-consensus on the importance of distinguishing between primary and secondary cam morphology in patients (clinical practice) with femoroacetabular impingement syndrome (Statement 34).

Qualitative analysis: Qualitative analysis of individual panellist feedback identified six themes (Data supplement 7, Table 4.1). First, although not agreed as critical by the panel, distinguishing between primary and secondary cam morphology in patients with femoroacetabular impingement syndrome (Statement 34) is important as secondary cam morphology could have a less favourable prognosis. Secondary cam morphology should therefore be distinguished to improve treatment planning. Second, the taxonomy is important for diagnosis. Third, the taxonomy is important for treatment. Fourth, the taxonomy is important for prognosis. Fifth, distinguishing between primary and secondary cam morphology is age dependent and perhaps less relevant if someone is 30 years old. Last, panellists commented on the challenge when a patient presents with a mix of both primary and secondary cam morphology.

Dissent analysis: (Data supplement 8, Table 4.1). *Outlier analysis:* Although strong consensus was achieved for statements 32, 33 and 35, few outliers (mainly orthopaedic surgeons and a physical therapist) were not convinced. After removing two outliers for statement 34, the Delphi panel reached consensus on the importance of distinguishing between primary and secondary cam morphology in patients with femoroacetabular impingement syndrome (Figure 4.5).

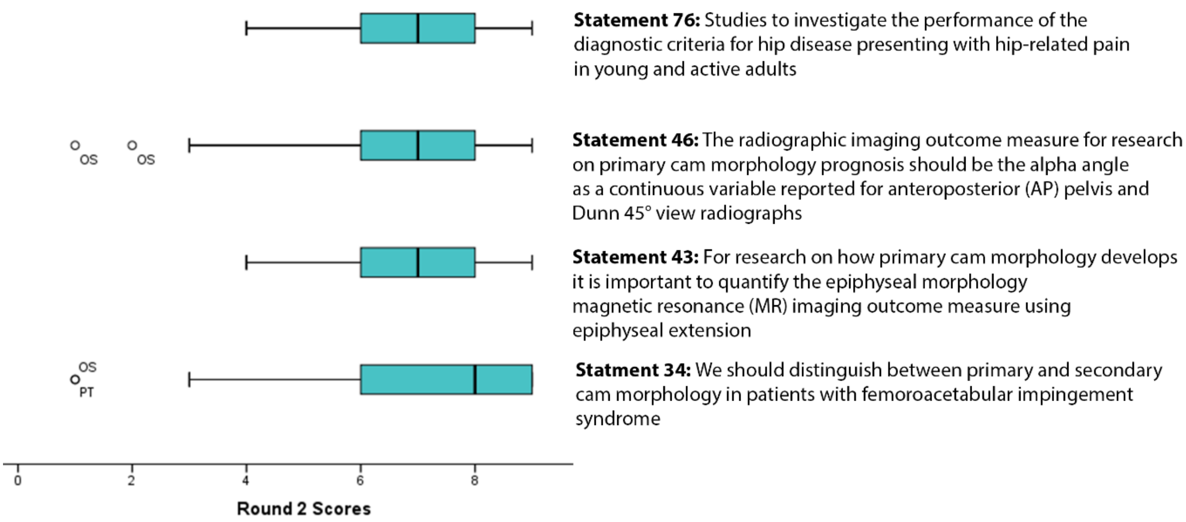


Figure 4.5. Marginally non-consensus statements 34, 43, and 46 (and statement 76 relevant to Delphi exercise domain 5; Oxford consensus study, Part 2). Recalculating consensus after removing the 4 outliers for statements 34 and 46 resulted in consensus (OS: Orthopaedic Surgeon; PPI: Patient & Public Involvement group member; MD: Physician; PT: Physical Therapist; Rad: Radiologist; Res: Researcher)

Bipolarity analysis: There was no evidence of bimodal distribution in the overall scoring of taxonomy statements. *Stakeholder group analysis:* The average scores for taxonomy statement 32 were significantly different for PPI group compared to the: (1) Orthopaedic Surgeon stakeholder group (round 2); (2) Physical Therapist stakeholder group (rounds 1 and 2); (3) Radiologist stakeholder group (rounds 1 and 2), and (4) Researcher stakeholder group (round 2). Compared to the Physical Therapist stakeholder group, the PPI stakeholder group scored statement 34 significantly different (rounds 1 and 2).

Interacting group process: I summarise the results of the interacting group process in Table 4.8. In sum, panellists agreed that it is important (and not necessarily difficult) to distinguish between primary and secondary cam morphology but likely clinically challenging when a combination of primary and secondary cam morphology exists in one patient.

Table 4.8. Interacting group process discussion summary - taxonomy domain

Topic	Discussion summary
The general agreement was that it is important (and not necessarily difficult) to distinguish between primary and secondary cam morphology	The general agreement was that it is important (and not necessarily difficult) to **distinguish between primary and secondary cam morphology** in clinical practice and in research: 'Where we can, we should make the differential diagnosis as it affects the prognosis and therefore the management of the problem.' A librarian panellist emphasised the benefit of 'consistent terminology' when reviewing the literature: 'using primary vs secondary allowed searching the literature more clear.' Although most panellists felt that 'history is key' to distinguish between primary and secondary cam morphology, others felt that 'obtaining a detailed history and discussion with patient is more important than a label of primary and secondary.'
It can be clinically challenging when a **combination of primary and secondary cam morphology**	It can be clinically challenging when a **combination of primary and secondary cam morphology** exists in the same patient as 'there are some cases where primary cam morphology exists prior to a secondary injury (e.g. SCE), and these cases can be a little more difficult to diagnose but are less commonly observed.'

4.4.4 Imaging outcomes – Delphi domain 4

The Delphi panel reached consensus on three of 12 imaging outcomes statements in round 1 and seven of 12 in round 2 (Table 4.5). Radial sequence 1.5 T or 3 T magnetic resonance (MR) imaging should be used for research on how primary cam morphology develops (Statements 36 - 38). Continuous bone and/ or cartilage alpha angles are the agreed outcome measure, reported for all the o'clock locations around the femoral head-neck junction regardless of the symptomatic state of the research participant (Statements 41 and 42). MR imaging protocols for research on how primary cam morphology develops should include: (i) unilateral small field-of-view (FOV) sequences and radial images of a randomly selected or both hips as well as (ii) femoral torsion assessment (fast axial sequences of the distal knee—femoral condyles—and proximal femoral neck) and (iii) a fluid sensitive sequence covering the whole pelvis (in axial or coronal planes to screen for soft-tissue and bone marrow oedema beyond the hip) (Statement 39).

In addition to reporting alpha angles as continuous in studies on aetiology or prognosis, other quantitative and qualitative imaging outcome measures to categorise cam morphology can be useful in research or clinical practice (Statement 47).

The Delphi panel did not reach consensus on five imaging outcomes statements[16]. First, panellists did not agree that every 18 to 24 months is the preferred time interval for serial MR imaging in prospective research on how primary cam morphology develops. Some commented that it depends on the research question. Acknowledging that it will be difficult, others suggested imaging should be more often, particularly if there is a critical window that we want to identify. A 2-year interval would then not be frequent enough. (Statement 40). Second, although it is 'probably critical', panellists felt insufficient data exist to support using epiphyseal extension or epiphyseal tilt to quantify epiphyseal morphology on MR imaging (Statements 43 and 44). Third, questioning the evidence for a 5-year imaging interval, panellists did not agree on the main imaging modality for longitudinal primary cam morphology prognosis research, nor how often to repeat the imaging. While some suggested frog-leg lateral or Dunn view radiographs, and others any lateral head-neck view depending on the particular centre, a few panellists preferred MRI with all clock positions included (Statement 45). Last, the panel failed to agree that radiographs (AP pelvis and Dunn 45° views) should be used to calculate the alpha angle for prognosis studies. Some preferred MRI with all clock positions while others felt AP pelvis alpha angles would be 'too imprecise.' Panellists reminded that, to date, there is no consensus on optimum threshold for dichotomizing the alpha angle. It makes comparing across studies very difficult when different thresholds are used. Despite this, a diagnostic threshold might be important for clinicians (Statement 46).

[16] Importantly, the Delphi process is not intended to reach full consensus; it is intended to reach as good a consensus as you can, and highlight areas of dissensus. I discuss in section 4.5.4 how these areas of inherent uncertainty could inform further deliberation and future research

Qualitative analysis: In addition to the above, qualitative analysis of individual panellist feedback identified nine more themes (Data supplement 7, Table 4.1): (1) the 'huge cost aspect' of MR imaging is an important consideration, especially for minoritised and marginalised research populations; (2) disagreement on primary cam morphology as a concept; (3) the importance of qualifying type of radial MR imaging; (4) fluid sensitive pelvis images are unnecessary when studying primary cam morphology development because the rationale for this is to find pathological processes elsewhere; (5) research question will determine the preferred imaging; (6) confusion created by alternative primary cam morphology imaging outcome measures; (7) importance of standardising imaging across research; (8) concern about radiation exposure of serial radiographs. While radiographs are inexpensive and fast to do, the concerns are radiation and less detail compared to MR imaging; (9) lack of appropriate technical and clinical knowledge to score imaging statements.

Dissent analysis: (Data supplement 8, Table 4.1). *Outlier analysis:* Six of 12 imaging outcomes statements (Statements 36, 39, 42, 44, 45, and 46) had outliers. After eliminating the two orthopaedic surgeon outliers for marginally non-consensus statement 46, the Delphi panel reached consensus that alpha angle as a continuous variable, reported for anteroposterior (AP) pelvis and Dunn 45° view radiographs, should be the radiographic imaging outcome measure for research on primary cam morphology prognosis (Figure 4.5). *Bipolarity analysis:* There was no evidence of bimodal distribution in the overall scoring of imaging outcomes statements. *Stakeholder group analysis:* There was no statistically significant difference in how stakeholder groups scored the imaging outcomes statements in rounds 1 and 2.

Interacting group process: I summarise the results of the interacting group process in Table 4.9. In sum, panellists agreed that (1) serial radiographs, in particular, to investigate primary cam morphology aetiology would be research waste; (2) in long-term prognosis studies, MR imaging trumps radiographs but warned about its cost, lack of availability (equipment and expert radiologists) particularly in the Global South, and the burden of procedure (time, claustrophobia etc); (3) further work is needed to develop and refine consensus on the specific and standardised imaging protocols; (4) dissemination of imaging findings in research (to, for example, individual research participants or their medical teams) need careful consideration.

Table 4.9. Interacting group process discussion summary - imaging outcomes domain

Topic	Discussion summary
'Ethical consideration for the amount or frequency of imaging'	Commenting on the 'obvious ethical consideration for the amount or **frequency of imaging'**, a radiologist in one of the mixed stakeholder groups felt 'the more the better in terms of insight' and raised the possible benefit of radial vs block imaging – 'block images may allow you to evaluate the images later through the use of novel techniques such as AI [artificial intelligence].' While one group felt that yearly MR imaging is appropriate when investigating how primary cam morphology develops in boys (from 11 to 16 years) and girls (from 9 to 14 years), another commented that 'the time interval should be much shorter if it is to be truly "ideal" (e.g. every 3 months). This would capture periods of considerably faster growth or considerable changes in load', while 'more frequent imaging will help in periods of rapid growth, but it is also important to have frequent serial imaging even in periods without rapid growth to assess the influence of growth spurts.' However, the value of serial imaging was questioned, as, for example, 'positions [of primary cam morphology] might vary making it impossible to use them to track changes over time.' One group **warned that the use of serial radiographs** to investigate primary cam morphology aetiology constitutes **research waste**: 'if you can't do serial MRIs at short enough intervals, don't waste time and money, don't do the study.'
Long-term prognosis studies	Discussing **long-term prognosis** studies, groups agreed MR imaging trumps radiography and 'should be the investigation of choice where at all possible in adolescent populations.' The quality of imaging is better, it better quantifies cartilaginous progression in adolescents where 'the use of alpha-angle on x-ray can be misleading and therefore inaccurate', and, as it does not pose a (cumulative) radiation risk 'ethics committees are more likely to accept MRI based studies.' However, there are at least **3 issues with MR imaging:** cost, availability (equipment and expert radiologists), and the burden of procedure (time, claustrophobia etc). MR imaging is challenging in young adolescents 'due to difficulty remaining still, i.e. movement artefact.'
Standardised imaging protocol	The group agreed that further work is needed to develop and refine consensus on the specific and **standardised imaging protocol**: 'If x-rays are utilised then it has to be reinforced on the views that are valuable and this message should be repeated in order to support this

	becoming routine practice; not all facilities are skilled with specific radiograph images e.g., Dunn.'
Dissemination of findings	It is further important to consider **dissemination of findings**: 'Do athletes want to know the results? How, what, and when do we communicate imaging results to participants or parents? Do we consider positive/negative response by athletes/parents, and provide them with the "opt in" opportunity not to be informed of their individual imaging results?' Group members raised four important points from the athlete/parent's perspective. First, parents 'were not comfortable' with cumulative radiation exposure associated with serial radiographs. Radiation exposure is an 'ethical dilemma in this area' with 'a need to be up front and transparent with information so parents are aware.' Second, sharing of imaging results is a 'hugely important area' and research teams should carefully consider the possibility that 'parents may pick up the information or interpret it differently than health care practitioners.' Third, research teams should consider 'an "opt-in" option for participants and parents where, except if there is an issue with an imaging finding, they will not be informed of the results.' Last, research teams should carefully consider how they communicate periodic imaging results and suggested a 'common approach to dissemination of results/imaging is needed.'

4.5 Discussion

An international Delphi panel of expert clinicians, athletes, patients and their representatives, and researchers—representing the YAHiR Collaborative—agreed on four key primary cam morphology elements: definition, terminology, taxonomy, and imaging outcome measures. In what follows, I discuss the Delphi panel's opinions on these key elements and summarise how agreement, and areas of tension and dissent, inform a more rigorous, inclusive, and evidence-based approach to research on primary cam morphology and its natural history.

4.5.1 Definitions – Delphi domain 1

The Delphi panel agreed on a comprehensive conceptual and operational definition for primary cam morphology (Figure 4.6).

The conceptual definition could equip all stakeholders, especially athletes and patients, with meaningful language to describe an abstract concept in their hip. It's a bony or cartilage prominence (or 'bump'), with shape (aspherical), size (most are small; some are large), location (anywhere around the head-neck junction of the hip but predominantly antero-lateral), and ownership (it is more prevalent in male athletes compared to females and non-athletes, and more common in both hips) [1]. Ownership also implies 'lived with', opening the door for conversations and qualitative research with athletes and patients on their experiences.

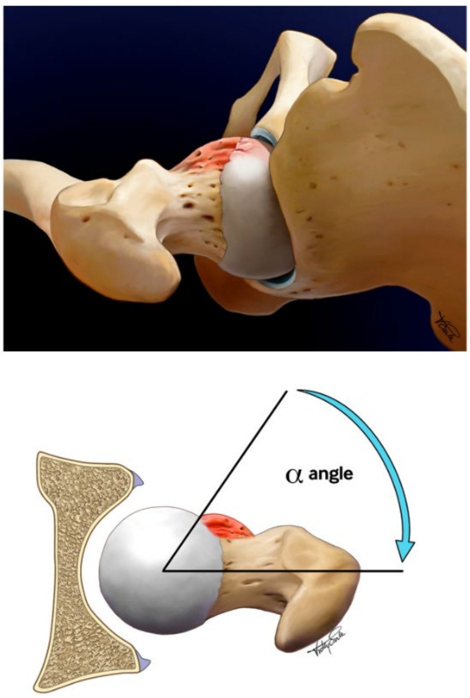


Figure 4.6. Primary cam morphology - an updated definition.

Primary cam morphology is a cartilage or bony prominence ('bump') of varying size at any location around the femoral head-neck junction of the hip, which changes the shape of the femoral head from spherical to aspherical. It occurs most often in asymptomatic male athletes in both hips.

The preferred outcome measure for research on primary cam morphology aetiology is a cartilage or bone alpha angle as a continuous variable on radial MR imaging along the axis of the femoral neck, using 30° intervals from 12 o'clock to 11 o'clock positions, reported per hip, per person or both. In addition to a continuous alpha angle, a dichotomous alpha angle (using a threshold of ≥ 60°) can be useful in clinical practice or research.

Primary cam morphology develops during skeletal maturation in young adolescents (with no current or previous hip disease), as a normal physiological response to high-load sporting activity and other unconfirmed risk factors.

While the research and clinical community could celebrate consensus, tension and dissent spotlighted three areas for future research. First, although this morphology is more prevalent in male compared to female athletes, very little research involves female athletes, and no research has been done in para-athlete cohorts or athletes from the Global South—researchers must cast a much broader net to involve minoritised and marginalised groups. Second, although the vast majority of athletes with primary cam morphology will never develop symptoms or hip disease, some do. Yet, we cannot predict with confidence who these athletes are. While important to investigate the morphology's prognosis, a common, mostly benign morphology should not be medicalised. The key messages are: (1) this largely benign morphology develops as a normal physiological response to high-load physical activity, and (2) childhood physical activity and sport are important. Third, the tension between 'normal and abnormal' as it relates to the capital femoral growth plate's physiological response to load, should be investigated. Bone is a dynamic tissue; how mechanical loading influences the epiphyseal growth plate is physiologically complex depending, for example, on the load type, and physical and physiological maturity. What might be a normal load for one athlete is abnormal or high load for another.

4.5.2 Terminology – Delphi domain 2

Confirming the Warwick Agreement's recommendations [36], this much larger, more inclusive, and more diverse panel agreed that primary cam morphology is a 'morphology' and not a 'lesion', 'abnormality' or 'deformity'; in athlete-patients presenting with symptoms the agreed term is 'femoroacetabular impingement syndrome.' However, while these are acceptable scientific terms, 'morphology' and 'syndrome' don't resonate with everyone. These terms are not necessarily patient-friendly, and 'morphology' doesn't translate well into at least some of languages spoken by expert panel members. With patient and public partners, more work is needed to further refine preferred patient-friendly terms.

4.5.3 Taxonomy – Delphi domain 3

Primary cam morphology, in contrast with secondary cam morphology, is a predominantly benign hip morphology that develops during maturation in many athletes. The Delphi panel agreed with this cam morphology taxonomy [1]. Distinguishing between primary and secondary cam morphology offers advantages. First, a cam morphology taxonomy could provide more clarity and consistent terminology with utility in research; researchers could describe their populations better with more specific inclusion and exclusion criteria. Second, primary and secondary cam morphology have distinctly different aetiology and prognosis. Contrary to secondary cam morphology, primary cam morphology develops during maturation due to load and is largely benign—an important distinction that could empower athletes and patients to embrace normality and their 'happy hips'. Third, the clinical approach to an athlete with FAI syndrome and primary cam morphology is different to a patient with FAI syndrome and secondary cam morphology. The general agreement was that it is not difficult to distinguish between primary and secondary cam morphology. However, some patients might have both types while in others, a clear distinction might only be possible later in the disease process.

4.5.4 Imaging outcomes – Delphi domain 4

Acknowledging that operationalising primary cam morphology remains challenging, the panel agreed to report a continuous alpha angle—the primary imaging outcome variable for aetiology and prognosis research (Figure 4.6). In agreement with a systematic review [184], and the Lisbon Agreement [344–346], and mainly for clinical research, a 60° alpha angle cut-off value can be used to classify primary cam morphology. However, alpha angle should be reported as a specific number (continuous variable).

Although the panel agreed that serial MR imaging (radial imaging) is needed in studies to investigate how primary cam morphology develops during maturation, opinions on how often this should be done varied. Some experts suggested MR imaging every three months during the growth spurt, while others opined that every 6 to 24 months would suffice. MR imaging, however, is expensive and access to it limited. Not everyone agreed to use AP pelvis and lateral radiographs in long term prognosis studies of primary cam morphology or FAI syndrome; however, anything but radiographs will exclude the vast majority of minoritised populations with limited access to expensive 3-dimensional imaging (MRI or CT scans) and expert radiologists.

Imaging findings could confuse and worry patients. Researchers should therefore consider how potentially sensitive imaging findings are communicated to athletes, patients, and other stakeholders (e.g. parents, coaches, club managers). A discussion paper on athlete data in professional sport by the Australian Academy of Sport describes some of the important aspects [378].

4.5.5 How this consensus exercise informs research on primary cam morphology and its natural history

Having standard primary cam morphology conceptual and operational definitions, taxonomy, and terminology, empower researchers in the field, including patient and public partners, to do more rigorous research—research that is more credible, consistent, replicable, and valid, and of a higher quality [321,379,380]. Although the panel reached strong consensus on key elements, this consensus exercise illuminates challenges relevant to the minoritised, including athletes and patients. It invites authentic collaboration on a level playing field, setting the scene for a more inclusive approach to clinical decision-making and research.

Inclusive primary cam morphology research should address issues that matter to patients and improve their lives, access and represent the patient's views and experiences, and treat them with respect [381]. To date, research on primary cam morphology and its natural history, continue to minoritise important patient-athlete populations – women, children and parents, para-athletes, and athletes from the Global South. Patient partners are to a large extent absent from the research process. While emphasising the importance of meaningful inclusion of patients, giving them an active voice in research, Frankena (2019) emphasised partnerships that value each other's skills [382]. Our consensus exercise served the inclusive agreement-seeking agenda well—not only did the pragmatic online approach limit travel, but it also invited the minoritised and marginalised into the room. PPI colleagues voiced their opinions on three key aspects: (1) improving conceptual and operational elements of the morphology's definition, (2) using more patient-friendly terminology, and (3) applying a taxonomy that reflects their needs. This inclusive partnership with PPI colleagues strengthens evidence-based research.

Evidence-based research uses 'prior research in a systematic and transparent way to inform a new study so that it is answering questions that matter in a valid, efficient, and accessible manner', minimising clinical health research that is unnecessary, irrelevant, unscientific, wasteful, and unethical [383–385]. While this consensus exercise on the key elements of primary cam morphology could help researchers to produce research that is more 'searchable' in a systematic and transparent way, it could also be a catalyst for a fresh look at evidence—a strong foundation for higher research value and less research waste.

4.5.6 Strengths and limitations

External validity of the Delphi method is often contested. Delphi panel judgements might differ from another equally diverse expert panel. However, many authors have argued that the Delphi method provides evidence of content and face validity—group opinion is more valid than that of a single person, and 'real-world' expertise provides confirmative judgement(s) on the subject/ phenomenon/ concept. Although we applied the 'closeness continuum' to purposively recruit a large and diverse expert panel (in terms of sex, geographical representation, and profession/ stakeholder group), this study's panel and steering committee could have been more representative of communities that are not widely represented in this field. While making explicit progress on diversity, equity, and inclusion, including actively involving a PPI stakeholder group (also as co-authors), we acknowledge that more could be done. This study, and the hip-and-groin research field in general, would benefit from actively involving researchers and participants from minoritised communities (diversity) '…including Black, Indigenous, and people of colour, People from the LGBTQIA2S+ Community, People with disabilities, People with complex/chronic illnesses, People from the Global South or Far North, People from low- or middle-income nations, People from stateless communities'[17]. However,

[17] BJSM Equity, Diversity, & Inclusion (EDI) Guiding Document: https://bjsm.bmj.com/pages/bjsm-key-publishing-resources

diversity in isolation is not enough. Clinicians and researchers should work to level the playing field (equity), and actively practice inclusivity (by creating, for example, a welcoming atmosphere, including a positive and supportive experience) to a diverse group of research participants. We used a modified (close ended) Delphi method—the classic open first round may create unambiguous, broad statements leading to bias from the outset. An open first round might also compromise assessment of reliability [386].

Although anonymity of the Delphi method and large panels have many advantages, we acknowledge that it has limitations too. These include low compliance, lack of responsibility for the end result and loss of flexibility and richness of non-verbal communication—important elements of unstructured, direct group interaction [351]. This study benefited from a closed first round and group interactions that were both anonymous for the Delphi surveys and direct, albeit online, for the interacting group process. Larger panels, however, might introduce more variation of opinion and false 'consensus' as panellists are 'forced' to reach consensus without any opportunity to debate the issues or areas of tension and dissent [302,387].

The increase in consensus between rounds 1 and 2 can be ascribed to iteration of judgement and partly to an artificial by-product of the pressure to conformity caused by feedback; we provided stakeholder group-specific histograms to all participants between rounds 1 and 2. In addition to anonymous feedback during the Delphi rounds, online mixed stakeholder group discussion meetings were opportunities to deliberate. Here it was possible for certain voices in the online room to dominate; however, group leads (including PPI colleagues) were carefully selected to guide conversations, guard against dominance, and to give minoritised groups a voice.

Because the aim of this study was not to pursue consensus at all cost, but rather to obtain reasonable consensus while mapping the level of agreement, the panel did not vote again on non-consensus statements during online meetings. Statistical consensus or non-consensus was therefore unchanged but enriched by including deliberations from multiple perspectives. Although the Delphi panel reached consensus on many statements, we acknowledge that consensus relies on ‘expert judgement’ with possible group pressure to conform. Consensus in a Delphi could therefore be seen as suspect [351].

Finally, a third Delphi round might have resulted in an even higher overall consensus, albeit limited to a small number of statements. After removing outliers and reanalysing panellists’ scores, the panel reached consensus on two statements (Statements 34 and 46) with marginal non-consensus after round 2.

4.6 Conclusion and chapter summary

A diverse Delphi panel agreed on four key issues essential to moving clinical practice and research forward in the area of primary cam morphology and its natural history: (1) definition (confirming its proposed conceptual attributes: tissue type, size, location, shape, and ownership); (2) terminology (use ‘morphology’ and not doom-and-gloom terms ‘lesion’, ‘abnormality’ or ‘deformity’); (3) taxonomy (distinguishing between primary and secondary cam morphology), and (4) imaging outcomes (continuous bone and/or cartilage alpha angles on radial femoral head-neck MR imaging for research on how primary cam morphology develops).

This broad consensus could provide athletes, patients, clinicians, and researchers with a stronger foundation for more precise communication, better clinical decision-making, and higher value research on primary cam morphology and its natural history.

In chapter 5, I present and discuss the results of objectives two and three of the Oxford Consensus Study: agreement on a set of research priorities on conditions affecting the young person’s hip, and the planning and delivery of two education events to engage stakeholders, disseminate the latest evidence, and stimulate debate - the *Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series*, and *Young Athlete's Hip Research Collaborative Symposium*.

Chapter five

Oxford consensus on primary cam morphology and femoroacetabular impingement syndrome: part 2—research priorities on conditions affecting the young person's hip

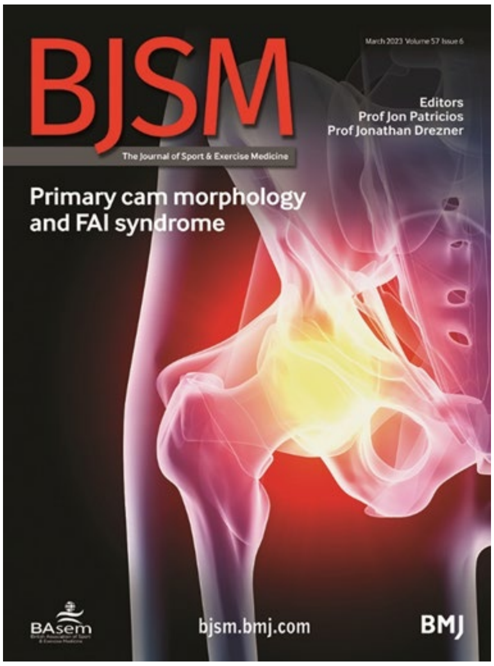
Key publications and conference presentations relevant to this chapter

Publication

Dijkstra HP, Mc Auliffe S, Ardern CL*, et al* Oxford consensus on primary cam morphology and femoroacetabular impingement syndrome: part 2—research priorities on conditions affecting the young person's hip. *Br J Sports Med* 2022;**57**:342–58. doi:10.1136/bjsports-2022-106092 [388].

My role in study and publication: I (HPD) was the lead investigator and first author.

This study is my original work. I proposed the idea of a Delphi consensus study on the topic, planned and coordinated the study as part of my DPhil Evidence-Based Health Care studies. Professors Trish Greenhalgh (TG), Mike Clarke (MC), Karim Khan (KK), and Sion Glyn-Jones (SGJ), and Dr Jason Oke (JO), as supervisors of my DPhil programme of research, provided oversight to this study with other members of the Delphi Study Steering Committee led by principal investigator TG: Dr Sean McAuliffe (SMA), Dr Clare Ardern (CLA), Associate Professor Joanne Kemp (JLK), Dr Andrea Mosler (ABM), Dr Amy Price (AP), Mr Paul Blazey (PB), Dr Andreas Serner (AS). In addition to the steering committee members, 5 co-researchers and/or Delphi panellists contributed, and therefore co-authored, the published paper. They were: Dr Dawn Richards (DPR), Dr Abdulaziz Farooq (AF), Dr Eugene McNally (EM), Professor Vasco Mascarenhas (VM), and Professor Richard Willy (RW). I wrote the first draft Delphi statements. Following that, all Steering Committee members contributed to, revised, and refined the list of Delphi statements. AP co-led the Patient and Public Involvement Group with HPD and, with DPR and RW, facilitated an authentic patient's voice throughout. AF, with oversight by JO, contributed to the statistical analysis of the study. Although EM and VM contributed to all stages of the Delphi study, their focus was revising the imaging- and research priorities domains. CLA and KMK co-chaired with HPD the online interacting group process while ABM, AP, JLK, SGJ, DPR, SMA, EM, PB, RW, AS and MC acted as group leads for the 6 small multistakeholder



groups. HPD wrote the first and all subsequent drafts of the published manuscript, including responding to peer reviewers' comments. All listed authors contributed to reviewing, editing, and revising the manuscript, and have read and agreed to the final publication. I convened the *Young Athlete's Hip Research (YAHiR) Collaborative* listed as 'collaborators' in the publication. They were all Delphi panel members and contributed to the online interacting group process and the ENHR ranking exercise. Relevance to this chapter: Significant sections from the BJSM publication are reproduced in this chapter. As lead investigator, I planned, managed, and delivered the study. Co-researchers contributed as stated above.
Conference presentations
I presented sections of this chapter: (1) as keynote lecture at the Canadian Arthritis Research Conference (February 2022) – I include the invitation letter as supplementary material (Appendix D.2); (2) as invited speaker, La Trobe Sport and Exercise Medicine Research Centre's Hip and groin pain symposium[18], June 2022 – the agenda is included as supplementary material (Appendix D.2); (3) in Webinar 11 of the Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series: 'Summary of the Delphi exercise to agree on a prioritised research agenda for conditions affecting the young person's hip' – described in more detail in section 5.4.5 of this chapter.

[18] http://semrc.blogs.latrobe.edu.au/events/hip-groin-symposium/

Chapter 5: Oxford consensus on primary cam morphology and femoroacetabular impingement syndrome: part 2—research priorities on conditions affecting the young person's hip

Significant sections of this chapter have been published in British Journal of Sport Medicine:

Dijkstra HP, Auliffe SM, Ardern CL, *et al.* Oxford consensus on primary cam morphology and femoroacetabular impingement syndrome: part 2—research priorities on conditions affecting the young person's hip. *Br J Sports Med* 2022;**57**:342–58. doi:10.1136/bjsports-2022-106092

Table 5.1. Supplementary material relevant to chapter 5 published in BJSM

Link to Article info: https://bjsm.bmj.com/content/early/2022/12/06/bjsports-2022-106092.info	
Data supplement 1	Oxford consensus on primary cam morphology and femoroacetabular impingement syndrome. Part 1 and 2 methods (duplicate of Data supplement 1 published with Oxford consensus, part 1 (Table 4.1) https://bjsm.bmj.com/content/bjsports/suppl/2022/12/06/bjsports-2022-106092.DC1/bjsports-2022-106092supp001_data_supplement.pdf
Data supplement 2, 3 and 4	Research Priority Setting – Essential National Health Research (ENHR) strategy Form 1 - Statements 48 to 54: https://bjsm.bmj.com/content/bjsports/suppl/2022/12/06/bjsports-2022-106092.DC1/bjsports-2022-106092supp008_data_supplement.pdf Form 2 – Statements 55 to 59: https://bjsm.bmj.com/content/bjsports/suppl/2022/12/06/bjsports-2022-106092.DC1/bjsports-2022-106092supp009_data_supplement.pdf Form 3 – Statements 64 to 69: https://bjsm.bmj.com/content/bjsports/suppl/2022/12/06/bjsports-2022-106092.DC1/bjsports-2022-106092supp010_data_supplement.pdf
Data supplement 5	ENHR ranking exercise results: average criterium scores (and their star plots) for all 18 prioritised statements ranked from 1 to 18 https://bjsm.bmj.com/content/bjsports/suppl/2022/12/06/bjsports-2022-106092.DC1/bjsports-2022-106092supp011_data_supplement.pdf
Data supplement 6	Research priorities on conditions affecting the young person's hip focussing on primary cam morphology and its consequences in athletes mapped against REporting guideline for PRIority Setting of health (REPRISE) framework https://bjsm.bmj.com/content/bjsports/suppl/2022/12/06/bjsports-2022-106092.DC1/bjsports-2022-106092supp002_data_supplement.pdf

Data supplement 7	Recommendations for the Conducting and REporting of DElphi Studies (CREDES) and how these will inform the primary cam morphology (PCM) Delphi Study (Duplicate of Data supplement 2, Table 4.1) https://bjsm.bmj.com/content/bjsports/suppl/2022/12/06/bjsports-2022-106092.DC1/bjsports-2022-106092supp003_data_supplement.pdf
Data supplement 8	Primary cam morphology Delphi study steering committee terms of reference (Duplicate of Data supplement 3, Table 4.1) https://bjsm.bmj.com/content/bjsports/suppl/2022/12/06/bjsports-2022-106092.DC1/bjsports-2022-106092supp004_data_supplement.pdf
Data supplement 9	Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series https://bjsm.bmj.com/content/bjsports/suppl/2022/12/06/bjsports-2022-106092.DC1/bjsports-2022-106092supp005_data_supplement.pdf
Data supplement 10	Prioritised research panellist information pack https://bjsm.bmj.com/content/bjsports/suppl/2022/12/06/bjsports-2022-106092.DC1/bjsports-2022-106092supp006_data_supplement.pdf
Data supplement 11	Comprehensive Delphi Round results (quantitative and qualitative) and analyses: statement 48 to 85 https://bjsm.bmj.com/content/bjsports/suppl/2022/12/06/bjsports-2022-106092.DC1/bjsports-2022-106092supp007_data_supplement.pdf
Data supplement 12	Young Athlete's Hip Symposium agenda https://bjsm.bmj.com/content/bjsports/suppl/2022/12/06/bjsports-2022-106092.DC1/bjsports-2022-106092supp015_data_supplement.pdf
Data supplement 13	Young Athlete's Hip Research Meeting https://bjsm.bmj.com/content/bjsports/suppl/2022/12/06/bjsports-2022-106092.DC1/bjsports-2022-106092supp016_data_supplement.pdf
Data supplement 14	Panellists' qualitative feedback for research priorities (Delphi Domain 5) for Delphi rounds 1 and 2, and Essential National Health Research (ENHR) ranking exercise https://bjsm.bmj.com/content/bjsports/suppl/2022/12/06/bjsports-2022-106092.DC1/bjsports-2022-106092supp012_data_supplement.pdf
Data supplement 15	Oxford consensus study – dissent analysis Delphi domain 5 – research priorities https://bjsm.bmj.com/content/bjsports/suppl/2022/12/06/bjsports-2022-106092.DC1/bjsports-2022-106092supp013_data_supplement.pdf
Data supplement 16	Interacting group process – Delphi exercise domain 5. Mixed stakeholder group online Zoom meeting: 23 September 2021 https://bjsm.bmj.com/content/bjsports/suppl/2022/12/06/bjsports-2022-106092.DC1/bjsports-2022-106092supp014_data_supplement.pdf

5.1 Introduction

As described in earlier chapters, primary cam morphology is mostly a benign bony prominence that develops at the femoral head-neck junction of the hip. It is, however, highly prevalent in many athlete populations [3,4,291], and causes debilitating hip osteoarthritis in some [5], thus placing existing and potential athlete-patients at risk of future hip disease.

Two aspects relevant to research focus and quality, highlighted in the introduction of chapter 4 (Oxford consensus study, Part 1) underpinned the work reported in this chapter. First, clinicians and researchers cannot predict with accuracy who will develop primary cam morphology, whose primary cam morphology will be inconsequential, and who will end up with a total hip replacement—research into risk factors for aetiology and poor outcomes of primary cam morphology is needed. Second, existing research is mired in confusion partly because clinicians, athletes, patients, and researchers have not agreed on a conceptual or operational definition of primary cam morphology, key terminology, or a taxonomy of subtypes [1].

I reported in chapter 4 how an international group of clinicians, athletes, patients, and researchers—representing the YAHiR Collaborative—engaged with, challenged, and improved four key areas on primary cam morphology and its natural history. The 4 key areas identified for further attention by the concept analysis study [1] (presented in chapter 2) were: (i) a new conceptual definition for the morphology based on five defining attributes; (ii) more consistent terminology commending the important (albeit from a small and select expert panel) Warwick Agreement [36]; (iii) taxonomy distinguishing between primary and secondary cam morphology; and (iv) challenges of operationalising the hip morphology. However, agreement on a prioritised research agenda for the field, the focus of this chapter, is lacking.

The problem of largely investigator-driven health research agendas, marginalising the voices of other stakeholders including patients, caregivers, and the community, has fuelled a mismatch between the interests of patients and researchers, and a possible misdirected allocation of limited resources [296,321,322]. This spotlighted the need for transparent research priority setting with stakeholders [296,323–330].

The Warwick Agreement expert panel, including one patient, prioritised, and ranked 23 femoroacetabular impingement (FAI) syndrome research questions in 2016 [36], while subsequent consensus statements on hip-related pain [49–52], and FAI imaging [344–346], proposed and discussed, without prioritising or ranking, additional research topics.

Research partnerships with athletes, patients, researchers, and clinicians should agree on a prioritised research agenda for conditions affecting the young person's hip. If not, crucial questions could remain unanswered, scarce resources would continue to be directed to areas with low or no impact, and research waste would continue.

5.2 Aim and objectives

In this chapter, I report the results of objectives two and three of the Oxford Consensus Study that aimed to inform a more rigorous, inclusive, and evidence-based approach to research on primary cam morphology and its natural history. The specific objectives of the research were to:

(1) ascertain the level of agreement among experts on definitions, terminology, taxonomy, and imaging outcome measures for research on primary cam morphology (reported in chapter 4);

(2) work towards agreement (and highlight residual disagreements) on a set of research priorities on conditions affecting the young person's hip, focussing primarily on primary cam morphology and its natural history;

(3) hold two education events to engage stakeholders, disseminate the latest evidence, and stimulate debate

   a. *Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series*, and

   b. *Young Athlete's Hip Research Collaborative Symposium*.

5.3 Methods

I described the methods for the Oxford Consensus Study and reported the results of objective one in chapter 4. In sum, I recruited a 65-member Delphi panel to: (1) explore the level of agreement on primary cam morphology definitions, terminology, taxonomy, and imaging outcome measures for research, and (2) work towards agreement on a set of research priorities on conditions affecting the young person's hip. Following the Delphi panel, I led, with members of the Delphi steering committee and patient partners, two synchronous online mixed stakeholder group meetings to deliberate areas of tension and dissent (interacting group process). The prioritised research statements were further ranked according to the Council on Health Research for Development's Essential National Health Research (ENHR) ranking method.

5.4 Results

Of the 73 experts invited to participate in this study, 65 completed rounds 1 and 2 of the Delphi exercise. As discussed in chapter 4, the Delphi panel from 18 countries represented six stakeholder groups—26 participants were female (Table 4.2). Results of the Delphi rounds for the definition-, terminology-, taxonomy, and imaging outcomes domains (Domains 1 to 4 of the Delphi method; objective 1), are reported in chapter 4 (section 4.4). In sum, the Delphi panel scored 85 statements (12 definition-, 19 terminology-, 4 taxonomy-, 12 imaging outcome-, and 38 research statements), and reached consensus on 43 of 85 (51%) statements in round 1, and 53 of 85 (62%) statements in round 2.

In the rest of this chapter, I present the results of the strategy working towards agreement on a set of research priorities on conditions affecting the young person's hip, focussing on primary cam morphology and its natural history (objective 2: Delphi domain 5, interacting group process, and ENHR ranking strategy). I also present the two education events to engage stakeholders, disseminate the latest evidence, and stimulate debate (objective 3).

5.4.1 Delphi exercise

This Delphi exercise results section includes three key elements: (1) quantitative results (Tables 5.2 and 5.3; Data supplement 11, Table 5.1); (2) qualitative analysis supported by quotations of panellists' feedback selected from across the Delphi database (Data supplement 14, Table 5.1), and (3) dissent analysis (Data supplement 15, Table 5.1). Through this comprehensive approach to results, I illuminate the quantitative and qualitative strengths of the Delphi method.

Quantitative results: The Delphi panel reached consensus to prioritise 14 of 38 research statements in Delphi round 1, and 18 in round 2 (Table 5.2). Twenty research statements were not prioritised (Table 5.3). Panellists listed reasons for score boundary changes between rounds 1 and 2 for each statement (Data supplement 11, Table 5.1); Statement 56 (Table 5.2) did not reach stability. The four highest ranked research statements following the Delphi rounds described studies to investigate primary cam morphology aetiology and prognosis (Statements 49, 48, 50 and 54; > 90% Delphi panellists agreed that these statements were 'critical' and 0% that it was 'not important'). This changed after the online interacting group process discussion and the ENHR ranking exercise.

Qualitative feedback: (Data supplement 14, Table 5.1): The Delphi panellists provided extensive qualitative feedback on each statement. I synthesised and iteratively discussed panellists' feedback (individual online meetings and through email) with members of the steering committee. This process informed six topics for further discussion during online mixed stakeholder group meetings:

- Topic 1 – authentic collaboration: We already prioritised prospective cohort studies on primary cam morphology aetiology and prognosis. How can we facilitate authentic collaboration on large multi-centre studies using similar methods to allow data-sharing? What are the challenges?
- Topic 2 – screening and compliance: What are the risks/ benefits of screening? Should we only screen for primary cam morphology as part of prospective research? What will facilitate athlete/ participant compliance in long-term follow up studies?
- Topic 3 – load management studies: How can we ensure load management studies (cohort studies/RCTs) during growth are feasible? What resources are required to make load management studies during growth feasible? Who should be involved in the conduct of such studies? How early should recruitment begin? When should the study end? What other aspects must researchers consider?
- Topic 4 – critical elements of physiotherapy/ rehabilitation: What are the critical elements of effective physiotherapy/ rehab for patients with FAI syndrome? What information/ data does one need to be sure of the elements of best practice physiotherapy? What information is lacking and what needs to happen to obtain that information/ those data?
- Topic 5– return to sport (RTS): 'As an elite athlete, worries about RTS (which was my living) caused major anxiety for me so this is important'. What are the challenges with studying RTS? (elite & recreational athletes) Based on an elite athlete panellist's earlier comment that 'worries about return to sport (RTS) caused major anxiety' as 'it was their living', stakeholder groups discussed challenges associated with studying RTS.

- Topic 6 – qualitative research: What types of questions should we prioritise? What are the barriers to doing high quality qualitative research? What do we want to know from patients/ athletes/ parents/ coaches?

The interacting group process (where these six topics were addressed) is discussed below (section 5.4.2 and Data supplement 16, Table 5.1).

Dissent analysis: (Data supplement 15, Table 5.1). *Outlier analysis:* two outliers for 16 of 38 research priority statements did not influence group consensus or non-consensus. *Bipolarity analysis:* There was no evidence of bimodal distribution in the overall scoring of research priority statements. *Stakeholder group analysis*: The average round two scores were significantly different for the physical therapist stakeholder group compared to the radiologist stakeholder group for statements 61, 74 and 75; for the physical therapist stakeholder group compared to researcher stakeholder group for statements 58, 61, 65, 68, and 74, and physician stakeholder group compared to radiologist stakeholder group for statements 61 and 74.

Table 5.2. Results of two Delphi survey rounds and ENHR ranking exercise showing the level of agreement and ranking of 18 prioritised research priority statements on conditions affecting the young person's hip#**

Statement		Round 1		Round 2		ICC*	ICC 95% CI		ENHR
		Not important/ Disagree	Critical/ Agree	Not important/ Disagree	Critical/ Agree		Lower bound	Upper bound	Rank (score)§
No.	**RESEARCH PRIORITIES**								
48	Prospective cohort studies to investigate risk factors (aetiological and prognostic) of primary cam morphology in different cohorts	**0%**	**87.3%**	**0%**	**95.3%**	0.85	0.74	0.91	13 (17.4)
49	Prospective cohort studies that investigate how primary cam morphology develops in cohorts with variable loading demands (e.g. difference sports/ dance/ physical activity level cohorts and sedentary cohorts) (causal inference approach to investigate load as a risk factor for primary cam morphology)	**0%**	**90.3%**	**0%**	**98.4%**	0.77	0.63	0.86	14 (17.2)
50	Prospective cohort studies that investigate how primary cam morphology develops in different sex/ gender cohorts, specifically women cohorts (causal inference approach to investigate gender as a risk factor for primary cam morphology)	**0%**	**88.9%**	**0%**	**93.8%**	0.75	0.60	0.84	7 (18.5)
51	Prospective cohort studies that investigate how primary cam morphology develops in different parasport cohorts (causal inference approach to investigate load as a risk factor for primary cam morphology)	3.2%	64.5%	**1.6%**	**71.4%**	0.87	0.80	0.92	18 (16.2)
52	Prospective cohort studies that investigate how primary cam morphology develops in different race/ ethnic cohorts (causal inference approach to investigate race/ ethnicity as a risk factor for primary cam morphology)	1.6%	66.7%	**0%**	**78.1%**	0.81	0.70	0.88	16 (16.9)
53	Prospective cohort studies that investigate other potential risk factors for primary cam morphology (causal inference approach to investigate the following risk factors: anatomical-spine; acetabulum; femur; kinetic and kinematic risk factors; mechanical and biomechanical; other possible risk factors that might emerge over time)	**1.6%**	**75.8%**	**0%**	**84.1%**	0.80	0.69	0.88	17 (16.3)
54	Prospective cohort studies that investigate prognosis (consequences) of primary cam morphology in different cohorts	**0%**	**85.5%**	**0%**	**93.8%**	0.83	0.71	0.90	4 (18.5)
55	Studies (including diagnostic accuracy studies) to determine the diagnostic criteria for Cam and Pincer morphology	**3.2%**	**76.2%**	**0%**	**84.6%**	0.78	0.65	0.86	11 (17.8)
56	Studies to develop and validate diagnostic and prognostic models for primary cam morphology in young (maturing) athletes	**1.6%**	**82.5%**	**0%**	**90.6%**	0.65	**0.47**	0.80	12 (17.4)
57	Prospective cohort studies to investigate how exercise intervention influences the development and prognosis of primary cam morphology in cohorts with variable loading demands	**4.8%**	**74.6%**	**3.1%**	**82.8%**	0.84	0.74	0.90	10 (18.3)

58	Randomised controlled clinical trials to investigate how exercise intervention (load management) influences the development and prognosis of primary cam morphology in different demographic (e.g. sex/ gender; race/ ethnicity) and load (variable loading demands - e.g. different sports, dance, and physical activity level) cohorts	**3.3%**	**72.1%**	**1.6%**	**79.4%**	0.93	0.88	0.96	6 (18.5)
59	Studies to investigate the potential benefits and harms of screening for primary cam morphology in young athletes	3.2%	66.7%	**0%**	**71.9%**	0.84	0.75	0.90	15 (17)
64	Prospective cohort studies to investigate risk factors for the development and prognosis of femoroacetabular impingement (FAI) syndrome in different cohorts	**0%**	**76.2%**	**0%**	**83.1%**	0.86	0.77	0.91	9 (18.37)
65	Randomised controlled clinical trials to investigate how exercise intervention influences the development and prognosis of femoroacetabular impingement syndrome in cohorts with variable loading demands	**3.2%**	**77.8%**	**1.5%**	**80.0%**	0.93	0.89	0.96	3 (18.9)
66	Randomised controlled clinical trials to investigate best practice physiotherapy vs arthroscopic hip surgery vs sham surgery in cohorts with variable loading demands diagnosed with femoroacetabular impingement syndrome	**6.5%**	**82.3%**	**4.6%**	**87.7%**	0.90	0.84	0.94	8 (18.4)
67	Prospective cohort studies to investigate the prognosis after best practice physiotherapy and/ or arthroscopic hip surgery in different sport/ dance/ physical activity level cohorts with femoroacetabular impingement syndrome	4.8%	68.3%	**1.5%**	**73.8%**	0.89	0.83	0.94	5 (18.5)
68	Randomised controlled clinical trials to investigate what best practice physiotherapy is (e.g. in different populations and settings; pre- and post-surgery)	**1.6%**	**79.4%**	**0%**	**78.1%**	0.96	0.93	0.98	1 (19.9)
69	Studies to determine the best criteria for rehabilitation progression and Return To Sport (RTS) following management of hip-related pain	**0%**	**71.4%**	**0%**	**73.4%**	0.86	0.78	0.91	2 (19.3)

Green (high agreement on 'consensus in'): Statement scored as critical (7 to 9) by ≥70% of panel members and not important (1 to 3) by <15% of panel members

Red (high agreement on 'consensus out'): Scored as not important (1 to 3) by ≥70% of panel members and critical (7 to 9) by <15% of panel members

Yellow (non-consensus): Neither of the "consensus in" or "consensus out" criteria were met

I reported the results of Statements 1 to 47 in chapter 4 (Oxford consensus study – Part 1)

* ICC: Intraclass Correlation Coefficient; Type A ICC coefficients using an absolute agreement definition; Two-way mixed effects model where people effects are random and measures effects are fixed. ICC is an indication of the level of agreement - stability (within-subject variation and between-subject variance of individual statement scores between Round 1 and Round 2.) We used the lower bound 95% confidence interval of the ICC estimate as the basis to evaluate the level of reliability (stability) using the following general guideline: values <0.5 were classified as poor reliability ICC values 0.5 to 0.75 moderate reliability and 0.75 to 0.9 indicated good reliability and ICC values >0.9 indicated excellent reliability.

*** Essential National Health Research (ENHR)

§ Average ENHR ranking score (maximum score=24, reporting the sum of average scores for four ranking categories, each with a maximum score of 6)

Table 5.3. Results of two Delphi survey rounds showing the level of agreement on 20 non-prioritised research priority statements on conditions affecting the young person's hip#

Statement		Round 1		Round 2		ICC*	ICC 95% CI	
		Not important/ Disagree	Critical/ Agree	Not important/ Disagree	Critical/ Agree		Lower bound	Upper bound
No.	**RESEARCH PRIORITIES**							
60	Studies involving economic evaluation to determine the cost-effectiveness of different diagnostic, prognostic, and therapeutic approaches to primary cam morphology	6.3%	55.6%	3.1%	62.5%	0.84	0.74	0.90
61	Qualitative / Mixed methods studies to investigate the perspectives/ preferences/ attitudes/ concerns/ experiences of primary cam morphology stakeholders (e.g. but not limited to: athletes/ parents/ coaches/ patients with hip disease/ clinicians/ researchers)	4.8%	52.4%	3.1%	53.1%	0.91	0.85	0.94
62	Prospective cohort studies that investigate how pincer morphology develops in different cohorts	0.0%	45.3%	0%	46.2%	0.87	0.80	0.92
63	Prospective cohort studies that investigate pincer morphology prognosis in different cohorts	1.6%	45.3%	1.5%	47.7%	0.94	0.90	0.96
70	Studies to investigate; report and improve the psychometric properties of tests of (1) range of motion; (2) muscle strength (3) functional performance (4) Quality of Life (QOL) and other psychological outcomes for studies on aetiology, diagnosis, treatment, and prognosis	4.9%	60.7%	3.2%	57.1%	0.95	0.92	0.97
71	Studies to investigate the relationship among movement-related parameters (biomechanics; muscle function), symptoms, function, quality of life, and imaging and intra-articular hip findings in individuals with hip-related pain	6.6%	54.1%	3.2%	52.4%	0.96	0.94	0.98
72	Studies (randomised controlled clinical trials, cohort studies, cross sectional studies, qualitative studies) to investigate the clinical effectiveness of other treatments used in people with hip-related pain (hip joint intra-articular injections; analgesic and anti-inflammatory medications; manual therapy adjunctive techniques such as taping; bracing and orthotics)	1.6%	57.1%	1.6%	62.5%	0.91	0.85	0.95
73	Studies to investigate cost-effectiveness of different diagnostic, prognostic, and therapeutic approaches to femoroacetabular impingement syndrome and primary cam morphology	3.1%	51.6%	1.5%	58.5%	0.92	0.87	0.95
74	Qualitative studies to investigate the perspectives/ preferences/ attitudes/ concerns/ experiences of femoroacetabular impingement syndrome (including FAI syndrome and primary cam morphology) stakeholders (e.g. but not limited to: athletes/ parents/ coaches/ patients with hip disease/ clinicians/ researchers)	6.6%	54.1%	3.1%	58.5%	0.93	0.88	0.96
75	Education intervention studies (pilot studies; RCT) in individuals with hip-related pain to assess the specific effect of patient education (in addition to other interventions e.g. exercise intervention) on pre-defined patient-related outcomes. For education intervention consider content, modes of delivery and the use of innovative technologies to enhance education benefits	6.5%	51.6%	1.5%	53.8%	0.95	0.91	0.97

76	Studies to investigate the performance of the diagnostic criteria for hip disease presenting with hip-related pain in young and active adults	1.6%	65.1%	0%	66.2%	0.87	0.79	0.92
77	Core outcome set (COS) development studies for each of the conditions related to hip disease/hip-related pain in young and active adults	1.6%	61.3%	0%	61.3%	0.88	0.81	0.93
78	Research studies into the utility of HAGOS§ and iHOTλ instruments in a non-surgical treatment context	0%	60.0%	0%	58.7%	0.93	0.88	0.96
79	Studies to analyse of content and structural validity; and the relationship between individual measurement error and the minimal clinically important change for the recommended PROMs	4.8%	54.8%	1.6%	51.6%	0.85	0.77	0.91
80	Studies to investigate the impact of the diagnostic components of a specific hip condition on diagnostic or prognostic thinking (e.g. stratifying patients into high and low risk) in young and active adults	1.6%	55.6%	0.0%	56.3%	0.92	0.87	0.95
81	Studies to develop and validate diagnostic and prognostic models for the different hip diseases presenting with hip-related pain in young persons	4.8%	63.5%	1.5%	64.6%	0.88	0.80	0.92
82	Studies to investigate the additional benefit of advanced imaging (e.g. magnetic resonance imaging and/ or computed tomography scan) for diagnosis of hip disease presenting with hip-related pain in young and active adults	7.9%	50.8%	1.5%	49.2%	0.88	0.82	0.93
83	Studies to investigate the additional benefit of advanced imaging (e.g. magnetic resonance imaging and/ or computed tomography scan) for agreeing on an appropriate treatment strategy for hip disease presenting with hip-related pain in young and active adults	8.1%	56.5%	1.6%	54.7%	0.84	0.75	0.90
84	Studies to investigate the additional benefit of advanced imaging (e.g. magnetic resonance imaging and/or computed tomography scan) for prognosis of hip disease presenting with hip-related pain in young and active adults	6.3%	52.4%	0.0%	53.8%	0.79	0.68	0.87
85	Studies to investigate cost-effectiveness of different diagnostic and therapeutic approaches in conditions affecting the young person's hip	7.9%	49.2%	6.2%	53.8%	0.91	0.85	0.94

Green (high agreement on "consensus in"): Statement scored as critical (7 to 9) by ≥70% of panel members and not important (1 to 3) by <15% of panel members

Red (high agreement on "consensus out"): Scored as not important (1 to 3) by ≥70% of panel members and critical (7 to 9) by <15% of panel members

Yellow (non-consensus): Neither of the "consensus in" or "consensus out" criteria were met

We reported the results of Statements 1 to 47 in a linked paper (Oxford consensus study – Part 1)

* ICC: Intraclass Correlation Coefficient; Type A ICC coefficients using an absolute agreement definition; Two-way mixed effects model where people effects are random and measures effects are fixed. ICC is an indication of the level of agreement - stability (within-subject variation and between-subject variance of individual statement scores between Round 1 and Round 2.) We used the lower bound 95% confidence interval of the ICC estimate as the basis to evaluate the level of reliability (stability) using the following general guideline: values <0.5 were classified as poor reliability ICC values 0.5 to 0.75 moderate reliability and 0.75 to 0.9 indicated good reliability and ICC values >0.9 indicated excellent reliability.

§ Hip and Groin Outcome Score

λ International Hip Outcome Tool

5.4.2 Interacting group process discussions (online)

Six mixed stakeholder groups (*n*=41) of 5 to 8 panellists each met online on 23 September 2021 to discuss the results of the Delphi exercise and areas of tension and dissent. This online meeting took place just after Webinar 11 of the *Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series* (see section 5.4.5 and Data supplement 9, Table 5.1)

Table 5.4 summarises the deliberation results of six discussion topics.

Table 5.4. Interacting group process discussion summary - research priorities domain

Topic	Discussion summary
Authentic research collaboration and 6 associated challenges.	While prospective cohort studies on primary cam morphology aetiology and prognosis are already prioritised, **authentic collaboration** on large multi-centre studies, using similar methods to allow data-sharing, should (1) involve patient and the public in everything, (2) focus on agreeing a standard set of variables (outcomes, interventions, assessments), and (3) ask very specific questions using clear methods. Discussion groups raised **6 challenges to authentic collaboration** (with possible solutions for some). First, authorship position, when publishing results, is often contested. Second, it is difficult to getting started with data sharing—larger/established research groups should lead. Third, early career researchers, especially from low and middle-income countries or resource poor settings, are sometimes not taken seriously enough. Fourth, equitable approach to funding division, although important, is difficult, especially dividing financial support across countries. Fifth, standardising of processes can be difficult for lower income countries or institutions. Last, funders should target grants to support collaborative projects.
Primary cam morphology screening	The panel agreed that **primary cam morphology screening** as part of research to inform our knowledge 'is fine', but screening as part of routine clinical practice may lead to over-medicalisation. **Risks of screening** for primary cam morphology include overtreatment in a condition that we know is often asymptomatic. The panel questioned the need to screen a condition that we've already agreed is a 'normal physiological response.' A biostatistician panel member commented on the importance of the World Health Organisation's **Wilson-Junger criteria** to inform whether screening is appropriate or not. Warning that **screening in younger cohorts** (8 to 18y) should carefully managed from an ethical perspective, the panel recommended qualitative studies to investigate the potential nocebo impact of any diagnostic labelling. It is also important to note the lack of scientific evidence to support 'advising younger individuals that they should limit participation in certain sports based on screening

	results. Screening results might provide a basis to offer preventative support at an earlier stage to a small percentage of those with primary cam morphology who go on to develop significant hip problems later in life.
Eight factors that will facilitate athlete/ participant compliance in long-term follow up studies	Stakeholder groups discussed **8 factors that will facilitate** athlete/ **participant compliance** in long-term follow up studies: (1) involve stakeholders in study designs; (2) focus on language – 'let's figure out how to keep your hip healthy'; (3) address a large qualitative research void with respect to compliance in prevention/cohort studies; (4) recruit full teams not individuals; (5) demonstrate [to athletes, coaches and managers] that performance improves—focus on performance development over hip health to get better buy-in from athletes, coaches, and parents; (6) foster wider organisational buy-in and involve policy-makers in priority setting; (7) consider how much is asked from participants—balance how much we measure to reduce the burden; (8) create a core outcome set for these areas to support streamlined research studies and participant burden.
Feasibility of load management studies during growth	Discussing the **feasibility of load management studies** during growth, discussion groups stressed the importance of involving methodology experts (e.g. study design and training-load monitoring) and the target group in the development of any research. Load management studies on primary cam morphology development during growth may not be the right priority for new research. Patient buy-in is likely to be low—elite sports children may be unwilling to reduce participation in their preferred sport and more attention needs to be given to context: optimal study designs may not be generalisable to suboptimal context.
Seven critical elements of effective physiotherapy/ rehabilitation	Warning not to focus on cam morphology as a problem, stakeholder groups mentioned 7 **critical elements of effective physiotherapy/ rehabilitation** ('best practice physiotherapy') for patients with FAI syndrome: clinicians should (1) apply a holistic approach to rehabilitation that uses the same language; (2) deal with patient expectations, especially time: life-long; (3) address fear of movement; (4) modify what the patient do; (5) consider who the advocate for the athlete/ patient should be; (6) deliver treatment programs of at least 6 months in duration, and (7) develop treatment programs with exercise interventions as the foundation, with potential room for manual therapy. Finally the field needs individual participant data (IPD) studies with subgroup analysis to inform best practice physiotherapy, as much of the therapy approaches that 'work' has been mixed methods so likely needs to be teased out as to which factors offer the greatest benefit.
Return to Sport (RTS) challenges	An ex-elite athlete panellist spotlighted **Return to Sport challenges** mentioning 'major anxiety' as a result of 'worries about Return to Sport (RTS) (which was my living).' A patient-clinician panel member commented on their **lived experience** as a patient with FAI/ labral tear, emphasising that 'all

	healthcare providers have to be on the same page when it comes to expectations and treatments. Patients struggle with learning how to ultimately 'keep their hip happy.' This panel member emphasised **3 RTS aspects from a patient's perspective,** and relevant to a **multidisciplinary team approach**. Clinicians should encourage and support patients to (1) work with a strength and conditioning coach 'who helped me really get over the fear that loading my hip would make it worse'; (2) work with a sports psychologist 'to work through catastrophizing thoughts I had about my hip imaging results', and (3) identify 'all lifestyle factors and training factors that will impact the hip: frequency of sport/ running, duration, intensity, sleeping, nutrition, strength training.'
Six additional factors that may influence RTS	Stakeholder groups commented on **6 additional factors that may influence RTS**: (1) Athlete expectations: what has the athlete been told about their condition and their potential prognosis by a health care practitioner? Does the athlete expect or feel that X intervention is the 'only way' to allow them to return to sport? Are we honest with athletes about the potential that they may not return to their previous playing levels due to the current status of their injury/ pain/ hip? (2) Quality of intervention: we still don't have a 'best practice' method/ guide for hip interventions in CAM and FAI. The treatment that an athlete receives, surgical or non-surgical, may have a large influence on them returning to sport; (3) Stage of career: as indicated in an earlier comment – considering the stage of the athlete's career may influence RTS. Older athlete towards the end of their career may not 'want to return to sport' to preserve long term health and quality of life; (4) Sport type: individual vs team. Knowledge of an individual's sport may have a large influence on their RTS. Often team sport athletes may be able to gradually RTS or have their load managed. In individual sports this may not be possible and there may be more pressure to RTS when they are not necessarily ready; (5) Contract status: in professional athletes an athlete's contract status or endorsements may influence their RTS timeframe; (6) Support structures: the support structures and expertise available may influence an athlete's RTS.
Definition of 'return to sport'	While there's a need for clarity around the **definition of 'return to sport'** – as return to sport is often very different than return to performance – stakeholder groups warned that the current binary ('yes' or 'no') method of outlining RTS may not be fit for purpose. They suggested the possibility of a sliding scale or some type of Likert Scale that assesses athletes confidence/ happiness with playing status pre/ post intervention. Finally, stakeholder groups emphasised the need for qualitative research in the area to ascertain players perspectives about RTS.
Qualitative research and mental health of young athletes	The importance of **qualitative research** was spotlighted by a patient-panellist's Delphi round 1 recommendation to add a research priority statement 'on how diagnosis, rehab, return to sport impacted the

	mental health of young athletes (and others).' Stakeholder groups emphasised considering all the aspects in anything that is labelled and how the label may impact future growth and bias. Differentiating between primary and secondary cam morphology is therefore important as an aid for better definition and intervention as the science evolves. It is 'super important' in this population to understand a patient's journey from diagnosis through treatment. Athlete-patients are interested in what primary cam morphology and/ or FAI syndrome means for their hip 'long term': 'Can we rehab or is surgery required?'; 'How will it impact my career and life, and do I need it fixed or not?' Stakeholder groups suggested researchers should embed what is important to patients or those with the morphology, work in co-production on experience videos, and frameworks; maybe starting with safeguarding or prevention. In addition, stakeholder groups recommended peer focus groups with young people, explaining the science and giving them the problems to 'solve for science' along with scenarios, risk communication, discuss pre-emptive or interventional screening and explain differences noting prostate-, breast-, lung screenings and costs.
Involving parents and coaches	The groups highlighted **involving parents and coaches** as it is difficult for athlete-patients to rest/ commit to physiotherapy especially when being pushed by parents/ coaches. It is also difficult to motivate patient-athletes to continue with exercise-based rehabilitation after 3-4 months especially with regional differences between effective physio/ rehab/ surgery and systems, for example pay for service and how that affects treatment decisions.

In the next section, I report the results of an online ENHR ranking survey (following the interacting group process) to rank the 18 prioritised research statements.

5.4.3 ENHR ranking exercise

The ENHR ranking exercise (three online ENHR strategy surveys: *n=49*; *n=44*; *n=42*) took place in October and November 2021. Panellists ranked the 18 Delphi-prioritised statements according to eight ranking criteria (Figure 4.2). I present the average criterium question scores for 18 prioritised statements in Table 5.2 (published as Data supplement 5, Table 5.1; see the example in Appendix E.1). Figure 5.1 presents the median, interquartile range (IQR), minimum, maximum, and outlier statements for the eight criteria used to rank research statements.

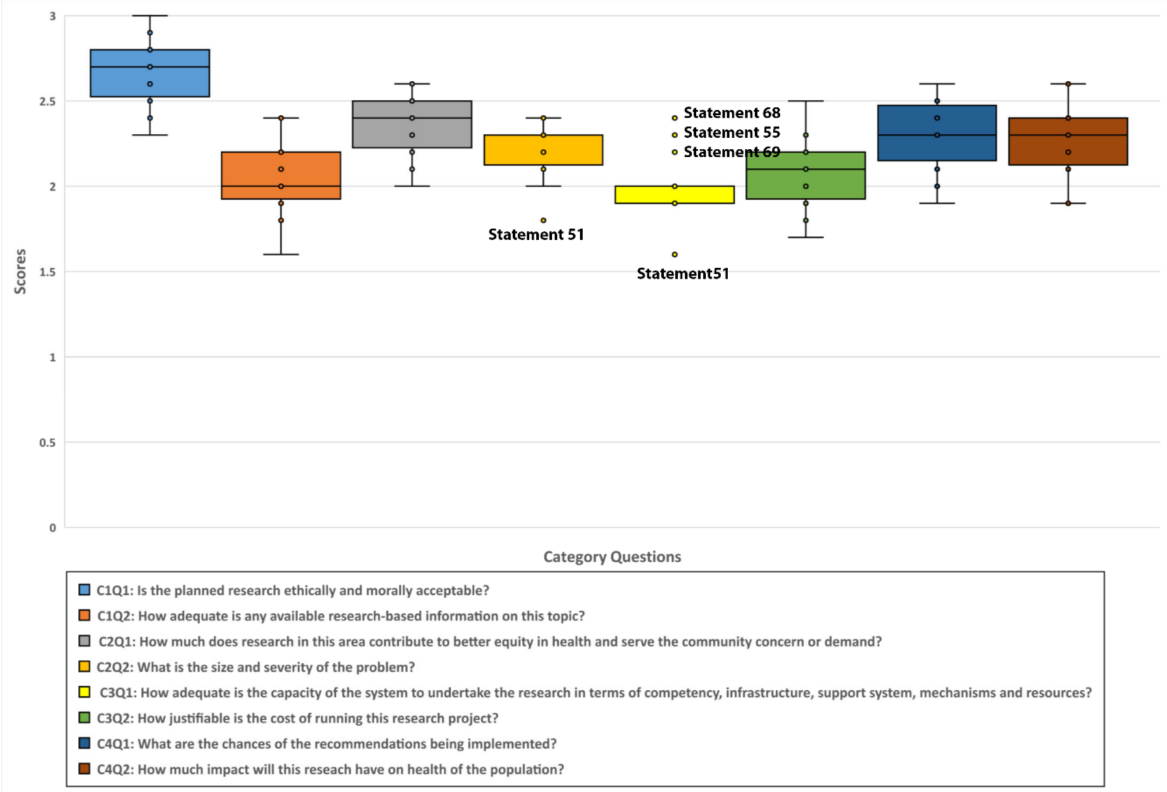


Figure 5.1. Box plots of Essential National Health Research (ENHR) strategy for research priority setting ranking data (18 prioritised statements) for each category question showing the third quartile (Q3) and first quartile (Q1), median, range and outliers. Statement 51 (mean score 1.8) was the only outlier in Category 2 (Relevancy), criterium question 2 (C2Q2). Category 3 (The chance of success), criterium question 1 (C3Q1) had four outliers: the mean scores were high for Statement 68 (mean score 2.4), Statement 55 (mean score 2.3), and Statement 69 (mean score 2.2), and low for Statement 51 (mean score 1.6). C1Q1 and C1Q2: Category 1, Questions 1 and 2; C2Q1 and C2Q2: Category 2, Questions 1 and 2; C3Q1 and C3Q2: Category 3, Questions 1 and 2; C4Q1 and C4Q2: Category 4, Questions 1 and 2.

5.4.4 Prioritised research domains

The 18 prioritised and ranked research statements, highlighted in green in Table 5.2, outlined seven research domains: (1) best practice physiotherapy, (2) rehabilitation progression and return to sport, (3) exercise intervention and load management, (4) primary cam morphology aetiology and prognosis, (5) FAI syndrome aetiology and prognosis, (6) diagnostic criteria, and (7) screening. These are medium- to long-term research priorities (Figure 5.2). A related Infographic paper [389] presents the prioritised research domains in the context of primary cam morphology's natural history (See chapter 7, section 7.1, and figure 7.10).

Prioritised research domain 1: Best practice physiotherapy

- What is **best practice physiotherapy** (e.g. in different populations and settings; pre- and post-surgery) (**Statement 68**, ranked 1)
- Prognosis after **best practice physiotherapy** and/ or arthroscopic hip surgery in different sport/ dance/ physical activity level cohorts with femoroacetabular impingement syndrome (**Statement 67**, ranked 5)
- Randomised controlled clinical trials to investigate **best practice physiotherapy** vs arthroscopic hip surgery vs sham surgery in cohorts with variable loading demands diagnosed with femoroacetabular impingement syndrome (**Statement 66**, ranked 8)

Prioritised research domain 2: Rehabilitation progression and return to sport (RTS)

- Studies to determine the best criteria for rehabilitation progression and return to sport (RTS) following management of hip-related pain (**Statement 69**, ranked 2)

Prioritised research domain 3: Exercise intervention (load management)

- Studies to investigate how **exercise intervention** influences the **development and prognosis of femoroacetabular impingement syndrome** in cohorts with variable loading demands (**Statement 65**, ranked 3)
- Studies to investigate how **exercise intervention** (load management) influences the **development and prognosis of primary cam morphology** in different demographic (e.g. sex/ gender; race/ ethnicity) and load (variable loading demands - e.g. different sports, dance, and physical activity level) cohorts (**Statement 58**, ranked 6)
- Studies to investigate how **exercise intervention** influences the **development and prognosis of primary cam morphology** in cohorts with variable loading demands (**Statement 57**, ranked 10)

Prioritised research domain 4: Primary cam morphology prognosis & aetiology

- Studies investigating **prognosis** (consequences) of primary cam morphology in different cohorts (**Statement 54**, ranked 4)
- Studies to develop and validate diagnostic and **prognostic models** for primary cam morphology in young (maturing) athletes (**Statement 56**, ranked 12)
- Studies to investigate risk factors (aetiological and **prognostic**) of primary cam morphology in different cohorts (**Statement 48**, ranked 13)
- Studies to investigate how primary cam morphology develops in different **sex/ gender** cohorts, specifically women cohorts (causal inference approach to investigate gender as a risk factor for primary cam morphology) (**Statement 50**, ranked 7)
- Studies to develop and validate **diagnostic** and prognostic **models** for primary cam morphology in young (maturing) athletes (**Statement 56**, ranked 12)
- Studies to Investigate risk factors (**aetiological** & prognostic) of primary cam morphology in different cohorts (**Statement 48**, ranked 13)
- Studies to investigate how primary cam morphology develops in cohorts with variable loading demands (e.g. difference sports/ dance/ physical activity level cohorts and sedentary cohorts) (causal inference approach to investigate **load as a risk factor** for primary cam morphology) (**Statement 49**, ranked 14)
- **Race/ ethnicity** (genetics) as risk factor – **Statement 52**, ranked 16; **Other risk factors** (e.g., anatomical) – **Statement 53**, ranked 17; **Parasport** (**Statement 51**, ranked 18)

Prioritised research domain 5: FAI syndrome prognosis & aetiology

- Randomised controlled clinical trials to investigate how exercise intervention influences the development and prognosis of **femoroacetabular impingement syndrome** in cohorts with variable loading demands (**Statement 65** ranked 9)
- Studies (including diagnostic accuracy studies) to determine the diagnostic criteria for Cam and Pincer morphology (**Statement 55** ranked 11)

Prioritised research domain 6: Diagnostic criteria (& accuracy) for primary cam morphology & pincer morphology

- Studies (including diagnostic accuracy studies) to determine the diagnostic criteria for Cam and Pincer morphology (**Statement 55** ranked 11)

Prioritised research domain 7: Screening for primary cam morphology (benefits & harm)

- Investigate the potential **benefits & harms of screening** for primary cam morphology in young athletes (**Statement 59** ranked 15)

Figure 5.2. Research priorities on conditions affecting the young person's hip, focussing primarily on primary cam morphology and its natural history (18 statements in 7 domains prioritised following two Delphi rounds and further ranked according to the Council on Health Research for Development (COHRED) Essential National Health Research (ENHR) strategy for research priority setting)

Best practice physiotherapy: The Delphi panel prioritised research on best practice physiotherapy including (1) what it is (Statement 68); (2) prognosis after best practice physiotherapy and/or arthroscopic hip surgery in patients with FAI syndrome (Statement 67); (however, current methods to capture outcomes are ‘controversial’), and (3) trials comparing best practice physiotherapy with arthroscopic hip surgery and sham surgery in patients with FAI syndrome (Statement 66). Acknowledging the fact that we already have three trials, the panel commented on the need to establish what best practice physiotherapy is before comparing it with other interventions. What best practice physiotherapy is, is also important for athlete-patients. An athlete-patient panellist commented on their ‘very mixed’ experience of physiotherapy as an elite athlete – ‘some good, some poor.’

Rehabilitation progression and return to sport: An ex-elite athlete panel member contextualised the importance of studying ‘best criteria for rehabilitation progression and Return to Sport (RTS) following management of hip-related pain.’ (Statement 69). They commented on ‘worries’ about RTS that caused ‘major anxiety’ as ‘sport was my living.’

Exercise intervention and load management: The panel recognised the size and cost of RCTs to investigate how exercise intervention influences the development and prognosis of primary cam morphology (Statements 57 and 58) and FAI syndrome in cohorts with variable loading demands (Statement 65). To address these challenges, they emphasised pooling of resources/skills, and to start with one sport/cohort—and do this well—before extending outwards. In addition, it could be very hard to get people to change behaviour regarding sports activities. Although prioritised, there are at least four challenges to plan and do ‘cohort studies to investigate how exercise intervention influences the development and prognosis of primary cam morphology in cohorts with variable loading demands’ (Statement 57). First, to date, exercise interventions are ill-defined. Second, cohort studies might not be the best study design to study the effects of interventions. Third, variable loading demands may be difficult to determine in some sports. Finally, it is necessary to consider load outside of the structured sporting environment.

Primary cam morphology and FAI syndrome aetiology and prognosis: The Delphi panel prioritised prospective cohort studies to investigate primary cam morphology and FAI syndrome risk factors (aetiological and prognostic). Acknowledging the importance of prospective research on aetiological risk factors for primary cam morphology (Statements 48 and 53), the panel also prioritised cohort studies on how the morphology develops in different sex/gender- (Statement 50), race/ethnic- (Statement 52), and variable load demand cohorts (Statement 49), including parasport (Statement 51), especially multicentre studies that would 'really improve' knowledge and patient care.

Primary cam morphology prognosis studies (Statements 48 and 54) are 'vitally important', however, panellists acknowledged 4 challenges. First, these studies are 'really difficult' to plan and execute. Second, funding is 'always an issue.' Third, these are long studies and, therefore, have a lower chance of success. Finally, scientific evidence is lacking for interventions to modify disease trajectory.

While prioritising 'studies to develop and validate diagnostic and prognostic models for primary cam morphology in young (maturing) athletes' (Statement 56), panellists commented that the field is not ready yet, and that identification of risk factors (e.g. explanatory analyses) should be prioritised. Another panellist, considering agreement on cam morphology being a finding and not a diagnosis, suggested rephrasing the statement to 'develop and validate *measurement methods* and prognostic models.'

Panellists emphasised two important considerations for 'prospective cohort studies investigating risk factors for the development and prognosis of femoroacetabular impingement (FAI) syndrome in different cohorts' (Statement 64): the impact on stakeholders and their involvement, and whether agencies/ governments will see this as a priority for funding.

The panel emphasised five important considerations for primary cam morphology and FAI syndrome risk factor research. First, it is ‘crucial’, to ensure there is more research in this space around females given the lack of current data. Second, race/ethnicity is a ‘hot topic right now’ and ‘a difficult construct’, especially when treated categorically. Resources are required to adequately sample diverse populations. Third, research on variable loading demands is challenging. It should focus on the effect of different loading patterns as it may be possible to modify loading in specific athletic populations. However, it is difficult to accurately capture training loads and ‘tough’ to get stakeholder buy-in. For example, there is ‘no way’ to convince disciplines such as dance ‘to change something in terms of load’ to prevent the development of health problems. Fourth, parasport, although ‘incredibly important’, is a ‘difficult population to study because infrastructure to support isn't as strong’, and large enough sample sizes is a ‘big challenge.’ Finally, it is ‘crucial’ to consider available data e.g. Generation R cohort in the Netherlands, a prospective general population study in children on which we have prospective follow-up imaging data of the hip of around 3000 children at ages 9, 13 and 17 years.

Diagnostic criteria for cam and pincer morphology: Research to determine diagnostic criteria for cam and pincer morphology, including diagnostic accuracy, (Statement 55), although prioritised by the panel, may focus too much on a dichotomous view rather than degrees (literally) of risk. While agreeing that consensus is needed regarding a gold standard diagnostic tool (if possible), this research needs to be ‘carefully developed/ investigated’ to focus on imaging outcomes that are correlated with clinical outcomes. A panellist questioned whether ‘a set of very clear diagnostic criteria’ is possible as FAI syndrome is a complex 3D dynamic problem.

Screening for primary cam morphology: Studies to investigate the potential benefits and harms of screening for primary cam morphology in young athletes (Statement 59) are not as important as some of the other research priorities; however, this research 'should be taken very seriously' and should involve all stakeholders.

5.4.5 Dissemination and implementation (objective 3)

This study informed the design of two education events to engage stakeholders, disseminate the latest evidence, and stimulate debate: the *Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series,* a series of 11 webinars delivered during the Covid-19 pandemic from December 2020 to September 2021 (see Data supplement 9, Table 5.1), and the YAHiR Collaborative's *Young Athlete's Hip Symposium* (see Data supplement 12, Table 5.1)

Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series

I developed 11 Webinars in close collaboration with members of the scientific planning committee and recruited 29 faculty members from nine universities and institutions to participate. The Webinar Series received the BJSM stamp of Quality International Education and was accredited for 17.5 hours of continuing professional development (CPD) credits by the Royal College of Surgeons of England (Figure 5.3).

However, the original plan was not a webinar series, but rather an in-person symposium and research consensus meeting planned for September 2020 at Worcester College, Oxford. Due to the Covid-19 pandemic, the 2020 Symposium was postponed to September 2021 (and later postponed again to September 2022). I changed the in-person research consensus meeting to an online Delphi panel. The original Symposium agenda informed the first eight webinars (Figure 5.4).

Scientific Planning & Organising Committee	Paul Dijkstra (Chair), Siôn Glyn-Jones (Co-Chair), Mike Clarke (Co-Chair), Joanne Kemp (Co-Chair), Karim Khan, Trisha Greenhalgh, Jason Oke, Clare Ardern, Andrea Mosler, Louise Strickland, Sofie Nelis, Faten Smiley, Sue King, Tiya Muluzi, Matt Brock, Ruth Davis
Scientific Faculty	Rintje Agricola, Clare Ardern, Femi Ayeni, Sheree Bekker, Paul Dijkstra, Scott Fernquest, Bruce Forster, Mo Gimpel, Siôn Glyn-Jones, Trisha Greenhalgh, Josh Heerey, Per Hölmich, Julie Jacobsen, Ara Kassarjian, Joanne Kemp, Stephanie Kliethermes, Sean Mc Auliffe, Eugene McNally, Inger Mechlenburg, Andrea Mosler, Jason Oke, Antony Palmer, Marc Philippon, Lauren Pierpoint, Lindsey Plass, Amy Price, Dawn Richards, Pim van Klij, Rich Willy
Cost	**£75 for all 11 webinars**
CPD Accreditation	The Royal College of Surgeons of England (17.5 CPD credits) http://accreditation.rcseng.ac.uk/Home/InfoAccredited
Collaborating Institutions	A **collaborative event** between the University of Oxford, Aspetar, Qatar Orthopaedic and Sports Medicine Hospital, and La Trobe University. **Approved by** British Journal of Sports Medicine (BJSM) as "Quality International Education" **Endorsed by:** CIHR Institute of Musculoskeletal Health and Arthritis (CIHR) **Faculty from:** Aarhus University, University of Bath, Copenhagen University, Erasmus University Medical Centre, McMaster University, Philippon Steadman Clinic, Southampton Football Club, Stanford University, Qatar University

Figure 5.3. Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series Scientific Planning Committee, Faculty, continuing professional development (CPD) accreditation and collaborating institutions

Webinar nine, on patient and public involvement in research, was co-developed and delivered with Drs Amy Price, Dawn Richards, Lindsay Plass, and Associate Professor Rich Willy—all members of the YAHiR Collaborative's patient and public involvement group. Webinar 10 and 11 were added to share and discuss the results of the Oxford Consensus Study. I planned and delivered all webinars using Zoom webinar technology. Dr Clare

Ardern (JOSPT Editor-in-Chief) and Associate Professor Joanne Kemp (from La Trobe Sport and Exercise Medicine Centre and Editor, BJSM) co-moderated all webinars with me.

NDORMS NUFFIELD DEPARTMENT OF ORTHOPAEDICS, RHEUMATOLOGY AND MUSCULOSKELETAL SCIENCES Medical Sciences Division | UNIVERSITY OF OXFORD DEPARTMENT FOR CONTINUING EDUCATION 140 YEARS | CEBM | UNIVERSITY OF OXFORD NUFFIELD DEPARTMENT OF PRIMARY CARE HEALTH SCIENCES Medical Sciences Division

The Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series

The Young Athlete's Hip Research (YAHiR) Collaboration

Protecting the young athlete's hip: the frontline of clinical practice and research on primary cam morphology and femoroacetabular impingement (FAI) syndrome

#OxfordHip2021

Date	Title and faculty	CPD 17.5
20th Nov 2020, 5pm GMT	**1. What is primary cam morphology? Taxonomy, terminology and definitions** Clare Ardern, Paul Dijkstra, Siôn Glyn-Jones, Karim Khan	1
11th Dec 2020, 6pm GMT	**2. Imaging strategies for primary cam morphology and FAI syndrome** Paul Dijkstra, Ara Kassarjian, Joanne Kemp, Andrea Mosler, Eugene McNally, Antony Palmer with Bruce Forster and Scott Fernquest	1.5
15th Jan 2021, 7pm GMT	**3. What causes primary cam morphology and FAI syndrome?** Clare Ardern, Joanne Kemp, Paul Dijkstra, Rintje Agricola, Siôn Glyn-Jones, Josh Heerey, Pim van Klij	1.5
5th Feb 2021, 7pm GMT	**4. Screening and prevention of primary cam morphology and its consequences in athletes** Clare Ardern, Joanne Kemp, Paul Dijkstra, Rintje Agricola, Andrea Mosler, Jason Oke	1.5
26th Feb 2021, 7pm GMT	**5. Hip dysplasia, cam morphology and FAI syndrome – is there a link?** Julie Jacobsen, Inger Mechlenburg, Siôn Glyn-Jones, Clare Ardern, Joanne Kemp, Paul Dijkstra	1.5
26th March 2021, 7pm GMT	**6. What are the consequences of primary cam morphology?** Andrea Mosler, Josh Heerey, Siôn Glyn-Jones, Rintje Agricola, Clare Ardern, Joanne Kemp, Paul Dijkstra	1.5
30th April 2021, 7pm BST	**7. Treatment and prognosis of primary cam morphology and FAI syndrome in young athletes** Joanne Kemp, Mo Gimpel, Per Hölmich, Siôn Glyn-Jones, Marc Philippon, Clare Ardern, Paul Dijkstra	2
Saturday 29th May 2021, 12.00 BST	**8. Young Athlete's Hip Research (YAHiR) collaboration** Sean Mc Auliffe, Paul Dijkstra, Femi Ayeni, Scott Fernquest, Antony Palmer, Sheree Bekker, Lauren Pierpoint, Clare Ardern	2
23rd June 2021, 8pm BST	**9. Involving patients and the public in developing, performing, and reporting research and education on FAI syndrome and primary cam morphology** Amy Price, Dawn Richards, Lindsey Plass, Rich Willy, Andrea Mosler, Clare Ardern, Joanne Kemp, Paul Dijkstra	1.5
22nd Sept 2021, 12pm BST	**10. Sharing results of the YAHiR Collaboration's Delphi exercise on primary cam morphology terminology, definitions and imaging outcome measures** Clare Ardern, Paul Dijkstra, Eugene McNally, Siôn Glyn-Jones, Joanne Kemp	1.5
23rd Sept 2021, 12pm BST	**11. Young Athlete's Hip Research Collaboration: Prioritising rigorous, inclusive, and evidence-based research on conditions affecting the young person's hip (focussing on primary cam morphology and its consequences in athletes)** Mike Clarke, Andrea Mosler, Stephanie Kliethermes, Trish Greenhalgh, Siôn Glyn-Jones, Karim Khan, Joanne Kemp, Clare Ardern, Paul Dijkstra	2.5

Version: 30 August 2020 (14)

Figure 5.4. The Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series

Following each webinar, participants were invited to complete a Microsoft Forms evaluation survey. Table 5.4 presents the number of attendees and surveys completed stratified by attendance (live online or watched the recordings on Oxford's Canvas course site) following each webinar.

Table 5.5. Webinar attendees (synchronous and asynchronous) and surveys completed

Live Webinar attendance	**Surveys completed**		
Webinar (Total live attendees, *n*) [Unique viewers, *n*]	**Attended live (*n*)**	**Watched recording (*n*)**	**Total surveys completed**
Webinar 1: (88) [70]	33	41	74
Webinar 2: (76) [59]	32	38	70
Webinar 3: (56) [43]	29	26	55
Webinar 4: (56) [43]	22	29	51
Webinar 5: (51) [40]	25	26	51
Webinar 6: (51) [39]	18	24	42
Webinar 7: (37) [24]	7	20	27
Webinar 8: (31) [21]	5	16	21
Webinar 9: (38) [23]	10	11	21
Webinar 10: (48) [38]	10	13	23
Webinar 11: (49) [33]	10	12	22
TOTAL: (581) [433]	**201**	**256**	**457**

Webinar survey results

Overall quality of each Webinar: Participants rated the overall quality of each webinar from 1 to 5 stars (5 stars = excellent). The overall mean (standard deviation, SD) rating was 4.7 (±0.6) (Figure 5.5).

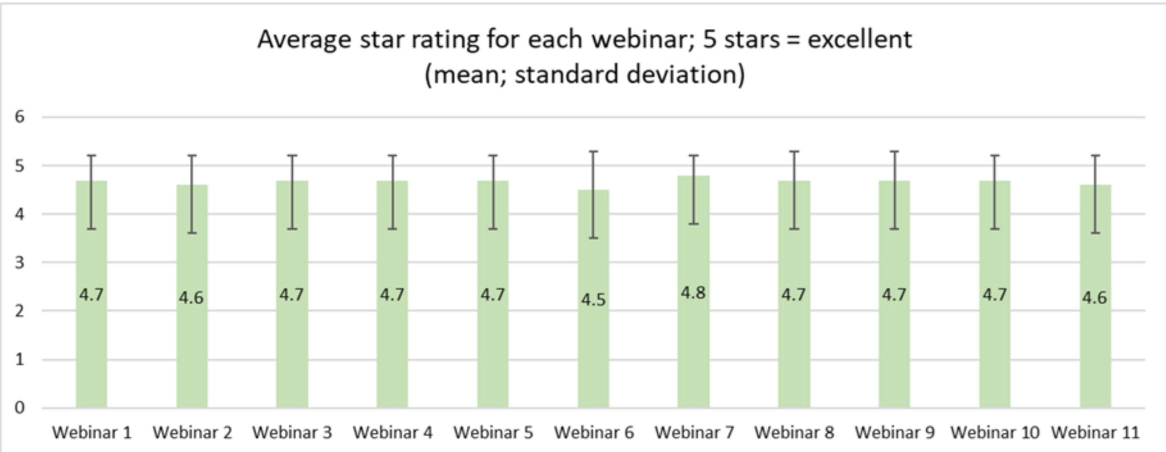


Figure 5.5. Mean, standard deviation (SD) quality rating for each webinar - maximum score = 5; overall mean (SD) = 4.7 (±0.6)

Learning experience: The majority of participants 'strongly agreed' or 'agreed' that the: (1) content of each webinar was evidence-based (Figure E-2.); (2) webinars were objective and balanced (Figure E-3); (3) presenters for each webinar were knowledgeable (Fig E-4); (4) webinar will change their research practice or clinic 'on Monday' (Figure E-5). (5) webinars were interesting and relevant (Figure E-8); and (6) webinars will improve clinical reasoning/ research planning and conduct (Figure E-7). Participants were less convinced that, based on these webinars, they will propose changes to their practice or hospital (Figure E-6).

Pre- post webinar series surveys: To measure the second level of Kirkpatrick's evaluation about participants' learning, participants completed a pre-webinar series survey (n=130) and post-webinar series survey (n=37). Thirty (23%) participants completed both pre- and post-webinar series surveys. Mean changes (and standard error of mean changes) of pre- and post-webinar series scores for 14 statements are reported in Table 5.6 and Figures 5.6 to 5.8.

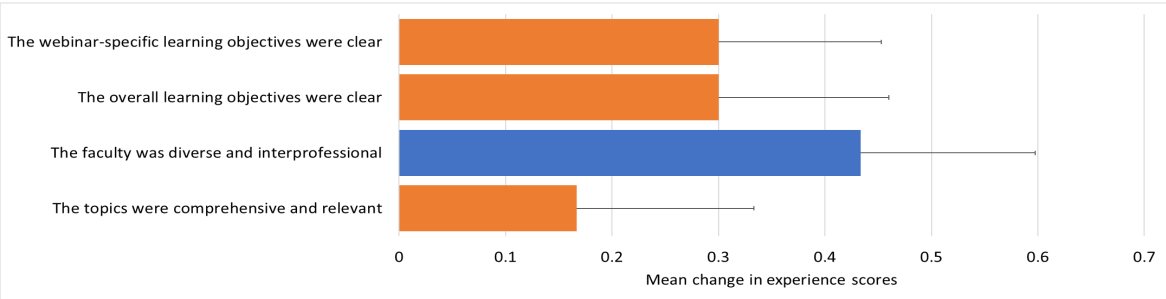


Figure 5.6. Mean change in participants' scores for four experience statements before and after the Webinar series (*n*=30)

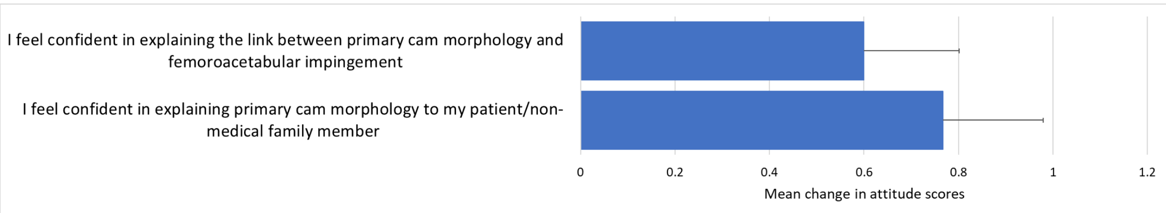


Figure 5.7. Mean change in participants' scores for two attitude statements, before and after the Webinar series (*n*=30)

Table 5.6. Mean changes (post-pre) standard error of mean changes, and p-values for participants' responses to Likert items evaluating their learning (knowledge, impact, and attitude) and Webinar series experience, *n*=30

Statement	Mean score (*SE)		Mean change (SE)	p-value
	Pre webinar series survey	Post webinar series survey		
Experience (Figure 5.6)				
The topics were comprehensive and relevant	4.50 (0.16)	4.67 (0.09)	0.17 (0.17)	0.33
The faculty was diverse and interprofessional	4.37 (0.16)	4.80 (0.07)	0.43 (0.16)	**0.01**
The overall learning objectives were clear	4.37 (0.16)	4.67 (0.09)	0.30 (0.16)	0.07
The webinar-specific learning objectives were clear	4.37 (0.16)	4.67 (0.09)	0.30 (0.15)	0.60
Attitude (Figure 5.7)				
I feel confident in explaining primary cam morphology to my patient/ non-medical family member	3.80 (0.19)	4.57 (0.09)	0.77 (0.21)	**0.001**
I feel confident in explaining the link between primary cam morphology and femoroacetabular impingement	3.97 (0.18)	4.57 (0.09)	0.60 (0.20)	**0.006**
Knowledge and Impact (Figure 5.8)				
I understand the concepts 'primary cam morphology' and 'secondary cam morphology'	3.41 (0.18)	4.55 (0.11)	1.14 (0.2)	**0.000**
I know how to diagnose cam morphology on a radiograph	3.21 (0.20)	4.28 (0.16)	1.07 (0.19)	**0.000**
I can summarise the key defining attributes of primary cam morphology	3.27 (0.19)	4.47 (0.09)	1.2 (0.20)	**0.000**
I am able to create a treatment plan for an athlete with hip-related pain and primary cam morphology	3.71 (0.20)	4.43 (0.11)	0.71 (0.21)	**0.002**
I am able to provide my practice/ hospital/ organisation with advice on how to implement a clinical service for athletes with hip-related pain	3.48 (0.15)	4.26 (0.14)	0.78 (0.15)	**0.000**
I am able to plan and undertake a research project on how primary cam morphology develops in athletes	3.03 (0.20)	3.90 (0.17)	0.86 (0.16)	**0.000**
I am able to teach someone else on the topics of cam morphology and femoroacetabular impingement syndrome	3.38 (0.20)	4.34 (0.15)	0.97 (0.16)	**0.000**
It is important to distinguish between primary and secondary cam morphology	3.54 (0.19)	4.38 (0.11)	0.85 (0.22)	**0.001**

*Standard Error

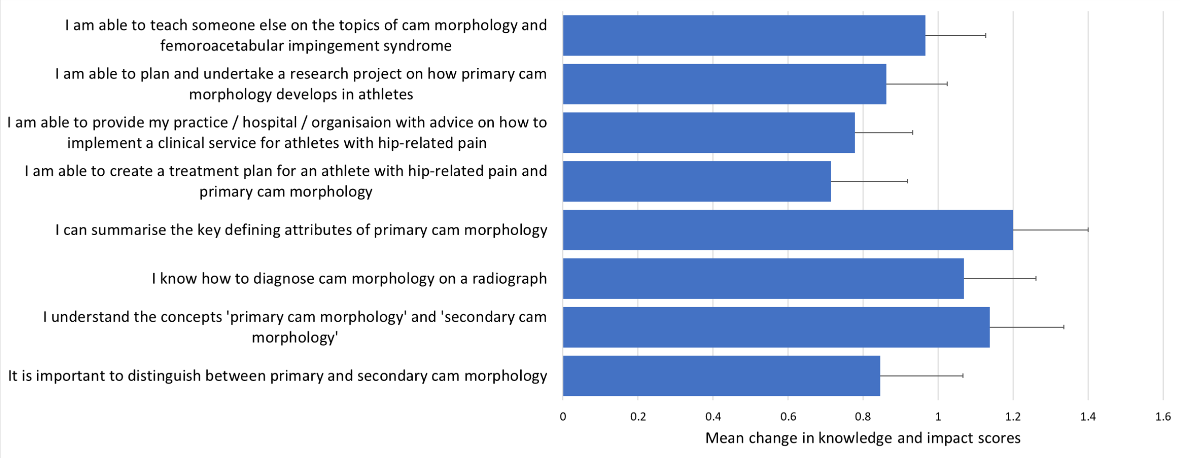


Figure 5.8. Mean change in participants' scores for knowledge and impact statements, before and after the Webinar series (*n*=30)

Young Athlete's Hip Symposium

I chaired the scientific planning committee of the hybrid *Young Athlete's Hip Symposium* held at Worcester College in Oxford on 22 September 2022 with Aspetar Sports Medicine and Orthopaedic Hospital in Qatar as organising partner (Figure 5.9 and 5.10). Co-chairs included my DPhil supervisors, Professors Siôn Glyn-Jones and Karim Khan as well as Associate Professor Joanne Kemp (La Trobe University Sport and Exercise Medicine Centre and Editor, BJSM) and Dr Clare Ardern (Editor in Chief, JOSPT). Thirty- nine faculty members from 13 countries participated (the Netherlands, Norway, Sweden, Canada, UK, USA, Australia, Denmark, South Africa, Qatar, Spain, Ireland, and Zimbabwe). The Symposium received the BJSM stamp of Quality International Education, was endorsed by JOSPT and The International Sports Medicine Federation (FIMS) (Appendix figure E-10), and accredited for 6 hours of continuing professional development (CPD) credits by the

Figure 5.9. The Young Athlete's Hip Symposium and Research Meeting banner at Worcester College, Oxford (Photo: Paul Dijkstra)

Royal College of Surgeons of England (Figure 5.10). This Symposium, attended by 101 participants in-person and online, focussed on dissemination and discussion of the Oxford Delphi consensus studies. In addition to faculty who attended in-person (n=37), 13 registered participants attended in-person while 51 participants and YAHiR members from 21 countries attended online. Following the symposium, seven more participants registered to access recorded material asynchronously.

The Young Athlete's Hip Symposium

A Young Athlete's Hip Research (YAHiR) Collaborative initiative

#AthletesHip

Partnering to promote and protect athletes' hip health

Organising partner

Date	**Symposium:** 22nd September 2022 – 8:30 to 17.40 (BST)
Venue	**Worcester College, University of Oxford** Sultan Nazrin Shah Centre Auditorium and online (live streamed)
Cost	£150 (in-person) / £50 (online) This fee includes free access to recordings of the *Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series* (11 webinars)
CPD Accreditation	**The Royal College of Surgeons of England has awarded up to 6 CPD points** Accredited Continuing Professional Development (rcseng.ac.uk)
Scientific Planning Committee	Paul Dijkstra (Chair), Siôn Glyn-Jones (Co-Chair), Joanne Kemp (Co-Chair), Karim Khan (Co-Chair), Clare Ardern (Co-Chair), Mike Clarke, Trisha Greenhalgh, Inger Mechlenburg, Andrea Mosler, Jason Oke, Amy Price, Dawn Richards
Scientific Faculty (including presenters, chairpersons and panellists)	Rintje Agricola, Thor Einar Andersen, Clare Ardern, Sheree Bekker, Paul Dijkstra, Jon Drezner, Kirsty Elliott-Sale, Siôn Glyn-Jones, Trish Greenhalgh, David Hanff, Josh Heerey, Per Hölmich, Lasse Ishøi, Christa Janse van Rensburg, Ara Kassarjian, Joanne Kemp, Vikas Khanduja, Karim Khan, Signe Kierkegaard, Stephanie Kliethermes, Cara Lewis, Sean McAuliffe, Inger Mechlenburg, Nonhlanhla Mkumbuzi, Andrea Mosler, Simon Newman, Jason Oke, Antony Palmer, Dora Papadopoulou, Lindsey Plass, Amy Price, Tanvi Rai, Dawn Richards, Andreas Serner, Pim van Klij, Fiona Wilson, Mara Yamauchi

Version 10: Sept22

Figure 5.10. Young Athlete's Hip Symposium Scientific Planning Committee, Faculty and CPD accreditation

Of the 101 participants and faculty who attended the symposium live, 27 (26.7%) completed a Symposium evaluation survey (11 in-person attendees and 16 online attendees; 18 physicians, 8 physiotherapists and one athlete).

Overall quality of the Symposium: (Likert scale: 1 star = poor; 3 stars = average; 5 stars = excellent). Seventeen (63%) attendees rated the overall symposium quality as excellent, including all 11 in-person participants (100%) and six (37.5%) online participants (Figure 5.11). The 10 remaining online participants rated two stars (n=*1*), three stars (n=*2*) and four stars (n=*7*). The mean rating was 4.5.

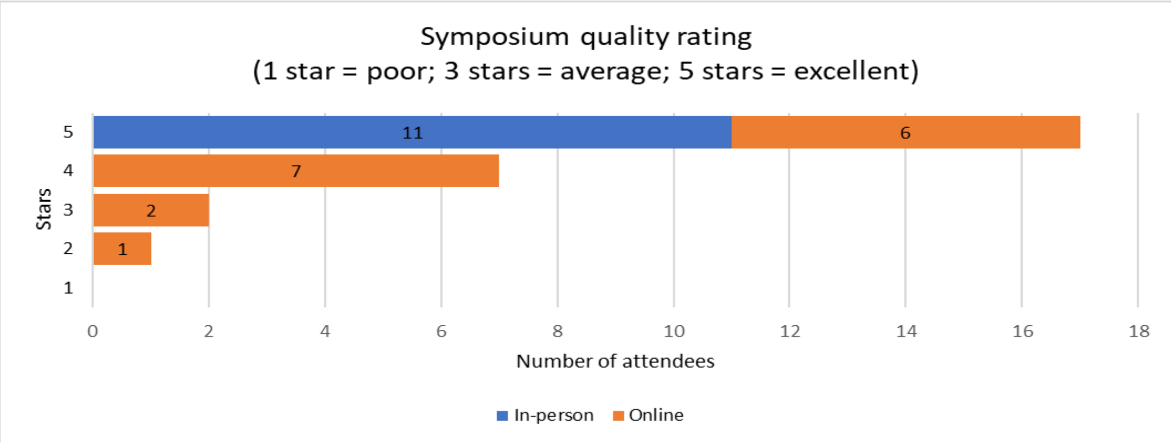


Figure 5.11. Participants' (*n*=27) Likert scale rating of the overall quality of the Young Athlete's Hip Symposium

Symposium quality: agenda, organization, and delivery: The scientific planning committee decided on a 1 slide, 5 minutes presentation style followed by a short interactive panel and audience discussion (Figure 5.12 and 5.14). Overall, this format worked well for all in-person participants and most, but not all, online participants who completed the evaluation survey (Figure 5.13). One participant commented: 'the 5 minute presentations were perhaps a little TOO concise! I'd prefer slightly longer and felt this was feasible as there was occasionally a little overlap. Fantastic event though.' Another participant commented the 1 slide, 5 min, concept 'was the perfect way to get the pearls from all the speakers and enough time for discussion and interactions. I have already discussed this pattern and model within my organisation referring to the Young Athlete's Hip Symposium.' Finally, although the 5 minutes format 'worked well for those present in person', it 'did not work equally well online.' (Appendix E.3.1).

Session 2: 11.00 to 12.30		
Femoroacetabular Impingement Syndrome in the athlete – treatment, thriving, winning		
Chairs: Andrea Mosler and Sean McAuliffe Objectives Following this session participants will be able to: 1. Construct a best-practice physiotherapy programme for the young athlete with FAI syndrome and primary cam morphology 2. Describe the appropriate imaging for studies on how primary cam morphology develops and for FAI syndrome in clinical practice 3. Describe realistic return to sport expectations after arthroscopic hip surgery for FAI syndrome		
10 min	Introduction and clinical cases	Andrea Mosler
5 min 1 slide	Three clinical pearls to diagnose FAI syndrome and primary cam morphology in the clinic	Antony Palmer
5 min	Panel and audience	
5 min 1 slide	Three key imaging considerations in the athlete with primary cam morphology and FAI syndrome	David Hanff
5 min	Panel and audience	
5 min 1 slide	Three priorities that will help young athlete-patients to thrive with FAI syndrome	Lindsey Plass
5 min	Panel and audience	
5 min 1 slide	Three key elements of best-practice physiotherapy treatment for the young athlete with FAI syndrome and primary cam morphology	Joanne Kemp
5 min	Panel and audience	
5 min 1 slide	Three key lessons from the 'Five-Year Follow-up After Hip Arthroscopic Surgery in the Horsens-Aarhus Femoroacetabular Impingement (HAFAI) Cohort'	Signe Kierkegaard
5 min	Panel and audience	
30 min	Clinical cases and discussion	All
12:30 – 13:30 Lunch		

Figure 5.12. Agenda, Session 2 demonstrating the 5 minutes, 1 slide, panel and audience discussion format

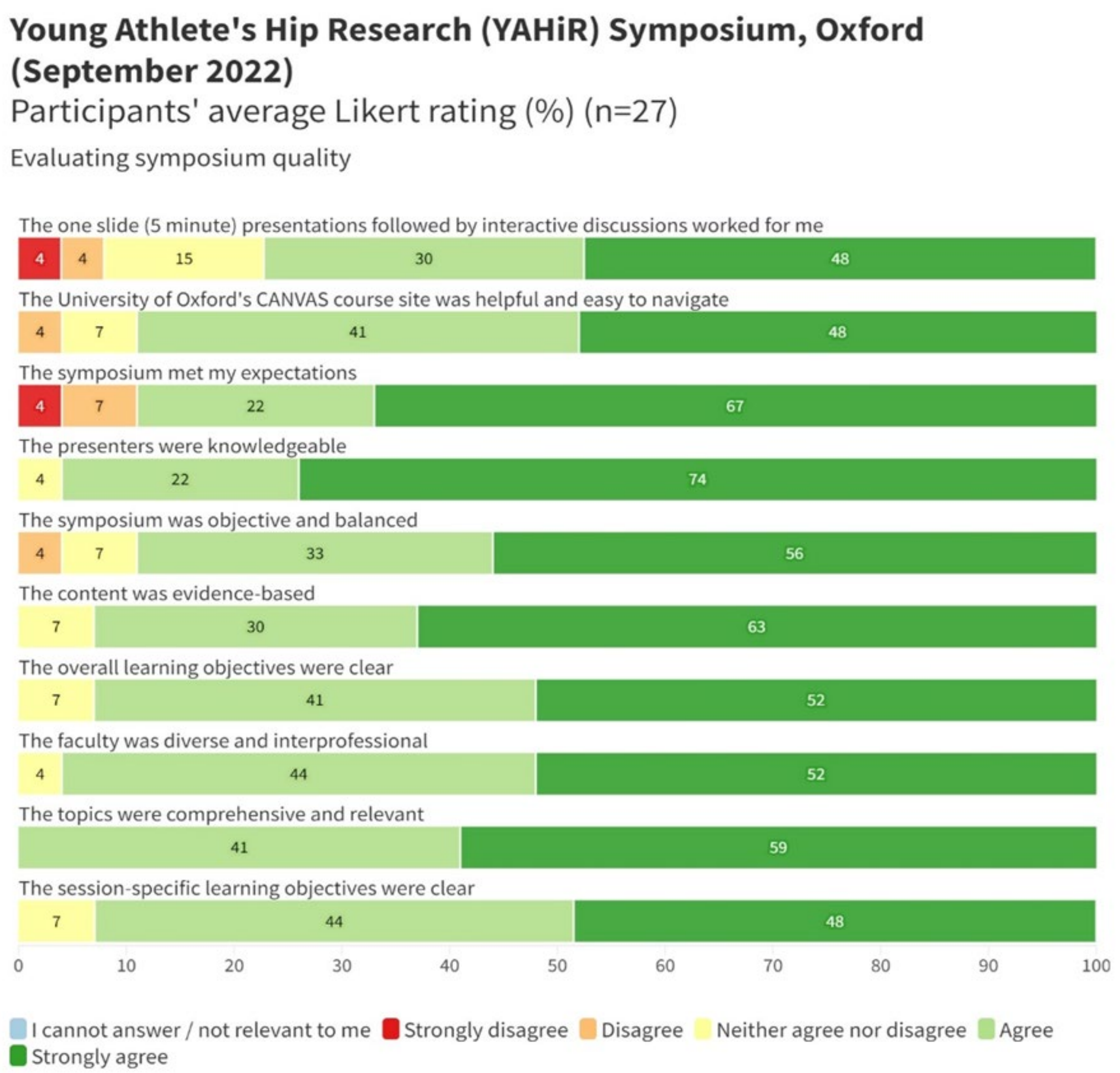


Figure 5.13. Stacked bar graph: participants' Likert scale rating of key Symposium elements

Figure 5.14. Dr Clare Ardern (moderating online participants) while session chairpersons, Dr Amy Price and Professor Karim Khan engage in-person participants in discussion

Participants' evaluation of Symposium learning objectives: Based in Bloom's verbs, I developed 11 learning objectives with oversight from the scientific planning committee and session chairpersons (Figure 5.15).

Overall Objectives

Following this symposium you will be able to:

1. Discuss the natural history of primary cam morphology
2. Recommend a strategy to protect the young athlete's hip while promoting physical activity and sport
3. Develop an evidence-based diagnostic approach to femoroacetabular impingement (FAI) syndrome and primary cam morphology in the young athlete
4. Construct a best-practice treatment plan for the young athlete with FAI syndrome and primary cam morphology
5. Appreciate the causal association between primary cam morphology and hip osteoarthritis
6. Discuss surgical management for athletes with femoroacetabular impingement syndrome and primary cam morphology
7. Develop a return-to-sport strategy for athletes with femoroacetabular impingement syndrome (for those managed non-surgically and surgically)
8. Incorporate the lived experiences of athletes with femoroacetabular impingement syndrome into your clinical and research practice
9. Construct a research plan to answer some of the pertinent questions on primary cam morphology and its consequences
10. Appreciate the key components of authentic research collaboration
11. Apply the principles of inclusivity to your clinical and research practice

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Figure 5.15. Overall learning objectives: Young Athlete's Hip Symposium

Following the Symposium, participants rated their learning (Likert scale 1 to 5) based on the overall Symposium learning objectives. Most participants who completed the Symposium evaluation survey (*n*=27) 'agreed' or 'strongly agreed' with the 11 learning objective statements (Figure 5.16).

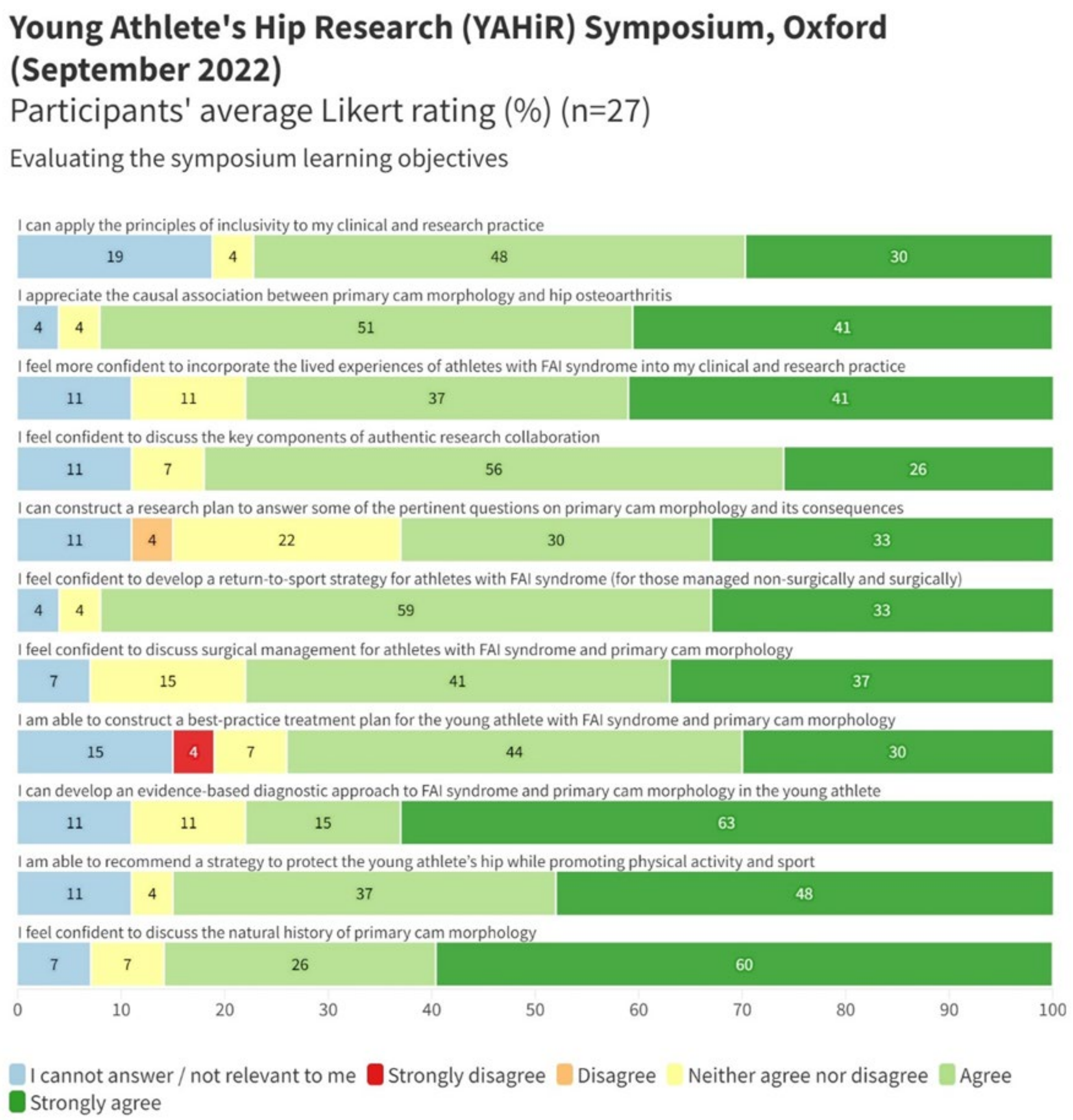

Figure 5.16. Stacked bar graph: participants' Likert scale rating of Symposium learning objectives

Primary cam morphology and FAI syndrome knowledge: Following the Symposium, participants rated their ability to apply primary cam morphology and FAI syndrome knowledge (Likert scale 1 to 5). Most participants who completed the Symposium evaluation survey (n=27) 'agreed' or 'strongly agreed' with the 10 knowledge statements (Figure 5.17).

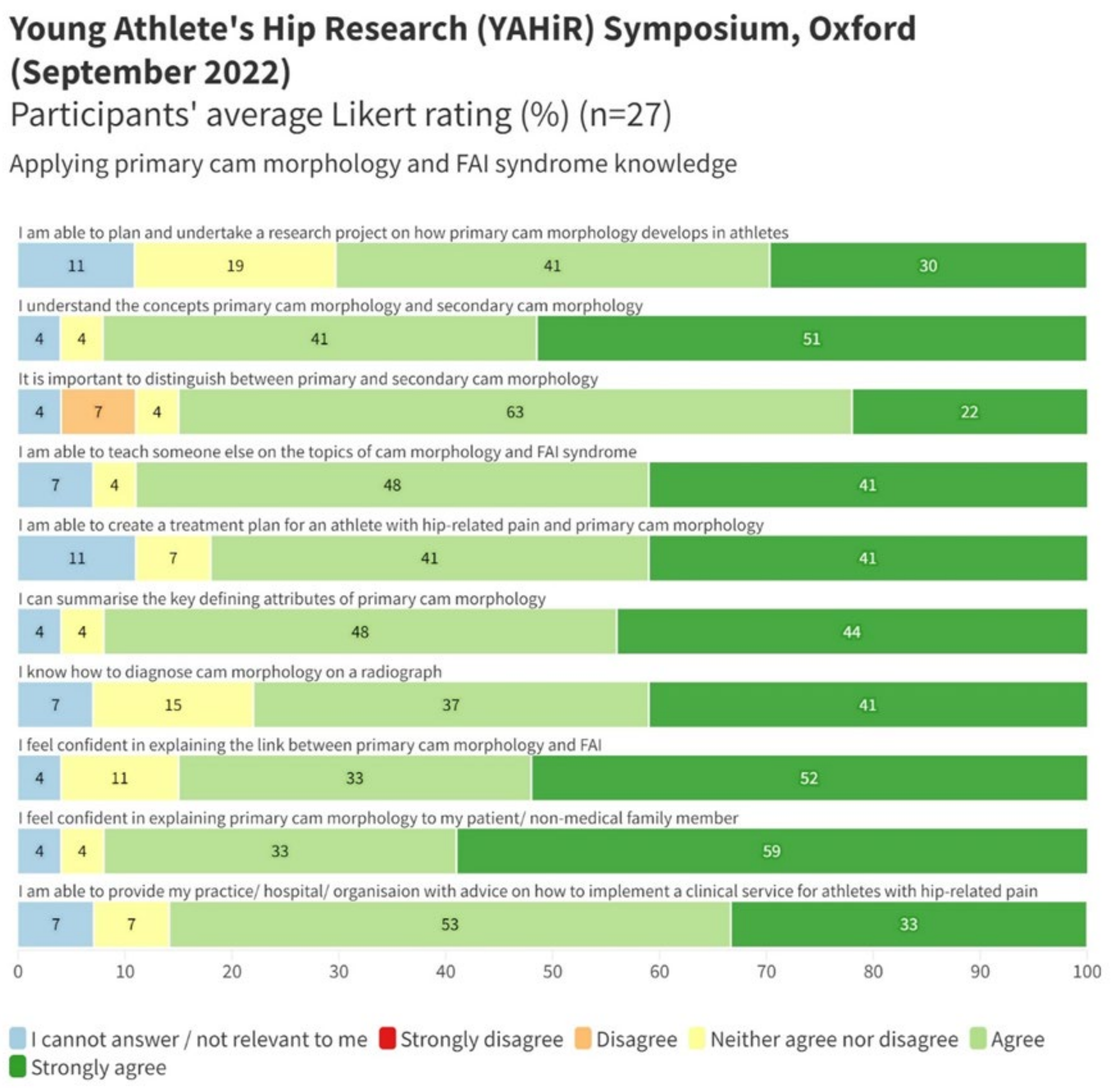

Figure 5.17. Stacked bar graph: participants' Likert scale rating of their ability to apply primary cam morphology and FAI syndrome knowledge

Symposium impact: Following the Symposium, participants rated the possible impact of the Symposium (Likert scale 1 to 5) based on 10 impact statements. Most participants who completed the Symposium evaluation survey (n=27) 'agreed' or 'strongly agreed' with the 10 impact statements (Figure 5.18).

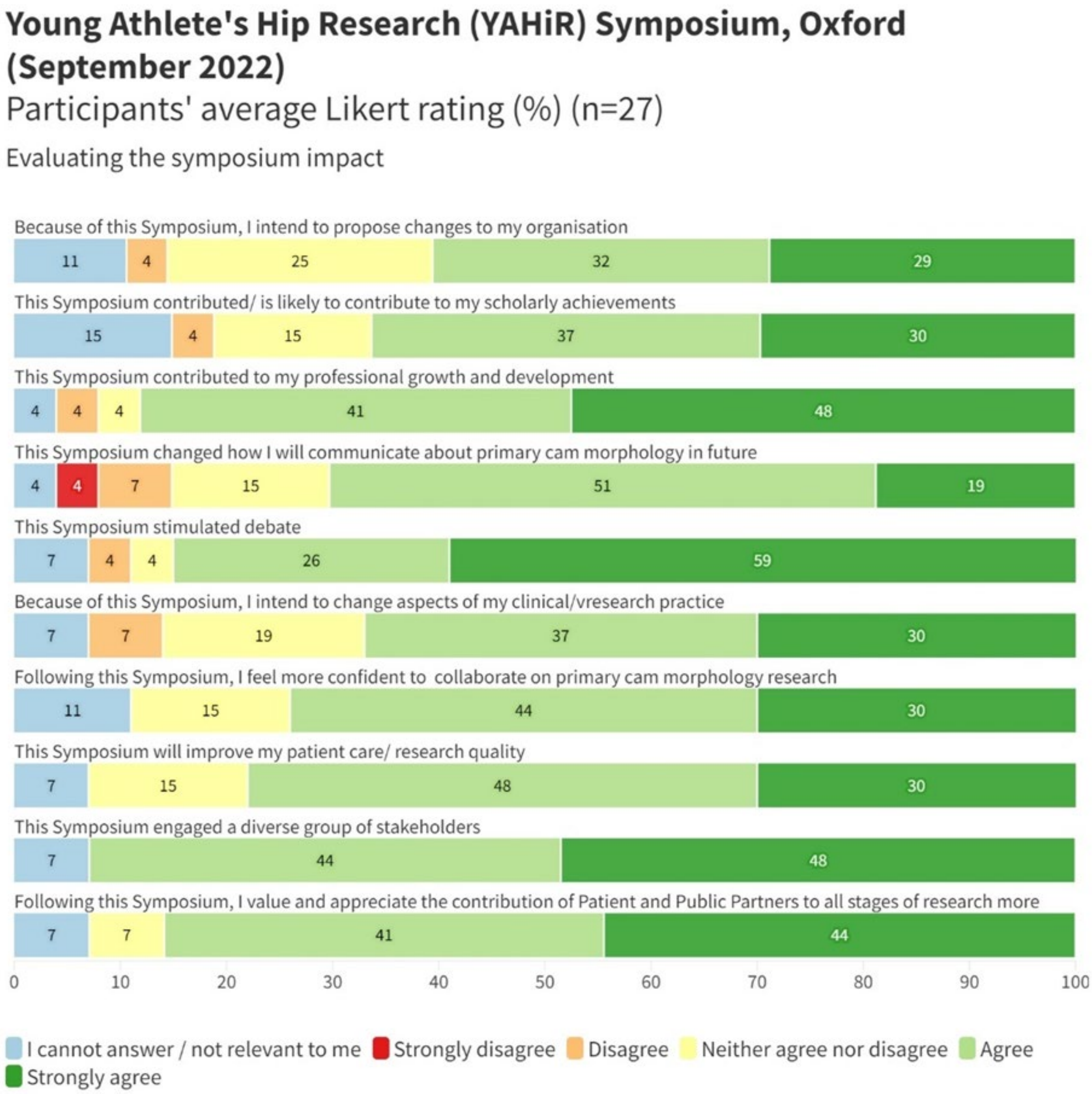

Figure 5.18. Stacked bar graph: participants' Likert scale rating of Symposium impact

Webinar Series and Symposium recordings: I created a 'course' on Oxford's Canvas Learning Management System (LMS) site to host recordings of all Webinar Series and Symposium presentations. This course site was available for registered participants to revisit presentation recordings while new participants could register to access the recordings asynchronously.

5.5 Discussion

An international Delphi panel of expert clinicians, athletes, patients and their representatives, and researchers—representing the YAHiR Collaborative—agreed on a set of research priorities on conditions affecting the young person's hip focussing on primary cam morphology and its natural history, reported here following REPRISE guidelines [296]. They outlined seven research domains: (1) best practice physiotherapy, (2) rehabilitation progression and return to sport, (3) exercise intervention and load management, (4) primary cam morphology aetiology and prognosis, (5) FAI syndrome aetiology and prognosis, (6) diagnostic criteria, and (7) screening. This consensus serves as a roadmap for researchers, policy makers and funders to prioritise research dedicated to reducing the cost and burden of conditions affecting the young person's hip, including hip disease related to primary cam morphology.

In what follows, I discuss the Delphi panel's opinions on a prioritised research agenda and summarise how agreement and areas of tension and dissent might inform future work—a more rigorous, inclusive, and evidence-based approach to research on primary cam morphology and its natural history. This consensus builds on other consensus statements [36,49–51,344–346], and a primary cam morphology concept analysis [1] and the consensus reported in chapter 4 (Oxford consensus study, Part 1).

Best practice physiotherapy is central to the treatment of hip-related pain in active adults, crucial to the understanding of effective treatment options for FAI syndrome, yet elusive and contested. The panel recommended research to (1) clarify what best practice physiotherapy is, (2) illuminate how it influences FAI syndrome prognosis, and (3) re-investigate its position as an effective treatment option compared to hip arthroscopy in patients with hip-related pain. First, practitioners and patients are confused by an elusive definition for best practice physiotherapy. A consensus on physiotherapist-led treatment for young to middle-aged active adults with hip-related pain recommended treatments that are exercise-based of at least 3 months duration, and recommended further research to investigate optimal frequency, intensity, time, type, volume, and progression of exercise therapy [50]. Second, heterogenous physiotherapist-led interventions might improve pain and function when compared with other non-surgical treatments or sham treatments in young and middle-aged adults with hip-related pain (including FAI syndrome); however, until recently, no high-quality trials existed to cement its superiority [390]. The PhysioFIRST study (see page 181) will provide clinicians with high quality evidence in this area. Finally, the only three RCTs comparing hip arthroscopy with prescribed physiotherapy [391–393] were compromised by out-of-date exercise therapy programmes [394]. New trials should do better.

The panel prioritised studies to determine best criteria for rehabilitation progression and RTS following management of hip-related pain. Such a study recently investigated RTS after criteria-based rehabilitation for acute adductor injuries [395]. RTS is complex, sport specific, multifactorial (depending, for example on the intervention), and an exercise in risk management [396–402]. The Delphi panel emphasised six considerations for rehabilitation and RTS studies, including (1) athlete expectations; (2) intervention quality; (3) career stage; (4) type of sport; (5) athlete contract status, and (6) athlete support structures.

The panel prioritised studies to investigate the role of exercise intervention (load management) on the development and prognosis of (1) FAI syndrome and (2) primary cam morphology. This should involve different demographic and load cohorts and include studies to develop and validate diagnostic and prognostic models for primary cam morphology in young athletes. While these studies should involve different sport, dance, and physical activity cohorts, the panel highlighted the importance of prioritising prospective research in girls'/women's sport. To date few prospective cohort studies investigated how (primary) cam morphology develops in athletes. However, none involved girls/women athletes, and only one involved a control group [60,62,228,245,403]. Finally, load intervention studies involving maturing athletes are easier said than done; they may be unwilling to reduce participation in their preferred sport.

Diagnostic criteria for cam- and pincer morphology are contested. The results of a systematic review to determine the diagnostic accuracy of clinical tests for cam or pincer morphology in individuals with suspected FAI syndrome, were inconclusive due to high risk of bias and low statistical precision of included studies [404]. There is to date no agreement on a radiographic definition of cam or pincer morphology. This Delphi panel agreed that an alpha angle threshold of ≥60° to classify cam morphology (Oxford consensus study, Part 1), proposed in a systematic review [184], and another consensus [344], is appropriate; however, further research should verify this.

Screening for primary cam morphology is contentious. The panel acknowledged the risk of harm—overdiagnosis and overtreatment—of a normal finding, prevalent in many athletes. Screening might benefit a small percentage of those with primary cam morphology who go on to develop significant hip problems later in life, offering them preventative support at an earlier stage. The World Health Organisation's Wilson-Junger criteria should inform whether screening is appropriate or not [405].

Although the Delphi panel didn't prioritise qualitative or mixed methods studies to 'explore perspectives/ preferences/ attitudes/ concerns/ experiences of primary cam morphology and FAI syndrome stakeholders' (Statements 61 and 74), mixed stakeholder groups highlighted the importance of understanding a patient's journey. They emphasised the importance of involving stakeholders in co-production – especially athletes, parents, and coaches. Stakeholder discussions underscored the fertile ground for co-producing qualitative research, especially with minoritised populations, to address pertinent questions [364]. Taking an evidence-based research approach, these studies should build on the results of systematic reviews and qualitative evidence synthesis relevant to the specific question [406].

5.5.1 How agreement on a prioritised research agenda advances research on primary cam morphology and its natural history

Strong consensus on primary cam morphology's conceptual and operational definitions, taxonomy, and terminology, reported and discussed in chapter 4, empowers researchers and their patient and public partners to do more rigorous research—research that is more credible, consistent, replicable, valid, and of higher quality [321,379,380]. Combining rigorous research with consensus on a prioritised research agenda, catalyses focussed, high quality research that is systematic in its inquiry, employs appropriate design, and asks challenging questions that matters [407]. This consensus exercise informs future research priorities, and illuminates challenging questions that are relevant to athletes and athlete-patients. It also invites authentic collaboration, setting the scene for a more inclusive approach to research.

As discussed in chapter 4 (section 4.5.5), inclusive primary cam morphology research, should address issues which really matter to athlete-patients, and should ultimately lead to improved lives for them. Furthermore, inclusive research respects patients and spotlights their views and experiences [381]. Research on primary cam morphology and its natural history, continue to minoritise important patient-athlete populations – women, children and parents, para-athletes, and athletes from the Global South.

It is worth emphasising the difference between doing inclusive research, 'a thing with criteria that define it', and 'doing research inclusively' [408]. The latter emphasises *doing*—a fluent and developmental *process*. Doing primary cam morphology research inclusively means the minoritized, including athletes and athlete-patients, are not merely 'involved' at every stage of research, but in charge as partners with power—exerting some control over all decisions. This is doing research that aims for the top rungs of Arnstein's ladder of citizen participation—partnership, power, and control [409,410]. Mere involvement of patients risks nonparticipation (e.g. manipulation as members of 'advisory boards'), or tokenism (being assigned but informed, or consulted and informed, or placated—pacified by the veneer of involvement) [411]. Practically, this means the minoritised should be involved in *and* in charge of the *process* of research on primary cam morphology and its consequences, including crafting and disseminating new knowledge—a process that de-medicalises and empowers. This inclusive partnership provides a powerful foundation for evidence-based research.

As discussed in chapter 4 (section 4.5.5), evidence-based research uses 'prior research in a systematic and transparent way to inform a new study so that it is answering questions that matter in a valid, efficient, and accessible manner', minimising clinical health research that is unnecessary, irrelevant, unscientific, wasteful, and unethical [383–385]. However, Anjum *et al* (2020, p6) appealed to the Evidence Based Medicine (EBM) community to expand their notion of 'evidence'. First, as 'evidence is typically evidence of causation', evidence-based researchers 'need to tackle the problem of causation head on', to better understand 'what is meant by "evidence", what is the "best available evidence", and how to apply it in the context of medicine.' Second, researchers should appreciate that multiple methods are needed to establish causation—not only the statistical approaches of randomised controlled trials and systematic reviews of trials. Third, researchers should use different types of evidence (e.g. case studies and case reports) to inform 'causal evidence'. Last, researchers should use patient narratives and phenomenological approaches as tools to look beyond evidence such as symptoms and outcomes [412]. Researchers should also specify their causal intent, when relevant, and use language consistent with that intent when reporting their studies [413]. Consensus on a prioritised research agenda on conditions affecting the young person's hip—underpinned by an evidence-based approach to research, and applying a more inclusive lens to the notion of evidence, knowledge, and co-production—is a strong foundation for higher research value and less research waste.

The prioritised research domains spotlight opportunities for research teams with expertise and experience in a specific area (including those not yet involved in the YAHiR Collaborative) to lead and build on current evidence. Two examples of ongoing research (April 2023) are:

(1) The Physiotherapy for Femoroacetabular Impingement Rehabilitation Study (the PhysioFIRST study) aiming to 'estimate the effect of a physiotherapist-led intervention with targeted strengthening compared with a physiotherapist-led intervention with standardised stretching, on hip-related quality of life or perceived improvement at 6 months in people with femoroacetabular impingement syndrome' [414,415]. The PhysioFIRST study is relevant to prioritised domain one (Figure 5.2), and the highest ranked statement (Statement 68, Table 5.2). Results of the PhysioFirst study, led by Professor Kay Crossley and Associate Professor Joanne Kemp (La Trobe Sport and Exercise Medicine Research Centre) are expected later in 2023;

(2) The PREVIEW study (led by Professor Olufemi Ayeni from McMaster University) aims to 'determine the association between sport specialisation in adolescence and the development of hip impingement' [416,417]. This study is relevant to domain four (Figure 5.2), and statement 49 (ranked 14th, Table 5.2).

Effective dissemination and implementation of the agreed prioritised research agenda, underpinned by an open science approach, is an important step. The YAHiR Collaborative values transparent and reproducible research, central to the aim of the Oxford Consensus

Study to inform a more rigorous, inclusive, and evidence-based approach to research on primary cam morphology and its natural history. Demonstrating that the YAHiR Collaborative and I value collaboration, equal opportunities, scrutiny, and critique, the Oxford Consensus Study and extensive supplemental material (Tables 4.1 and 5.1) were published open access in BJSM. Sharing material open access would stimulate readers to engage with the material, participate in wider dissemination, and possibly collaborate to co-create knowledge that matters. Open science aims to make scientific knowledge (in different languages) openly available, accessible and reusable for everyone. Our approach aimed to reinforce quality and integrity, collective benefit, equity and fairness, diversity and inclusion—the core values of open science [418].

5.5.2 Dissemination and implementation

Collaborative work to disseminate and implement the findings of the Oxford Consensus Study was essential, not only to the ethical conduct of future research, but also to authentic co-production of new knowledge [373].

Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series

This Delphi study was a catalyst for authentic involvement of PPI partners. We co-designed and co-delivered, with members of the PPI group, Webinar 9 of the *Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series.* The process emphasised collaborative and inclusive work beyond involvement—PPI colleagues took charge. We disseminated the early study results in Webinar 10 (agreement on primary cam morphology definition, terminology, taxonomy, and imaging outcomes) and Webinar 11 (prioritised research agenda). As mentioned earlier, these webinars were recorded and online access provided to registered Webinar participants, and the Oxford Delphi consensus panel.

Young Athlete's Hip Research Collaborative Symposium and Research Meeting

The YAHiR Collaborative's 2-day Symposium and Research Meeting built on the Webinar Series. The focus of the meeting was to disseminate and discuss the results of the Oxford Consensus Study amongst all stakeholders (athletes, patients, parents and coaches, clinicians, and researchers), deliberate areas of ongoing tension and dissent, and collaborate to implement the consensus by developing and curating resources, as well as sharing and aggregating large datasets. With co-researchers, I plan to publish the results of this research meeting in the second half of 2023[19].

5.5.3 Strengths and limitations

I discussed strengths and limitations to the Delphi method in chapter 4 (Section 4.5.6). I anticipated survey fatigue—not completing the survey or reluctance to participate when faced with extensive and complicated surveys—as a possible major limitation [419]. The Delphi- and ENHR ranking exercise surveys were long and potentially complicated. I introduced, with oversight by the study steering committee, four measures to mitigate participant fatigue. First, the Delphi survey was structed in 5 domains. Second, I invested time to optimise statement wording and kept the statements and survey structure the same for both Delphi rounds. Third, I authentically engaged participants, including PPI group members, through a Webinar series described above, and additional online information and discussion sessions. Last, I divided the 18 research statements for the ENHR ranking strategy between three surveys of five to seven statements per survey. All 65 participants completed the two Delphi rounds and more than 40 the three ENHR surveys. A strength of this study is the large, international panel representing six stakeholder groups, including a PPI group. Although some statements (and domains, e.g. imaging outcomes) required technical knowledge, potentially limiting some panellists' ability to answer, I invested time

[19] See section 7.5: Implications of this research and future work (p261)

to share relevant knowledge, and allowed the option ‘not able to score’. Acknowledging that a spectrum of expertise is key to inform a group’s opinion, I applied the more inclusive ‘closeness continuum’ to expertise [338].

Research priorities are based on this diverse international Delphi panel’s opinion. Despite progress on diversity, equity, and inclusion, including actively involving a PPI stakeholder group (also as co-authors), I acknowledge that more could be done. Another panel, more representative of communities that are not widely represented in the hip-and-groin research field (our Delphi panel only involved three participants from Africa, all from the same country), might have different opinions. Although all panel members completed the two Delphi rounds, panel attrition resulted in an ENHR ranking exercise panel dominated by physical therapists. This might have skewed ranking results towards research questions important to this stakeholder group.

Finally, many research statements included a method clause and referred to ‘physiotherapy’ as treatment. Panellists might have scored research topic/question-specific statements without referring to method (e.g. RCT, cohort study) differently. I acknowledge my implicit bias that only physiotherapists could deliver ‘physiotherapy’ or ‘personalised hip therapy’. This is not the experience for everyone. ‘Clinician-led progressive exercise rehabilitation’ might have been a better phrase than ‘best practice physiotherapy’. Equally, ‘physiotherapist-led treatment’ might have been a better phrase to reflect contemporary physiotherapy practice. This is an important topic for further scrutiny with clinician-researchers and patient partners.

5.6 Conclusion and chapter summary

Building a more rigorous, inclusive, and evidence-based research ecosystem is not only an important and deliberate task but also potentially daunting and disruptive. I report in this chapter how a diverse and international Delphi panel of 65 stakeholders (representing six stakeholder groups) agreed on the first ranked set of research priorities on conditions affecting the young person's hip, focussing on primary cam morphology and its natural history. Although the 18 research priorities identified signal possible gaps in the current evidence base, researchers, PPI partners and clinicians should spotlight these gaps through an evidence-based approach to future research. While informing more rigorous, inclusive, and evidence-based research, this consensus is a roadmap for researchers, policy makers and funders to implement research dedicated to reducing the cost and burden of conditions affecting the young person's hip, including hip disease related to primary cam morphology.

In the next chapter, I present a qualitative interview study of stakeholders' perspectives on research quality in the field of primary cam morphology.

Chapter six

More value and less waste in research on primary cam morphology and its natural history: a qualitative interview study of stakeholders' perspectives

Chapter 6: More value and less waste in research on primary cam morphology and its natural history: a qualitative interview study of stakeholders' perspectives

6.1 Introduction

As explained in previous chapters, primary cam morphology develops as a largely benign prominence at the head-neck junction of the hip in many young athletes. The risk of developing primary cam morphology is associated with the level of athletic activity during skeletal growth [60,151,152]. Although largely benign, this morphology is associated with femoroacetabular impingement (FAI) syndrome [36], and causes early hip osteoarthritis, with potentially significant consequences for hip-health and athletic careers [12,34,35,133]. I discussed in chapter 5, that, despite the morphology's high prevalence (up to 80% in many athletic populations [3]), many questions remain unanswered. For example, to date, no prospective studies have examined this morphology's formation and/or prognosis in girls or in populations from the Global South. Scientists cannot yet predict the individuals who might develop the morphology or its hip disease consequences, or who might need their hips replaced. Multi-centre and multi-profession collaboration to produce higher quality research with impact is paramount when promoting research value and avoiding research waste [420].

A concept analysis of primary cam morphology, presented in chapter 2, was an important first milestone towards more clarity on the morphology and its natural history [1]. In addition, the YAHiR Collaborative's *Aspetar-Oxford-La Trobe Young Athlete's Hip Webinar Series*, 11 webinars delivered during the Covid-19 pandemic (section 5.4.5), mobilised an international community of athletes, patients, clinicians, and researchers interested in improving clinical outcomes through coproducing knowledge in the field. This collaboration paved the way for the Oxford Consensus Study on primary cam morphology definitions, terminology, taxonomy, and imaging outcomes as well as a prioritised research agenda on conditions affecting the young person's hip [290,388], presented in chapters 4 and 5. However, at the time of the empirical work described below, no peer reviewed evidence existed on the perspectives of stakeholders in this research field on factors contributing to high quality research. Informed by the comprehensive framework for Increasing QUality In patient-orientated academic clinical REsearch (INQUIRE) [33], I aimed to address this gap.

6.2 Aim

This study aimed to explore research quality on primary cam morphology and its natural history through the perspectives of athletes, patients, parents and coaches, clinicians, and researchers. Exploring stakeholders' diverse perspectives on high-quality research through the lens of an existing research quality framework (INQUIRE) could pave the way for authentic collaboration to enhance research quality on primary cam morphology and its natural history.

6.3 Methods

In this section, I discuss the ontological and epistemological orientation, study design, ethical considerations, sampling strategy, data collection and analysis, and research team reflexivity for this study.

6.3.1 Ontological and epistemological orientation, and study design

This was a descriptive qualitative study [421,422], situated within a pragmatism-informed interpretive description research paradigm [423–425]. By 'pragmatism-informed' in this context, I mean drawing on the practical wisdom of practitioners *and* oriented to informing their practice in concrete situations. An interpretative orientation acknowledges that human experience is both constructed and contextual.

While some qualitative methodologies have a primary aim of developing theory, interpretive description emphasises the need for 'informed action':

> Interpretive description is an approach to knowledge generation that straddles the chasm between objective neutrality and abject theorizing, extending a form of understanding that is of practical importance to the applied disciplines within the context of their distinctive social mandates. It responds to the imperative for informed action within the admittedly imperfect scientific foundation that is the lot of the human sciences ([426], p26).

Interpretative description, responding to the needs within applied health sciences to address pragmatic questions [427], seeks to describe and understand a process or phenomenon (in this case, research on primary cam morphology and its natural history) through the subjective perspectives of research participants and, importantly, intends to use this knowledge to inform practice [428,429].

This study's pragmatic orientation manifests at different stages of the research process. For example, the research team's expert clinical knowledge is seen as solid grounding for research design. It is this practical knowledge, tested and validated in the clinic, which is emphasised in interpretive description and used as a way to provide answers to solve real-world problems [429]. Particularly in areas where there is little prior research or empirical data about a health phenomenon, such foreknowledge and expertise are viewed as a useful starting place for orienting research [427].

Alongside the foreknowledge that the researcher brings to the study, interpretative description aims to explore the subjective experiences of participants relevant to this study: the experiences and perspectives of doing research on primary cam morphology and its natural history. Participants should therefore be a purposive sample representing the full breadth of different kinds of knowledge and experience of the topic being researched [430,431]. Within interpretive description research, this knowledge and understanding is constantly revised in a continuous process of (re)negotiating, where both researchers and participants co-construct a coherent narrative that can inform clinical—and research—practice [432].

In summary, interpretive description suits the research question for this study. It facilitates straightforward and pragmatic answers to questions that are relevant to researchers, clinicians, patients, and policy makers, [421,422] and helps to improve understanding of what works (or might work) best to promote high-quality research in the field of primary cam morphology and its natural history.

Ethical approval was received from the University of Oxford's Medical Sciences Interdivisional Research Ethics Committee (Project ID R66281) and Qatar University Institutional Review Board (QU-IRB 1239-EA/20) prior to conducting the study (Supplementary files F.1 and F.2). I followed the 'Standards for Reporting Qualitative Research: A Synthesis of Recommendations' for this report [433].

6.3.2 Instrument development

I developed, piloted, and adapted an interview guide based on the INQUIRE framework to explore participants' perspectives of research quality on primary cam morphology and its natural history. The INQUIRE framework provides a guide for the practical assessment of clinical research quality at all stages of a research project, and for developing quality enhancement initiatives (Figure 6.1) [33].

This framework was a useful scaffold for developing quality enhancement initiatives (Figure 6.1), addressing five study stages (concept, planning and feasibility, conduct, analysis and interpretation, and reporting and knowledge translation), and six dimensions: (1) protection of patient safety and rights, (2) relevance/patient centredness and involvement, (3) minimisation of bias[20] (internal validity), (4) precision, (5) transparency/access to data, and (6) generalisability[21] (external validity) of the study results.

[20] The term 'bias' is usually used in relation to quantitative research. A related term in qualitative research is 'perspective'. Interpretive qualitative researchers consider that there is no such thing as an *unbiased* sample, but that it is important to include a wide range of *perspectives*. This is how I interpreted this criterion in the framework when exploring stakeholders' perspectives on qualitative research.

[21] The term 'external validity' is usually in relation to quantitative research. 'Transferability' refers to the generalisability of inquiry in qualitative research.

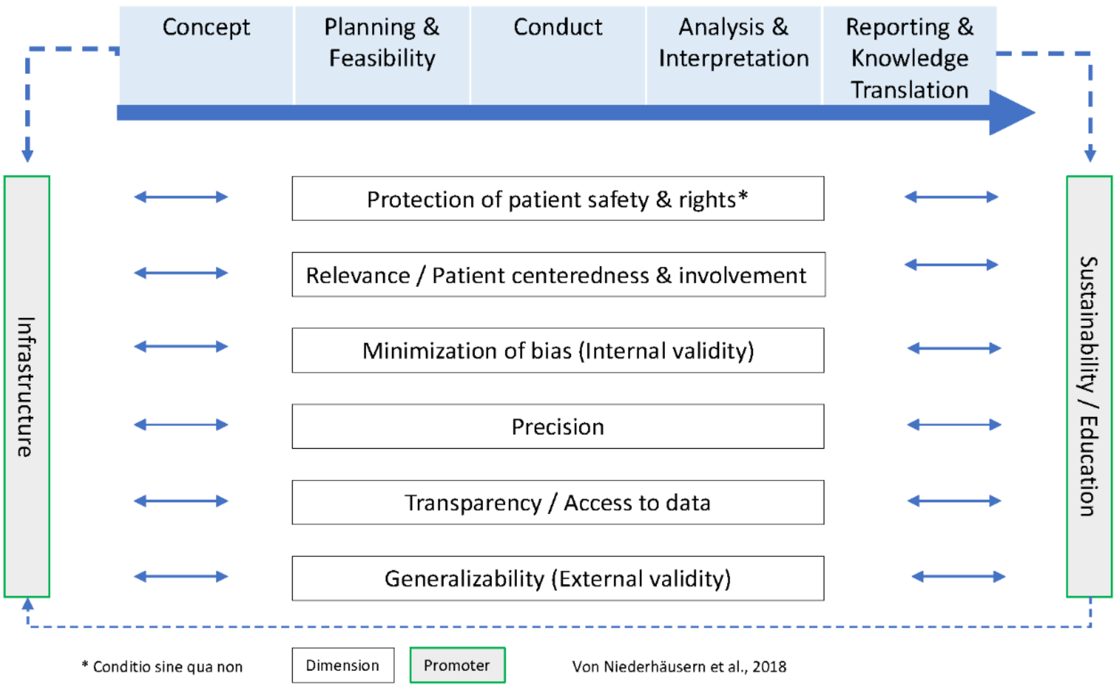

Figure 6.1. Framework for INcreasing QUality In patient-orientated academic clinical Research (INQUIRE) (Adapted from [33])

The six dimensions interact with two promoters, a set of factors that may enhance all quality dimensions at a research institution: (1) an established research infrastructure (e.g. well-trained personnel and functional facilities on-site: 3T MRI with trained radiographer and radiologist for serial hip joint imaging), and (2) sustainability through education (the structures and systems to support young researchers and build capacity through mentoring and developing the next generation, and continuous education of all study personnel to secure a long term productive clinical research environment). The Interview Protocol Refinement (IPR) Framework [434] was then used to develop and refine the interview guide (Figure 6.2).

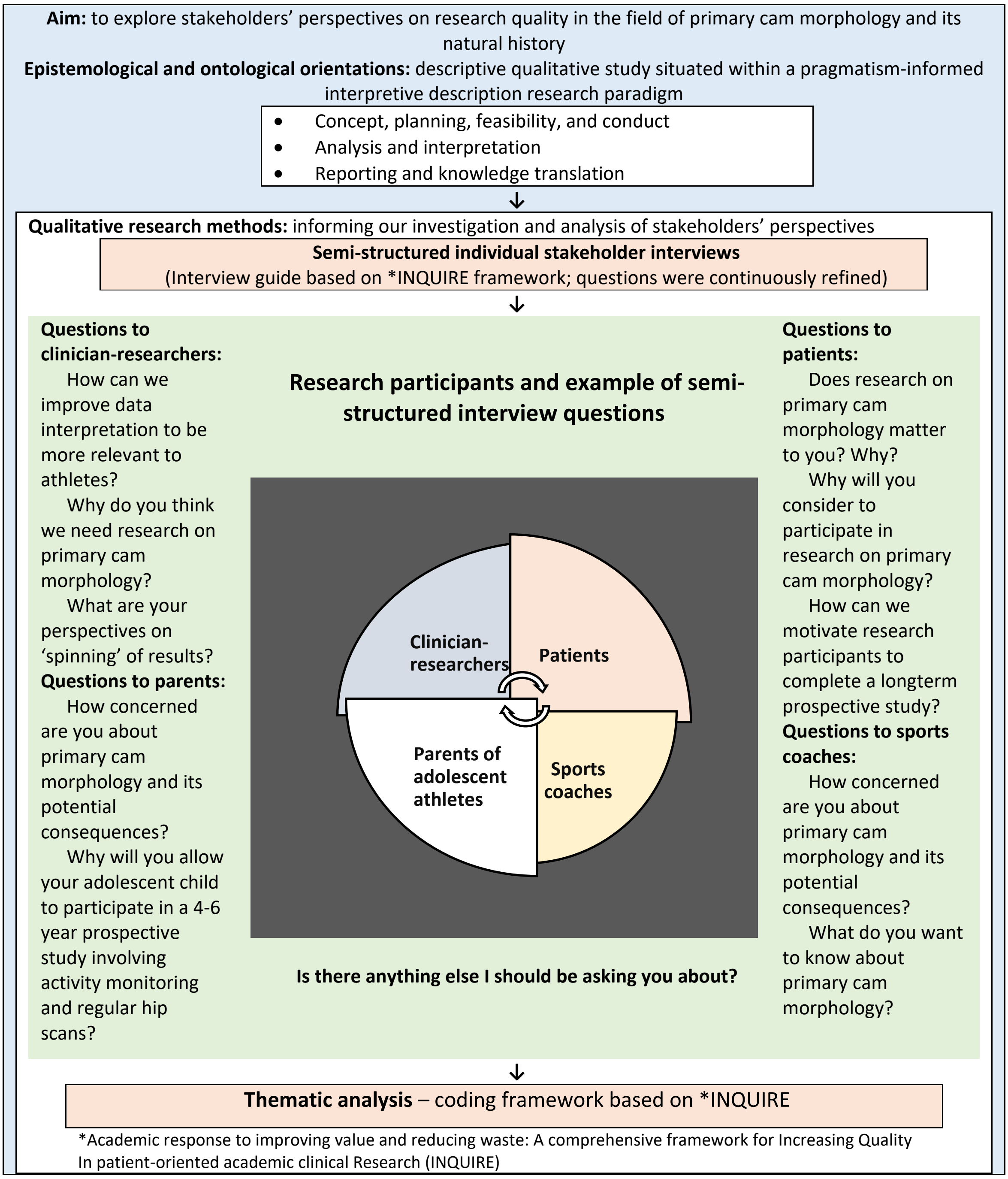

Figure 6.2. Study's conceptual framework and interview guide development

6.3.3 Sample

A purposive and structured variation approach was used to select the sample for this study. This method allowed me to select a sample of stakeholders representing a wide range of expertise and experience. Participants were purposively identified. Most were clinician-researchers who have published in the field between 2010 and 2021 (*n*=9). Other participants

(n=6) were identified from my collegial, athlete and patient networks, and that of co-researcher Dr Sean McAuliffe (SMA) with oversight by study supervisors: Professors Trisha Greenhalgh (TG), Siôn Glyn-Jones (SGJ), Karim Khan (KK) and Mike Clarke (MC). The professional background of the research team allowed us to reach a large population of primary cam morphology research stakeholders, guarding against over-representation of one group. I invited all potential participants through e-mail. This sampling strategy is common in interpretive description and rests on the premise that researchers' knowledge of the topic area enables them to identify participants who are especially knowledgeable about or experienced with the topic of interest [423,424,428,432,435]. Potential participants included clinicians, researchers, patients, athletes, sports coaches, and parents of competitive adolescent athletes. Most participants had more than one role, 'researcher, clinician, and parent', for example. This often allowed me to explore a multiplicity of perspectives in each individual interview.

The sampling strategy, aimed at maximum variation in stakeholder background and expertise, was informed by literature and the 'closeness continuum'[22] model [338]. According to this model, participants can have different types of expertise, based on closeness to the topic of interest. Some individuals have a degree of 'subjective closeness' to a topic, which involves deep experiential knowledge or real-life experiences. Patients may have this kind of subjective closeness. Participants with professional and/or legal (ethical) responsibility represent a 'mandated closeness'. Finally, individuals can have a degree of 'objective closeness' to a topic, because of their profession or occupation [338]. To represent a wide range of experience and expertise in our sample, we purposively included participants from all three categories,.

6.3.4 Data collection

Fifteen individuals participated: six physiotherapists, five physicians, a sport scientist, and three athletes/patients (Table 6.1). Two physiotherapists were also patients, four participants

[22] See chapter 4, section 4.3.2.3 and figure 4.3

had adolescent children playing competitive sport, while three were sports coaches. I conducted semi-structured online interviews during the Covid-19 pandemic between June 2020 and February 2022. The interviews lasted on average 60 minutes (range 44:32 to 68:08 minutes).

Table 6.1. Research participant demographics and roles

Pseudonym	Sex	Profession/Education	Role(s)
P1	Female	Physiotherapist	Researcher, Clinician, Parent
P2	Male	Physician	Researcher, Clinician
P3	Male	Physiotherapist	Parent, Researcher, Clinician
P4	Male	Sport scientist	Parent, Researcher, Coach
P5	Male	Physiotherapist	Researcher, Clinician
P6	Male	Orthopaedic surgeon	Researcher, Clinician
P7	Female	Physiotherapist	Clinician, Researcher, Parent, Coach
P8	Female	Physiotherapist	Clinician, Athlete, Patient
P9	Male	Athlete	Patient/athlete
P10	Female	Occupational therapist	Patient/athlete, Coach
P11	Male	Radiologist	Researcher, Clinician
P12	Female	Sports coach	Coach, Athlete
P13	Male	Physiotherapist	Researcher, Clinician, Patient
P14	Male	Radiologist	Researcher, Clinician
P15	Male	Orthopaedic surgeon	Researcher, Clinician

Using video conferencing technology (Zoom®), all interviews were audio-recorded with permission. Informed oral consent was recorded during the first part of each interview after confirming that participants understood the research project and their rights. Co-researcher (SMA) attended 14 of 15 interviews and kept field notes that provided further interview context for analysis [355]. Audio-recorded interviews were transcribed by a third member of the research team, Ms Jolanda Boersma (JB), a research assistant who was experienced in conducting and transcribing qualitative research, before being imported to qualitative data analysis software NVivo® (QRS international Pty Ltd, Burlington, Massachusetts, United States). To protect their privacy, I assigned a unique number to each participant and deleted identifying information from the transcript.

Given the semi-structured nature of the interview guide, I had the flexibility to invite participants to elaborate on their responses; they could discuss their perspectives in whatever direction, and in as much depth as they wished. I was therefore able to probe beyond the specific questions of the interview guide, exploring participants' unique personal experiences, practices, and preferences, which shaped their perspective on primary cam morphology research [436]. These included, for example, concerns about the morphology that competitive athletes, who were worried about their future sporting careers, might have. I also asked parents and coaches of adolescent athletes how they perceived high load training and competition that might put young athletes at risk of primary cam morphology and future hip disease (Figure 6.2).

6.3.5 Analysis

Consistent with interpretive description, I used thematic analysis to analyse the data [365,437,438]. Thematic analysis is an approach that seeks to develop themes across cases, through reading, re-reading, and charting of data [437]. It is a form of pattern recognition where identified themes become the categories for analysis [436]. Often misunderstood as a single method with one set of procedures, thematic analysis is best thought of as a continuum of methods—from types that place prominent emphasis on developing codes and categories and demonstrating their reliability (both within and between different coders), to more reflexive approaches which place more emphasis on a single researcher developing a plausible and coherent account of the data [437,438].

In this study, I chose not to prioritise 'coding reliability' since this notion rests to some extent on positivist philosophical assumptions (e.g. that the data are 'out there' waiting to be collected and that every researcher analysing the same data should get identical findings). Rather, I sought to use a structured coding framework to support and inform my reflexive thematic analysis [437].

The analysis therefore incorporated both a deductive coding approach (based on a priori codes generated from the quality dimensions and promoters of the INQUIRE framework [33]) and a data-driven inductive approach. Early analysis of the transcripts was *guided but not constrained* by the preliminary codes derived from the INQUIRE framework: we populated codes according to the coding framework, but we also flagged instances in the data that did not fit. Consistent with thematic analysis, two co-researchers (SMA and JB) and I immersed ourselves in the data to become familiar with the depth and breadth of the content. We read interview transcripts several times. Based on the INQUIRE framework, JB and I independently coded all interviews and SMA coded half of the interviews. I regularly met with both co-researchers to discuss and reflect on our perspectives that shaped how we identified primary patterns in the data. Once initial coding was complete, discussions among the research team and further analytic work allowed us to identify underlying patterns of shared meaning that drew together several of the initial 'domain summary' codes into richer and more complex themes (more 'fully realised themes') that revealed multiple facets of a particular meaning or experience [437,438].

For example, the initial coding framework emphasised 'Protection of patient safety & rights' and 'Relevance / Patient centeredness and involvement' as possible 'domain summary' themes. This evolved into 'Research communities should partner with patients/athletes' to better represent authentic involvement—athletes/patients co-driving research. The process of coding and theme development had both descriptive and interpretive elements, representing what participants said and subjective considerations by the research team of patterns that were not directly evident. Here we aligned with the notion that themes are not 'discovered' nor do they represent pre-existing forms of knowledge waiting to 'emerge' [365,437,438]. Thematic analysis is seen as an active process of knowledge production by the researcher—themes are patterns that a researcher identifies through their perspective of the data.

6.3.6 Research team and reflexivity

Interpretive description also draws attention to researchers' disciplinary orientations and subjectivity. To account for their perspectives, researchers should engage in reflexivity. Reflexivity involves recognising that researchers are part of the process of producing data and their meanings—a 'sensitivity to the ways in which the researcher and the research process have shaped the collected data, including the role of prior assumptions and experience…' ([439], p51). The researcher is a 'valuable instrument' of the research in interpretive description; their technical knowledge, research background and personal experience are 'major sources of insight' [428]. Findings do not 'emerge' from the data, nor do data 'speak for themselves'. No matter how participatory and collaborative the method, it is the researcher who ultimately determines what constitutes data, which data are relevant, how the final dataset will be presented and structured, and how and to whom the findings will be disseminated [440]. Therefore, although we acknowledge the influence of our preconceptions, we perceived our subjective clinical experience and prior knowledge (particularly HPD, SMA) to be a resource in this study [441].

This study's research team consisted of the following: HPD, lead researcher, a practising sport and exercise medicine physician, director of medical education, and DPhil candidate responsible for the overall design of the study, participant recruitment, data collection and analysis; SMA, a practising sports physiotherapist, and PhD-trained qualitative researcher, acted as Qatar-based co-principal investigator, attended 14 of 15 online interviews as an observer and contributed to the analysis; JB, a medical anthropologist with experience in qualitative research (sociology and anthropology) but no clinical experience or prior knowledge of the topic, aided in transcribing and analysing data; TG, a professor of primary healthcare with extensive experience in qualitative and mixed-method research, supervised on all aspects of the study as DPhil supervisor to HPD; SGJ, a practicing orthopaedic surgeon, professor of orthopaedic surgery and experienced researcher, oversaw all aspects of the study as principal investigator and DPhil supervisor to HPD; MC, experienced researcher and DPhil supervisor to HPD, provided oversight to all aspects of the study; KK, sport and exercise medicine physician, and previous journal editor, provided oversight to all aspects of the study as an experienced researcher and DPhil supervisor to HPD. HPD and SMA, SGJ and KK had working relationships with some of the participants.

The research team's diverse academic training and experiences set the foundations for interdisciplinary dialogue and helped to promote reflexivity throughout the project [431]. Olmos-Vega and colleagues (2022, p6) put it thus: '... assumptions become most evident when viewed from the point of view of others who do not share them' [442]. Several discussions, for example, brought together an anthropological, non-clinical perspective (JB) to theme development with that of a physician with intimate knowledge of the field (HPD), and a PhD physiotherapist working in research and elite sport (SMA). In addition, TG, with vast clinical and (qualitative) research experience, shaped how I approached the complicated deductive-inductive coding dance. An excerpt from my research and DPhil supervision diary provides nuance: 'Don't get boxed-in by your (INQUIRE-informed) coding framework. Dive deeper and search for meanings and insightful, new patterns/themes to inform future (research) practice'.

6.3.7 Methodological reflections

It is important to consider how my professional identity and positionality might have influenced aspects of this study, including the research topic, research design, context and process, participants, data collection and analysis [443,444]. In chapter one I introduced myself as a 'cisgender white male, married with two daughters, and first-generation South-African' who 'bathed in the privileges' of the Whiteness and Eurocentrism of the societies I have lived and worked in; privileges that were 'amplified by the power of being a bilingual Afrikaans-English male physician.’ I described how, at the start of my DPhil journey at Oxford, and in addition to my clinical sports medicine physician role, I also accepted a role as Director of Medical Education at Aspetar, a sports medicine hospital in Qatar.

When selecting a sample, I recruited participants who could contribute meaningfully to the aims of the study, either through their research experience, professional involvement, or personal experience with primary cam morphology. Participants were purposively identified, including from my collegial network (research and clinical), as described. Although diverse to a certain extent (clinicians, researchers, athletes, patients, parents), the ten men and five women participants were all white and from the Global North. Participants representing research teams and athletes from the Global South could have shared different perspectives on research quality.

It is important to reflect on the prior relationship with some interviewees, as this ultimately shaped the data collected during this study. Garton and Copland refer to such interviews as ‘acquaintance interviews’ [445]. Data are generated in a particular way because participants may invoke prior relationships (most often implicitly, but at times explicitly) in these interviews [445].

‘Insider status’ offers affordances and challenges. Insider status can often lead to valuable and even unique insights [446]. A certain social or professional proximity often allows researchers access to resources that are not always available in more traditional interviews and might not be available to researchers who do not share this familiarity with their participants [445]. Thus, some participants could have regarded me as a professional or social proximate rather than an outsider; they might therefore have been more comfortable sharing their perspectives. In keeping with interpretive description, it is through this deep involvement with a small number of individuals familiar with the researcher and willing to share their experiences that it is possible to build trust and gather valuable data [429].

Cognisant of the fact that insider status could also be a challenge—participants might feel obliged to assist the researcher because of their prior relationship—I ensured participants knew their rights, including the right to change consent or retract completely [447]. Participants received an email explaining the study, their rights, and the informed consent process. They were able to ask questions or raise concerns at any time before or during the interview. Before starting the formal interview, I briefly explained the aim and background of the study again, including participants' rights. As mentioned earlier, the interview started after verbal consent was recorded and documented in the presence of a second member of the research team (SMA).

6.4 Results

Below, I set out my findings on stakeholders' perspectives of high-quality research on primary cam morphology and its natural history, structured according to five themes (informed by the INQUIRE framework's six dimensions and two promotors). These action-inviting themes could bolster efforts by research communities to perform higher quality research in this field: research communities should (1) partner with athletes/patients; (2) collaborate with one another; (3) pursue open science; (4) champion equity, diversity, and inclusion; and (5) nurture young scholars. Each theme is described and illustrated with excerpts from one or more participant interviews. Where appropriate, I refer to intersectionality, for example, an athlete-patient and clinician (P8) describing how her experiences and perspectives as an athlete-patient informed clinical practice (Section 6.4.1, pp202, 203). As a result, some quotations are longer when I desired to communicate *the way* a participant illustrated or described a specific situation.

6.4.1 Theme 1: Research communities should partner with athletes/patients

This theme combines and extends two INQUIRE dimensions: protection of patient safety and rights and relevance/patient centeredness and involvement. Our interviewees reported that athlete/patient-centred research is important and multifaceted. The athlete/patient distinction is important—most athletes with primary cam morphology will never become patients. Athletes are at risk of developing primary cam morphology but 'we know that obviously only a small percentage of people, even if they have primary cam morphology, develop symptoms'. (P5)

More than just being involved, athletes/patients should co-drive research as equal partners. Athletes/patients in this study expressed keenness to get involved in research. This was especially true 'if patients are aware that the ultimate goal is to help people to get better and to utilise the information in a way that's going to help people.' (P8 – physiotherapist, athlete, patient) She continued to explain:

> I think patients will be willing to help. I think a lot of people want to share their story. And I think it's actually like a therapeutic part of the journey as well. At least I noticed that for me, when I'm able to, even now, kind of reflect on how far I've come. There's a benefit of that. And you realize that: 'Okay, my struggle is actually helping other people. (P8)

Involvement, however, could be therapeutic at more than one level. Another athlete-patient (P10), discussing how involvement helped her 'own learning about the condition', also felt proud to contribute to research (table 6.2, quote 1). Educating research teams and other stakeholders 'can provide valuable input that other people might not be able to give'. (P10)

Discussing his 'passion to try and create change' and 'to try and educate' (especially parents of young athletes) about the morphology and its hip-disease consequences, another athlete (P9) shared how his 'whole life was changed because of [his] hips':

> I think that's where my story, me speaking and educating the parents, and showing them: 'If this resource was available to my family, and this testing or research project, whatever you want to call it, was there …it would have stopped me going through a year of operations. Untold pain, untold misery, sadness, heartache, you know, financial.' The list goes on. I think, one thing that we can do, as people who have a voice is to make sure that these parents [are educated] (P9)

Our interviewees gave several examples of how a partnership approach could facilitate more value and less waste in research. First, engagement pivots on *and* promotes the relevance of research:

> I think, to really explore your question beforehand, and spend quite a lot of time doing that [is important]. So, refining your research question by involving

> stakeholders, involving clinicians, involving athletes …seeing what is meaningful to them, what do they want to know. (P7)

Second, athletes/patients (including adolescents, their parents, and coaches) could enlighten, not only researchers, but also the research process by illuminating blind spots in their research plans (table 6.2, quote 2). In addition to gaining such insight to 'the practicalities of what is realistic', professionals also learned that patients ascribe importance to different things than researchers do (table 6.2, quote 3). Additionally, patients can help in planning research; 'they give us ideas that we wouldn't have if we just think with our research hat on'. (P14)

Third, athlete/patient partnerships change how research communities communicate about research and research findings. A recurring theme in our interviews was the need to avoid jargon and use a language that everyone understands. The way to achieve this, they felt, was to involve all stakeholders from the outset, as illustrated by quote 4 (table 6.2). Clinician-researchers and parents of competitive adolescent athletes, in particular, stressed the importance of avoiding alarming and inflammatory language (table 6.2, quote 5). A former elite athlete and now sports coach warned that 'things like "abnormality" perhaps trigger a lay person to automatically think that this is something damaging and negative, and will be inhibiting: so, "lesion", when you say to me "lesion", I'm thinking of something more like a scar or an abrasion'. (P12) Although femoroacetabular impingement (FAI) syndrome is the agreed term, 'syndrome is a negative thing' (table 6.2, quote 6).

Sharing their experiences, several participants were concerned that language and communication style—in research and in the clinic—could create the need for (unnecessary) interventions. A clinician-researcher shared how a patient's expectations had been shaped by an older footballer-brother who had bilateral hip surgery. The older brother framed the problem based on his own surgical experience (table 6.2, quote 7). An athlete-patient and clinician shared her experience as a patient—how the language used and framing of the condition by a surgeon in a position of power left her vulnerable, confused, and distressed:

> And so, I ended up going to this surgeon who's pretty well-known… And I remember, I had not tried physical therapy yet. This was before starting physical therapy. I go in, and I remember, he takes my imaging out that I had, puts it up on the screen and says: ‘Oh, you have a large labral tear, you have a cam and pincer lesion. And if you don't have a hip arthroscopy, you're going to get hip arthritis, and end up needing a hip replacement.’ And I remember I just sat there, and I was just crying, and I was alone… I didn't know much about cam or pincer or labral tear. And then I remember asking: ‘Well, if I don't get the surgery, and I keep running, what will happen?’ and I remember him saying like, feeling very, you know, definitive in his wording: ‘well, you'll get hip arthritis.’ …The appointment ended with him saying: ‘Okay, well, you can schedule the surgery on your way out and then we’ll be in touch.’ …I remember leaving there and I just thought, like: ‘Wow!’ Like ‘this is terrible.’ I remember I just was crying because here I was an athlete my whole life. I played college soccer, running was a huge part of my life and to then just be told that I have this condition in my hip. And if I don't get the surgery, I'm going to end up with hip arthritis. And I have to stop running. And it really just led me down that spiral of catastrophising. (P8)

Fourth, our participants, including parents of young competitive athletes, raised the importance of safe research, particularly when children, female athletes, and competitive athletes are involved. Research communities should guard against breaches of confidentiality (table 6.2, quote 8), and protect, especially children, from unnecessary exposure to imaging-related radiation (table 6.2, quote 9). Protecting athletes’ health, including those participating in long-term research, and the influence of power-dynamics in competitive sport—especially when ‘juggling’ several managers at the same time—was raised as a safety concern by participant 9. Medical teams, particularly those involved in long-term research, must be empowered to protect athletes, and should, with club managers, be accountable to a higher management (table 6.2, quote 10).

Finally, engagement could also be a challenge for athletes/patients, given that it requires them to share knowledge of living with primary cam morphology, which, in most, is an asymptomatic, benign morphology—unlike, for example, knee osteoarthritis (OA) (table 6.2, quote 11).

In sum, when athletes/patients are equal partners in research—when they share their experiences and expertise—research would likely be more relevant, safer, and more ethical. Athlete/patient partners, as people who have a voice, could help to shape clearer and less threatening communication in research and in the clinic, and expressed eagerness to share their stories and struggles—to get involved in research and education to help others. Healthcare professionals and researchers seemed equally keen to involve and learn from athlete/patient partners.

Table 6.2. Quotes, theme 1: research communities should partner with athletes/patients

Quotation
1. 'This injury has had a massive impact on my life, whether I sort of accepted it until now is a different story. …So being able to contribute to maybe the future planning and research and things like that, I think, for me is a very proud moment. And it's something that, like I said, I do feel strongly about.' (P10)
2. 'And I think it's key [involving children/parents], you know, you might plan a great study, but then the parent tells you: "This is impossible, because…" for example: "I drive my son from school to this place. So, in the meantime, I can't get him on this device" or "I can't charge the device, because…" or "He doesn't wear these shoes, because…" you know, all the practicalities of what is realistic only come out when you speak to the relevant people. And the relevant people in that case, are the parents and the kid. You know, like, no one asks the kids: "do you like to wear this? Do you like to put this in your shoes?" And then they go: "Well, I don't like those, because they're too big you or I don't like the colour".' (P4)
3. '…what we find is important isn't important for some patients. … We want to look at the alpha angle and measuring, but the patient doesn't care about the size of the alpha angle. They're concerned about getting back to football.' (P11)
4. 'I think the first thing is in plain language. Because that's the biggest mistake we make, in language that even clinicians and other researchers don't understand. So, I'm taking some time to, again, involve the stakeholders, people, end-users, the knowledge-users, and actually involve them right from the beginning. In terms of, how you're going to communicate your findings, and is it meaningful to the people [who] are going to use it?' (P7)
5. '…there's still a lot of hysteria and alarming language being used in conjunction with things like cam morphology, cam lesions and femoroacetabular impingement syndrome. So, I think, to a certain extent, we need to make sure we don't use that kind of inflammatory language in any kind of education of cam.' (P1)
6. 'So, I've been much more inclined to say somebody has hip pain and maybe associated with cam morphology rather than telling somebody: 'You've got a syndrome, you've got FAI syndrome.' …you've got to be really careful what your wording is, especially in young people …16-year-olds are usually really worried about their future…' (P15)
7. '…I had the experience of a player whose… older brother ends up having bilateral hip surgery over the course of a number of years and has to retire from football. And the younger brother… had fixated in his head that he had to have surgery. And the way he described his hip to us, he was using all those words that were scary words, in his mind. About this impingement, and his bone rubbing on bone, and his cartilage wearing off … And he said: 'I've got to be shaved back; it's got to be smoothened out. So, I got a smooth surface that rubs against a smooth surface' that sort of talk. And I was like, if there's

anything I learned from this… I have to be really careful on the terminology that I use, because they will create a picture in their mind. And this poor fella ended up having surgery; the surgery didn't go to plan. He's back playing but he's not at the level that he could've been.' (P3)

8. 'Look I don't have any concerns about my children participating in research. The only concern I would have, is if their photos somehow identify them as individuals, and they were available on the web without us knowing it. …A sort of breach of confidentiality.' (P1)
9. 'The other concern that I would have, is exposure to radiation. I wouldn't be too keen on my children being exposed to CT-scans and repeated radiation.' (P1)
10. 'The problem being - as the level increased and I got onto the senior team - the training increased, the volume in terms of the sessions and intensity on top of the gym work and not having anyone kind of looking out for me… I was trying to juggle four or five different managers. But if they [sport scientist, 'strength conditioner', physio and doctor] are not strong enough to speak up to the manager, then who's held accountable? So, then it goes back to the county boards. If the county board is employing a manager to manage a team, they're there to get results. But the players are the people that are being mismanaged. …So, until the manager has a guideline to say: "You're only allowed to do this much training in a week, and that's your responsibility. And if you break this, you're held liable, as is your medical team".' (P9)
11. 'Is it something that they can provide really valuable insight into? …we're almost asking someone's input about a condition [primary cam morphology] that they may be completely asymptomatic for their whole life…if you have a problem, which is already there, like, for example, knee OA…and you're trying to get participant involvement, there's so many people living with knee OA that have really good insight about the burden that it gives them in their life, their health care…' (P5)

6.4.2 Theme 2: Research communities should collaborate with one another

This theme combines and extends elements from several INQUIRE dimensions and promotors, including minimisation of bias (internal validity), precision, infrastructure, and sustainability.

Interviewees discussed the need for coordinated efforts to plan and deliver multi-centre and multidisciplinary research on, for example, primary cam morphology aetiology and prognosis (table 6.3, quote 12). To strengthen large-scale multi-centre research collaborations—'helping each other'—research teams should agree on research questions (table 6.3, quote 13). Such studies should use the same methodology and capitalise on transparent research centre-specific expertise to facilitate high quality data sharing (table 6.3, quote 14).

To reduce attrition and measurement bias, research centre-specific expertise is particularly important when performing and analysing imaging. Long-term prospective studies (with serial hip imaging over time—every five years, for example) could benefit from an international network of collaborating imaging units to accommodate elite athletes who are often contracted to live and play around the world. They could be accommodated at an imaging centre close to them. Imaging collaboration could include shared (online) infrastructure like *Digital Imaging and Communications in Medicine* (DICOM) (table 6.3, quotes 15 and 16).

International collaboration on a registry or large database could have a 'really big impact' on this field, benefitting research teams, patients, and healthcare systems (table 6.3, quote 17). Collaboration could be bolstered when—with a 'we need each other'-approach—coordinated by global sporting bodies like the IOC or FIFA (table 6.3, quote 18). Participants commented on data sharing, including their frustration with it. Meaningful data sharing was acknowledged as 'my biggest problem' (P4). However, if done well, for example through the 11 IOC Research Centres[23], such data sharing could improve small sample bias and result in large datasets 'that could be interrogated with better techniques, and with better statistical knowledge' (table 6.3, quote 19).

A common theme was also multidisciplinary team approach to *intra-team* collaboration, including with academic partners. Multidisciplinary team collaboration should involve athletes, coaches, different medical specialties and topic experts, researchers, and methodologists, for example (table 6.3, quote 20 and 21). Some participants described their perspectives and experiences on multi-stakeholder collaboration to facilitate research buy-in. Buy-in could make or break research in this field. How researchers frame their research question, especially in elite sport, is key for engaging with management, big stakeholders, and decision-makers, including finance decision-makers (table 6.3, quote 22).

[23] International Olympic Committee (IOC) Research Centres for the Prevention of Injury and Illness. Eleven IOC Research Centres are supported by a four-year grant for 2023-2026: https://olympics.com/ioc/medical-research/research-centres

Effective research collaboration among academia and professional sports clubs is important in this field [13,60,245,403]. Researchers working with football clubs benefit when clubs, especially the coaches in the clubs, determine the research questions before engaging ‘the right university’ (table 6.3, quote 23). However, such a collaboration could often be a slog, and someone needs to ‘kind of steer the University’ on what is possible and what is not impossible (table 6.3, quote 24).

In sum, participants discussed how ‘we are stronger together’ when aligning to pursue large-scale, multi-centre and international collaborations to answer research questions that matter to all. Effective multidisciplinary intra-team collaboration resonated with our interviewees too.

Table 6.3. Quotes, theme 2: research communities should collaborate with one another

Quotation
12. ‘So we need to identify groups around the world that at are working particularly with adolescent football players and try to link data between athletes that are playing without developing hip and groin pain and without developing cam morphology and those who are developing hip and groin pain and cam morphology …and then to be able to track these over time and determine some of the differences that exist between players that go on to develop hip and groin pain, so we can intervene better at earlier stages.’ (P1)
13. ‘So, it's more interesting, if you are collaborating with each other and defining exactly what you're doing. What more research do we need to have in this kind of field of area? And if you have the same participants at different hospitals. You don't need to do it all by yourself. No, you can ask each other, helping each other and getting large cohorts and groups with the same questions we want to have answered.’ (P11)
14. ‘Some groups in the world are dedicated in studying this topic [primary cam morphology formation], of whom some already have some collaborations. But I think that is one of the most important aspects, to collaborate in studies, multi-centre studies… Using the same methodology, so using the same type of clinical examination, questionnaires, imaging, and stuff like that. So that you can also interchange the data. And more in detail also, quantifying things. So, how do you quantify when somebody has cam morphology? I mean, we talk a lot about that. But I think all the quantitative measures we have to date, they're okay, but they can be improved… So also, that is a field where we can improve and where we preferably use the same methodology as well.’ (P6)
15. ‘In terms of infrastructure, it is very important that well, in practical ways, the centre where the expertise is, probably does their part of the study. So, the participants come from everywhere, but the imaging analysis might be done somewhere, where they have a lot of expertise and statistical analysis might be done somewhere else… But what I find really important, especially with the imaging analysis, and software techniques used for that, is that people should be very transparent in what they use, how to use it, and everybody should have the possibility to use it.’ (P6)

16. ‘I think the infrastructure is also the internet. Databases. So, I think, if that infrastructure is to improve, we have connection … using the same DICOM images… then connecting them with the same server. I think that infrastructure would be the most important thing to improve on, then we can have large cohorts and large studies. And then you don't need to travel because you're in Australia or somewhere else. And then you can combine it with the same protocol, with the same images, and maybe a computer helping you to investigate the things you want to see.’ (P11)
17. ‘…to really have a meaningful impact, this kind of work would need to involve an international collaboration. Some sort of registry, a large database, and that will make a really big impact. So this is the challenge, to actually make sure that there are various stakeholders. But I think there is the possibility to do that, because there’s a wide interest, there is no competitive advantage anywhere. …because everyone can gain something, you know. If research shows better, kind of procedures to reduce the risks and better clinical outcomes, that's going to save money anyway on the healthcare system as well. So there should be a vested interest, and the financial return for the investing, by doing wider type of collaborations.’ (P4)
18. ‘…collaboration, international collaboration, and you know, we're always competitive. I'm not particularly competitive; I suppose … because we're smaller, there's not a lot of money, we're really, really good at being collaborative, because we need each other. But I think in in other areas of research, it can be a little bit competitive. So, I think … we're stronger together; that [collaboration] needs to be driven probably by very global bodies, like the IOC, or FIFA or whatever.’ (P7)
19. ‘Data sharing is my biggest problem and has always been. And it has never been solved. And it needs to be solved. And I think now there is the technology to do it. So there is a plethora of studies, that are conducted on 10 subjects, 15 subjects, 20 subjects, 30 subjects at best. And none of these actually contribute to really a consensus. So usually, the consensus comes 10 to 15 years later, when there is a big systematic review and meta-analysis that says: ‘This thing works, and this thing doesn't work.’ And to me, it's a waste of time. Because you have to wait 15 years and a lot of effort from various research groups. While, in a couple of years with the right structure in place, it could be possible to interrogate it.’ (P4)
20. ‘We’re doing a multi-disciplinary approach of orthopaedic surgeons, sports medicine physicians and the radiology department. So that we can have a collaborative team of three different medical specialties, and I think we’re all good at one part. So, the orthopaedic surgeon knows how to carry on when it’s symptomatic and probably do surgery or something like that. The sports medicine physician is probably the more conservative part, and the radiologist can give information on how to image those hips for example. I think that might work together really well.’ (P2)
21. And I know that it's that word, it's used all the time, but ‘stakeholders’. So, it's multiple stakeholder-involvement, I think, really makes a difference. Because each person is going to add a different dimension to it. The challenge comes in integrating all of that into your outputs. But it can be done. And I think we're seeing a move in sports medicine to do that. …And I think that's one of the things where there is that disconnect between researchers and clinicians. Now because …research is often done in a sterile environment, and clinicians go: ‘Well that doesn't work for me.’ (P7)
22. ‘…understand the rationale. And converting that into a performance- and a financial rationale. So, for me, just to say: ‘Do you want to do a hip study, to find out how hips

grow?' That's not going to land. But to map it out: 'This is the performance-challenge we have. This is a financial challenge we currently have and this is what the future could look like, financially-performance wise.' You have to convert that. So that's number one. The internal messaging has to be: What's in it for the coach. What's in it for the finance director. What's in it for everyone.' (P3)

23. 'And the questions were determined initially by the medical staff, but ultimately, we had coaches starting to determine the questions, going: 'Here's my performance challenge, how do we unpick that?' So, when you come to find the question and then go to the right university and the right group of people, that understand the landscape of professional sport, that's the easiest mix.' (P3)
24. 'So, you're getting your question answered. Gone are times … where the University determines the question. And if they did offer a question, it would have to be twisted to be beneficial for the football club. But that went really well actually, us going to university with a series of questions. …So, both sides need to work collaboratively to the same solution. And it's just communication, isn't it? It's really, really trying to understand, what does success look like and how long does it take to do it. I think that's a key one. Because Universities work at such a slow pace, in comparison to a football club, that works so quick.' (P3)

6.4.3 Theme 3: Research communities should pursue open science

This theme includes and extends the INQUIRE dimension, transparency / access to data. Access—for everyone—to as much information as possible, and translated to lay people's language, resonated with our interviewees (table 6.4, quotes 25 and 26). All stakeholders, including athlete/patients and coaches, should have access to research—in 'plain language':

> So, it's going to be athletes and coaches. A lot of scientific language isn't particularly meaningful to them. And even clinicians, who would have been taught in that area, they still have moved into an environment where they don't use that language anymore. So, I think, I think Open Access is good, but I think it still needs plain language. (P7)

An athlete/patient participant warned that financial and career benefits for researchers should not trump end users' access to research —'it's silly and very naïve in this day and age that it's happening'! (P9):

> If a person is paid to do this research and is then publishing papers on their own study, it's again for their benefit. And it's for the benefit of the financier. So why, even though they're doing it for themselves, why should we [athletes/patients] not have access to that? (P9)

Peer reviewed publications buried behind paywalls are problematic for young scholars and clinicians alike (table 6.4, quote 27). Access should be easy—'simply click on a button'—and include study protocols to reduce research waste (table 6.4, quote 28), and data (table 6.4, quote 29). Although open access to data resonated with our interviewees—even if it becomes a future journal requirement for new studies—there are important considerations, including informed consent from participants for anonymised patient data to be shared among research groups (table 6.4, quote 30).

Some participants felt that prioritising open access was easier said than done. For example, particularly for early career researchers, impact factor might trump open access; an approach that could disrupt effective dissemination of results (table 6.4, quote 31).

Researchers should think carefully when sharing test results with individual research participants (and, in the professional football club context, their sports club medical teams and managers): they should have an agreed protocol for this (table 6.4, quote 32) and be comfortable to say: 'there's nothing to share'. Particularly when sharing, for example, 'normal' imaging results of 'frankly, probably a pretty typical development [primary cam morphology]' in athletes (table 6.4, quote 33). Research teams should also give athletes/patients ownership of the decision to share, or not to share, their results with club medical staff (table 6.4, quote 34).

Finally, participants also expressed concern about, or questioned the need for, open access. They discussed: the high ('extortionate') cost of open access publication (table 6.4, quote 35); the 'completely crazy' academic publication system—paying to sign away copyright (table 6.4, quote 36); the problem of predatory or low-quality open access journals (table 6.4, quote 37); and their perspective that open access papers are 'not that important' as the average clinician 'don't really read research papers'—the cost of open access publication 'pull money away' from research (table 6.4, quote 38).

In sum, our study participants discussed how research communities could pursue open science to improve research quality. Clinicians, researchers, and athletes/patients need to have easy access to important findings. There are perverse incentives (e.g. researchers seeking publication in a high impact factor journal that is only available to readers via a paywall). Finally, the cost of making publications open access could be prohibitive.

Table 6.4. Quote, theme 3: research communities should pursue open science

Quotation
25. '…everyone should have access to as much information as possible, in the most accurate up to date information, where possible. But at least to have the summary or the breakdown, if not the whole thing. To still be able to have access to that information and understand what the study was and what the concluding things were from it.' (P10)
26. 'Everyone. Everyone should have access. And study results should be translated to lay people's language, for access to the information for the community. So, using things like infographics or factsheets etcetera is absolutely essential. And that's the kind of thing that can help educate parents and football clubs, and coaches.' (P1)
27. 'Once I stopped studying, obviously, you stop having access to all the database and the resources that the university provides. …Even for my work now, I regularly quote journal articles and research to back up what I'm saying. And so, it is important to have more access to that, to be able to better justify and explain or backup what we're recommending.' (P2)
28. '…it is basic methodological practice that is going to improve the quality …having protocols, being registered and available in open forums so that people are aware of studies that are happening.' (P1)
29. 'Most of the bigger studies will publish their protocol, specified which analysis they will do, the outcome measures, the factors they study... So that's the first thing and the other thing might be to publish your database open access.' (P6)
30. …you have to publish your data set open access. I'm a fan of that, but there are quite some issues involved in that. And probably journals in the future will require that much more. …for me, it's a no-brainer. I think everybody should do that [share anonymised patient data between research groups]. Even for the grants we apply for now, it's even, how you say, necessary to do that. To have your data open access. And I think it's moving more like that. And it might be difficult, what I experienced with other consortia that I worked in, with cohorts that are already established. Because participants did not already give their informed consent for sharing the data outside the centre or whatever. So that might be sometimes a problem. But for newly studies, that should certainly be the case. And for us, we can only run studies if we do that. (P6)
31. An early career researcher, trying to get his name out there a little bit, is probably …more inclined to go with the high impact, high ranking journal, because it's important for, whatever you're trying to do, whether it be your next job. But I'm aware that that is not great for the dissemination of research, more often than not, because then you've got to drive that separately. On top of the fact that it's already in that journal, you've got to drive it to other people that need to know about it. That creates a lot of work for the researcher. (P5)
32. 'We had a clear protocol that we discussed with players beforehand: "This will be the approach, this is what you need to sign off, the club doc needs to sign off. And then we release the scans" and so on.' (P15)
33. 'I would say that there's nothing to share. I mean, I would say that you really don't know enough about that [primary cam morphology]. Because we know that this is, frankly,

probably pretty typical development. I don’t think you can sit here and say that this is atypical. And I would say, unless you see something that is not something you’re looking for, like an osteosarcoma or something like that, I don’t think it’s warranted to share that with them, other than saying: ‘we’re in the data collection process and we’re trying to understand these things. And we just don’t know enough about this.’ And I think that would be where I would leave it.’ (P13)

34. ‘We also asked them if they wanted their medical staff to be involved or not. Because they are the participants and scientifically seen and ethically seen, their medical staff does not have any right to know their personal information.’ (P2)
35. ‘What I’m not in favour of, is the extortionate costs of open access. …the production costs are a lot less. And I’m also a reviewer and an editor that doesn’t get paid to do any editing or reviewing. So that is the thing I can’t get my head around, you know, we are all doing this work for free.’ (P4)
36. Well, I would say that open access research is paramount. And the basis of research, as we know it nowadays, is completely crazy. So, what we do is that we publish, sometimes with our effort and with our money, and then we transfer our copyrights to an editor and then the editor will ask for money from the universities. …So, this is completely crazy. Right? (P14)
37. …the problem with open access now, in science in general, is that there is a plethora of low-quality journals that pretty much pay - publish anything, provided that you pay. And the scary thing is that, even researchers don’t know what’s the difference between a good journal and a bad journal. You know, I had staff in the past that approached me to say: ‘Oh, I've been invited to write a paper for this journal.’ And I’m thinking about writing it. And I have to explain them what a predatory journal is. And that’s people with PhDs and years of experience, and you think: ‘Wow, we’ve got it wrong here.’ (P4)
38. ‘I think that Open Access papers are probably not that important. And I say that because there’s a fee that’s associated with that. And when you do that, then that makes things more difficult to get papers published, because it takes more money to do that, and it pulls money away from doing other research efforts.’ (P13)

6.4.4 Theme 4: Research communities should champion equity, diversity, and inclusion

This theme includes and extends the INQUIRE dimensions: generalisability (external validity), and relevance / patient centredness & involvement. Our interviewees highlighted several equity, diversity, and inclusion (EDI) elements of high-quality research relevant to the steps of a research project in the hip-and-groin research field.

First, as I described in theme 1, research communities should partner with athletes/patients. Such partnerships, to inform research questions, for example, should focus on racial/ethnic and sex/gender minoritised individuals and groups in the EDI context of this research field (e.g. girls, women, Black people, and people from the Global South).

Second, considering study populations, the primary cam morphology research field is largely void of research involving girls and women, and people from the Global South—particularly athletes. This was emphasised by our interviewees too (table 6.5, quote 39). To engage more diverse populations, research should not only consider the different impact on males and females, but also involve people of different ages, people with disabilities, and people with different ethnicities (P12). To date, very little research in this field is done in the Global South, for example. A clinician-researcher and patient warned that 'to understand the injury or morphology well' it is important not to 'shut out certain geographical areas' (P13). Participant 7 confirmed this perspective, discussing research that involved diverse populations with 'genetic variation' and different athletic backgrounds (table 6.5, quote 40).

Third, research team-specific EDI considerations include fostering an inclusive and equitable research climate within teams and their collaborative networks. Our interviewees discussed: (1) team diversity (e.g. female research participants might feel uncomfortable when male researchers perform a groin evaluation, as illustrated in quote 41, table 6.5); (2) access for team members who live remotely (e.g. accessible and inclusive online meetings, as illustrated in quote 42, table 6.5); (3) building capacity (e.g. team member compensation and mentoring ensuring socioeconomic status and knowledge about the research topic do not exclude certain team members, as illustrated in quote 43, table 6.5).

Finally, EDI in knowledge translation include, as discussed above, easy access to research reports written in lay language, ideally with patient partners (table 6.4, quote 26).

Table 6.5. Quotes, theme 4: research communities should champion equity, diversity, and inclusion

Quotation
39. 'A major thing is to include women, which I think there's a bit of a void. So that's very underrepresented across everything, and particularly across elite athletes. To look at the

	complexities of researching elite athletes. …listening to the athlete voice …And not just take them as this commodity, with, let's say, a combination of anatomy, physiology - but actually bringing in the bio-psychosocial. So, making it a lot more multi-dimensional, making a lot more inclusive in terms of beyond the elite.' (P7)
40.	'Having inclusions throughout the world, throughout genetic variation, I guess. So, most of the studies done so far… are in Caucasians. And I think it's important to have people involved as well with different genetic backgrounds. I'm especially interested as well in Asia.. Because we know already that their hip morphology is way different than people with other genetic backgrounds. And well, just having enough numbers in different age groups from different athletic backgrounds… (P6)
41.	'I think the primary [female participant recruitment issue] was, that there were three male researchers that were doing the recruitment. And that required a physical examination of the hip-groin area, which is obviously a sensitive area…' (P5)
42.	'Move that [meeting] around the world, to try to make it as accessible as possible. And I think doing it via zoom, is really probably the best way to do it. …so you reduce those costs as well. …I think the other part of it, is to include all stakeholders in it. So, the researchers, I think clinicians, and coaches. That is going to be really important. Parents.' (P13)
43.	'For different countries, it's access to the same resources that we have. So, a good way of trying to encourage this, is getting competent people from other countries, and trying to link up. Try and make links, and then helping provide resources. You know, so developers together and making sure that - maybe an academic unit, where things are more set up, can help. But then you have things like visitation. So it could be that somebody doesn't have much research experience, then comes visits for a few weeks and get some experience and just develops these links that way.' (P15)

6.4.5 Theme 5: Research communities should nurture young scholars

This theme includes and extends the INQUIRE promotor: sustainability / education. Mentoring seems to be key for scholarly growth and has been defined as 'a dynamic, reciprocal relationship in a work environment between and advanced career incumbent (mentor) and a beginner (protégé) aimed at promoting the career development of both.' ([448] p17). Four archetypes of mentorship have been proposed: the traditional mentor, the coach, the sponsor, and the connector [449].

> …the mentor guides, the coach improves, the sponsor nominates, and the connector empowers, but always the mentee benefits. ([449], pE2)

Interviewees illuminated how research communities could nurture young scholars through mentoring, deconstructed here using the four archetypes above. First, through careful mentoring by humble mentors. Humble mentors model imperfection—they are willing to say, 'I don't know' [450]. They seem to carefully guide young scholars to pursue relevant research questions 'as part of something bigger', as quote 44 (table 6.6) illustrates. Second, through mentors that challenge mentees in safe spaces (the coach or supervisor-type mentorship), as quote 45 (table 6.6) illustrates. Third, through mentors that create opportunities – the sponsor-type mentorship. Scholars should not be 'dumped' into research with a 'good luck, my friend' approach (P2). Rather, research teams—especially senior researchers and mentors—should create opportunities for young scholars to lead (table 6.6, quote 46). Finally, through mentors that empower. Clinician-researcher (P3) described his role (as a connector-type mentor) in creating a stable and sustainable environment for young scholars, connecting them with a professional sporting organisation (football club) as employer and a university for academic training:

> Why don't we ask the real - performance, injury, whatever it is – questions? Why don't we generate the questions and then go to the Universities? Get the contract which [is] always the most painful bit. But get the contract sorted out and then doing. If it's a PhD, we do an interview to find the right student that would fit the University and also our needs. Because they'll be imbedded for three years within our program, became effectively a member of staff for us, the players knew no difference, they just saw a member of staff and it went really well. (P3)

A clinician-researcher and young scholar (P2) stressed the importance of 'insight in the ethical way of things' when creating opportunities for young scholars, and warned against research for the sake of research:

> You cannot just only say: 'I want to do research as quick as possible and get the highest paper with the best impact-factor' but also think of sustainable quality research… (P2)

Several participants mentioned lack of sustainable employment and funding as a problem, creating 'considerable stress and lack of certainty about the long-term job and continuity' (P1), as quote 47 (table 6.6) illustrates. Research in this field ('arthritis') seems to struggle for funding compared to other fields like cancer (table 6.6, quote 48). However, protected employment seems not enough; financial and collegial support for relevant research, with continued access to data after employment, should be cemented in employment contracts (table 6.6, quote 49).

In addition to mentoring, participants discussed personal growth when well-organised research teams created opportunities for structured education, for discussing ideas (quote 50), and for sharing the struggles of being a young scholar (table 6.6, quote 51). Participants emphasised structured education programmes for young scholars. One participant urged education on 'the rules and the processes of research.' (P4) Although important, this element is often missing in education; 'that a lot of people, despite the fact that they have PhDs, still don't understand the research process, is fascinating to me.' (P4) Participant 2 agreed, advocating for a structured education programme: 'We had like a course of two weeks on biomedical statistics, but to be honest, how can you learn biomedical statistics in two weeks?' (P2) Another participant advocated for 'having the right people in the right positions to educate the team' on more field-specific knowledge and skills. (P5)

In sum, creating opportunities for young scholars to learn, teach, and lead even large-scale studies in well-supported teams, resonated with participants. Participants agreed that stable and sustainable research environments are key for supporting young scholars' development into independent researchers.

Table 6.6. Quotes, theme 5: research communities should nurture young scholars

Quotation
44. '…one of the things that really helped me was having mentors that were able to represent what we don't know, rather than saying that we have all the answers; we just need you to prove them. To be very open to the fact that there's so much unknown in this area and we would like you to [focus on] this particular aspect of it, so we can built on that and I think that's a really important thing as a PhD-student but also mentoring a PhD-student, that you are part of something that's much, much bigger and you're coming into a team that are trying to answer a bunch of questions that is going to move the field forward and reduce the burden of these injuries to help society. So, I think putting it in perspective of what's happened before and what will happen in the future is very beneficial.' (P1)
45. 'In the beginning he was very strict, and we had. some really strict deadlines, and there were sometimes that I really hated him, but afterwards that probably was a good lesson for me. So, I think it's really important to have a good supervisor, to have the opportunity to ask questions, to not have a really strict hierarchy. So, we have a professor that is really easy to

go to, to talk to, to ask questions to, not only on scientific basis, but also financially and things like that. So that also makes it a really safe environment for scientific research.' (P2)

46. '…as a student, I provided most of the education for the other researchers. Not the junior researchers, because I was the first one on there. And I set up the protocol and all that sort of thing. So, I was sort of leading that and like, I was thrown in the deep end effectively, but a great learning experience.' (P5)
47. 'So, providing positions that will facilitate the collection of data would be really beneficial. …at the moment a lot of our positions are very short term and tied to external funding, so that creates considerable stress and lack of certainty about the long-term job and continuity. And that's a problem if you're trying to do long-term prospective studies. And we're already seeing that with our prospective studies, which is now up to five years, that the PhD-students are starting to finish and if we don't have positions available then we lose all the intellectual property that's been developed with this cohort, that incredibly deep and rich intellectual property with that cohort if we can't ensure positions for those PhD-students once they finish. So that is a problem, yes.' (P1)
48. 'When they go into postgrad, funding is a huge thing. Just trying to support themselves and live as a postgraduate student can become a big issue, getting funding for their research, it tends to be specific areas that are probably over funded. So, things like cancer are hugely funded. Arthritis isn't as well funded, considering it's one of the biggest problems.' (P7)
49. 'So, until someone has longevity, in a sense of 'Ok, I'm going to do a project that, I'm comfortable I can put 3 to 5 years PhD focus on, and it's protected.' So, we ended up creating agreements for a member of staff, who was doing a PhD, saying, even if you leave the club, you can have access to the data, you can use the data, publish data, right off the bat, to protect him. Because it was ridiculous otherwise. But that insight doesn't really exist in many clubs.' (P3)
50. 'We had a big group, with probably ten or twelve different scientific researchers from different fields, and we had education every week and we discussed our own progress, our pitfalls, our positive sides, suggestions for others. That was really useful as well in my opinion. So, every week, one or two hours a week, just to evaluate and discuss every project. And that gave me a lot of good ideas, to include in my own research. So, if you stick ten smart heads together, you might create some good thoughts on performing research in the future.' (P2)
51. 'Because a PhD has a lot of downsides, again a rejection, again a wrong interpretation of the data, again a manuscript that had major revisions but got rejected afterwards, again congresses in corona-time that just don't go on… But if you stick your heads together and just discuss those downsides and positive sides, that might be really useful.' (P2)

6.5 Discussion

The findings of this study show that, for higher quality research in the field of primary cam morphology and its natural history, research communities should: partner with athletes/patients; foster collaboration; pursue open science; champion equity, diversity and inclusion, and nurture young scholars (Figure 6.3). Informed by the INQUIRE framework, these action-inviting themes provide important insights for higher quality research—more value, less waste—on primary cam morphology and its natural history, including hip-disease consequences.

High quality research on primary cam morphology and its natural history is ultimately aimed at benefitting athletes/patients. It is therefore important to keep their preferences, experiences and needs at the centre of research (Figure 6.3). This approach to research in the field of primary cam morphology and its natural history is supported by the results of the Oxford Consensus Study [290,388]: athletes/patients should be 'in charge as partners with power—exerting some control over all decisions' [388].

6.5.1 Summary of findings and implications for research and practice

Our first theme echoed that authentic patient and public involvement (PPI) in research—partnering with athletes/patients—could facilitate more relevant, safer, and more ethical research [451]. Patient-centred research could help to identify unmet needs and gaps for research communities to prioritise—research questions that are relevant to athletes/patients with primary cam morphology or a related hip disease. These include qualitative research to explore experiences, preferences, and perspectives. It goes without saying that athlete/patient-centred research must be safe and ethical. In the context of primary cam morphology and its natural history this means, for example, avoiding radiographs when researching aetiology in maturing athletes, protecting participants' personal information, prioritising general and research-specific ethics and integrity, and valuing methodological rigour.

A haphazard approach to language (including terminology and definitions) could confuse patients [452]. This gap was addressed when the research community agreed on primary cam morphology terminology, definitions, taxonomy, and imaging outcomes for research [290]. The YAHiR Collaborative and others are working to implement this agreement and to address areas of tension and dissent. This will take time; many clinicians and researchers still use cam 'lesion', 'deformity' or 'impingement' instead of the agreed 'morphology' [36,290]. With athletes/patients as partners, research communities would likely be more inclined to prioritise clear and non-threatening language when stakeholders communicate about the morphology and its hip-disease consequences.

Figure 6.3. Five action-inviting themes that could inform higher quality research—more value, less waste—on primary cam morphology and its natural history

Second, high-performing research teams should collaborate with one another—a key INQUIRE element of high-quality research [33]. Such collaborations could catalyse, among other benefits, larger data sets (through well-planned multi-centre research projects on primary cam morphology aetiology and prognosis, for example), increased methodological rigour (by involving, for example, methodologists and specialist radiologists from the outset), and better framing of research questions to secure wider buy-in (of football club managers, for example). Professor Trish Greenhalgh shared '3 tips for authentic research collaboration from interdisciplinary health research' in Session 4 of the 2022 Oxford Young Athlete's Hip Symposium: 'build relationships and trust', 'foster tolerance of uncertainty', and 'harness conflict productively' (Figure 6.4).

Figure 6.4. Tweet by Professor Karim Khan sharing Professor Trisha Greenhalgh's '3 tips for authentic collaboration from interdisciplinary research' [453]

Third, the research community should pursue open science. Participants emphasised access for everyone to as much information as possible—including protocols, datasets, and summaries of results in non-scientific language. Several participants discussed 'extortionate' costs of open access publishing and warned against predatory and low-quality open access journals. These problems are not unique to the hip-and-groin research field. With an estimated annual turnover of $2 billion, the open access publishing model has become the 'mainstream approach to delivering scientific knowledge with Article Processing Charges as driving force' [454]. Predatory journals and publishers, a problem in all research fields [455], were defined as 'entities that prioritize self-interest at the expense of scholarship and are characterized by false or misleading information, deviation from best editorial and publication practices, a lack of transparency, and/or the use of aggressive and indiscriminate solicitation practices' [456]. This consensus definition is likely to contribute to a coordinated strategy aimed at eradicating the plague of predatory journal and publishers.

Fourth, high-quality research on primary cam morphology champions EDI. An EDI-conscious research community at each stage of the research process, would be more aware of possible blind spots, including a tokenistic, tick-box approach to EDI [457]. Similar to other research fields, there is a lack of diversity and inclusion in sport and exercise medicine, science and rehabilitation in general, but specifically Black female athletes [458–460]. Other fields have prioritised efforts to improve EDI, including in academia [461] and nursing [462]. An EDI lens should not only inform research populations but also research teams. Our findings suggest such a research community would likely (1) prioritise more diverse research populations and research teams with an immediate focus on girls and women, and the Global South (diversity); (2) secure access to equal and fair opportunities to minoritised individuals and populations (equity); and (3) emphasise inclusion as 'a sense of belonging: feeling respected, valued, and seen for who we are as individuals' [463].

Figure 6.5. Dr Nonhlanhla Mkumbuzi from Zimbabwe (now living in South Africa) discussing three tips for prioritising minoritised and marginalised populations in research during the Young Athlete's Hip Symposium, September 2022, Oxford: 'acknowledge', 'represent', and 'collaborate' (Photo: Paul Dijkstra)

Finally, participants in this study emphasised young scholars, in high-quality research, should be nurtured. This echoed the move away from an 'unhealthy reliance on impact factors' to assessing scientific research quality [464], to rather focus on nurturing and mentoring the next generation of scholars [465]. They are carefully mentored, share, and learn together, benefit from opportunities created by their mentors and seniors, and thrive when employed with funding—creating a stable and sustainable research environment.

6.5.2 Comparison to the research quality literature

The findings of this study, informed by the six dimensions and two promotors of the INQUIRE framework, are consistent with current trends in assessing research. However, what research quality in health care is, also depends on context and research type. The INQUIRE framework's dimensions—‘minimisation of bias’, ‘precision’, and ‘generalisability’—illuminate a predominantly positivist lens to assessing research quality. For example, we don’t trust results of cohort studies plagued by researcher bias and imprecision. ‘Confirmability’, ‘credibility’, and ‘transferability’, on the other hand, are concepts for defining and investigating rigorous qualitative research [466–468]. A carefully constructed conceptual framework for research quality in health care can inform efforts to improve research in a specific field. A new, more inclusive framework could, for example, be the catalyst to moving a field beyond the ‘impact-factor-is-king’ approach to assessing research quality, to embracing a more contemporary approach. In this study, our analysis started with the INQUIRE framework but also explored research quality beyond the positivist frame of enquiry.

Despite worldwide quests, a uniform approach to describing and assessing research quality and impact is still contested. The 2014 ‘Increasing Value, Reducing Waste’ series in *The Lancet* [321,379,469–472] spotlighted waste in biomedical research and made 17 recommendations to increase research value, addressed to five main stakeholders—funders, regulators, journals, academic institutions, and researchers. The authors of this series formed an alliance (the Reduced Research Waste and Reward Diligence [REWARD] campaign) [473], emphasising five principles—several echoed in our findings—to maximise research potential, including (1) the right research priorities; (2) robust research design, conduct and analysis; (3) regulation and management that are proportionate to risks; (4) access to all information on research methods and findings; and (5) complete and usable reports of research. However, a follow-up article in 2016, providing an overview of the effects of *The Lancet*’s Series and REWARD campaign, concluded that, overall, and despite early corrective actions by some stakeholder groups, further work was needed to increase research value [420]. Six years later, the tide continues to turn against research waste and, importantly, the narrow notion that high quality research and impact can only be ‘measured with a number’ [465,474].

The findings of this study resonate with the key quality concepts of the *Agreement on Reforming Research Assessment*[24].This agreement emphasises research (quality) assessment based primarily on qualitative judgement and more-inclusive assessment systems [474]. Commendably, this agreement was co-produced 'bottom-up' by research stakeholders from 350 research organisations and 40 countries as 'an exercise of consensus', based on a 'common vision, and shared responsibility and direction.' [475]. This inclusive approach is a foundation to collaborate—a call for collective action. To date (12 January 2023) and supported by the *Coalition for Advancing Research Assessment* initiative [476], 441 organisations worldwide have signed the agreement [477]. Others have paved the way for this approach, notedly in the transdisciplinary research context [478], and patient-orientated academic clinical research' (the INQUIRE framework described earlier) [33].

Belcher *et al.* (2016) proposed a framework of four main principles when assessing research quality in transdisciplinary research [478]. These principles are (1) relevance (the importance, significance, and usefulness of the research problem, objectives, processes, and findings to the problem context); (2) credibility (the research findings are robust, and the sources of knowledge are dependable. This includes a clear demonstration of the adequacy of the data and the methods used to procure the data including clearly presented and logical interpretation of findings); (3) legitimacy (the research process is perceived as fair and ethical, including ethical and fair representation of all involved, and the appropriate and genuine inclusion and consideration of diverse participants, values, interests, and perspectives); and (4) effectiveness

[24] Work on this Agreement, drafted by Science Europe, the European University Association, and Dr Karen Stroobants, supported by the European Commission, started in January 2022. This agreement '… set a shared direction for changes in assessment practices for research, researchers, and research performing organisations, with the goal to maximise the quality and impact of research. It includes principles, commitments, and timeframes for reforms and lays out principles for a Coalition of organisations willing to work together in implementing the changes.' - https://www.scienceeurope.org/our-resources/agreement-reforming-research-assessment/

(the research generates knowledge and stimulates actions that address the problem and contribute to solutions and innovations).

In sum, there are no shortage of research quality frameworks; however, how these frameworks are applied to inform research practice depends on several factors, including context. Nevertheless, there seems to be a world-wide movement towards a more qualitative assessment of research quality.

6.5.3 Strengths and limitations

To my knowledge, this is the first study in the hip-and-groin research field exploring research stakeholders' perspectives on research quality. In light of these efforts to articulate research quality, limitations of this study deserve particular attention. Although my aim was to explore (describe and understand) perspectives on research quality of a diverse stakeholder group (rather than a deep case-by-case phenomenological analysis of a smaller homogenous group) the study population could have been even more diverse—I did not, for example, recruit any participants from the Global South or Black female athletes. This was perhaps a blind spot – patients, particularly in this research field, are *not only* middle-aged white males. Participants from the Global South at the intersection of race and gender, compared to their white Global North counterparts, would likely have different perspectives on participation and access to three-dimensional imaging, for example. This was evident in the interacting group process of the Oxford Consensus described in chapters 4 and 5.

Although the data in this study provided a rich and complex picture of a diverse group of participants' experiences and perspectives on research in the field of primary cam morphology and its natural history, it did not aim to completely capture the phenomenon under scrutiny [479]. Our interviewees emphasised language and communication about the morphology, referring to 'inflammatory' language, for example. However, what 'inflammatory' is depends on the hearer. Research communities might therefore choose to adopt a more flexible approach to defining ‘inflammatory’ language. We need more research on the perspectives and needs of subgroups living with primary cam morphology and its hip disease consequences, focussing on women, adolescents and the Global South. Village-born Kenyan long-distance runners who pad 25 miles a day barefoot, for example, or youngsters playing football for many hours per week in rural villages in South Africa: do they develop primary cam morphology or its hip disease consequences? what are their challenges, priorities and concerns? These and other gaps in current research (as discussed in chapter 5) should be addressed by the YAHiR Collaborative and collaborators[25].

The research team reflected on two aspects of our sampling strategy. First, the structured variation approach to sampling (informed by the ‘closeness continuum’) resulted in breadth, rather than individual depth, of perspectives. However, our purpose was not an in-depth phenomenological analysis; we were interested in multiple perspectives on research quality from a diverse stakeholder group. Second, the role of prior relationships between researchers and some participants. The familiar nature of some ‘acquaintance interviews’ might have shaped the data gathered during this study [445]. For example:

> …*But you know better than anybody*, that some of the athletes may feel that osteoarthritis in 10 years’ time is much less important than what their pain-and-function is during the season. (P15)

Starting the sentence with ‘you know better than anyone’, the participant aligned himself with me as lead investigator and interviewer, drawing upon our shared knowledge. The participant was still the interviewee, but it could be seen that he also invoked our professional relationship [445]. Some participants might have assumed that I knew the answer anyway, limiting the extent to which the interviewee elaborated on their responses. For that reason, we had a third person (SMA) present during the interview allowing me the opportunity to ask, for example: ‘For SMA’s benefit, could you just explain why?’

[25] See section 7.5: Implications and future work.

Finally, I briefly mention critical orientations like power and equity. Epistemologically, were my orientation more 'critical theory' than pragmatism-informed interpretivist, I would have paused to unpack these constructs more.

6.6 Conclusion and chapter summary

Exploring stakeholders' perspectives on research quality through an established research quality framework (INQUIRE) illuminated areas for immediate action in the research field of primary cam morphology and its natural history. Research communities in this field should: partner with athletes/patients; collaborate authentically with one another; champion equity, diversity, and inclusion; pursue open science, and nurture young scholars. Such an approach would ultimately benefit athletes and patients.

The findings of this study could inform concrete actions by research communities to pursue higher quality research—more research value and less waste—in the field of primary cam morphology and its natural history. Although the five action-inviting themes reflect contemporary trends in research, and could therefore be transferable to other areas of research, their practical application remains context- and field-specific.

Chapter seven

Summary and conclusion

‘Thank you so much for including me in this study. I am incredibly honored to be a part of this study and to be able to interact with such well known/accomplished researchers and clinicians. It is hard for me to put into words what this opportunity means to me. If you would've known me back in 2014-2015, I was a very scared 26 y/o who had given up hope that my hip would be okay—that I would get back to running.

I can finally reflect on my journey, my hip and my struggles and be proud knowing that my story is helping others. THANK YOU PAUL and thank you to your team for studying CAM morphology and changing the way society views and treats CAM morphology. There are probably hundreds and thousands of stories just like mine---but through your work and research—you will change the way healthcare providers identify, discuss, and treat CAM morphology. One by one we will treat people with CAM morphology without language that causes fear, anxiety, depression and catastrophizing.

Something I never thought I'd say: I am grateful for that bump in my hip – it has made me a smarter athlete, a more empathetic physical therapist, and it has given me opportunities to learn from the best hip researchers and clinicians in the world.
How cool is that?!?!’

(Email to Paul Dijkstra by a research participant and patient partner – reproduced here with consent)

Chapter 7: Summary and conclusion

Sections of this chapter have been published in British Journal of Sport Medicine:

Dijkstra HP, Auliffe SM, Ardern CL, *et al.* Infographic. Oxford consensus on primary cam morphology and femoroacetabular impingement syndrome-natural history of primary cam morphology to inform clinical practice and research priorities on conditions affecting the young person's hip. *Br J Sports Med* 2023;**57**:382–4. doi:10.1136/bjsports-2022-106094

In this chapter, I revisit the strategic objectives and key findings of the programme of research presented in this thesis that aimed to transform research and clinical practice on primary cam morphology and its natural history in a more pragmatist and patient-centred direction. I summarise the key findings, discuss the methodological contribution, and reflect on the overall strengths and limitations of the programme of research presented in this thesis. I then return to my personal and scholarly journey focussing on the eight years of this part time DPhil, and describe the key consequences of the Covid-19 pandemic. Finally, I consider the implications of my research and further work.

7.1 Summary of key findings

In this research, I aimed to answer the following question: 'How could research and clinical practice on primary cam morphology and its natural history be transformed in a more pragmatist and patient-centred direction?' The seven strategic objectives were to:

1. explore the concept of primary cam morphology and its natural history, including hip disease;
2. mobilise and engage a community of athletes, patients, clinicians, and researchers;
3. ensure buy-in and diverse participation to facilitate inclusive co-production partnerships;

4. inform a more rigorous, inclusive, and evidence-based approach to research on primary cam morphology and its natural history by:
    a. ascertaining the level of agreement among experts on definitions, terminology, taxonomy, and imaging outcome measures for primary cam morphology
    b. working collaboratively towards agreement and highlighting residual disagreements on a set of research priorities on conditions affecting the young person's hip;
5. surface and discuss competing perspectives on primary cam morphology and its natural history, including hip disease;
6. explore stakeholder (athletes, parents, coaches, patients, clinicians, and researchers) perspectives on research quality relevant to primary cam morphology and its natural history, including hip disease;
7. disseminate findings through education events and otherwise.

In chapter 2, I presented a concept analysis method literature review to address the first strategic objective 'to explore the concept of primary cam morphology and its natural history, including hip disease.' In this first concept analysis of primary cam morphology (and, to my knowledge, the first concept analysis in the fields of sports medicine and sports science), I proposed five defining attributes for the morphology—tissue type, size, location, shape, and ownership—in a new conceptual and operational definition. I introduced and clarified primary cam morphology as a distinct concept. It has a unique aetiology that is likely related to a normal physiological skeletal response to physical loading patterns during maturation, and important to be distinguished from secondary cam morphology. Primary cam morphology is prevalent in many athletes, associated with the burden of future hip disease, particularly FAI syndrome and osteoarthritis, but inconsequential in most. However, in the literature (and in clinical conversations as demonstrated in the qualitative study presented in chapter 6) the morphology is medicalised as an ‘abnormality’ or ‘lesion’ that needed to be addressed. Figure 7.1 illustrates how I presented primary cam morphology and its natural history in chapter two (despite the ‘bog-standard’ title!); one could argue this was a very disease-orientated view that did not reflect the fact that—in most—this morphology is benign. However, this medicalised view changed.

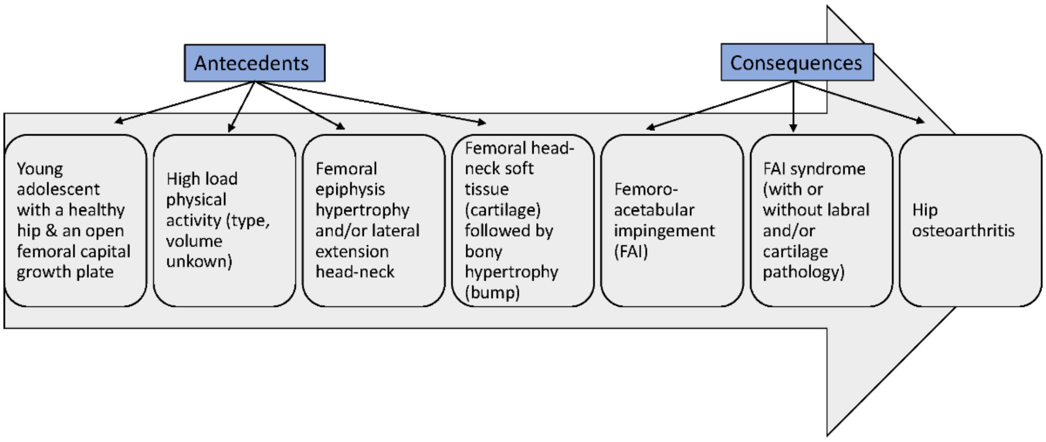

Figure 7.1. The antecedents and consequences of primary cam morphology (its natural history) as described in chapter 2.

I argued that several elements of the concept of primary cam morphology remained unclear and contested. Proposing more consistent terminology, a new conceptual definition and a taxonomy of types, chapter 2 set the stage for addressing areas of confusion, and for a more inclusive approach to creating new knowledge through co-production. An important next step was therefore for a diverse group of experts to agree on the proposed new taxonomy, terminology, and definition that better reflect the primary cam morphology landscape—a bog-standard bump in most athletic hips, and a possible hip disease burden in an unfortunate few.

Addressing the second and third strategic objectives of this thesis, ‘to mobilise and engage a community of athletes, patients, clinicians and researchers’, and ‘ensure buy-in and diverse participation to facilitate co-production’—and appreciate their diverse expertise to inform a different look at primary cam morphology and its natural history—I started the YAHiR

Collaborative. Soon after publishing the 2018's Zurich consensus papers as panellist and co-author, I proposed a follow-up and in-person consensus meeting in Oxford in September 2020. This meeting would have addressed areas of confusion on primary cam morphology and its natural history (surfaced through the empirical work presented in chapter 2), and served as a catalyst for a more inclusive approach to co-creating new knowledge. Our Symposium on 14 March 2020 at the *IOC World Conference on Prevention of Injury & Illness in Sport* in Monaco (Figure 7.2) would have set the stage for the planned September meetings in Oxford. These two events did not take place. Importantly, however, our IOC Symposium was one of the successful symposia (around 50) selected by an IOC-appointed international panel from more than 400 applicants. Covid-19 struck, and the IOC Conference in Monaco was postponed to October 2020. (This conference was postponed again and eventually took place in Monaco on 25-27 November 2021; I chaired Symposium 44 – Figure 7.2 and Appendix G-1 [480].

15.30-16.30 **Session C • SYMPOSIUM 49**
Room Camille Blanc

PREVENTING PRIMARY CAM MORPHOLOGY AND FEMOROACETABULAR IMPINGEMENT SYNDROME IN THE YOUNG ATHLETE: IS THE 'HOP' REALLY THE HIP'S DEMISE? [227]

Chairs: **Paul DIJKSTRA** - Qatar, **Andrea MOSLER** - Australia

15.30-15.42 Our confusing hip language is undermining prevention and protection
Clare Ardern - Sweden/Australia

15.42-15.54 To prevent and protect the hip, we have to understand primary cam morphology, its cause and prognosis – but can we yet?
Paul Dijkstra - Qatar

15.54-16.06 Screening and intervention to prevent primary cam morphology – is too much sports medicine creating a mountain out of a molehill?
Andrea Mosler - Australia

16.06-16.18 Protecting the athlete with primary cam morphology from developing femoroacetabular impingement syndrome and osteoarthritis
Sion Glyn-Jones - United Kingdom

16.18-16.30 Panel Discussion : This discussion will focus on the current state of evidence on protecting athletes from developing cam morphology, femoroacetabular impingement syndrome and early hip osteoarthritis. The importance of multi-center collaboration for clinical research, to reach consensus on sharing data and experiences, and develop the foundations for a prospective Individual Patient Data Meta-analysis will also be discussed
Ardern, Dijkstra, Mosler, Glyn-Jones

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Figure 7.2. Symposium 49* 'Preventing primary cam morphology and femoroacetabular impingement syndrome in the young athlete: is the 'hop' really the hip's demise'?

***This changed to Symposium 44 in the final programme and Dr Clare Ardern co-chaired as Dr Andrea Mosler couldn't travel to Monaco due to ongoing Covid restrictions on travel**

I soon realised that my September 2020 symposium and consensus meeting in Oxford would be unrealistic. In discussion with the scientific planning committee I postponed this event to September 2021. 'Locked down' and working from home in Qatar, I enrolled for the first online delivery of the 'Knowledge into Action' module of the University of Oxford's MSc in Evidence-Based Health Care. Professors Trisha Greenhalgh and Kamal Mahtani were the module tutors. This module, and the new knowledge gained, had four important consequences: (1) I changed the September 2020 Oxford Symposium into eight webinars; (2) I changed the September 2020 in-person consensus meeting in Oxford to an online Delphi method consensus process; (3) Professor Trisha Greenhalgh agreed to join my DPhil supervisory team; and (4) as a result of the Webinar Series and Delphi method, the YAHiR Collaborative was born. My DPhil (and I) changed.

YAHiR is an international grouping of multi-profession stakeholders aiming to increase value and reduce waste through higher quality research on the aetiology, treatment and prognosis of conditions that affect the young person's hip, including bony morphologies. 'Yahir' is also an Arabic name that means 'they will enlighten'; the YAHiR Collaborative aims to 'enlighten' better clinical decisions for patients through higher quality research. The systematic review and concept analysis co-researchers (and authors of the concept analysis publication in BJSM), Webinar Series faculty, and Delphi panellists all agreed to join the journey as members of the YAHiR Collaborative.

The 2021 Symposium and Research Meeting in Oxford was postponed again due to ongoing Covid-19 restrictions. This Symposium became Webinar 10 (delivered live on 22 September 2021) and Webinar 11 (delivered live on 23 September 2021) of the *Oxford-Aspetar La Trobe Young Athlete's Hip Webinar Series*. Through these two webinars, I disseminated the results of the Oxford Consensus Study. Each Webinar was followed by an online research meeting: the interacting group process as described in chapters 4 and 5.

Figure 7.3. Tweet by Dr Amy Price on YAHiR and the 2022 Young Athlete's Hip Symposium and Research Meeting [481].

Finally, on 22 and 23 September 2022 at Worcester College in Oxford, the *Young Athlete's Hip Symposium and Research Meeting* became YAHiR's first in-person event (described in chapter 5). Figure 7.3 is a Tweet by faculty member Dr Amy Price referring to YAHiR and the *Young Athlete's Hip Symposium and Research Meeting*. As described in chapter 5, I chaired the scientific planning committee of this event and crafted YAHiR's first Newsletter[26], sent to

[26] https://sway.office.com/dNwYlb2FNbvGKnt6?ref=Link

more than 200 collaborators in December 2022 (Figure 7.4). A YAHiR Website will be hosted by the Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences (NDORMS), and the next YAHiR Symposium and Research Meeting will be held at Worcester College in Oxford in September 2024. Referring to two Oxford Consensus papers, the YAHiR Collaborative and consensus format has been described as 'an inclusive process in every sense, from the make-up of the diverse international expert panel (18 countries, 6 stakeholder groups, 40% women), the two-round Delphi process, rigorous deliberations and voting procedure…' [482].

Figure 7.4. YAHiR's first newsletter, December 2022.

In chapter 4, I addressed the strategic objective 'to inform a more rigorous, inclusive and evidence-based approach to research on primary cam morphology and its natural history by ascertaining the level of agreement among experts on definitions, terminology, taxonomy, and imaging outcome measures for primary cam morphology' [290]. A diverse and inclusive Delphi panel agreed on four key issues essential to moving clinical practice and research forward in the area of primary cam morphology and its natural history: (1) definition, confirming its proposed conceptual attributes (tissue type, size, location, shape, and ownership); (2) terminology—use 'morphology' and not doom-and-gloom terms 'lesion', 'abnormality' or 'deformity'; (3) taxonomy, distinguishing between primary and secondary cam morphology, and (4) imaging outcomes, continuous bone and/or cartilage alpha angles on radial femoral head-neck MR imaging for research on how primary cam morphology develops. This broad consensus could provide athletes, patients, clinicians, and researchers with a stronger foundation for more precise communication, better clinical decision-making, and higher value research on primary cam morphology and its natural history.

In chapter 5, I addressed strategic objective 'to inform a more rigorous, inclusive and evidence-based approach to research on primary cam morphology and its natural history by working collaboratively towards agreement and highlighting residual disagreements on a set of research priorities on conditions affecting the young person's hip' [388]. The 65-member Delphi panel, representing six stakeholder groups, agreed on the first ranked set of research priorities on conditions affecting the young person's hip, focussing on primary cam morphology and its natural history. While informing more rigorous, inclusive, and evidence-based research, this consensus on 18 ranked research priorities could serve as a roadmap for researchers, policy makers and funders to implement research dedicated to reducing the cost and burden of conditions affecting the young person's hip, including hip disease related to primary cam morphology.

I demonstrated in chapters 4 and 5 how I also addressed strategic objective five: 'to surface and discuss competing perspectives on primary cam morphology and its natural history, including hip disease'. The Delphi panellists had the opportunity to provide individual feedback to each statement. These were synthesised to inform discussion topics for two online meetings in small mixed stakeholder group meetings (interacting group process). The empirical work presented in chapters 4 and 5 included a formal dissent analysis, to my knowledge a first for the fields of sports medicine and science.

In chapter 6, I addressed strategic objective 6 'to explore stakeholder (athletes, parents, coaches, patients, clinicians and researchers) perspectives on research quality relevant to primary cam morphology and its natural history, including hip disease.' Exploring stakeholders' perspectives on research quality through an established research quality framework (INQUIRE) illuminated areas for immediate action in the research field of primary cam morphology and its natural history. The findings of this study could inform concrete actions by research communities to pursue higher quality research—more research value and less waste—in the field of primary cam morphology and its natural history. Research communities in this field should partner with athletes/patients, collaborate authentically with one another, champion equity, diversity, and inclusion, pursue open science, and nurture young scholars. Such an approach would ultimately benefit athletes and patients. Although the five action-inviting themes resonate with contemporary trends in research in general and could therefore be transferable to other areas of research, their practical application would remain context and research field specific.

I addressed the final strategic objective 'to disseminate findings through education events and otherwise', throughout the thesis. I described (in chapter 5) the planning and delivery of two key education events: the *Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series*, and the *Young Athlete's Hip Symposium*. I demonstrated how these events mobilised and cemented the YAHiR Collaborative—participants and faculty—to share and discuss evidence. Furthermore, the empirical work presented in chapters 2 [1], 4 [290], and 5 [388] were all published open access with extensive supplementary data.

Finally, following the Oxford Consensus Study, I designed and published an Infographic [389], described by BJSM Editor-in-Chief, Professor Jonathan Drezner, and Professor Jon Patricios (BJSM Editor) as 'easy-to-follow' and 'an excellent desktop guide to patient care in young athletes with FAI syndrome' [482]. This Infographic illustrates the natural history of primary cam morphology (PCM) and FAI syndrome to inform the Oxford Consensus Study's seven prioritised research domains on conditions affecting the young person's hip [290,388]. It is distinctly different from the medicalised lens to primary cam morphology and its natural history presented in chapter 2 (Figure 7.1). In the Infographic, I share the following 16 key messages—a new look at primary cam morphology—for athletes, patients, clinicians, and researchers:

1. Among other possible risk factors (including genetics), playing a high-load sport like football (soccer) or ice hockey while growing (during adolescence) is *the* key risk factor for developing PCM [60,403,483].
2. Many young athletes have asymptomatic PCM. However, at present, no one knows how many; clinicians and researchers have 'measured' PCM in different ways (often using alpha angles on imaging) [1].
3. PCM seems more common in males. Research on PCM in females is sparse; no studies have yet investigated how PCM develops in female athletes [1].
4. Clinicians and researchers cannot predict who will develop PCM. Therefore, coaches cannot, with confidence, manipulate training to reduce a young athlete's risk of developing PCM.
5. Most athletes who have PCM thrive; they compete with 'happy hips' and never develop symptoms (Figure 7.5) [2,484].

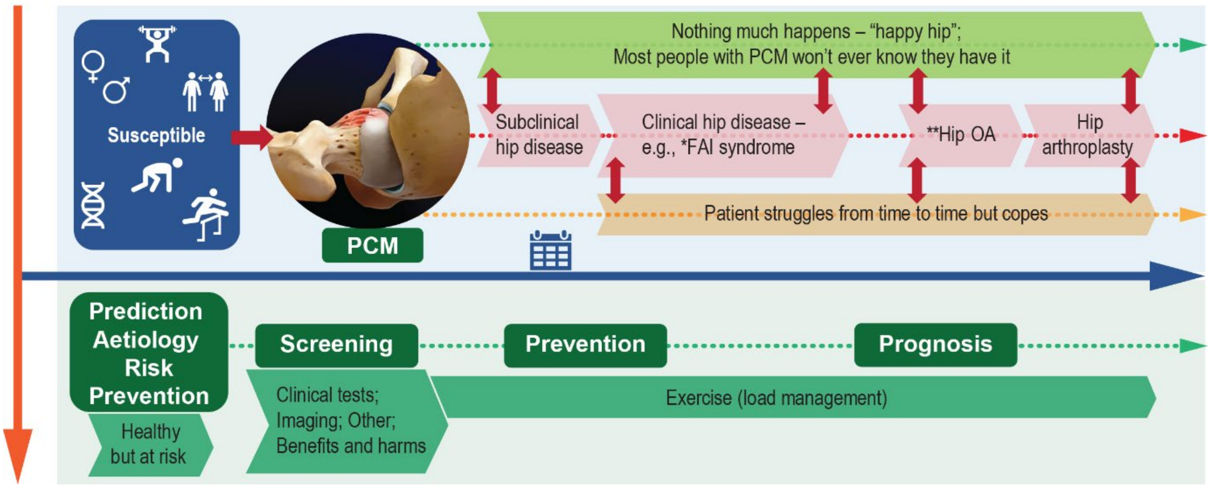


Figure 7.5. A novel and more-inclusive view of primary cam morphology and its natural history, emphasising the fact that this morphology is benign in most: the 'happy hip' concept.

6. Some athletes with PCM develop symptoms like hip-related pain. This is called 'femoroacetabular impingement (FAI) syndrome' [36]. A few athletes with FAI syndrome might develop hip osteoarthritis (OA) in the future [5].

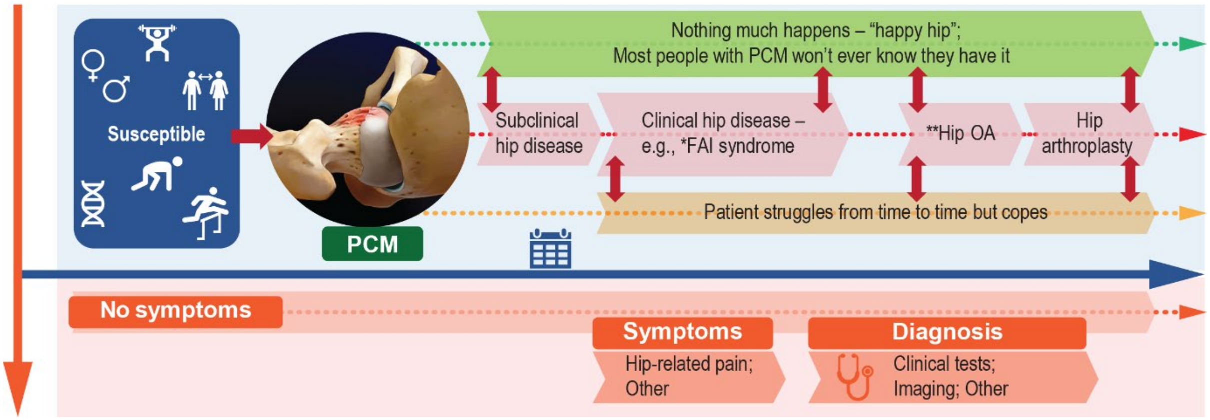


Figure 7.6. The hip disease consequences of primary cam morphology could include femoroacetabular impingement syndrome and hip osteoarthritis. Importantly, many athletes with these hip disease consequences might struggle from time-to-time but would generally cope well.

7. Clinicians and researchers cannot yet predict the 'at risk' athletes with PCM who might develop hip disease such as FAI syndrome or hip OA. However, size matters; large alpha angles are associated with a greater risk of developing hip osteoarthritis [12,35,485].

8. The word ‘syndrome’ has a negative connotation to many patients. Most athletes with FAI syndrome do well when treated with a combination of education and progressive exercise rehabilitation [290].
9. Clinicians, researchers, and patient partners should prioritise research to determine what ‘best practice physiotherapy’ is by comparing different treatment options [394].
10. Other clinicians besides physiotherapists can lead exercise rehabilitation. When referring to non-surgical treatment for hip-related pain, the term ‘clinician-led progressive exercise rehabilitation’ is better than ‘physiotherapy’ (Figure 7.7) [394].

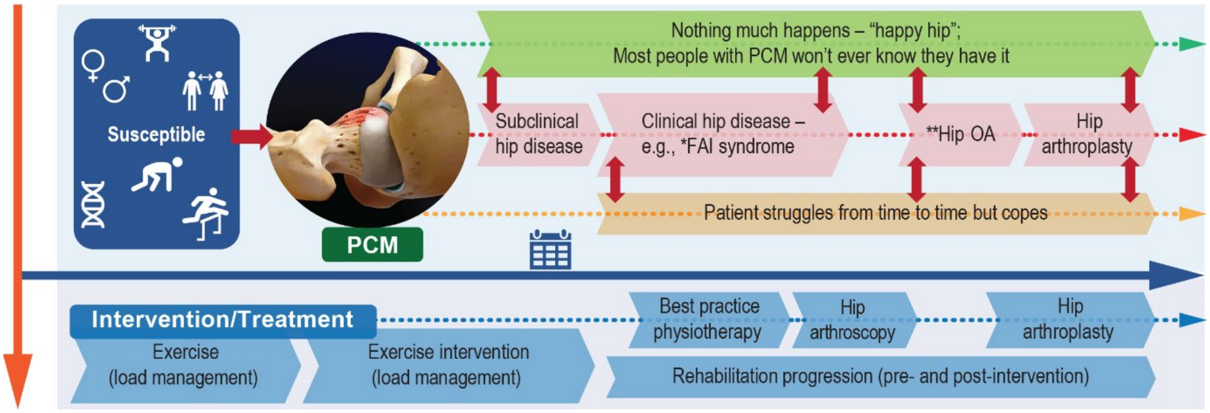


Figure 7.7. The intervention/treatment timeline for primary cam morphology and its related hip disease consequences.

11. Some patients with FAI syndrome might need surgery—it’s a small proportion but clinicians and researchers cannot yet predict who (Figure 7.7). However, this is changing. A prediction model published in March 2023 identified common clinical variables (including demographics, radiographic parameters of hip morphology, and self-reported measures) able to predict the probability for unsuccessful outcomes one year after hip arthroscopy for patients with hip-related pain [486].
12. Surgery can be hip arthroscopy to remove the bony prominence and/or repair damaged tissue like the hip’s cartilage. On occasion older athletes with advanced hip OA might need their hips replaced (hip arthroplasty) (Figure 7.7).

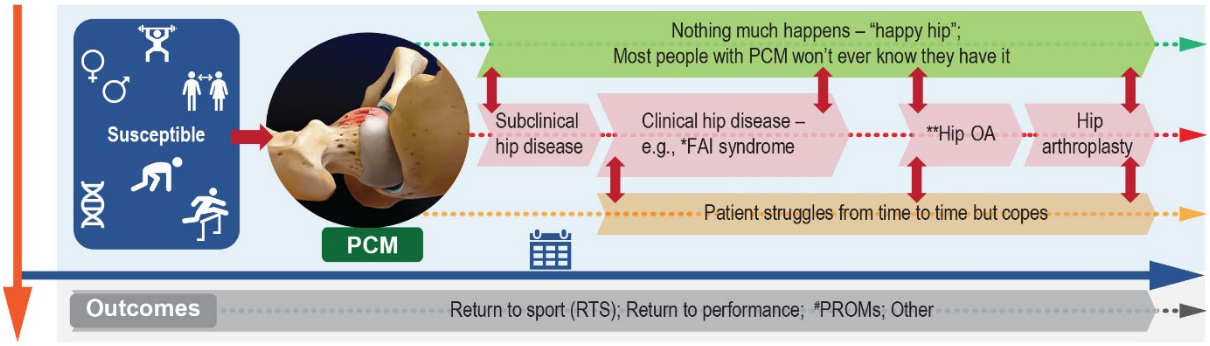


Figure 7.8. The outcome timeline for primary cam morphology and following treatment for its related hip disease consequences.

13. Return to sport (RTS) after treatment for hip-related pain is important, especially to career athletes. However, clinician-scientists cannot yet, with confidence, advise on the best time to RTS. Following hip surgery, some athletes return to compete at their previous sporting levels; others have compromised performance (Figure 7.8).
14. Should clinicians and/or researchers screen young athletes for PCM? Probably not, but we do not know for sure. Some asymptomatic athletes with PCM might benefit from early intervention like adapting training load or targeted muscle strength training.
15. In addition to the cost and possible x-ray exposure, screening can also cause psychological harm. This happens when athletes are labelled with, and might worry about, a 'condition' (PCM) that will never bother them (Figure 7.9) [388].

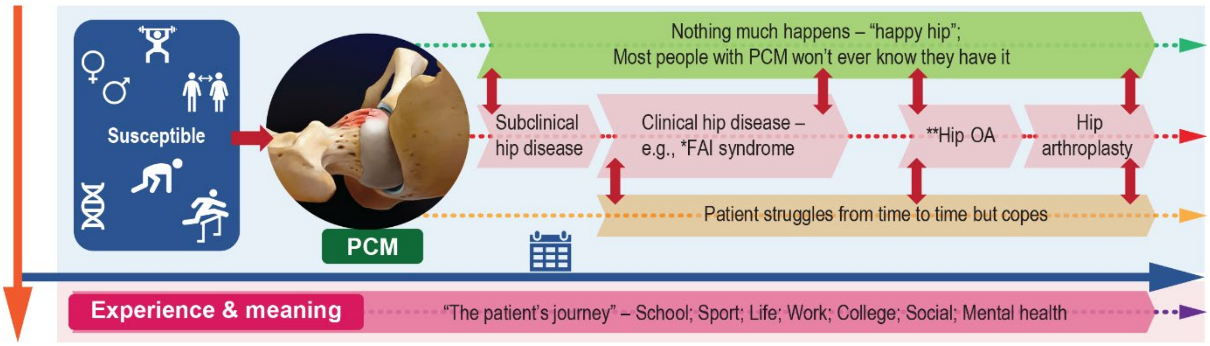


Figure 7.9. Experience and meaning: important considerations for primary cam morphology and its related hip disease consequences.

16. Some athletes (and their parents) worry that knowledge about PCM might negatively influence coaching decisions and their sporting careers [388].

In sum, the empirical work presented in this thesis aimed to expand knowledge on primary cam morphology and its natural history, including FAI syndrome and other hip disease consequences, so that it takes a more pragmatist and patient-centred direction. Several elements of the concept of primary cam morphology and its natural history have been clarified to better reflect the primary cam morphology landscape—a bog-standard 'bump' in most athletic hips, and a hip disease burden in an unfortunate few. A diverse group of international experts [482] agreed on: (1) definition, confirming the morphology's conceptual attributes (tissue type, size, location, shape, and ownership); (2) terminology—use 'morphology' and not terms with a negative connotation like 'lesion', 'abnormality' or 'deformity'; (3) taxonomy, distinguishing between primary and secondary cam morphology, and (4) imaging outcomes, a continuous bone/cartilage alpha angle on radial femoral head-neck magnetic resonance imaging for primary cam morphology aetiology research [290]. Experts also prioritised and ranked 18 of 8 research priority statements [388]. The prioritised statements outlined seven research domains (Figure 7.10): (1) best practice physiotherapy, (2) rehabilitation progression and return to sport, (3) exercise intervention and load management, (4) primary cam morphology prognosis and aetiology, (5) femoroacetabular impingement syndrome prognosis and aetiology, (6) diagnostic criteria, and (7) screening. This consensus provides athletes, patients, clinicians, and researchers with a strong foundation to guide more precise communication, better clinical decision-making, and higher value research about primary cam morphology and its natural history.

Finally, stakeholders' perspectives on high quality research on primary cam morphology and its natural history, described in chapter 6, could guide research communities on the narrow and complex road towards more research value and less waste in the field: partnering with athletes/patients; collaborating with one another; pursuing open science; championing equity diversity and inclusion, and nurturing young scholars.

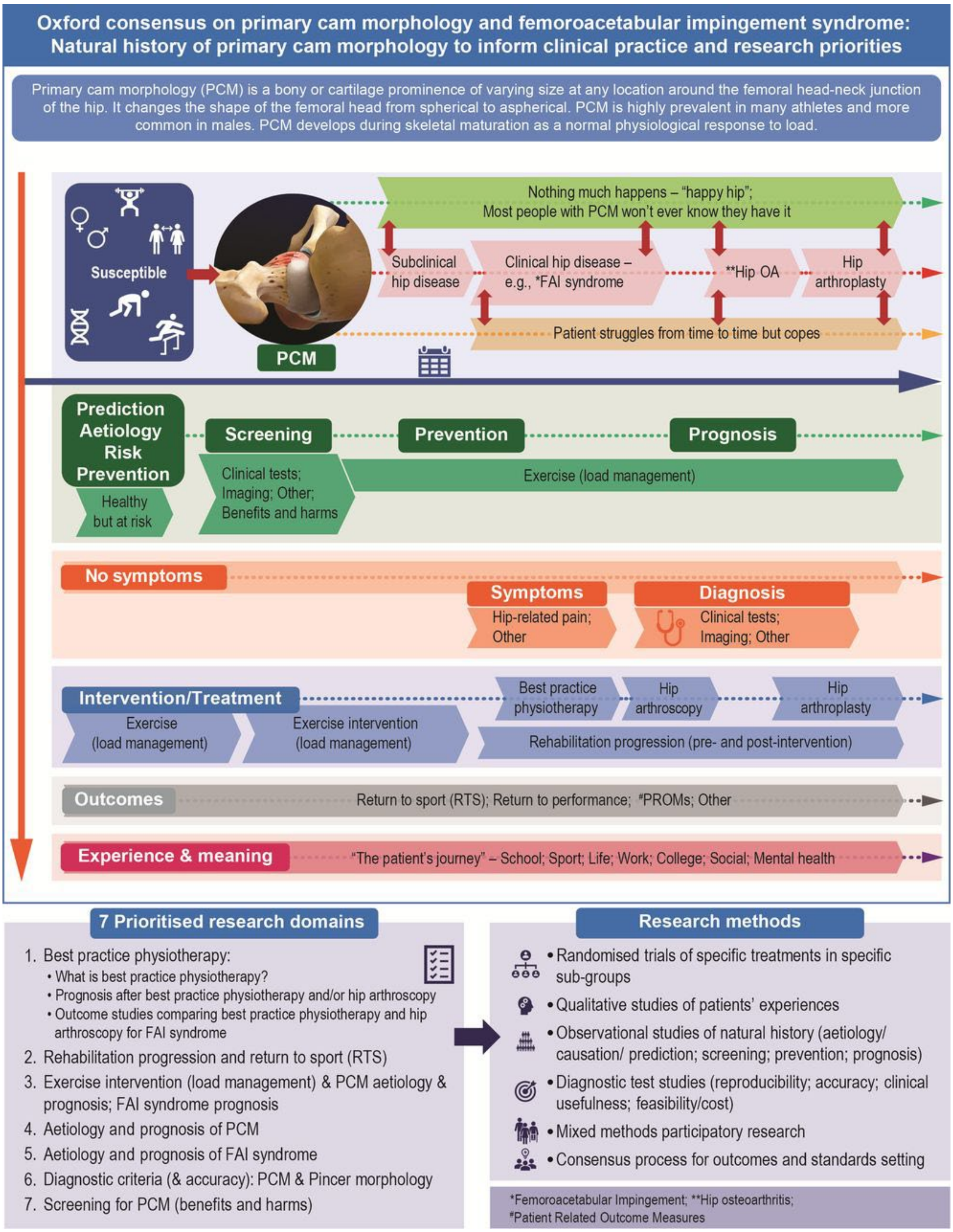


Figure 7.10. Infographic Oxford Consensus. Reproduced from Dijkstra et al (2023), published CC-BY-NC [389].

Other dissemination strategies of the empirical work presented in this thesis include:

- Several conference and webinar presentations as described throughout this thesis, specifically in section 5.4.5.

- JOSPT Insights Podcast[27]: ‘Primary cam morphology—benign bump or painful prominence?’ (Figure 7.11).

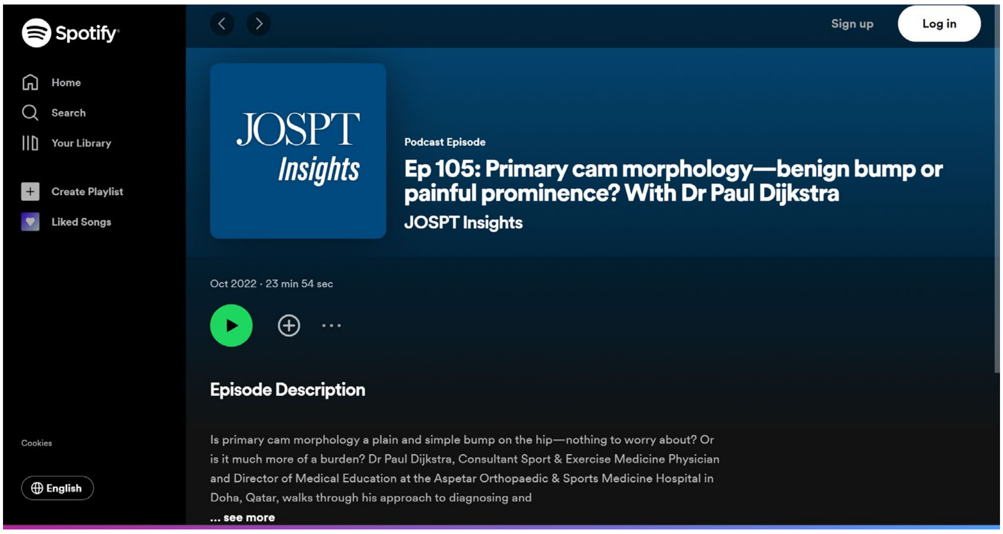


Figure 7.11. JOSPT Insights Podcast: ‘Primary cam morphology—benign bump or painful prominence?’ [487].

In sum, I have used several linked approaches to answer the main research question of this thesis—‘How could research and clinical practice on primary cam morphology and its natural history be transformed in a more pragmatist and patient-centred direction?’ Before I revisit in a reflexive statement (Section 7.4) my personal history and positionality (described in chapter one), I discuss the methodological contribution, and strengths and limitations of the empirical work presented in this thesis.

7.2 Methodological contribution

The pragmatism-informed co-production paradigm for this thesis amplified the overall aim to support the transformation of research and clinical practice on primary cam morphology and its natural history so that it takes a more pragmatist and patient-centred direction. Although some scholars have argued that pragmatism is ‘unfit for purpose’ (e.g. it is a ‘paradigm of convenience’ and takes a ‘consequentialist view of good research and of truth’) [488], Allemang *et al* (2022) describe how pragmatism aligns with patient-orientated research. They

[27] https://open.spotify.com/episode/6mRMMmli5WEGINRUjDIxra

describe three intersecting concepts—all relevant to the programme of research for this thesis: ‘democratic values, collaborative approaches to problem solving and the pursuit of social justice’ [489].

First, applying the concept of democratic values, I attended to authentic research partnerships with multiple stakeholders, including athletes and patients, and promoted a sense of community through YAHiR. I prioritised relationship-building with and among individual collaborating team members.

Second, collaborative approaches to problem-solving in this thesis afforded opportunities to engage athlete and patient partners in all stages of the Oxford Consensus Study. They co-led, for example, mixed stakeholder group meetings (interacting group process meetings described in chapters 4 and 5). Open-ended questions to explore stakeholders’ perspectives on high quality research (chapter 6) allowed participants, including athletes and patients, to steer conversations and describe their lived experiences.

Third, the pragmatic paradigm in pursuit of social justice in the context of this thesis meant action-oriented enquiry that is context-specific. For example, athlete and patient partners (the PPI stakeholder group) were important and valued Delphi panel experts and co-led the interacting group process meetings (as mentioned above and described in chapters 4 and 5). I ensured they were mentored through regular online meetings and had access to resources (as described in chapter 4). This facilitated their active engagement. Exploring patients’ perspectives on, for example, ‘inflammatory’ and ‘catastrophising’ language (e.g. ‘lesion’ or ‘deformity’ when referring to a benign morphology) allowed for a more nuanced understanding of how communication could amplify power imbalances in this field.

The pragmatism-informed co-production methodology underpinning the programme of research presented in this thesis could inform research in other areas of sport and exercise medicine, orthopaedics, and musculoskeletal rehabilitation where definitions are contested, asymptomatic people are over-medicalised, and monitoring and treatment vary between clinics and countries. These areas include shoulder impingement, rotator cuff syndrome, meniscus 'lesion', lumbar degenerative disc disease, and 'conditions' diagnosed through athlete screening programmes.

7.3 Strengths and limitations, including Covid-19

Although the pragmatism-informed co-production paradigm was a key strength of the programme of research presented in this thesis, it also shaped my empirical work in particular ways. First, pragmatism-informed co-production was not the chosen paradigm at the outset of the programme of research presented in this thesis. As described in chapter 2, it came later when the focus of my research changed. I invested time and resources to become familiar with the key elements of pragmatism and co-production (chapter 3). I acknowledge, however, that my research doesn't propose to be an in-depth study of this ontological and epistemological paradigm. Second, it took time to adequately prepare for and deliver the studies presented in chapters 4 to 6, specifically to ensure a spotlight on the expertise of athletes, coaches, parents and patients, for example. Therefore, in discussion with my DPhil supervisory team, I refocussed and postponed further work on the ongoing systematic review of primary cam morphology risk factors. Third, discrepancies between different types of data (e.g. 'voices' of tension and dissent despite strong 'statistical' Delphi panel consensus, as described in chapters 4 and 5) were sometimes challenging to manage. Rather than focussing on reconciling different views, I created opportunities—and safe spaces—to work with dissenting views as a catalyst for further research. This is one of the strengths of a mixed methods approach to research.

In the rest of this section, I will reflect on the overall strengths and limitations of the programme of research presented in this thesis focussing on the: (1) mixed methods approach; (2) research team; and (3) research process (including participants, and inference quality and transferability). I also reflect on how the Covid-19 pandemic impacted my research.

7.3.1 Mixed methods approach

The mixed methods approach to the programme of research presented in this thesis offered both affordances and drawbacks.

Affordances of mixed methods approach: First, the blending of quantitative and qualitative data and analysis illuminated different elements of primary cam morphology and its natural history. This facilitated a more comprehensive, deeper, and nuanced understanding of the morphology. Second, mixed methods allowed me to uncover information that could otherwise have been unnoticed (e.g. the problem in other languages with the agreed term 'morphology').

Drawbacks of mixed methods approach: First, the mixed methods approach was time-consuming as I had to manage several research projects and dissemination activities at the same time. This required careful planning and sustained efforts to involve and lead a diverse research team and recruit participants who represented multiple perspectives (research, clinical and lived experiences) on primary cam morphology and its natural history. Second, the various types of data and data analysis did not always 'merge' or 'integrate' happily into a coherent story from the outset. Amplified by the sheer volume of data (another challenge of mixed methods research), it took time and effort, including many iterative conversations with research team members, to grapple with sensibly 'mixing' quantitative and qualitative data and data analysis of the Oxford Consensus Study. This process, facilitated by the constructive BJSM peer review process, resulted in two publications and an infographic, described by the BJSM Editor-in-Chief as a 'sterling job of using text boxes, graphics and figures to deliver succinct clinical and research messages' [482]. Finally, another drawback of mixed methods research was the possibility that one method got more emphasis or attention than another, almost accidentally or emergently (e.g. one data set turned out to be easier to gather than another, so I ended up with 'more' and it took up more space in the project and in my head). In the earlier stages of this DPhil (and the Oxford Consensus Study), I felt more comfortable with quantitative- rather than qualitative methods, so it got more attention for that reason, rather than because of the nature of the study or the data. This changed overt time as I became more comfortable with the different methods presented in this thesis.

7.3.2 Research team

As part of this DPhil, I had the privilege to work with, learn from, and lead several research teams. I will discuss the research team of each study separately: (1) concept analysis (and systematic review); (2) Oxford Consensus Study; and (3) qualitative study on research quality.

In addition to my DPhil supervisory team, the concept analysis (and systematic review) research team included experienced systematic reviewers, a librarian, and subject-matter experts. However, I did not include any athletes/patients at the time. A limitation is the scale of the ongoing systematic review and strain on research team time and resources. Several key members of the research team relocated just before or during the Covid-19 pandemic, not only to new jobs, but also new countries. I therefore made the pragmatic decision, in discussion with my DPhil supervisors, to postpone the next stage of the systematic review until after the DPhil and recruit young scholars to join the team.

For the Oxford Consensus Study, I recruited an experienced and diverse steering committee, including Dr Amy Price who co-led the YAHiR PPI-group with me. The steering committee members (section 4.3.1), 5 women and 8 men, were English-speaking white academics (11 with PhDs); 4 were physicians, 6 allied healthcare practitioners, and 3 health researchers. One resided in the Global South. Although diverse, experienced and international, the steering group could have been more representative were adolescent athletes/patients, Black female athletes/patients and research team members from the Global South included.

Finally, I reflected on the research team for the qualitative study on stakeholders' perspectives of research quality in the field in chapter 6 (section 6.3.6). As lead researcher I benefitted from a very experienced research team. Dr Sean McAuliffe, a practising sports physiotherapist and PhD-trained qualitative researcher, acted as Qatar-based co-principal investigator. He attended 14 of 15 online interviews as an observer and contributed to the analysis. Ms Jolanda Boersma, a medical anthropologist with experience in qualitative research (sociology and anthropology) but no clinical experience or prior knowledge of the topic, aided in transcribing and analysing data. Professor Trisha Greenhalgh, a professor of primary healthcare with extensive experience in qualitative and mixed-method research, supervised on all aspects of the study as my DPhil supervisor while Professor Siôn Glyn-Jones, a practicing orthopaedic surgeon, professor of orthopaedic surgery and experienced researcher, oversaw all aspects of the study as principal investigator and my DPhil supervisor. Professor Mike Clarke, experienced researcher and my DPhil supervisor, provided oversight to all aspects of the study while Professor Karim Khan, sport and exercise medicine physician and previous journal editor, provided oversight to all aspects of the study as an experienced researcher and my DPhil supervisor. I discussed how the research team's diverse academic training and experiences set the foundations for interdisciplinary dialogue and helped to promote reflexivity throughout the project. Several discussions, for example, brought together an anthropological, non-clinical perspective (JB) to theme development with that of a physician with intimate knowledge of the field (HPD), and a PhD physiotherapist working in research and elite sport (SMA). In addition, TG, with vast clinical and (qualitative) research experience, shaped how I approached the complicated deductive-inductive coding dance.

In sum, the diverse knowledge and experience of the international and multi-profession research team members involved in the four empirical studies presented in this thesis significantly contributed to the studies' methodological rigour, and to my scholarly learning and growth. Research teams could have been more representative of minoritised groups in this research field, specifically Black female- and adolescent athletes/patients.

7.3.3 The research process

The research process had strengths and limitations. Here I reflect on participant recruitment (including data quality and completeness), inference quality, and inference transferability.

Research participants: The Oxford Consensus Study has been referred to as 'an inclusive and comprehensive consensus process that involved diverse stakeholders, athletes, and even a dissenting opinion analysis…', representing 'an inclusive process in every sense, from the make-up of the diverse international expert panel (18 countries, 6 stakeholder groups, 40% women), the two-round Delphi process, rigorous deliberations and voting procedure all of which are documented in the [open access] papers and supplements' [482]. I contended in section 4.5.6. (and in the BJSM publication) that, although we applied the 'closeness continuum' to purposively recruit a large and diverse expert panel (in terms of sex, geographical representation, and profession/ stakeholder group), this study's panel and steering committee could have been more representative of communities that are not widely represented in this field. While making explicit progress on diversity, equity, and inclusion, including actively involving a PPI stakeholder group (also as co-authors of the two publications), I acknowledge that more could be done: 'This study, and the hip-and-groin research field in general, would benefit from actively involving researchers and participants from minoritised communities' [388].

I contend in section 6.5.3 that, although the data in this study provided a rich and complex picture of a diverse group of participants' experiences and perspectives on research in the field of primary cam morphology, it did not aim to completely capture the phenomenon under scrutiny. I acknowledge that we need more research on the perspectives and needs of subgroups living with primary cam morphology and its hip disease consequences, focussing on women, adolescents and people from the Global South.

Inference quality: Inference—in the context of mixed methods research—has been described as the 'conclusions and interpretations based on the results of data analysis in a study' ([54] p297). The 'integrative framework for inference quality' described by Tashakkori *et al* (2021, p318) is based on *quality of design* and *quality of interpretations* and provides a lens for reflecting on the 'inference quality' of the empirical research presented in this thesis [54].

Design quality—selecting and implementing the most appropriate procedures for answering the research question—has four proposed criteria: design suitability (e.g. was appropriate methods used for answering the research question?), design implementation fidelity (e.g. was sampling, data collection procedures and analysis appropriate?), within-design consistency (e.g. do the strands of the mixed methods study follow each other in a logical way?), and analytic adequacy (e.g. was data analysis strategies appropriate and adequate?) [54]. Based on these criteria, the overall design quality of the studies reported in this thesis is a strength, including within-design consistency (Figure 3.3). I discussed the limitations for each study in the respective strengths and limitations sections.

Interpretive quality (or rigor) has six proposed criteria: interpretive consistency (e.g. do inferences closely follow the relevant findings?), theoretical consistency (are inferences consistent with theory and state of knowledge in the field?), interpretive agreement (e.g. would other scholars likely reach the same conclusions based on the same results? do the inferences match participants' constructions?), interpretive distinctiveness (is each inference distinctively more credible/plausible than other possible conclusions based on the same results?), integrative efficacy (do the meta-inferences adequately incorporate the inferences made at each strand of the study?), and interpretive correspondence (e.g. do the inferences correspond to the stated purposes/questions of the study?) [54]. Based on these criteria, the overall interpretive quality of the studies reported in this thesis is a strength, including the meta-inferences summarised in section 7.1 above. I discussed the limitations for each study in the respective strengths and limitations sections.

Inference transferability: Transferability of inferences—how useful the research outcomes are to the consumers of research—addresses the important issue of generalisation. I summarised, in section 7.1, how the empirical research presented in this thesis addressed the main aim and strategic objectives. I concur with Tashakkori et al (2021) that 'inferences and their resulting recommendations will almost always be transferable (in varying degrees) to some other settings, people, organisations, time periods, or ways of defining your constructs.' ([54] p329). For example, despite strong agreement by a diverse international Delphi panel that 'morphology' is the preferred term for 'primary cam morphology' (Chapter 4, Table 4.5 – statement 13), others thought that 'morphology should be avoided in patient consultations as it's unfriendly, not well understood and likely medical "jargon".' A further problem is that 'morphology' doesn't always translate well into other languages (Table 4.7). Similarly, the five action-inviting themes for research communities in the field of primary cam morphology and its natural history described in chapter 6 could be transferrable to other research fields (settings and contexts).

I conclude that the findings of the qualitative study (reported in chapter 6) could inform concrete actions by research communities to pursue higher quality research—more research value and less waste—in the field of primary cam morphology and its natural history. Although the five action-inviting themes resonate with contemporary trends in research in general and could therefore be transferable to other areas of research, their practical application would remain context and research field specific.

Akin to my overall approach, each of the four primary research projects had particular strengths and limitations. I discussed these in chapter 2 (section 2.5.7), chapter 4 (section 4.5.6), chapter 5 (section 5.5.3), and chapter 6 (section 6.5.3).

7.3.4 The impact of Covid-19

The Covid-19 pandemic radically impacted my working environment in Qatar, my access to the University of Oxford's online education programmes, and my DPhil studies. Before reflecting on these, it is important to recognise my own privilege. My family and I were, to a large extent, protected from the devastating effects of the Covid-19 pandemic. I significantly benefited from a safe and comfortable home environment in Qatar. I had a secure job, no child or other care responsibilities, easy access to excellent medical services, a fast internet service, a laptop computer, and a suitable home environment to collaborate online, and participate in or conduct online education. I was ultimately able to continue with my work and studies. My wife and I received Covid-19 vaccines in early 2021. This allowed us to travel to South Africa in March 2021 to support and care for close family members who were severely ill with Covid-19 at the time.

Similar to most countries, Qatar enforced a strict lockdown in early March 2020. Aspetar Hospital closed, and my colleagues and I had to work from home. I soon realised a need among athletes, coaches and the sports medicine community for credible information about Covid-19. As part of my role as Director of Medical Education at Aspetar, I led a team to develop and implement (on 6 April 2020—less than one month after the Qatar lockdown) the 'Aspetar Covid-19 Evidence for Athletes Service'[28]. My education team and I rapidly moved all Aspetar's accredited health professions education online, including the increasingly popular 'Aspetar Tuesday Lecture Series'[29] (Grand Rounds). At the same time I led the Aspetar Sports Medicine team in reviewing online clinical sports medicine services that resulted in a BJSM publication in June 2020: 'Remote assessment in sport and exercise medicine (SEM): a narrative review and teleSEM solutions for and beyond the COVID-19 pandemic' [490].

[28] https://www.aspetar.com/en/about-us/press-room/news/aspetar-announces-the-launch-of-a-unique-covid-19-evidence-for-athletes-service

[29] https://www.aspetar.com/en/professionals/medical-education/education-initiatives/tuesday-lectures

The University of Oxford also moved several courses relevant to my DPhil studies online. This was a very significant development that provided me and other 'remote' students with easy online access to a wealth of education opportunities. My fellow part-time DPhil EBHC students and I, not resident in Oxford, have commented—long before the Covid-19 pandemic—on the relative lack of adequate (online) access to the University's graduate education programmes. I enrolled for many online courses and modules during the pandemic, including, as described earlier, the first online delivery of the 'Knowledge into Action' MSc module. I described earlier how this module, with Professors Trisha Greenhalgh and Kamal Mahtani as tutors, represented another key turning point in my DPhil (the other turning point was the findings of the risk factors systematic review described in chapter 2).

I completed the primary cam morphology concept analysis study in 2019 while preparing for the qualitative study on stakeholders' perspectives of research quality. All interviews would have been in-person and I received IRB approval from Oxford in December 2019 and Qatar University in February 2020. The Covid-19 pandemic had five important consequences on this study. First, it became clear that in-person interviews would not be possible and IRB approval was given for all interviews to be conducted online using Zoom technology. Second, due to my work-related challenges and Aspetar education priorities, I only managed four interviews in 2020, six in 2021 and five in 2022. This prolonged approach had advantages too—it afforded time for a more iterative and reflective process; I amended, for example, the interview guide based on the early results of the initial interviews. Third, the final 15 participants were more diverse and international compared to the predominantly Qatar-based participants initially planned. Fourth, co-researcher Dr Sean McAuliffe was able to attend 14 of 15 online interviews from Ireland, and kept an interview diary. His interview diary was an additional data source for more comprehensive analysis. Finally, the end-result, reported in chapter 6, is arguably a better one; I was able to recruit a third co-researcher Ms Jolanda Boersma to transcribe, and, in addition to my NVivo® coding, independently code all interviews. She is a human anthropologist and experienced qualitative researcher with no knowledge or experience in the field of primary cam morphology. I described in section 6.3.6 how the research team's diverse academic training and experiences set the foundations for interdisciplinary dialogue and helped to promote reflexivity throughout the project.

Covid-19 had a significant positive impact on the Oxford Consensus Study. First, as described earlier in this chapter, what would have been an in-person Symposium and Consensus Meeting at Worcester College in Oxford in September 2020, turned into 11 webinars (the *Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series*) and an online Delphi method consensus (the Oxford Consensus Study). Second, the Webinar Series from November 2020 to September 2021, mobilised a community of faculty and participants, shared latest evidence and stimulated debate during the Covid-19 pandemic. This laid the foundation for the Delphi method consensus that commenced online following IRB approval in March 2021. Third, I was able to recruit a much larger, more international and more diverse Delphi panel than the planned in-person consensus panel. Fourth, the Webinar Series was an ideal vehicle for engaging PPI partners in co-developing and delivering Webinar 9, and to co-lead on key elements of the Oxford Consensus Study as described in chapters 4 and 5. Fifth, the Webinar Series, specifically Webinars 10 and 11, was ideal to disseminate early results of the Delphi panel. These two Webinars laid the foundation for grappling with areas of tension and dissent during online mixed stakeholder group meetings (interacting group process) that followed immediately after the Webinars in September 2021.

In sum, Covid-19 had a significant impact on my clinical and education work, and the programme of DPhil research presented in this thesis. As described above, the impact was predominantly positive—unlike millions around the world who endured unimaginable suffering. For that, I am eternally grateful.

7.4 Reflexive statement

In chapter 1, I discussed how the different stages of my life and career informed the context that led me to pursuing this DPhil. I described how my journey from Apartheid South Africa to London and finally to Doha prepared me for the ultimate scholarly journey of a DPhil at Oxford. While this thesis aimed to explore and transform a field, it changed me from a clinician with a predominantly positivist world view to a scholar adopting pragmatism-informed co-production with elements of *bricolage* [25–27]. I explored these concepts in chapter 3. *Bricoleurs* 'examine phenomena not as detached things-in-themselves, but as connected things-in-the-world' [28]. Although living and working in multicultural environments in post-apartheid South-Africa, the UK and Qatar, amplified by the power of being a bilingual Afrikaans-English male physician, I continued to benefit from the privileges of these societies' predominantly Whiteness and Eurocentrism. The Covid-19-fueled social and academic debates, including Black Lives Matter, #MeToo and 'traditional' vs 'contemporary' Evidence-Based Medicine, ignited further transformation—a personal journey from being 'non-racial' and 'non-sexist' to being more sensitive to an 'anti-racist' and 'anti-sexist' agenda; a scholarly journey from initially aligning more with quantitative 'positivism' to aligning with pragmatist-underpinned co-design.

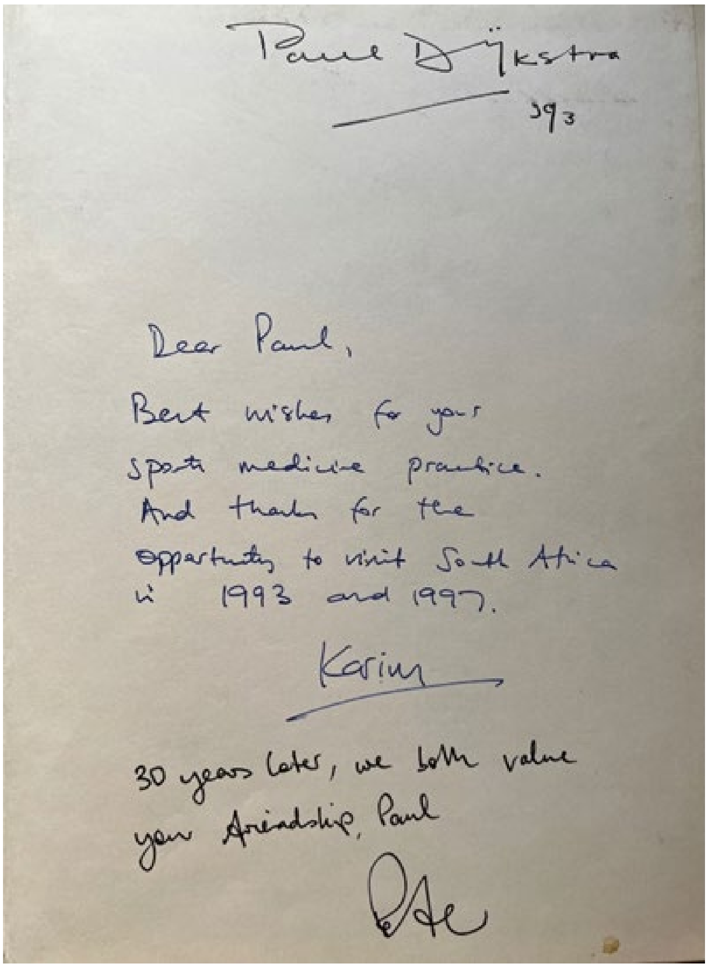
I broadened my predominantly positivist and monological research horizon, to also embrace research pursuits that appreciate the complexity of the lived world. A mixed methods approach to this thesis' programme of research, as alluded to earlier in this chapter, complemented my scholarly and personal transformation and I creatively combined quantitative and qualitative methods. However, this did not happen overnight; I had to—throughout this DPhil—invest in further education and experience to equip me for a more complicated and multi-perspectival lens on primary cam morphology and its natural history.

I completed seven University of Oxford MSc in Evidence-Based Health Care modules as part of this DPhil (most for academic credit): Knowledge into Action (2020), Qualitative Research Methods (2018), Meta-analysis (2018), Essential Medical Statistics (2017), Evidence-based Practice (2016), Systematic reviews (2015), and Introduction to study design and research methodology (2015). In addition to the formal training listed above, I was invited as an expert panel member to several consensus studies and co-published 12 papers as a result: (1) Consensus statement on the methodology of injury and illness surveillance in FINA[30] (aquatic sports) [491]; (2) International Olympic Committee consensus on load in sport and risk of injury and illness (2015) [492,493]; (3) A consensus statement on direct-to-consumer genetic testing for predicting sports performance and talent identification [494]; (4) A Delphi developed syllabus for the medical specialty of sport and exercise medicine [495,496]; (5) Warwick consensus on femoroacetabular impingement [36]; (6) The International Hip-related Pain Research Network (IHPRN) consensus in Zurich (2018) [49–52]; and (7) 'Implementing the 27 PRISMA 2020 Statement items for systematic reviews in the sport and exercise medicine, musculoskeletal rehabilitation and sports science fields: the PERSiST (implementing Prisma in Exercise, Rehabilitation, Sport medicine and SporTs science) guidance' [497]. I was also asked to co-author, with Professor Siôn Glyn-Jones and Dr Antony Palmer, the UpToDate paper on femoroacetabular impingement syndrome [177]. The knowledge and skills gained through these consensus studies—including authentic collaboration with many research teams—served me well in preparing for the Oxford Consensus Study described in chapters 4 and 5.

I have illustrated how people, circumstances, challenges, opportunities, and strokes of luck shaped the context for pursuing this DPhil and continue to transform me. While writing this chapter, Professor Peter Brukner (the 'Brukner' of Brukner and Khan's textbook) and his son

[30] FINA has since become World Aquatics (6 sports and 209 National Federations) – https://www.fina.org

Bill stayed with Andrea and me in Doha, attending the 2022 FIFA World Cup. Thirty years later, he ‘extended’ Professor Karim Khan’s personal note in my first edition of *Clinical Sports Medicine* (Figure 7.12). The journey continues.


Paul Dijkstra

Dear Paul,
Best wishes for your sports medicine practice.
And thanks for the opportunity to visit South Africa in 1993 and 1997.
Karim

30 years later, we both value your friendship, Paul

Figure 7.12. The updated personal note in my copy of the first print run of *Clinical Sports Medicine*, and a new personal message by Professor Peter Brukner. (Photo: Paul Dijkstra)

However, this DPhil did not only change me. It also changed the patients involved. A patient participant reflected in an email to me (copied with permission on the introduction page of this chapter): ‘I can finally reflect on my journey, my hip and my struggles and be proud knowing that my story is helping others’. This is ultimately what I hoped for when I started this scholarly journey: that my research would contribute to better lives for patients with primary cam morphology and its hip disease consequences.

7.5 Implications of this research and future work

The scope of the programme of research presented in this thesis was to support the transformation of research and clinical practice on primary cam morphology and its natural history so that it takes a more pragmatist and patient-centred direction. Earlier in this chapter, I summarised the empirical- and methodological contributions (sections 7.1 and 7.2) and, confirming the academic relevance and early impact of the empirical work presented in this thesis, I have published features of this thesis in peer reviewed open access publications [1,290,388,389], presented results at multiple conferences and webinars, and regularly updated my *UpToDate* paper on femoroacetabular impingement syndrome [177]. In an editorial, the Editor-in-Chief of BJSM referred to the Oxford Consensus Study as a 'model consensus' [482]. Finally, a few days before defending this thesis in Oxford, I will deliver two presentations at the Edinburgh Orthopaedics and Sports Medicine Conference (1-2 June, 2023) on (1) 'Natural history of FAI' and (2) 'Collaborative IOC session: YAHiR'. This conference, in particular the final session on YAHiR and collaboration, provides an opportunity to further collaborate on the research priorities presented in chapter 5.

In the rest of this section, I briefly revisit Jason, the 15-year-old male academy-level football player introduced in chapter 2 (Table 2.4A). I illustrate how the programme of work presented in this thesis (which aimed to answer the research question: *how could research and clinical practice on primary cam morphology and its natural history be transformed in a more pragmatist and patient-centred direction?*) could refine clinicians' approach to athletes while spotlighting knowledge gaps to inform future work.

Jason reports occasional left groin (anterior hip) stiffness associated with high-intensity football practice or match play for one month. He also reports a feeling of restricted left hip movement but cannot explain exactly what he feels. He is a striker who prefers to kick with his right foot and has played competitive football at his London-based club academy since age nine. He is otherwise healthy and denies any previous hip or groin injuries. The hip and groin examination findings are unremarkable apart from reduced left hip internal rotation (20°) compared to the right side (35°). Following a shared decision-making discussion [399], Jason and his parents are keen to know more and agree to further special investigations: AP-pelvis and lateral radiographs of both hips[31]. The radiologist reports cam morphology of the left hip visible on both AP-pelvis and lateral radiographs (alpha angles in both views are 65° and 58° respectively). As a result of the work presented in this thesis, Jason's physician is confident to refer to the bony bump in Jason's left hip as a morphology (and NOT a lesion, abnormality or deformity), and classify it as *primary* cam morphology. He uses the consensus conceptual definition (Figure 4.6) to describe the morphology to Jason and arranges for a team consultation involving the club's physiotherapist.

During the team consultation, Jason's physician and physiotherapist explain how primary cam morphology likely develops during the growth spurt in maturing athletes as a result of high-load sporting activity. Jason and his parents are relieved by three aspects emphasised by their up-to-date medical team:

(1) primary cam morphology is a common (and normal) hip morphology in many athletes, including competitive young footballers. (However, we don't know enough about the true prevalence, the type of load, and other risk factors for the development of primary cam morphology in athletes like Jason. Importantly, we know nothing about the morphology's aetiology, prevalence or incidence in girls/female athletes, and athletes from the Global South—prospective research hasn't yet covered these demographics);

(2) it is unlikely that the morphology in Jason's left hip will increase in size. (However, we need prospective studies with long-term follow up to confirm this); and

[31] For Jason, radiographs are not necessary – therefore the shared decision-making discussion. If Jason complained of hip-related *pain* with a positive FADIR test, the working diagnosis would have been FAI syndrome with AP pelvis and lateral radiographs indicated to confirm the diagnosis (following the Warwick Agreement on FAI Syndrome).

(3) the majority of football players with this morphology don't know they have it and will never have pain—Jason can look forward to a long and healthy sporting career. (However, Jason has a small increased risk of developing hip-related pain due to, for example, FAI syndrome or hip osteoarthritis. How much the risk is, is still unknown. We need long-term prognosis studies to learn more about the natural history of primary cam morphology in athletes and other populations).

Importantly, clinicians and researchers know very little about the lived experience of competitive athletes with FAI syndrome or hip osteoarthritis. However, should Jason develop hip disease related to primary cam morphology in ten years' time (while playing professional football for England, maybe!) we should know more. The uncertainties highlighted as 'howevers' above, signpost at least five areas for future work.

First, with co-researchers, I plan to extend and publish the systematic review of primary cam morphology risk factors based on update searches of January 2021 (full text review completed; data extraction, risk of bias assessment of 38 included publications, and analysis pending) and February 2023 (no work on this search has been done at the time of submission of this thesis in April 2023), and the current 111 included publications (chapter 2).

Second, the results of Oxford Consensus Study could provide athletes, patients, clinicians, and researchers with a stronger foundation for more precise communication, better clinical decision-making, and higher value research on primary cam morphology. In addition, the 18 prioritised and ranked research statements signal possible gaps in the current evidence base for researchers, PPI partners and clinicians to pursue. While informing more rigorous, inclusive, and evidence-based research, this consensus exercise could serve as a roadmap for researchers, policy makers and funders to implement research to reduce the cost and burden of conditions that affect the young person's hip. This includes hip disease related to primary cam morphology. The Oxford Consensus Study pave the way for higher quality multi-centre studies on primary cam morphology aetiology and prognosis, for example. With other collaborating institutions, the IOC research centres network is well-positioned to contribute to (and lead) such a large-scale and long-term prospective study.

Third, I described above and in chapters 4 and 5 how I mobilised and engaged an international community of athletes, patients, clinicians and researchers—the YAHiR Collaborative—and ensured buy-in and diverse participation to facilitate inclusive co-production partnerships. We are cementing the work of YAHiR through Oxford's Nuffield Department of Orthopaedics, Rheumatology, and Musculoskeletal Science (NDORMS). Professor Jonathan Rees approved a future webpage for the YAHiR Collaborative as part of the NDORMS website. The YAHiR steering group and I are actively planning and delivering on four important projects: (1) a YAHiR newsletter every term; (2) a YAHiR-JOSPT Insights collaboration to deliver regular podcasts (managed by Dr Joshua Heerey in collaboration with Dr Clare Ardern, Editor-in-Chief of JOSPT); (3) the second YAHiR Young Athlete's Hip Symposium and Research Meeting at Worcester College in Oxford in September 2024 in collaboration with JOSPT; and (4) the third Oxford Consensus paper based on the September 2022 YAHiR Research Meeting in Oxford. In addition, I have proposed (with others) an athlete's hip symposium at the IOC's Research Centres Meeting in South Africa in November 2023.

Fourth, the qualitative study to explore stakeholder (athletes, parents, coaches, patients, clinicians, and researchers) perspectives on research quality relevant to primary cam morphology and its natural history, illuminated areas for immediate action in the research field. Further work will include open access publication of this study, including the infographic (Figure 6.3), and actively working with YAHiR and other collaborators to implement the findings of this study. The Editor-in-Chief of JOSPT and I are proposing, for example, a special young scholars' session for the 2024 Young Athlete's Hip Symposium in Oxford.

Finally, athletes value their health and fitness, an active lifestyle, and their ability to compete—these are often core aspects of their identity. The disruptive experience of a sports-related injury or illness can devastate an athletes' emotional wellbeing. It disrupts the core assumptions about their world, former conduct, and their athletic identity. Patient participants in the qualitative study presented in chapter 6 described the emotional impact of receiving the diagnosis of FAI syndrome/hip osteoarthritis and their struggles to continue their sport. They highlighted the harmful impact of certain terminology and language, 'sending them down a negative spiral of catastrophising'. This is comparable to the more extreme variants of biographical disruption[32] described in the literature on chronic illness [498], especially when it involved a career-ending injury [499]. Using biographical disruption as the theoretical lens, I plan research to explore the lived experiences of athletes living with the consequences of primary cam morphology. I am especially interested to explore the impact of disruptive experiences on athletes' mental health and how this can be mitigated or even prevented.

7.6 Conclusion

In conclusion, the empirical work presented in this thesis represents early steps to move research and clinical practice on primary cam morphology and its natural history in a more pragmatist and patient-centred direction. It informs a more rigorous, inclusive and evidence-based approach to research on primary cam morphology and its natural history, and lays a foundation for YAHiR and other collaborators—in partnership with athletes and patients—to co-produce knowledge that matters.

[32] Professor Michael Bury coined the term 'biographical disruption' in 1982. Biographical disruption involves the impact of injury or illness on personal meaning, disrupting taken-for-granted assumptions about the self, health and conduct of life.

Appendices Chapters 1 to 7

A Chapter 1 appendices

No chapter 1 appendices.

B Chapter 2 appendices

B.1 Primary cam morphology terminology and attributes based on included publications (*n=111*)

Section: Themes/ Categories	**Subthemes / subcategories**	**Codes: Definition terminology used**
1. General terminology for the concept	1.1 Morphology: FAI morphology / Cam morphology / Cam-type morphology / morphologic variation / pathomorphology / pathological morphology	Hip bony morphology [124]; bony morphological parameters [124]; bony hip morphology [127]; Cam morphology [60,66,75,86,124,127]; Cam-type FAI morphology [109,118]; cam-type morphology [61,68,75,111,118,119,122]; cam morphology type [127]; cam-type FAI [114]; FAI-type morphologies [64]; Cam morphologic changes; morphologic variation [119]; bony morphological variant [127]; morphologic changes of the proximal femur [104]; femoral morphology [60]; proximal femoral morphologic characteristics [153]; proximal femoral morphology [86]; femoral head-neck morphology [75]; hip pathomorphology [64]; pathological morphology [60]; cam-type pathomorphological features of the femur [150]; morphological features of the femoral head-neck junction [61,150]; femoroacetabular morphologic features [89]; morphological variation [70];
	1.2 Deformity / pistol-grip deformity (introduce by Stulberg in 1975 [134]) / tilt deformity / Abnormality / abnormal hip architecture / Lesion / Malformation / maladaptive disorder / Qualitative cam-type findings / deviation / defect / hypertrophy / overgrowth	Deformity [13,61,65,66,69,75,86,93,98,104,105,109,114,119,123,126,132,136,139,150,158,159,159,160,165]; structural hip deformity [107,165,167]; cam-type deformity [62,95,116,118,119,146,150,152,165,167]; cam-type femoroacetabular deformity [116]; abnormal cam-type deformity of the proximal femur [152]; femoroacetabular impingement deformity [123]; morphologic deformity [105]; developmental deformity [150]; pistol grip deformity [95,114]; tilt deformity [128] structural hip abnormality [109]; anatomic abnormality of the femoral head-neck junction [165]; MRI anatomic abnormality [167]; abnormal morphology of the cam type [111]; morphologic abnormality [105]; femoral morphological abnormality [89,111]; hip morphological abnormalities [95]; FAI bony abnormality [106,144]; abnormality of the anterior femoral head-neck junction [134]; bony hip morphological abnormality [126]; bony

		abnormality of the hip joint [137]; abnormal hip architecture [128]; abnormal head-neck junction [75]; abnormal morphology [124]; lesion [61,111,119,136,144,165]; Cam malformation [98] Preosteoarthritic malformation [98] Maladaptive structural disorder [165]; qualitative cam-type findings [114]; deviation from the normal geometry is usually associated with larger α-angles [76,89]; cam defect [93]; cam-defect [93]; epiphyseal hypertrophy and extension was the most frequently observed source of cam morphology [60]; bony overgrowth on the femoral neck [137];
2. Tissue	2.1 Bone 2.2 Cartilage	Cam morphology was quantified using the alpha angle for bone and cartilage, which was treated as a continuous variable given there is no agreed diagnostic threshold [60]; cam morphology is first evident as cartilaginous hypertrophy at age 10 years [60]; bony adaptation in response to high-impact sports practice during skeletal growth [158]; extra bone formation at the anterolateral head-neck junction [158]
3. Size / magnitude	3.1 Small 3.2 Moderate 3.3 Large 3.4 Pathologic 3.5 Significant / severe 3.6 Definite	Pilot data suggested the magnitude of cam morphology was greatest at 1 o'clock [60]; Large cam morphology [127]; large cam deformity [132]; significant alpha angle [136]; severe CAM-type deformity [136]; definite cam-type deformities [146]; pathological cam deformity – α-angle >78° [13,158]; the significant sex difference in regard to location and size of cam deformity [75]; males have larger cam deformities [75]; moderate cam femoroacetabular impingement abnormalities [105]; Measurement: On computed tomography (CT) the angle alpha was measured on at 1:30 (anterosuperior) and at 3:00 (anterior) o'clock positions. An angle alpha >60˚ at 1:30 o'clock position or/and >50.5˚ at 3:00 o'clock position was defined as a cam deformity [65];
4. Location / Position / site variable location	4.1 Femur / femoral head-neck junction / femoral head / femoral head-neck transition / femoral head-neck type	Proximal femoral [86,103,123,152,153]; femoral head / femoral head-neck transition [125]; presence or absence of a bump at the femoral head-neck junction [125]; osseous bumps at the femoral head-neck junction [144]; femoral head loses its normal sphericity, specifically at the femoral head- neck junction [152]; morphological features of the femoral head-neck junction [61]; aspherical portion of the femoral head and neck junction [68]; flattening of lateral aspect of femoral head [114]; 'cam' shape at the head-neck junction of the femur [122]; anatomic abnormality of the femoral head-neck junction [165,167]; enlarged femoral head-neck asphericity [132,134]; nonspherical extension of the femoral head and a decreased anterior head-neck offset [146]; femoral head-neck type [123]; superior half of the femoral head is the predominant location of cam-type deformities [150]; the anterosuperior head-neck quadrant and especially the anterosuperior area (1° to 2° position) has been described as the predominant site of cam-type deformity [150];
	4.2 Anterior, anterolateral, lateral, inferior, posterior, superior (anterior-superior and superior-anterior [109]);	To account for variation in the location of cam morphology [60]; cam pathology usually located on the anterosuperior aspect of the femoral neck [114]; insufficiently waisted femoral head-neck junction anterosuperiorly [149]; decreased head-neck offset anterosuperiorly [149]; anterolateral femoral head-neck junction [167]; significantly decreased head-neck offset in the anterosuperior femoral quadrant [149]; cranial hemisphere of the femoral head [149]; the morphology of the femoral head-neck junction is such that the alpha angle measurements

	superior, superior-anterior, anterior-superior, anterior [123];	are significantly higher at the anterosuperior femoral head-neck position (1:30 radial position) compared with the anterior position (3:00 radial position) [75]; the circumference of the deformity clearly extended from anterior to anterolateral quadrants [75]; males anterolateral quadrant; females anterior quadrant [75]; anterior; anterosuperior [76];
	4.3 O'clock positions (12 o'clock to 11 o'clock) [123]	12-, 1-, 2- and 3-o'clock positions [123]; anterosuperior region (12-3 o'clock as viewed on the right hip and 9-12 o'clock as viewed on the left hip) [137]; "We used a clock face system to record the localization of cam-type deformities on radial sequences, with 12 o'clock denoting a superior location, 3 o'clock an anterior, 6 o'clock an inferior, and 9 o'clock a posterior location" [146] clockface system on the radial cuts at 7 defined points ranging from 9 o'clock (posterior head-neck junction) to the 3-o'clock position (anterior head-neck junction). The analysis was simplified by converting left sided images into right-sided joints [152]; seven measurements from 9 o'clock to 3 o'clock positions - superior half of the femoral head) [61]; cam deformity defined as α-angle ≥50.5° at the 3 o'clock position [75]; around the axis of the femoral neck at 30° intervals with 12 o'clock being superior and 3 o'clock anterior [86]; two separate definitions for cam morphology: a hip with an α-angle >55° at 3 o'clock or a hip with an α-angle >83° at any position around the femoral neck [86]; femoral head-neck structure assessed by measurement of the alpha angle at the 12-o'clock (superior), 1-o'clock (superior-anterior), 2-o'clock (anterior-superior) and 3-o'clock (anterior) positions [123]; to account for variation in the location of cam morphology, the primary outcome measure was maximum cartilage alpha angle from 11 o'clock through to 3 o'clock [60]; Similar to previously performed studies, seven 1 mm thick radial reformats spaced clockwise in 30° intervals around and perpendicular to the femoral neck axis (Figure 4) [38] were measured. These positions are anterior, anterior-superior, superior-anterior, superior, superior-posterior, posterior-superior and posterior and are represented by the clock positions (9, 10, 11, 12, 1, 2, 3). The clock positions are generated from the 3-D data set by using multiplanar reconstruction software [160]; On computed tomography (CT) the angle alpha was measured on at 1:30 (anterosuperior) and at 3:00 (anterior) o'clock positions. An angle alpha >60˚ at 1:30 o'clock position or/and >50.5˚ at 3:00 o'clock position was defined as a cam deformity [65];
5. Shape / morphology / structure / architecture / contour / condition	5.1 Morphology / structure / Bump / Hump / Prominence / enlarged / excessive bone / pathology / pathomorphology / structure / reduced (less) femoral head-neck junction concavity / diminished concavity or 'waisting' / convex / incongruity / contour /	Cam hip shape [86]; abnormally shaped proximal femur [89]; Proximal femoral morphology / FAI morphology [139]; femoral head-neck structure [123]; primary cam deformity gradually worsens over time, with a 'bump' growing as a consequence of reactive bony deposition [139]; Osseous (cam) bump [144]; Presence of a bump on the femoral head / bump on the femoral head-neck transition [125]; femoral "bump" [127]; focal femoral humps [114]; Osseous bump formation at the femoral neck / anterosuperior femoral head-neck junction [111]; obvious "bumps" were present in soccer players [62]; bumps are a factor of cam FAI [76]; presence of a prominence - a convexity in the anterior head-neck junction as opposed to a concavity [13,62]; Prominence at the femoral head-neck junction [117,134]; focal prominence [122]; Enlarged femoral head-neck junction [165]; Enlarged femoral head-neck asphericity [132]; Excessive bone formation [96] femoral head-neck junction structure [123]; cam pathology [122]; pathological head-neck junction [116]; cam pathomorphology [122]; cam pathology usually located on the anterosuperior aspect of the femoral neck [114]; reduced femoral head-neck junction concavity [124]; less concavity at the femoral head-neck junction [134];

	three-dimensional condition / cam-positive	to ascertain the anterior concavity of the head-neck junction [148]; diminished 'waisting' at the junction [134]; insufficiently waisted femoral head-neck junction anterosuperiorly [149]; the anterosuperior head-neck junction gradually changed from being concave at the age of 12 years to being flattened around the age of 14 and finally to a concavity around the age of 16 years [13]; anatomical abnormalities and the resultant incongruity of the hip [128]; contour of the femoral head-neck junction [134]; shape of the proximal femur in the AP and FLL radiographs [62]; shape defined by a set of landmark pints that are positioned along the contour of the bone [62]; FAI is a three-dimensional condition [139]; cam-positive [119]; increased MRI morphological characteristics of hip joint cam deformity [160];
	5.2 Flattening	flattening of the head-neck junction - moderate decrease in the anterior head-neck offset with respect to the posterior head-neck junction [13,62]; a flattened head-neck junction can evolve toward a prominence over time [62]; flattening of lateral aspect of femoral head [114] Flattening of the femoral head-neck offset [96];
	5.3 Asphericity of the femoral head / aspherical / nonspherical / Oval-shaped head / 'cam' shape at the head-neck junction / medial angulation of the femoral head - tilt deformity / increased radius of the femoral head	A condition in which the femoral head loses its normal sphericity, specifically at the femoral head-neck junction [152]; the α-angle is an indicator for head asphericity [152]; Enlarged femoral head-neck asphericity [132,134]; Oval-shaped head Asphericity of the femoral head [98,126]; head-neck asphericity [126]; femoral head/neck asphericity [106]; Complex 3-dimensional structure qualitatively defined by asphericity [103] Aspheric deformity of the femoral head [117]; presence of an aspherical femoral head [159]; Aspherical portion of the femoral head-neck junction [109]; aspherical portion of the femoral head [152]; aspherical portion of the femoral head and neck junction [68]; Loss of normal femoral sphericity [96] nonspherical extension of the femoral head / nonspherical femoral shape [146]; nonspherical femoral head [104,149]; Non-spherical shapes (bumps) of the femoral head [76]; 'cam' shape at the head-neck junction [122]; medial angulation of the femoral head in relation to the femoral neck - "tilt deformity" [128]; increased radius of the femoral head associated with cam-type deformity [146]; Extent to which the femoral head deviates from being spherical [158];
	5.4 Decreased offset / decrease in hip clearance / extra bone formation	Decreased femoral head-neck offset [104,105,109,146]; decreased anterior head-neck offset [132,134,146]; decreased head-neck offset [149]; Decreased cranial offset (of femoral head-neck junction) [98]; offset abnormalities of the femoral head-neck junction [167]; decrease in hip clearance [167]; diminished femoral head-neck offset [70]; loss of femoral offset [70]; loss of femoral head-neck offset [118]; deficient femoral head-neck offset [75]; poor head-neck offset [89]; prominent lateral offset of the femoral head neck junction [95]; α-angle quantifies the level of femoral head-neck offset [104]; extra bone formation at the anterolateral head-neck junction [158]
	5.5 Measurement of shape and size	Quantifying the shape of the femoral head (Figure 4) was by measuring the alpha (α) angle according to Nötzil et al. The α-angle was measured in all planes from 9 to 3 o'clock [160] ;
6. Ownership	6.1 Sex/gender	Primary cam morphology is more prevalent in males compared to females [96,113].

	6.2 Athletes	Primary cam morphology is more prevalent in athletes compared to non-athletes. There is strong evidence that high activity levels during adolescence promote cam morphology development with a dose-response relationship [60,75,158]. *'Males participating in competitive sport are at particularly elevated risk of developing cam morphology…';* [60] *'…CAM impingement is more common in the elite ice hockey athlete in comparison with non-athletes.'* [68]
	6.3 One or both hips (per hip; per person)	The presence of a cam deformity per hip was defined when it was present in either view. The presence per person was defined when a cam deformity was present in either view in either hip [159]; flattening or prominence in at least one hip in either AP or frog-leg lateral view [62]; Randomly assigned one hip to be evaluated for each athlete [152]
	6.4 Symptoms	The majority of individuals with primary cam morphology are symptom free [2,127]. In a 2-year prospective cohort study of professional adult male soccer players, bony morphology, including cam morphology, was not associated with the risk of groin injuries. Despite the high prevalence of cam morphology (71% of players), only 1 of 113 index hip/groin injuries recorded was hip-related [2]. '*Cam-type deformities were seen in 868 male and 1192 female participants, respectively, as follows: pistol grip deformity, 187 (21.5%) and 39 (3.3%);'* [113]
7. Imaging	7.1 Radiographs 7.1.1 AP 7.1.2 Dunn 45 7.1.3 Frog-leg lateral 7.1.4 Other (Von Rosen view) [165,167] 7.1.5 Lauenstein [168] 7.2 Dual-energy X-ray absorptiometry (DXA) 7.3 CT 7.4 MRI 7.4.1 0.5 Tesla 7.4.2 1 Tesla 7.4.3 1.5 Tesla 7.4.4 3 Tesla 7.4.5 Sagittal	Radiographs: Presence of a bump in the AP-, Dunn-, Dunn 45°- or Ducroquet view [125]; flattening or prominence in at least one hip in either AP or frog-leg lateral view [13,62]; MRI-verified cam [61]; radiological CAM impingement [68]; femoral sphericity was assessed on both the frog-leg lateral and the anteroposterior radiograph with the use of the alpha angle [105]; radiographic FAI abnormality [106]; radiographic cam-type deformity [107]; radiologic cam deformity [119]; cam radiographic deformity [119]; DXA: One of the included articles used posterior-anterior dual-energy X-ray absorptiometry bone mineral density images to quantify bony morphology of the hip [129]. CT: On computed tomography (CT) the angle alpha was measured on at 1:30 (anterosuperior) and at 3:00 (anterior) o'clock positions. An angle alpha >60˚ at 1:30 o'clock position or/and >50.5˚ at 3:00 o'clock position was defined as a cam deformity [65]; Axial alpha angle measured on oblique-axial plane of the longitudinal femoral neck axis (cam deformity in the anterior aspect of the femoral head); radial alpha angle obtained through a 1:30 clockface rotation about the longitudinal femoral head neck axis (anterosuperior quadrant); axial AA > 50.5˚ (Axial 3:00) or radial AA > >60˚ were considered as cam deformity (radial 1:30) [132] CT images were acquired in the axial plane and used to generate oblique coronal planes parallel to the femoral neck axis. The oblique coronal image was then used to prescribe an oblique axial image parallel to the femoral neck axis (Fig. 1), called the 3:00 plane (11,14) and is used for measurement of the traditional alpha angle (11). An oblique sagittal image, perpendicular to the femoral neck axis through the subcapital zone of the femoral neck was used to prescribe the radial series of images using the femoral neck axis as the axis of rotation, described by Rakhra

	7.4.6 Sagittal-oblique 7.4.7 Radial 7.4.8 Axial 7.4.9 Axial oblique 7.4.10 Transverse oblique 7.4.11 Axial oblique, sagittal and coronal 7.4.12 Coronal oblique 7.5 Ultrasound	et al. (14) An image in the 1:30 plane was generated corresponding to a 45° rotation of the 3:00 plane (Fig. 1) as described by Rakhra et al. (14) The alpha angle was then measured on two images to evaluate the femoral head-neck junction anteriorly and anterosuperiorly in the traditional axial oblique (11) (3:00) and 1:30 planes, respectively. Asymptomatic subjects with an alpha angle greater than or equal to 50.5° measured in the 3:00 plane (15,16) or greater than 60° in the 1:30 plane were classified as 'Bump' whereas subjects with both alpha angles less than the respective thresholds were classified as 'Control'. [154] MRI: 3.0-T MRI using large flexible surface coils - 3T MRI (proton-weighted radial sequence used to evaluate the femoral head, femoral head-neck junction, and acetabulum. Radial planes rotated clockwise in 30° intervals around and perpendicular to the femoral head-neck axis) [152] "We suggest frequent evaluation of hip morphology during the period of closure of growth plates with no radiation load (MRI) and also the monitoring of loading variables during the years before this closure" [158]; "MRI scan protocols were performed on both hips for all participants. The MRI machine GE Optima 450 Wide 1.5T was used for all examinations; a coil surface HD 8ch Cardiac Array by GE was used. The total time for examination of two hips was approximately 20 minutes. The protocol was repeated twice in order, first for the right hip and then the left hip. The coil surface was shifted at each hip for maximum signal. Similar to previously performed studies, seven 1 mm thick radial reformats spaced clockwise in 30° intervals around and perpendicular to the femoral neck axis (Figure 4) [38] were measured. These positions are anterior, anterior-superior, superior-anterior, superior, superior-posterior, posterior-superior and posterior and are represented by the clock positions (9, 10, 11, 12, 1, 2, 3). The clock positions are generated from the 3-D data set by using multiplanar reconstruction software" [160]; Sagittal [60] Axial: Axial angled on the femoral neck [61] Axial oblique [68] Axial with multiplanar reformation to generate radial images using the center of the femoral neck as the axis of rotation; 2mm thick images at 30° intervals [75] Oblique sagittal [83] Radial [60,89] Transverse oblique with radial images reformatted by using the femoral neck long axis as a rotation axis [90] Axial oblique, sagittal and coronal [93] Coronal oblique [149] Ultrasound: Ultrasound was used to measure alpha angles in a publication included after the January 2021 update search (Section 2.5.6) [173]. The authors used a previously validated ultrasound technique [174].

B.2 Cam morphology definitions used in included publications (*n=111*)

Author	Descriptive Definition - language used in relation to primary cam morphology	CAM Definition	Imaging in CAM Outcome Measurement
Agnvall *et al*., 2017	cam deformity; cam-type FAI; cam-type morphology; cam lesion; morphological features of the femoral head-neck junction; MRI-verified cam	DICHOTOMOUS: Alpha angle $\geq$ 55° (7 measurements from 9 o'clock to 3 o'clock positions - superior half of the femoral head)	1.5T MRI (axial angled on the femoral neck;
Agricola *et al*., 2012	Cam-type deformity; cam impingement; flattening of the head-neck junction - moderate decrease in the anterior head-neck offset with respect to the posterior head-neck junction; presence of a prominence - a convexity in the anterior head-neck junction as opposed to a concavity	DICHOTOMOUSs: Alpha angle > 60° VISUAL: normal, flattening, prominence	Alpha angle (>60°) and visual scoring system (normal, flattened and prominence) on RADIOGRAPHS - shape of the proximal femur in the AP and frog-leg lateral radiographs was assessed using a statistical shape modelling software.
Agricola *et al*., 2014	cam deformity; flattening of the head-neck junction - moderate decrease in the anterior head-neck offset with respect to the posterior head-neck junction; presence of a prominence - a convexity in the anterior head-neck junction as opposed to a concavity	DICHOTOMOUS: alpha angle >60° cam deformity) and >78° (pathological cam deformity); VISUAL: (normal, flattened, prominence) CONTINUOUS: Mean alpha angle (at baseline and follow-up)	Radiographs: Anteroposterior (AP) pelvic view and a frog-leg lateral view.
Ahn *et al*., 2016		DICHOTOMOUS: "Pistol grip morphologic features"; Bump; Flattening; AA > 55°	Radiographs: AP Pelvis; Sugioka View (hip flexed 90° and abducted 45°; 45° Dunn view
Anderson *et al*., 2016	cam-type FAI; cam FAI; hip pathomorphology; FAI-type morphologies;	DICHOTOMOUS: The alpha angle was measured on the frog-leg lateral but no indication about the diagnostic cut off given. A histogram gave 50, 55 and 60 degrees. Gamma angle	X-ray alpha angle, assessed on the frog-leg lateral view, is between the longitudinal axis of the femoral neck and a line connecting the femoral head center and the point where the head exceeds the radius of the best-fit sphere. Similarly, the gamma angle was measured on the AP view

Anwander *et al*., 2015	cam deformity;	DICHOTOMOUS (alpha angle > 60° at 1:30 o'clock position or/and > 50.5° at 3:00 o'clock position) The average alpha angle at the 2 positions in the cam and control groups are also reported.	No details on CT details used for CAM measure. Only details on MRI sequences for T1p value measures to detect early chondral damage; .
Anwander *et al*., 2017	cam morphology; cam deformity	DICHOTOMOUS: "A cam deformity was defined as an alpha angle >51°at the 3:00 position and/or >60°at the 1:30 position	1.5T MRI scan
Audenhaert *et al*., 2012		DICHOTOMOUS alpha angle > 55° on AP and Dunn	Radiographs - AP Pelvis and Dunn views (45° hip flexion, neutral rotation and 20° of abduction)
Ayeni *et al*., 2014	radiological CAM impingement; CAM-type morphology; CAM-impingement FAI; aspherical portion of the femoral head and neck junction	DICHOTOMOUS: Alpha angle > 50° (MRI) CONTONUOUS: mean alpha angle for ice hockey group vs controls	1.5T MRI (axial oblique sequences)
Azevedo *et al*., 2016	cam deformity;	DICHOTOMOUS alpha angle > 55° on axial MRI to categorize the 3 study groups CONTINUOUS - mean AA	MRI (axial)
Bagherifard *et al*., 2018	deminished femoral head-neck offset; loss of femoral offset; cam impingement; cam-type impingement;	DICHOTOMOUS alpha angle > 60°; CONTINUOUS mean alpha angle in ACL vs no ACL; The alpha angle was calculated for all the patients in accordance with Dunn's radiographs (Fig.1).To calculate the alpha angle, a spherical template was placed over the femoral head and a line was drawn along the longitudinal axis of the femoral neck between the centre of the femoral head and the centre of the neck at its narrowest point. The point was then marked where the radius of the curvature of the femoral head first exceeded that of the template anteriorly. A straight line connecting this point and the centre of the head was drawn. The angle between this line and the neck axis line was the alpha angle. The measurements were made by saving the digital images in Autocad (version 2013) and were recorded in degrees	RADIOGRAPHS (45° Dunn) - All the participants underwent a 45° Dunn radiograph of hip on the side of the symptomatic knee. The radiographs were performed with the patient supine, and the symptomatic hip flexed at 45° and abducted 20° while being maintained in a position of neutral rotation. The crosshairs of the beam were then directed to a point midway between the anterior superior iliac spine and the pubic symphysis
Bagwell *et al*., 2016		DICHOTOMOUS: Alpha angle > 50.5° (Persons with cam FAI were eligible if they were skeletally mature (Song et al., 2012), 45 years of age or younger, and had an alpha angle measurement of greater than 50.5°)	Not specifically described for CAM group, but authors mentioned that if radiographic signs of OA were seen they would be excluded. Therefore it may be assumed that alpha angle was also measured radiographically. It could also have been measured with MRI as described for the control group.

Barrientos *et al*., 2016		CONTINUOUS: AA on CT scan at the 1:30 position (middle 1/3 of the femoral neck)	CT Scan
Beaule *et al*., 2005		CONTINUOUS - mean alpha angle	CT Pelvis with multi-planar reformation (Patients also had AP pelvis, frog leg lateral and MRI arthrogram)
Bittersohl *et al*., 2009		DICHOTOMOUS measuring alpha angle on cross-table radiograph (referring to Notzli *et al*., 2002) CONTINIOUS (Mean AA, SD in all the different clock positions)	Radiographs - AP Pelvis (qualitative: lateral pistol grip deformity) and cross-table lateral (alpha angle - quantitative; ? > 50° as per the paper referenced but not clearly stated in this paper) and MRI
Carsen *et al*., 2014	cam deformity; cam morphology; cam-type morphology; deformity; cam-type FAI; abnormal head-neck junction; defiecient femoral head-neck offset; circumference of the deformity extends from anterior to anterolateral quadrants	DICHOTOMOUS: Alpha angle ≥ 50.5° at the 3 o'clock position on MRI (using the centre of the femoral neck as the axis of rotation); CONTINUOUS: mean alpha angle (SD) at 1:30 and 3:00 position (in open and closed physes) The alpha angle was measured at 2 positions along the femoral head-neck junction, anterior and anterosuperior denoted 3:00 and 1:30 o'clock locations	1.5T MRI (axial with multiplanar reformation to generate radial images using the center of the femoral neck as the axis of rotation; 2mm thick images at 30° intervals)
Charbonnier *et al*., 2010	FAI of the cam type; bumps are a factor of cam FAI; deviation from the normal geometry;	DICHOTOMOUS alpha angle more than 55° on MRI using Notzli's method (anterior and anterosuperior positions); CONTINUOUS - mean alpha angle in anterior and anterosuperior positions on MRI	MRI scan (not reported if 1.5T or 3T)
Cobb *et al*., 2010		DICHOTOMOUS: alpha angle greater than 50°	CT and radiographs
Cooke *et al*., 2013		CONTINUOUS: mean alpha angle	CT (reconstructed axial oblique CT running along the axis of the femur neck)
Cooper *et al*., 2017	Excess bone on the femoral neck; GEOMETRY: Concept of "shape" and "position" of 'cams'; "volume" and "span"; "size"; POSITION & EXTENT: cam-angle and cam-width; SIZE: cam-rad	"patients with cam-type impingement" but not clearly defined in terms of AA. "Clinical diagnosis of cam FAI with preoperative CT scans available". ON CT-scan "Cam-rad" measures the size of a "cam": Cam-rad is the greatest planar distance between the head centre and the anterior half of the fitted ellipse, recorded as a percentage of the head radius. This indicates the level of offset between the head and neck in the cam region	Radiographs reconstructed in 2D from CT

deBoer *et al.,* 2013	Coxa recta: aspherical femoral head and/or reduced head-neck concavity	CAM called coxa recta: Aplha angle on frog leg lateral > 62 degrees	Radiographs: 45° frog leg lateral
Diamond *et al.,* 2015		DICOHOTOMOUS: alpha angle > 55 degrees (on x-ray and/or MRI) Control group < 50	Radiographs (no information given); MRI (detail given for control participants)
Diamond *et al.,* 2018		DICHOTOMOUS: PATIENTS (X-ray and/or magnetic resonance imaging (MRI)); alpha angle > 55° (cam FAI) [20], or alpha angle >55° and lateral centre edge angle (CEA) > 39° and/or positive cross-over sign (combined FAI); CONTROLS: 3T MRI - Alpha angle was measured in the oblique sagittal plane	Definitive signs of FAI on imaging (X-ray and/or MRI); AA > 55° (cam FAI), or AA > 55° and lateral CEA > 39° and/or positive cross-over sign (combined FAI). Controls: MRI to ensure an absence of FAI morphology (AA < 50° and CEA < 40°), via a 3-Tesla scanner and 16-channel body coil (coupled with a Siemens Spine array). AA was measured in the oblique sagittal plane and CEA was measured in the coronal plane via OsiriX imaging software.
Diamond *et al.,* 2017		DICHOTOMOUS: Alpha angle > 55 degrees on x-ray or MRI scan (no clock position specified); Control, non cam morphology: alpha angle < 50°	Radiograph and/or MRI in FAI group; MRI in the control group (oblique sagittal plane)
Diamond *et al.,* 2017		DICHOTOMOUS: "Participants had definitive signs of FAI on imaging (X-ray and/or magnetic resonance imaging [MRI]); alpha angle>55˚(cam FAI),and lateral centre edge angle>39˚and/or positive crossoversign (combined FAI)"	Radiographs and/or MRI for patients and 3T MRI for controls
Diamond *et al.,* 2016		DICHOTOMOUS alpha angle >55°	"Imaging" (presume x-ray) for patient; MRI for controls (to confirm no FAI)
Dickenson *et al.,* 2016	cam morphology; cam hip shape; cam deformity; proximal femoral morphology; two separate definitions for cam morphology: a hip with an α-angle >55° at 3 o'clock or a hip with an α-angle >83° at any position around the femoral neck	DICHOTOMOUS: AA > 55° at 3 o'clock and AA > 83° at any position around the femoral neck CONTINUOUS: Median (IQR) AA in trail hip and leading hip	1.5T MRI (around the axis of the femoral neck at 30° intervals with 12 o'clock being superior and 3 o'clock anterior)
Diesel *et al*., 2015		DICHOTOMOUS: alpha angle > 55 in the Dunn 45° view or an abnormal triangular index (TI)	Radiographs - AP and Dunn 45° views (alpha angle ≥ 55 on Dunn 45 view or abnormal TI = cam)

Dudda *et al*., 2011	Nonspherical "pistol grip" deformity of the femoral head and neck; femoral head/neck deformities "cam impingement"; femoral head-neck junction that is too broad or aspherical	CONTINIOUS: **Mean Impingement angle**. A perfect circle that encompasses the inferior and superior portions of the femoral head is drawn. A line passing through the center of both femoral heads is found and used as a reference line. An angle is formed by drawing a line perpendicular to the horizontal reference line and a line connecting the center of the femoral head to the first part of the lateral femoral head, which is outside the perfect circle. An angle of 70° is defined as pathologic, assuming that a neck shaft angle in adults is on average 130°. **Mean Femoral head ratio of Murray.** The ratio MH:LH of the femoral head width lying on each side of a line drawn through the middle of the femoral neck and middle of the line connecting the greater and lesser trochanters is determined. A larger ratio implies a more "pistol grip" shape of the femoral head. The mean femoral head ratio is 0.92 (range 0.66–1.36) in women and 1.17 (range 0.62–1.92) in men.	Radiographs - standard AP pelvis
Duthon *et al*., 2013	abnormally shaped proximal femur (poor head-neck offset; coxa vara); cam type FAI; femoroacetabular morphological features; deviation from the normal femoral neck geometry	DICHOTOMOUS (alpha angle > 55°) CONTONIOUS: mean alpha angle in different positions	1.5T MRI (radial: Alpha angle measured in accordance with Notzli et al in 8 positions: anterior, anterosuperior, superior, posterosuperior, posterior, posteroinferior, inferior, anteroinferior around the femoral neck)
Ehrmann *et al*., 2015	Nonspherical femoral head with an osseous deformity of the femoral head-neck junction POSITION: lowest OFFSET values in anterosuperior position; highest mean FEMORAL DISTANCE enterosuperior or anterior	CONTINUOUS: mean (SD) **Offset** in 5 regions (patients vs asymptomatic volunteers); mean **Femoral distance** in 5 regions (patients vs asymptomatic volunteers)	1.5T MRI (transverse oblique water excitation true fast imaging with steady-state precession (FISP) sequence parallel to the femoral neck axis; from this dataset radial images were reformatted by using the femoral neck long axis as a rotation axis. In total 11 radial images were obtained which correspond to 22 locations circumferentially around the femoral head neck junction.

Espie *et al*., 2016	bone anomalies loacted in the antero-superior portion of the femoral neck	CONTINUOUS: ALpha angle FAI vs controls; modified Head Neck Offset; modified antero-superior offset ratio; Eijer Head Neck Offset; Eijer anetro-superior ratio DICHOTOMOUS: Diagnostic thresholds provided by the 95% RI limits of the control group: eHNO<6.7mm; mHNO<5.2mm; eAOR<0.133; mAOR<0.098; alpha angle >65.6°	FAI GROUP: Radiographs and/or computed tomography (CT) and/or magnetic resonance imaging (MRI). CONTROL GROUP: radiographs
Farkas *et al*., 2016		DICHOTOMOUS: Alpha angle ≥ 50°. The AA was measured by a line from the centre of the femoral head that bisects the femoral neck and the line from the center of the femoral head to the point where the femoral head loses sphericity. The largest measured AA was selected at the cam deformity as it may be more prominent on varying views depending on its location	Radiographs
Farrell *et al*., 2016	cam defect; cam-defect; head and neck deformity of the femur;	DICHOTOMOUS: alpha angle ≥ 50.5° at 3 o'clock position using the method of Notzli (measured at 1:30 and 3 o'clock positions although only > 50.5 at 3 o'clock used to diagnose cam). CONTINIOUS: mean alpha angle of RIGHT vs LEFT in rugby cohort	MRI - 3T non-arthrographic in axial oblique, saggital and coronal
Ferro *et al*., 2015		DICHOTOMOUS: alpha angle > 55°	3T MRI confirmed radiographic cam (but not clearly specified in paper)
Fukushima *et al*., 2016	pistol grip deformity; cam-type impingement; cam-type deformity; prominent lateral offset of the femoral head neck junction; cam-type FAI; hip morphological abnormalities	DICHOTOMOUS - Visual - presence of Pistol grip deformity	Radiographs (AP-pelvis)
Gerhardt *et al*., 2012	excessive bone formation at the femoral head-neck junction; loss of normal femoral head sphericity; flattening of the femoral head-neck offset	DICHOTOMOUS: presence of the following on frog-leg lateral: alpha angle > 55°; excessive bone formation at the femoral head-neck junction; loss of normal femoral head sphericity; flattening of the femoral head-neck offset. CONTONIOUS: mean alpha angle	Radiographs: AP pelvis and frog-leg lateral

Golfam *et al*., 2017		CONTINUOUS: mean alpha angle at the 1:30 clockface position in the oblique axial and radial views on 1.5T MRI: To standardize the point of measurement on the femoral head-neck junction on the oblique axial and radial images,a previously described clockface descriptor was used. 25 The 12- and 3-o'clock positions corresponded to superior and anterior locations, respectively. On oblique axial MPR,the middle image between the anterior (3 o'clock) and superior (12 o'clock) images was selected, corresponding to the antero-superior position (1:30) of the femoral head-neck junction. On radial MPR, using 15° intervals and the same clock face descriptor, the corresponding 1:30 clock face position was chosen	1.5T MRI
Gosvig *et al*., 2008	Decreased cranial offset of the femoral head-neck junction; asphericity of the femoral head	DICHOTOMOUS: alpha angle > 83° in males and > 57° in females (on AP Pelvis radiographs) DICOTOMOUS: Triangular index: if R >=r + 2mm in an ordinary x 1.2 magnification radiograph CONTINIOUS: mean alpha angle and mean TI	Radiographs: AP pelvis
Gosvig *et al*., 2010		DICHOTOMOUS: pistol grip deformity (quantified as the triangular index =>0 mm; R - (r + 2mm))	Radiographs: AP Pelvis
Grammatopoulos *et al*., 2018		DICHOTOMOUS: Alpha angles greater than 50.5˚ (anteriorly) and/or greater than 60˚(antero-superiorly) were considered as positive for cam morphology. CONTINUOUS: mean AA (SD) antero-superior and anterior for the whole cohort, the no CAMs and CAms as well as controls, Asymptomatic CAMs and Symptomatic CAMs	CT scan
Guo *et al*., 2017	Enlarged femoral head-neck junction	DICHOTOMOUS: Cam was defined as an alpha angle > 55°	Radiographs (AP pelvis and 45 Dunn)
Hack *et al*., 2010		DICHOTOMOUS: An alpha angle of >50.5 was considered elevated and thus positive for cam-type morphology CONTINUOUS: mean AA in different MRI o'clock positions for males vs females	1.5T MRI
Harris *et al*., 2016	Complex 3-dimensional structure, qualitatively defined as asphericity	DICHOTOMOUS (unsure of cut-off value used); CONTINUOUS (Mean AA; Mean head-neck offset; mean head-neck offset ratio)	RADIOGRAPHS: Standing anteroposterior pelvis; Standing false profile right hip; Standing false profile left hip; Supine Dunn 45°pelvis
Ito *et al*., 2001		CONTINUOUS: mean femoral head-neck offset	MRI (with gadolinium-diethylenetriamine penta-acetic acid for cases)

Johnson *et al*., 2012	Morphologic changes of the proximal femur; cam deformity;cam impingement; nonspherical femoral head; decreased femoral head-neck offset;	DICHOTOMOUS: In addition, each reviewer measured and recorded the alpha angle from the frog-lateral view. In cases where disagreement existed, they reviewed the radiographs together and conferred until agreement was reached. The reviewers were blinded to which group each patient pertained. Hips with alpha angles that measured greater than or equal to 55° were deemed to have cam deformity	Radiographs: AP pelvis and frog-lateral (FLL used to measure alpha angle)
Kapron *et al*., 2011	morphologic abnormalities; morphologic deformities; cam deformity; cam femoroacetabular impingement; cam impingement; femoral sphericity was assessed on both the frog-leg lateral and the anteroposterior radiograph with the use of the alpha angle; decreased femoral head-neck offset	DICHOTOMOUS: Alpha angle > 50°; head-neck offset <8mm; on either APP or FLL radographs; CONTINUOUS: can be worked out for AP and Frog leg lateral; Femoral head neck offset: The femoral head-neck offset, which is the difference in radius between the femoral head andneck, was measured on the frog-leg lateral radiograph	Radiographs: AP pelvis and frog-lateral
Kapron *et al*., 2015	Structural hip deformity; radiographic cam-type deformity; cam FAI;	DICHOTOMOUS: alpha angle (>50°), head-neck offset (<8mm); CONTINUOUS: mean alpha angle, mean head-neck offset	Radiographs: AP pelvis and frog-lateral (Alpha angle) and HNO (measured on FLL radiographs only)
Kapron *et al*., 2012	bony abnormalities of FAI; femoral head/neck asphericity;	DICHOTOMOUS: alpha angle > 50°; head-neck offset <8mm; (AA on AP films and frog-leg lateral; HNO only FLL) (data for each view reported); Head-necl offset less than 8mm	Radiographs: AP pelvis and frog-lateral
Kennedy *et al*., 2009		DICHOTOMOUS: alpha angle > 50.5°; The control group is said to have a "spherical femoral head" but this is not further defined	Radiographs (AP pelvis and Dunn view) for FAI group and only AP pelvis for controls
Kienle *et al*., 2012	decrease in the femoral head-neck offset (mainly in the anterior-superior part of the joint; aspherical portion of the femoral head-neck junction	CONTINUOUS: alpha angle; DICHOTOMOUS: alpha angle >55°	MRI (3T) (seven radial slices rotating in 30° increments from anterior to superior to posterior position as described by Locher et al)

Kohno *et al*., 2016		DICHOTOMOUS: Alpha angle >55° at any location around the femoral neck; CONTINUOUS: mean alpha angle at each of the different locations around the femoral neck; HEAD-NECK OFFSET RATIO	CT scan
Kolo *et al*., 2013	Osseous bump formation at the femoral neck / anterosuperior femoral head-neck junction; deviation from normal geometry; wasting of the cervico-cephalic junction (femoral alpha neck angle)	DICHOTOMOUS alpha angle greater than 55° on MRI (max of 8 positions around the femoral neck)	1.5T MRI (supine with virtual 3D reconstructed hip joint model) Alpha angle measured in 8 positions around the femoral neck using radial plane images centred around the femoral neck axis and superimposed on the 3D reconstructed bony models
Kopec *et al*., 2017		DICHOTOMOUS: >55° (Dunn view)	Radiographs (AP pelvis and Dunn 45)
Laborie *et al*., 2014	cam-type pathology; (referencing 3 papers: pistol grip deformity; focal femoral humps; flattening of the lateral aspect of the femoral head)	CONTINUOUS: median alpha angle (with range)	Radiographs (AP pelvis weight bearing and frog-leg lateral)
Laborie *et al*., 2011		DICHOTOMOUS: visual (n with pistol grip deformity, n with focal prominence, n with flattening of lateral head)	Radiographs: (AP pelvis - weight-bearing; Frog-leg - supine)
Lahner *et al*., 2014	cam impongement; prominence at the anterolateral femoral head-neck junction (referencing Notzli et al)	DICHOTOMOUS AA greater than 55° (on 1.5T MRI but unsure if they used the maximum value for any of the o'clock positions); CONTINIOUS: mean AA 2 groups (T7F and non-athlete); LEFT and RIGHT hip	1.5T MRI (Axial oblique orientated along the axis of the femoral neck)
Lahner *et al*., 2014	Prominence at the anterior femoral head-neck junction; aspheric deformity of the femoral head	DICHOTOMOUS alpha angle greater than 55°; CONTINIOUS mean alpha angle in each group	1.5T MRI (Axial oblique orientated along the axis of the femoral neck)
Lahner *et al*., 2014	cam-type femoroacetabular deformity; cam impingement; pathological head-neck junction	DICHOTOMOUS: AA greater than 55°); CONTINIOUS: ARITHMETIC mean AA in 2 soccer groups (LEFT and RIGHT hips; kicking legs)	1.5T MRI (Axial oblique orientated along the axis of the femoral neck)

Larson *et al*., 2017	cam-type morphology; cam-type deformity; cam-type FAI; loss of femoral head-neck offset;	DICHOTOMOUS: ALpha angle > 50° on AP Pelvis or Dunn lateral; CONTINUOUS: mean alpha angle on AP Pelvis and Dunn lateral radiographs reported; mean head-neck offset ratio on APP and Dunn lateral;	Radiographs: AP pelvis; Dunn lateral
Lerebours *et al*., 2016	Morphologic variation; cam-type morphology; cam radiographic deformity; radiologic cam deformity; cam deformity; cam-type deformity;	DICHOTOMOUS: AA $\geq$ 55°; CONTINUOUS: Mean (SD)	Radiographs: AP Pelvis and Frog leg lateral
Leunig *et al*., 2013		DICHOTOMOUS: Grade 0 - 3 CAM-type deformity; To determine the presence of cam-type deformities, we graded the maximum offset at the head-neck junction on the radial sequences using a semi-quantitative scoring system. This system involved grades ranging from 0 to 3, as follows: 0=normal, no evidence of a nonspherical femoral shape (cam deformity) on any sequence; 1=possible deformity with cortical irregularity and a possible mild decrease of the anterior head-neck offset; 2= definite deformity with an established decrease of the anterior head-neck offset (cam deformity of less than 10 mm); and 3 = severe deformity with a large decrease in the anterior head-neck offset (cam deformity of more than 10 mm) 13. Grades 2 and 3 were pre-specified as indicating a definite cam-type deformity. We determined the alpha angle on radial sequences, which is located in the middle of the anterosuperior quadrant, as recommended by Pfirrmann et al. CONTINIOUS: Mean alpha angle	1.5T MRI
Mantovani *et al*., 2016		DICHOTOMOUS Alpha angle > 50.5° in axial 1:30 CT and > 60°in the radial 1:30 view: " Pelvic CT images were acquired from each participant using either the Toshiba Acquilion (Toshiba Medical Systems Corporation, Otawara, Japan) or the Discovery CT750 (GE Healthcare, Mississauga, ON, Canada). The scan was executed in a supine position, with a pillow underneath the lumbar vertebra to mimic the natural lordosis of the standing position. FAI participants were selected based on their hip deformity, quantified by an alpha angle larger than 50.5 in the axial or 60 in the radial 1:30 view on CT data"	CT scan

Masjedi *et al*., 2013	a 'cam' shape is observed at the head-neck junction of the femur; focal prominence; cam-type morphology; cam pathology	CONTINIOUS: mean AA (2 groups: Cam and no cam)	CT scan
Mayer *et al*., 2016	femoral head-neck junction structure; femoral head-neck type; femoroacetabular impingement deformity	DICHOTOMOUS: Alpha angle > 55° at 12 o'clock, 1 o'clock, 2 o'clock and 3 o'clock on radial CT scan; CONTINUOUS: Mean Alpha angle 12, 1, 2 and 3 o'clock positions (dislocation vs controls)	CT scan (radially orientated CT - 12-, 1-, 2- and 3-o'clock positions)
Mayes *et al*., 2017	(reduced) femoral head-neck junction concavity; cam morphology; hip bony morphology; abnormal morphology;	DICHOTOMOUS: Alpha angle > 50 and > 60° reported (per person); CONTUNUOS: Mean Alpha angle (anterior and superior)	3T MRI (Anterior alpha angle: anterior on the oblique axial images; Superior alpha angle: superior position on mid-cornal images)
Miguel *et al*., 2012	Presence of a bump on the femoral head / femoral head-neck transition / femoral head-neck junction (in AP, Dunn, Dunn 45° or Ducroquet radiographs)	DICHOTOMOUS: Alpha angle and the presence of a "bump" on AP pelvis; Alpha angle and the presence of a bump on Dunn view and the Dunn 45°; femoral offset, the alpha angle and the presence of a "bump" on Ducroquet view CONTINIOUS: Mean alpha angle (SD) in AP, Dunn, Dunn 45° and Ducroquet views	Radiographs (AP pelvis; Lequesne false profile; Dunn; Dunn 45 degrees; Ducroquet)
Mosler *et al*., 2018	femoral "bump"; cam morphology; bony hip morphology; cam morphology type	DICHOTOMOUS: AA > 60° on either the AP or 45 Dunn view; LARGE cam morphology: AA > 78° on AP or 45 Dunn view	Radiographs (AP pelvis and 45 degree Dunn view)
Mosler *et al*., 2016	cam deformity; bony hip morphological abnormality; head-neck asphericity; asphericity of the femoral neck	DICHOTOMOUS: alpha angle >60° in either view; large cam = alpha angle >78°; CONTINUOUS: alpha angle; triangular index	Radiographs (AP pelvis and 45 degree Dunn view)
Murray *et al*., 1971	abnormal hip architecture; minor anatomical abnormalities and the resultant incongruity of the hip; medial angulation of the femoral head in relation to the femoral neck - "tilt deformity"	DICHOTOMOUS - "Tilt Deformity" defined as FEMORAL HEAD RATIO greater / equal than 1.35 in one or both hips; CONTINUOUS: Mean femoral head ratio	Radiographs: AP Pelvis (standing)

Muthuri *et al*., 2017		Hip Mode type 2 on DEXA SCAN using statistical shape modelling: Hip Mode 2 ("scores reflect a shorted femoral neck and wider and flatter femoral head. These shapes are similar in appearance to those described for a cam or mixed FAI. Cam FAI is characterised by a thicker cortex in the lateral femoral neck resembling a 'pistol-grip' deformity, more common in men.")	posterior-anterior dual-energy X-ray absorptiometry bone mineral density images of the proximal femur recorded at age 60–64 were included in analyses. Statistical shape modelling was applied to quantify independent variations in hip mode (HM). positive HM2 scores reflect a shorter femoral neck andwider andflatter femoral head (Fig. 1a, Table S1). These shapes are similar in appearance to those described for a cam or mixed femoro-acetabular impingement (FAI) which, in turn, may indicate a higher risk of OA. A cam FAI is characterised by thicker cortex in the lateral femoral neck
Nelson *et al*., 2016		DICHOTOMOUS (Categorical): > 60° CONTINIOUS: mean (SE) are reported for White and African American cases and controls	Radiographs (AP pelvis)
Ng *et al*., 2018	cam deformity; enlarged femoral head-neck asphericity	DICHOTOMOUS: Alpha angle: Cam deformity (axial 3:00 or radial 1:30 alpha angle >50.5°or 60°, respectively, on computed tomography[CT]); CONTINUOUS: mean AA (SD) - Axial 3:00 and Radial 1:30 as well as mean femoral head-neck offset in mm	CT scan (Axial 3:00; Radial 1:30)
Ng *et al*., 2015		DICHOTOMOUS: AA greater than 50.5° (axial CT scan) or radial alpha angle greater than 60°	CT scan
Nicholls *et al*., 2011		CONTINIOUS: mean alpha angle (in control group without THA and case group with THA)	Radiographs (AP pelvis)
Notzli *et al*., 2002	Impingement by prominence at the femoral head-neck junction; deminished concavity at the femoral head-neck junction	CONTINIOUS: mean Alpha angle, SD, range; relationship between the width of the femoral neck and the diameter of the femoral head as mean ratios: T1a/r and T2a/r; (T1a + T1p)/2r; (T2a + T2p)/2r	1T (cases: MR arthrography - axial parallel to the axis of the femoral neck) and 0.5T (controls: axial parallel to the axis of the femoral neck) MRI (tilted axial passing through the centre of the head)

Palmer *et al*., 2018	cam morphology; pathological morphology; femoral morphology;	CONTINUOUS: mean alpha angle "Cam morphology was quantified using the alpha angle for bone and cartilage, which was treated as a continuous variable given there is no agreed diagnostic threshold (figure1). 19 Radiographic epidemiological studies suggest alpha angles above 60° are elevated and potentially diagnostic. 20 Cartilage alpha angle was chosen as the primary outcome measure because in the skeletally immature hip the secondary ossification centre does not accurately reflect overall hip shape"; to account for variation in the location of cam morphology, the primary outcome measure was maximum cartilage alpha angle from 11 o'clock through to 3 o'clock	3T MRI scan (radial slices at 11 o'clock, 12 o'clock, 1 o'clock, 2 o'clock and 3 o'clock)
Palmer *et al*., 2017		Cam morphology was evaluated on anteroposterior and lateral radiographs using the alpha angle and was defined as an alpha angle greater than 60° on anteroposterior radiographs; CONTINUOUS: mean AA reported at baseline and 5 year follow up	Radiographs and in the different o'clock positions on 3T MRI (mean AA correlated with Mean T1 relaxation time in different regions of acetabulum and femoral head)
Palmer *et al*., 2017	cam deformity; severe CAM-type deformity; cam-type lesions;	DICHOTOMOUS: CAM lesions defined by a mean alpha angle of > 65°. CONTINUOUS - mean AA in different groups	Radiographs: AP Pelvis
Philippon *et al*., 2013	bony overgrowth on the femoral neck; bony abnormality of the hip joint; amount of cam impingement; cam-type FAI; cam FAI;	CONTINIOUS (mean alpha angle; range) DICHOTOMOUS: alpha angle ≥ 55°	3T MRI dominant hip (oblique axial orientated along the axis of the femoral head and neck of the hip); anterosuperior region (12-3 o'clock as viewed on the right hip and 9-12 o'clock as viewed on the left hip
Phillips *et al*., 2016		When an axial oblique sequence was available, an alpha angle of greater than 55° was used as 1 criterion to determine the presence of femoroacetabular impingement. In these cases and in cases without an axial oblique sequence, other characteristic findings, in-cluding an osseous bump at the anterolateral head and neck junction, synovial herniation pits, labral tears, cartilage lesions, subchondral cysts, and subchondral bone marrow edema, were used to make a final decision about the diagnosis of cam-type femoroacetabular impingement	MRI or MRI-arthrogram

Pollard *et al*., 2013		CONTINIOUS: alpha angle and anterior offset ratios on lateral radiograph CATEGORICAL: Alpha angle greater than 62.5° or anterior offset ratio less than 0.135	Radiographs (cross table lateral)
Pollard *et al*., 2010		DICHOTOMOUS: AA > 62.5 on cross-table lateral radiograph; CONTINUOUS: mean AA	Radiographs (cross table lateral)
Pollard *et al*., 2010	cam deformity; the condition is primary / idiopathic; FAI is a three-dimensional condition;	DICHOTOMOUS: Alpha angle more than 62.5 or Anterior Offset Ratio less than 0.135. From the cross-table lateralradiograph, the alpha angle16,29-31 and anterior offsetratio16,18,31,32 were measured by saving the digital images as TIFF files, which were then analysed in a custom-designedsoftware program in Matlab version R2007a (The Math-works Inc, Natick, Massachusetts). The accuracy of thisprogram had been tested and confirmed during its development.31 Based on a previous study from our institution of 157 normal subjects using the same standardised radiological and measurement technique,31 95% referenceintervals33 for the alpha angle and anterior offset ratio were calculated and a cam deformity was defined as an alpha angle > 62.5° or an anterior offset ratio < 0.135	Radiographs (cross table lateral)
Pollard *et al*., 2010		DICHOTOMOUS: Prevalence of a high AA or a low Anterior Offset Ratio in males and females; CONTINIOUS: mean AA on lateral radiographs	Radiographs: AP and cross table lateral
Raveendran *et al*., 2018		DICHOTOMOUS: AA > 60°: "cam morphology (anteroposterior [AP] alpha angle, triangular index sign (34)). An AP alpha angle>60° (35) or the presence of a triangular index sign (34) were considered consistent with cam morphology."	Radiographs: AP pelvis (supine with feet in 15° internal rotation)
Register *et al*., 2012	Osseous bumps at the femoral head-neck junction; osseous (cam) bump; FAI bony abnormalities; hip lesions;	DICOHOTOMOUS: as osseous bump; CONTINIOUS: (mean AA)	3T MRI (oblique axial orientated along the axis of the femoral neck and head of the hip)
Reichenbach *et al*., 2010		DICHOTOMOUS: VISUAL: to determine the presence of a cam-type deformity, we graded the maximal offset at the head–neck junction on the radial sequences using a semi-quantitative scoring system that ranged from grades 0–3, where 0 = normal, no evidence of a non spherical femoral shape on any of the sequences; 1 = possible deformity with cortical irregularity and a possible mild decrease of the anterior head–neck offset; 2 = definite deformity with an established decrease of the anterior head–neck offset; and 3 = severe deformity	1.5T MRI The location of any cam-type deformity was determined in a clockwise manner, with 12:00 superior, 3:00 anterior, 6:00 inferior, and 9:00 posterior on radial sequences, with their extension recorded in hours. For example, a grade 2 cam-type deformity extended from 1:00 to 3:00 and was most pronounced at 2:00. We recorded start and end locations, the location of the maximum deformity at 2:00, and the extension of the deformity, which was 2 hours (Figure 3B).

		with a large decrease of the anterior head–neck offset. The location of any cam-type deformity was determined in a clockwise manner, with 12:00 superior, 3:00 anterior, 6:00 inferior, and 9:00 posterior on radial sequences, with their extension recorded in hours. For example, a grade 2 cam-type deformity extended from 1:00 to 3:00 and was most pronounced at 2:00. We recorded start and end locations, the location of the maximum deformity at 2:00, and the extension of the deformity, which was 2 hours. CONTINUOUS: mean alpha angle	
Reichenbach *et al*., 2011	cam-type deformities; a nonspherical extension of the femoral head and a decreased anterior head-neck offset; nonspeherical femoral shape; decrease in anterior head-neck offset	CATEGORICAL: using a semi-quantitative scoring system grading (from 0-3) the maximal offset at the head-neck junction on radial MRI sequences: 0 = normal, no evidence of a nonspherical femoral shape on any sequence; 1 = possible deformity with cortical irregularity and a possible mild decrease in the anterior head-neck offset; 2 = definite deformity with an established decrease in the anterior head-neck offset (cam deformity < 10mm); and 3 = severe deformity with a large decrease in the anterior head-neck offset (cam deformity of >10mm)	1.5T MRI (saggital oblique orientated parallel to the femoral head-neck axis)
Schaeffeler *et al*., 2012		CONTINIOUS: mean alpha angle ; SD	1.5T MRI
Scheidt *et al*., 2014	Came'-type FAI; "to acertain the anterior concavity of the femoral head-neck junction"	DICHOTOMOUS: AA greater or equal than 50°; VISUAL: aspericity of the femoral head CONTINIOUS: mean AA	Radiographs (AP pelvis; DUNN 45 degrees)
Siebenrock *et al*., 2011	cam-type deformity; cam-type impingement; morphologic features of the head-neck junction;	CONTINIOUS: mean AA in the different o'clock positions on MRI	3T MRI (radial sequence; radial planes rotated clockwise in 30°-intervals, and perpendicular to the femoral neck axis)

Siebenrock *et al.*, 2004	nonspherical femoral head; insufficiently waisted femoral head-neck junction anterosuperiorly; decreased head-neck offset; growth abnormality of the capital physis; growth disorder of the proximal femur	Head-neck offset: CONTINUOUS: On each section, the contour of the femoral head was outlined by a circle and the corresponding femoral head center was determined. The femoral neck axis was drawn as a line through the center of the head and the midpoint of the most narrow portion of the neck. The two intersection points, A and B, of the circle outlining the head con-tour and the femoral neck were determined (Fig. 4A). The points A and B represent the definite end point of hip motion in this plane and the potential location for impingement on the femoral side. Two tangents to the circle of the head contour parallel to the neck axis were drawn. A vertical line to this tangent through Point A or Point B resulted in the corresponding femoral head-neck offset distances T1A and T2B, respectively. The offset measurements were adjusted to the magnification factor in each case. With the use of eight MRI sections in each hip, this resulted in a measurement of the head-neck offset at 16 points	1.5T MRI (coronal oblique - 8 serial sections planes perpendicular to the femoral neck axis starting with the most coronal plane and rotating clockwise in 22.5° intervals around the neck axis)
Siebenrock *et al.*, 2013		CONTINIOUS: mean alpha angle in open vs closed epiphyseal growth plates at each clockwise position of the cranial hemisphere from 9 o'clock (posterior femoral head-neck junction) to 3 o'clock (anterior head-neck junction).DICHOTOMOUS: greater than 55° degrees	3T MRI
Siebenrock *et al.*, 2013	Abnormal cam-type deformity of the proximal femur; a condition in which the femoral head loses its normal sphericity, specifically at the femoral head-neck junction; head asphericity; aspherical portion of the femoral head	DICHOTOMOUS: alpha angle $\geq$ 55° CONTINIOUS: mean alpha angle (measured using the clockface system on the radial cuts at 7 defined points from 9 o'clock (posterior) to 3 o'clock (anterior) head neck junction)	3T MRI (radial sequence used to evaluate the femoral head, femoral head-neck junction, and acetabulum. Radial planes rotated clockwise in 30° intervals around and perpendicular to the femoral hed-neck axis)
Silvis *et al.*, 2011	proximal femoral morphologic characteristics	(NB: Difference between methods and results. Methods: Alpha Angle > 50° intext but results > 55°) DICHOTOMOUS: alpha angle > 55°	3T MRI (PD-weighted images aligned obliquely with the femoral neck)

Speirs *et al*., 2013		DICHOTOMOUS: The alpha angle was then measured on two images to evaluate the femoral head-neck junction anteriorly and antero-superiorly in the traditional axial oblique 11 (3:00) and 1:30 planes, respectively. Asymptomatic subjects with an alpha angle $\geq$ 50.5 measured in the 3:00 plane 15,16 or greater than 60 in the 1:30 plane were classified as 'Bump' whereas subjects with both alpha angles less than the respective thresholds were classified as 'Control'	CT Scan
Speirs *et al*., 2013		DICHOTOMOUS: The alpha angle was then measured on two images to evaluate the femoral head-neck junction anteriorly and antero-superiorly in the traditional axial oblique 11 (3:00) and 1:30 planes, respectively. Asymptomatic subjects with an alpha angle greater than or equal to 50.5 measured in the 3:00 plane 15,16 or greater than 60 in the 1:30 plane were classified as 'Bump' whereas subjects with both alpha angles less than the respective thresholds were classified as' Control'	CT Scan
Sutter *et al*., 2012		CONTINUOUS: Mean, SD AA in different o'clock positions in patient and volunteer group DICHOTOMOUS: AA > 55° in any one of the o'clock positions "Cam-type deformities at the femoral head-neck junction were defined as an alpha angle greater than 55° at any location around the femoral neck for patient inclusion"	1.5T MRI
Sutter *et al*., 2012		DICHOTOMOUS: Alpha angle > 55° in ANY location around the femoral neck	1.5T MRI
Tak *et al*., 2016	cam deformity; the presence of an aspherical femoral head;	DICHOTOMOUS: alpha angle > 60° on AP pelvis AND frog leg lateral	Radiographs: (AP Pelvis and Frog-leg lateral)
Tak *et al*., 2015	cam deformity; extra bone formation at the anterolateral head-neck junction; extent to which the femoral head deviates from being spherical	DICHOTOMOUS: Alpha angle > 60° ; Alpha angle > 78° (CATEGORICAL - 2 CATEGORIES)	Radiographs (AP pelvis and / or frog-leg lateral) Prevalence reported for each type of radiograph in the different football categories

Todd *et al*., 2016	Cam type femoroacetabular impingement; hip joint cam femoro-acetabular impingement; cam FAI; cam deformity; increased MRI morphological characteristics of hip joint cam deformity;	DICHOTOMOUS: alpha angle >55° on 1.5T MRI	1.5T MRI scan (7 radial reformats spaced clockwise in 30° intervals around and perpendicular to the femoral neck axis)
Valera *et al*., 2018		CONTINUOUS: mean AA: The alpha angle (AA) was calculated obtaining an angled axial plane parallel to the axis of the femoral neck and passing through the centre of the femoral head, on the basis of a coronal scout view. The femoral neck axis line was defined in this image (Fig. 2). The best matching circumference was then drawn over the femoral head contour. The angle was calculated between the axis, the center of the femoral head and the point where the femoral head outlines the circumference anteriorly	CT scan
Van Houcke *et al*., 2014		DICHOTOMOUS: Alpha angle > 55° (control group Alpha angle < 50°)Cam type impingement confirmed on volumetric imaging	Radiographs: AP Pelvis and 45 Dunn view (AND ARTHRO MRI FOR PATIENTS)
Van Spil *et al*., 2015		Presence of radiographic (superior) cam deformity was defined by an alpha angle threshold of > 60 on the anteroposterior radiographs, as was recently validated in the CHECK and Chingford cohorts. (Possible) Cam impingement was defined by the presence of cam deformity together with limited internal hip rotation of 20 (as measured in 90 of hip flexion), the latter being a clinical sign suggestive of cam impingement	Radiographs: AP Pelvis
Weinberg *et al*., 2016		DICHOTOMOUS: AA > 55° on MRI; CONTINUOUS: mean AA	3T MRI scan or CT
Wyles *et al*., 2017	structural hip deformity; anatomic abnormalities of the femoral head-neck junction; Cam deformities; cam-type deformities; cam lesion; maladaptive structural disorder	DICHOTOMOUS: Alpha angle > 55° on cross table lateral / axial oblique MRI; CONTINUOUS: mean AA on 3T MRI: Low Internal Rotation ROM vs Normal Internal Rotation ROM groups	Initially Radiographs (AP and Von Rosen view) but at 5y follow up cross table lateral radiographs; Alpha angles (continuous variable) also measured at baseline on 1.5T or 3T MRI and 5-year 3T MRI - axial oblique scans

Yamauchi *et al*., 2017		DICHOTOMOUS VISUAL (pistol grip deformity: "a prominent lateral offset of the femoral head-neck junction') "The PGD was defined as a prominent lateral offset of the femoral head-neck junction"	Radiographs: AP Pelvis
Yuan *et al*., 2013	structural hip deformity; decrease in hip clearance; offset abnormalities of the femoral head-neck junction; anatomic abnormalities of the femoral head-neck junction	DICHOTOMOUS: alpha angle >55°. The presence or absence of a cam-type deformity (a angle >55° on Von Rosen view and alpha angle ≥55° at the anterosuperior junction of the femoral neck at the 1:30 clock position. In table 3 - AA measured on MRI) CONTINIOUS: mean AA at 1:30 and also measure on the Von Rosen view	Radiographs: AP Pelvis and Van Rosen MRI: All participants were scanned on GE Signa MRI systems operating at 3T (21 participants) or 1.5T (5 participants) - radial sequence
Zilkens *et al*., 2013		DICHOTOMOUS: alpha angle in the Lauenstein radiograph of > 50°; CONTINUOUS: in several regions of the hip; a = anterior; a-s = anterosuperior; s-a = superoanterior; s = superior; s-p = superoposterior;p-s = posterosuperior; p = posterior	Radiographs: standard pelvic AP and a Lauenstein radiograph

B.3 Antecedents and consequences of primary cam morphology

Themes / Categories	**Subthemes / subcategories**	**Codes: Definition terminology used**
Antecedents: Time point (age) of development	Adolescence / childhood / maturation / young adulthood / during skeletal growth	developmental deformity – its expression in young adulthood may be triggered by environmental factors such as high-level sports activity during childhood and around the time of closure of the capital growth plate [150]; bony adaptation in response to high-impact sports practice during skeletal growth [158]; effect of hip loading during bone growth on the formation of a cam deformity [158];
Antecedents: Causal/ other risk factors	Primary or idiopathic [139]	Increased extension of the physeal scar and a lateral extension of the femoral head epiphysis onto the neck [149]; growth abnormality of the capital physis / growth disorder of the proximal femur [149]; “the longer lateral extension of the epiphysis into the neck that we frequently noticed indicates that a growth abnormality of the epiphysis due to the high shear

		stresses applied on the proximal femoral epiphysis might be a cause of a cam-type deformity" [62]; This growth abnormality might be caused by a delayed separation of the common physis between the femoral head and the greater trochanter or by a structural adaptation of the epiphysis to resist the higher demands of the proximal femur [62]; A cam deformity developed and continued to evolve over time in adolescent hips with an open growth plate at baseline [13]; a cam deformity is gradually acquired and probably only during skeletal maturation [13]; cam morphology exclusively present in closed physeal group strongly supports its development during the period of physeal closure with increased activity level as a possible risk factor [75]; developmental phenomenon [75]; strong association between activity level and the development of proximal femoral head-neck morphology [75]; "properties inherent to ice hockey likely enhance the development of a bony overgrowth on the femoral neck, leading to cam FAI" [137]; repeated subclinical physeal injury due to the unique stress placed on the hip as a result of ice hockey skating motion [137]; soft tissue hypertrophy at the head-neck junction preceded epiphyseal extension and osseous cam morphology [60]; epiphyseal hypertrophy and extension represented the salient mechanism of cam development in this cohort [60]; the relationship between epiphyseal extension and alpha angle is particularly weak in females where alternative cam development pathogenesis may dominate, such as asphericity secondary to dysplasia [60]; cam morphology at 3 o'clock appeared more frequently dictated by femoral neck retroversion than epiphyseal morphology [60]; "Our large cohort provides strong evidence that high activity levels during adolescence promote cam development secondary to epiphyseal extension with a dose-response relationship" [60]; Repetitive high-intensity hip loading during sport played throughout a critical period of hip development may be the salient risk factor for cam development [60]; "we speculate that the cumulative effect of high stresses and perhaps more or less subtle differences in the direction of loading on the proximal femur during growth may modulate growth and abnormal shape" [150]; developmental deformity – its expression in young adulthood may be triggered by environmental factors such as high-level sports activity during childhood and around the time of closure of the

		capital growth plate [150]; bony adaptation in response to high-impact sports practice during skeletal growth [158]; probable dose-response relationship between the frequency of football practice during skeletal growth and the development of 'cam deformity' [158]; higher prevalence of cam deformities was found in players who report starting high-frequency football training before 12 years of age – this suggests a dose-response relationship of football during skeletal growth [158] Measurement: 3-T MRI 3-dimensional True FISP (true fast imaging with steady-state precession) sequence to assess the status of the epiphyseal growth plate [152]; Activity: frequency of football practice during adolescence (football club implied as maximum 3x/week; professional club at least 4x/week), the age at which they started playing football and the leg dominance [158];
Consequences	i. Femoroacetabular (FAI) impingement ("cam impingement") ii. Limited hip range of motion iii. FAI syndrome (symptoms: pain, stiffness, other) iv. Soft tissue damage: labral; chondral v. Osteoarthritis vi. Other a. Diminished posterior pelvic tilt approaching maximum squat depth b. Decrease in mean hip extensor moment	FAI of the cam type [76,111]; cam-type FAI [61,64,75,95,114,118,123,137,152]; hip joint cam-type FAI [61]; hip joint cam femoro-acetabular impingement [160]; 'came'-type FAI [148]; cam FAI [64,71,105,107,132,137,160]; cam impingement [62,68,70,104,105,115,116,146,150]; CAM-impingement FAI [68]; cam-type impingement [70,95]; cam type femoroacetabular impingement [160]; impingement by prominence at the femoral head-neck junction [134]; amount of cam impingement [137]; limits the physiological range of motion, typically flexion and internal rotation [70]; the femoral head-neck morphology influences the hip's ROM with smaller alpha angles being associated with greater internal rotation [75]; decreased internal hip rotation [67]; less but non-significant internal rotation in hips with cam deformity [159]; "On average, the cam FAI group had approximately 6° less hip internal rotation compared to the control group" (decreased peak hip internal rotation during squat) [71]; "A post-hoc analysis of the data obtained in the current study revealed that the degree of cam morphology and peak hip internal rotation during the deep squat task were inversely correlated (R = 0.48; P = 0.04). We postulate that cam morphology may be limiting hip internal rotation in persons with cam FAI during squatting. However, further research is

		needed to confirm this hypothesis." [71] "Despite the diminished peak hip internal rotation observed in the cam FAI group, there was no difference in the mean hip external rotator moment between groups. Therefore, it can be indirectly inferred that the observed decrease in peak hip internal rotation may be due to factors other than external rotator muscular control. This suggests that bony abutment may have contributed to the diminished hip internal rotation observed in the cam FAI group." [71] Groin pain [152]; T1ρ – mapping: T1ρ can detect early chondral damage in asymptomatic hips with dam deformity [65]; Individuals with an asymptomatic cam deformity exhibit prolonged T1ρ relaxation time compared to normal hip suggesting PG depletion. This may reflect early cartilage degradation possibly predisposing to eventual osteoarthritis [65]; Anwander assessed T1ρ values in six hip joint regions of interest (ROI) reflecting "the known anatomic regions of the hip preferentially damaged in cam FAI seen at surgery mainly in the lateral third of the cartilage and in the anterosuperior quadrant". T1ρ relaxation time was prolonged in the lateral and medial thirds of the anterosuperior quadrant of the hip; this is consistent with the "pathomechanism of cam FAI". [66] T2-mapping: (analysing the degree of collagen fibers organization in the cartilage (Ronga M, 2014 – reference 27 in ANwander, 2016); Delayed gadolinium-enhanced magnetic resonance imaging of cartilage (dGEMRIC): (assessing loss of proteoglycan in cartiage) (Ronga M, 2014 – reference 27 in ANwander, 2016); Osteoarthritis:, Patients with cam deformity and decreased internal rotation were at significantly higher risk of developing end stage osteoarthritis (odds ratio 25.21) in a large cohort of individuals with early onset hip pain with osteoarthritis [12,35]* *These articles are not part of the 111 included articles Other: "Persons with cam FAI also exhibited diminished posterior tilt of the pelvis as participants approached their maximum depth, resulting in a relatively more anteriorly tilted pelvis at the time of peak hip flexion

		compared to the control group."; "significant decrease in the mean hip extensor moment was found in the cam FAI group. One possible explanation for the decreased hip extensor moment could be decreased utilization of the hip extensors to accomplish the squat task. In particular, decreased activation of the gluteus maximus and/or hamstring muscles could have contributed to the lack of posterior pelvis tilt. Hypothetically, relative posterior tilt of the pelvis during this phase of squatting would limit the potential for impingement in the presence of cam morphology" [71]

C Chapter 3 appendices

No chapter 3 appendices.

D Chapter 4 appendices

D.1 Ethics approval

MEDICAL SCIENCES INTERDIVISIONAL RESEARCH ETHICS COMMITTEE
Research Services, University of Oxford, Wellington Square, Oxford, OX1 2JD
Tel: +44(0)1865 616577
ethics@medsci.ox.ac.uk

UNIVERSITY OF OXFORD

CONFIDENTIAL

Dr Paul Dijkstra
Nuffield Department of Primary Care Health Sciences
University of Oxford
Radcliffe Primary Care Building
Woodstock Road
Oxford

4 March 2021

Dear Dr Dijkstra,

Research Ethics Approval - CUREC 1

Ethics Approval Reference: R73576/RE001

Study title: An international Delphi study on a more rigorous and evidence-based approach to research on primary cam morphology

The above application has been considered on behalf of the Medical Sciences Interdivisional Research Ethics Committee (IDREC) in accordance with the procedures laid down by the University for Ethical Approval of all research involving human participants.

I am pleased to inform you that, on the basis of the information provided to the IDREC, the proposed research has been judged as meeting appropriate ethical standards, and approval has been granted for a period of **21 months**, commencing on **4th March 2021.**

Approval is **subject to:**

a) **you following the BPS guidelines for online research**

b) **the PI agreeing to comply with the requirements for administering any tests or questionnaires and, if in doubt, to contact the publisher of those tests or questionnaires**

c) **the PI ensuring that, where new research staff are engaged, they are suitably qualified by training and/or experience.**

I would like to remind you that your study may be selected for review for the purposes of monitoring and/or audit.

Amendments

Should there be any subsequent changes to the study, you should submit details to the MS IDREC for consideration and approval. Details of changes must be listed on an amendment form.

Yours Sincerely

H. Barnby-Porritt

Dr. Helen Barnby-Porritt
Research Ethics Manager, Medical Sciences

D.2 Conference presentations

Canadian Arthritis Research Conference – February 2022

October 29th, 2021

Dear Dr. Paul Dijkstra,

Thank you for joining us as a presenter at the virtual Canadian Arthritis Research Conference on February 7 and 8, 2022. This third annual conference is led in partnership by Arthritis Society (AS), Canadian Rheumatology Association (CRA) and Canadian Institutes of Health - Institute of Musculoskeletal Health and Arthritis (CIHR-IMHA).

The Canadian Arthritis Research Conference provides a unique platform for the arthritis research communities from across Canada to collaborate and share learnings among clinicians, scientists, patients and stakeholders nationally and internationally. The goal is to improve the health of Canadians in the mandate areas of the three lead organizations under three themes:

1) Patient-oriented arthritis in research
2) Precision medicine in arthritis
3) Sexual and reproductive health in arthritis

The conference will run from **11:40 AM ET to 4:30 PM ET on Monday, February 7** and from **11:50 AM ET to 4:30 PM ET on Tuesday, February 8, 2022**, after the Canadian Rheumatology Association Annual Scientific Meeting.

Here are your session details:

PRESENTATION

Session Title & Topic:
Primary cam morphology: an international agreement on terminology, taxonomy and definitions
Date: February 8, 2022
Time: 12:30 – 12:55 ET
Panel: Ask Me Anything Time: 13:45 – 14:00 ET (attendance mandatory)

It is important that we keep to this timeline to maintain the conference schedule.

A **requirement of the Royal College for accreditation** involves a minimum of 25% interactivity incorporated into each presentation. Interactivity considerations for virtual learning activities include:

- Audience polling questions
- Question and answer time

FINANCIAL INCLUSIONS

The following will be provided to you:

- $500 CDN honorarium for presentation (a link will be provided to you after the conference to claim the honorarium)

La Trobe Sport and Exercise Medicine Hip and Groin Symposium – June 2022

"Hip and Groin pain: what's the latest evidence?"

Friday 17th June, 2022

2:45-3:00pm		REGISTRATION
		Session 1: Consensus update *(Chair: Andrea Mosler)*
3:00	Kay Crossley	LASEM hip/groin research projects: past, present, and future
3:15	Joanne Kemp	Physiotherapist-led or surgical treatment for FAI Syndrome?
3:45	Adam Weir	Classifying groin pain – An update on using the Doha agreement
4:15	Paul Dijkstra	Communicating your findings - Terminology in hip and groin pain
4:35	Joshua Heerey	Hip osteoarthritis in the athlete
4:55		PANEL QUESTIONS/DISCUSSION
5:10-5:30		TEA/COFFEE
		Session 2: Hip/groin pain in athletic populations *(Chair: Mark Scholes)*
5:30	Roald Otten	Non-surgical management of inguinal-related groin pain
6:00	Julie Jacobsen	Assessment and management of acetabular dysplasia
6:30	Sue Mayes	Hip and groin pain in the elite dancer
6:50	Andrea Mosler	Preventing groin pain in athletes
7.10pm		PANEL QUESTIONS/DISCUSSION
7:30-8:30pm		REFRESHMENTS AND NETWORKING

Saturday 18th June, 2022

8:30-9am		REGISTRATION
		Session 3: Breaking research updates *(Chair: Joshua Heerey)*
9:00	Mark Scholes	Running biomechanics in athletes with hip and groin pain
9:15	Peter Lawrenson	Muscle morphology and activation in the hip and groin region
9:30	Rachael Cowan	Navigating greater trochanteric pain syndrome in clinic
9:45	Michael O'Brien	Impairments in people with hip dysplasia
10:00	Matt King	Is hip/groin pain different between men and women?
10:15-10:30		PANEL QUESTIONS/DISCUSSION
10:30-11am		MORNING TEA

MORNING WORKSHOPS

All Saturday participants can attend all workshops, with two workshops being run simultaneously each session. Attendees will separate into 2 groups, completing 2 two workshops in Sessions 4 & 5, before completing the remaining two workshops in Sessions 6 & 7.

WORKSHOPS A, B (60 mins each) [Run in Physio Prac rooms]	
Session 4: 11:00am-12:00pm	**Session 5: 12:10pm-1:10pm**
Workshop A	Josh Heerey/Michael O'Brien - Imaging
	Change Over (10 mins)
Workshop B	Mark Scholes/Andrea Mosler - Groin assessment
1:15-2:00pm	**LUNCH**

AFTERNOON WORKSHOPS

WORKSHOPS C, D (60 mins each) [Run in Physio Prac rooms]	
Session 6: 2:00-3:00pm	**Session 7: 3:15-4:15pm**
Workshop C	Joanne Kemp/Peter Lawrenson/Josh Heerey - Management of hip pain
	Change Over (10 mins)
Workshop D	Rachael Cowan/Anthony Nasser - Lateral and posterior hip pain
	Change Over (10 mins)
4:25-4:45 Close (Lecture Room) Andrea Mosler- summary of symposium and presentation of gifts	

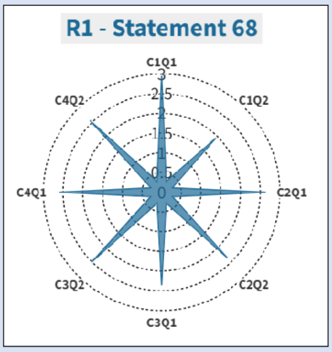
E Chapter 5 appendices

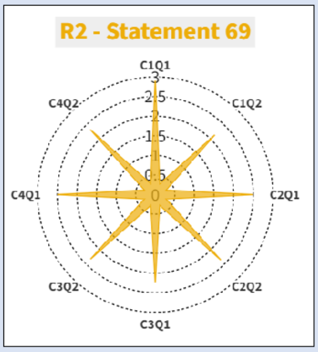
E.1 ENHR ranking exercise results

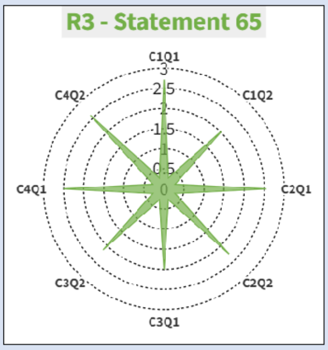
Statements ranked 1 to 18 – average criterium scores and their associated star plots for each statements published in BJSM as Data supplement 5, Table 5.1 (Appendix figure E-1)

SUPPLEMENTARY FILE 9
***ENHR ranking exercise: average criterium scores for statements 68, 69 and 65, ranked 1st to 3rd of 18**

Statement Detail	C1Q1	C1Q2	C2Q1	C2Q2	C3Q1	C3Q2	C4Q1	C4Q2	Rank
R1 - Statement 68: Randomised controlled clinical trials to investigate what best practice physiotherapy is (e.g. in different populations and settings; pre- and post-surgery)	2.95	1.95	2.64	2.36	2.36	2.51	2.60	2.57	1
R2 - Statement 69: Studies to determine the best criteria for rehabilitation progression and Return To Sport (RTS) following management of hip-related pain	2.90	2.15	2.48	2.36	2.23	2.33	2.50	2.34	2
R3 - Statement 65: Randomised controlled clinical trials to investigate how exercise intervention influences the development and prognosis of femoroacetabular impingement syndrome in cohorts with variable loading demands	2.71	2.05	2.55	2.29	2.00	2.15	2.51	2.59	3







Category (C)	Question (Q)
1. Appropriateness: should we do the research?	1. Is the planned research ethically and morally acceptable? (C1Q1)
	2. How adequate is any available research-based information on the topic? (C1Q2)
2. Relevancy: why should we do the research?	1. How much does research in this area contribute to better equity in health and serve the community concern or demand? (C2Q1)
	2. What is the size and severity of the problem? (C2Q2)
3. The chances of success: can we do the research?	1. How adequate is the capacity of the system to undertake the research in terms of competency, infrastructure, support system, mechanisms and resources? (C3Q1)
	2. How justifiable is the cost running this project? (C3Q2)
4. Impact of the research outcome: what do the stakeholders get out of the research?	1. What are the chances of the recommendations being implemented? (C4Q1)
	2. How much impact will this research have on health of the population? (C4Q2)

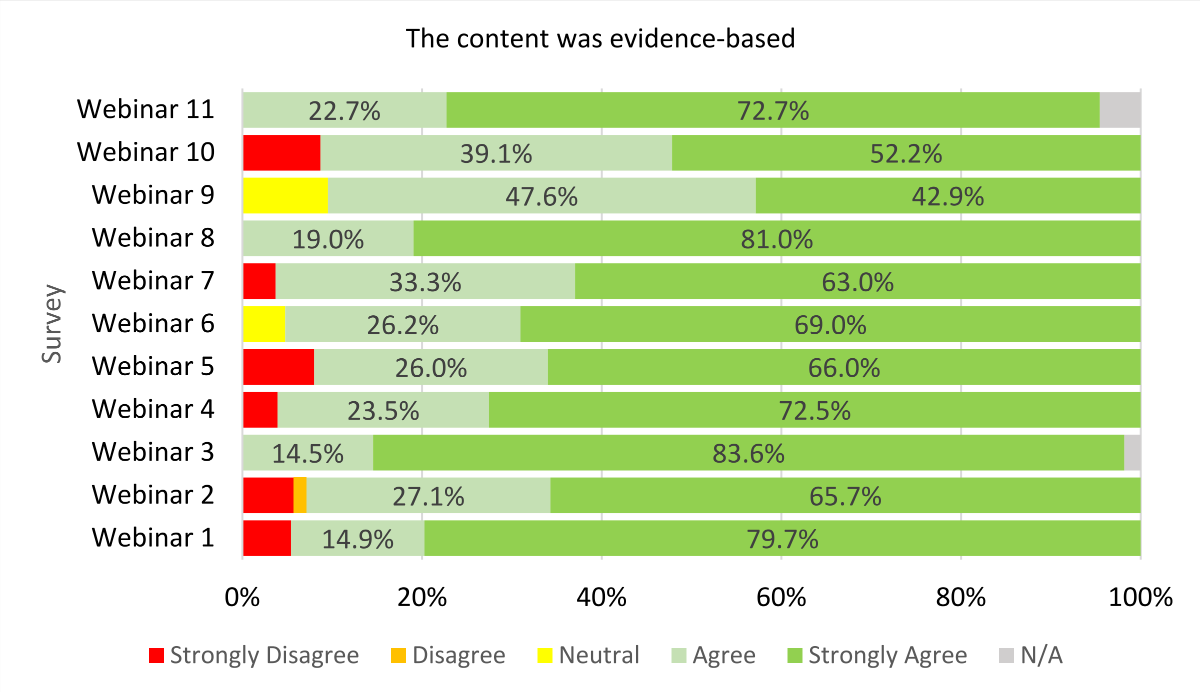
* Essential National Health Research

Appendix figure E-1. ENHR ranking exercise: average criterium scores for statements 68, 69 and 65 (ranked 1st to 3rd of 18 prioritised statements)

E.2 Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series survey results

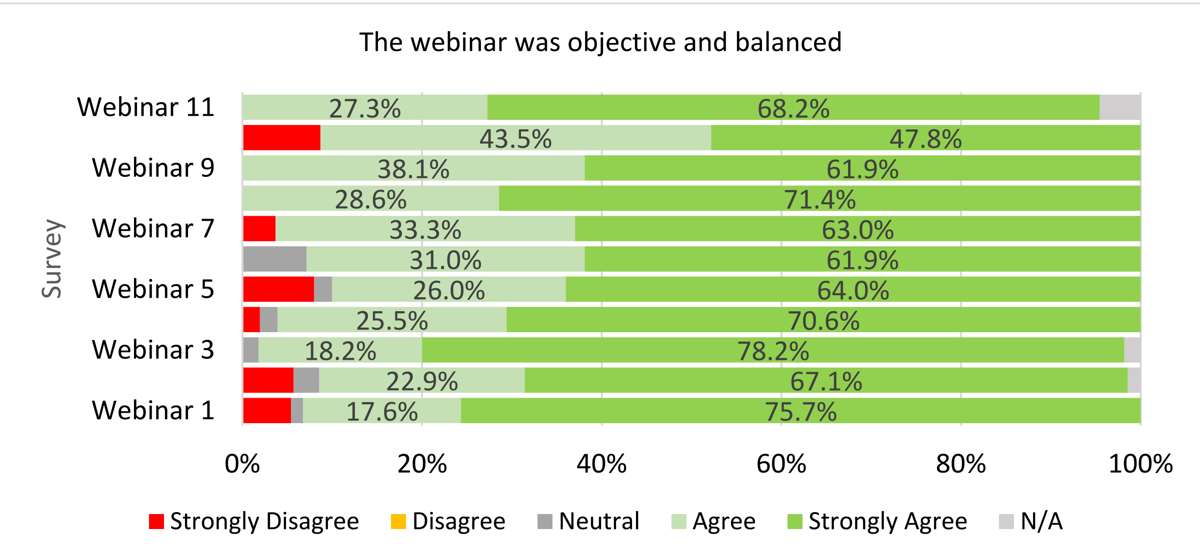
E.2.1 Quantitative results

The content was evidence-based



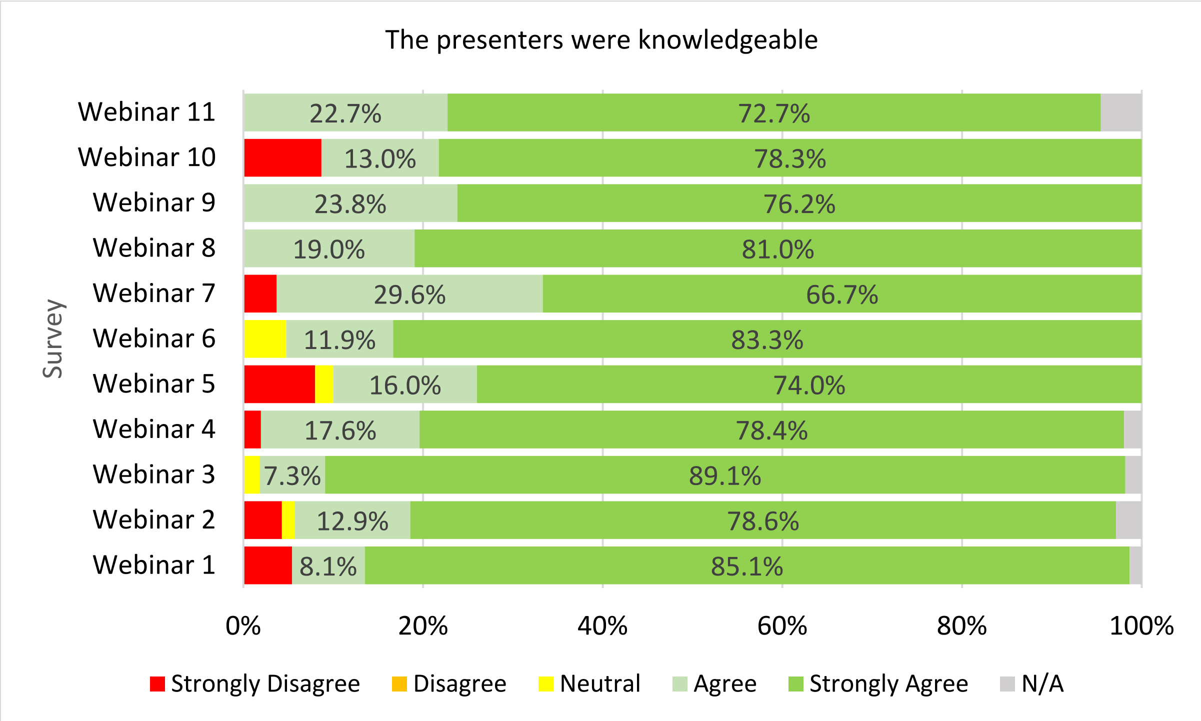
Appendix figure E-2. Participants' Likert scale responses, for each webinar, to the statement: 'The content was evidence-based'

The webinar was objective and balanced



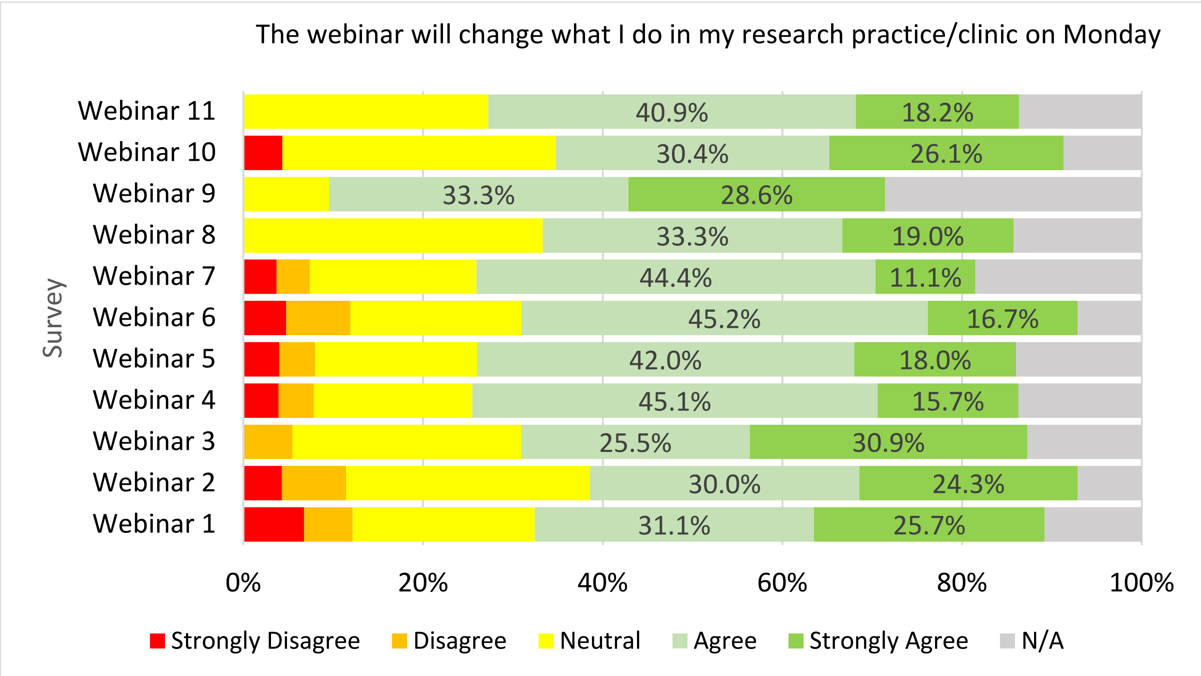
Appendix figure E-3. Participants' Likert scale responses, for each webinar, to the statement: 'The webinar was objective and balanced'

The presenters were knowledgeable



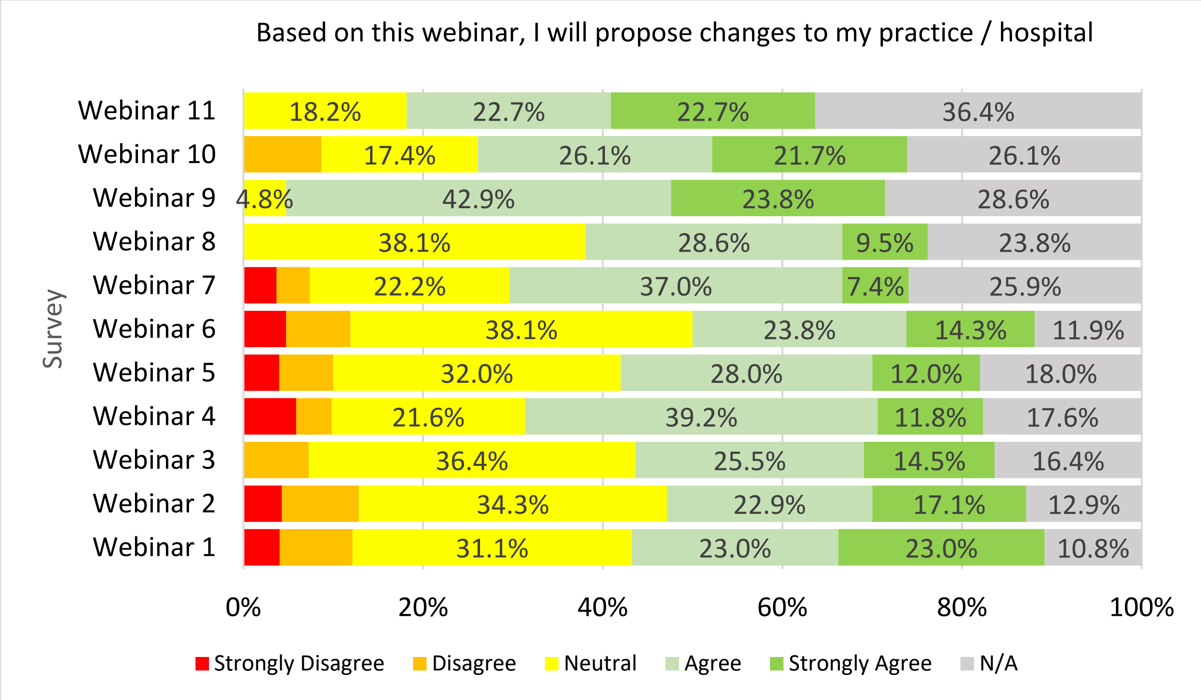
Appendix figure E-4. Participants' Likert scale responses, for each webinar, to the statement: 'The presenters were knowledgeable'

The webinar will change what I do in my research practice/ clinic on Monday



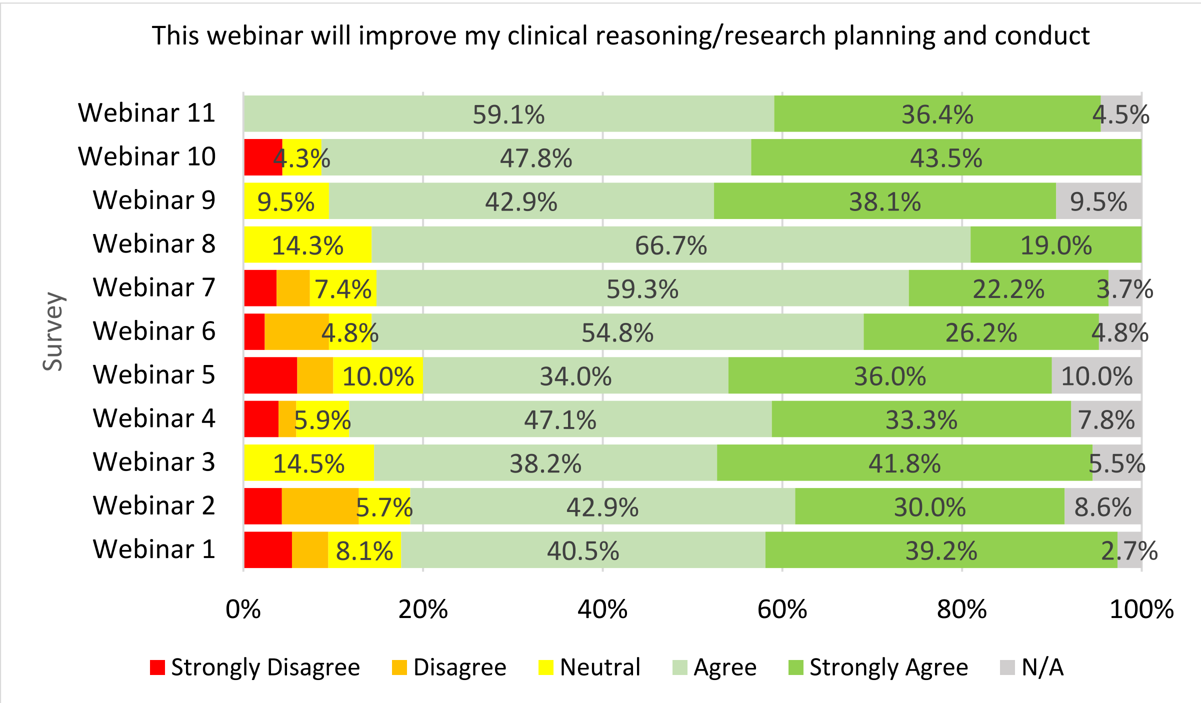
Appendix figure E-5. Participants' Likert scale responses, for each webinar, to the statement: 'The webinar will change what I do in my research practice/clinic on Monday'

Based on this webinar, I will propose changes to my practice / hospital



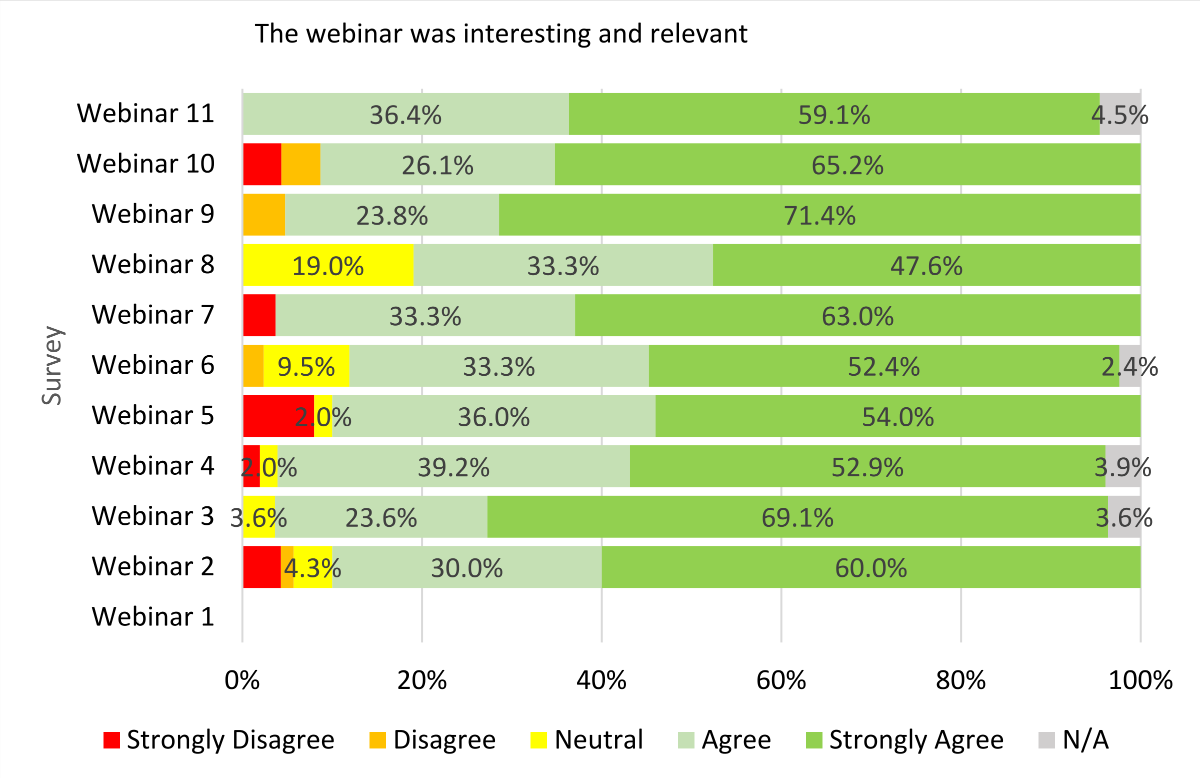
Appendix figure E-6. Participants' Likert scale responses, for each webinar, to the statement: 'Based on this webinar, I will propose changes to my practice/ hospital'

This webinar will improve my clinical reasoning/ research planning and conduct



Appendix figure E-7. Participants' Likert scale responses, for each webinar, to the statement: 'The webinar will improve my clinical reasoning / research planning and conduct'

The webinar was interesting and relevant



Appendix figure E-8. Participants' Likert scale responses, for each webinar, to the statement: 'The webinar was interesting and relevant'

E.2.2 Qualitative results

Webinar 1	• Although the webinar was exceptionally presented by the three speakers on November 20, I would recommend additionally invite a player (maybe famous) to talk about their experience involving a CAM morphology and how their experience was whilst carrying along with the process of treatment till they return to play. It would be much clearer to other listeners as well as the speakers to note important points and focus on preventing the injury in less time frame. • Very good seminar and start of the Webinar series • As a student of exercise science and clinical physiology would be very appreciate any material of what we spoke or a series of papers available to deepen the knowledge just after the webinar. But thank you for dr. Sion for his great presentation. • Excellent webinar! • Thank you to all the speakers for this high quality webinar. I am very enthusiastic about the rest of the course given the quality of the content today. • simple, clear. go on. • Really effective and engaging despite not being in person. Thank you! • no comments, looking forward to next webinar • Thanks for a great webinar. It was good to highlight the four key papers at the start of the talk. Looking forward to the next one. • Overall an excellent presentation

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- Thanks
- The content was great. The program would benefit from interaction so people immediately practice what they have heard. You could plant someone to lead with questions as well. Possibly a slide with photos of those who are involved , introduced, but not present. A very short lead into next seminar
- I thought it was excellent. I have said that it won't change my practice because I feel that I am currently working in a similar way to that which was presented. So what I have watched today confirms my practice. The graph on alpha angle and progression to OA was particularly interesting/startling.
- clear and concise presentations of clinically relevant information
- Great work Paul and team!
- Well balanced webinar. Interested in attending the next one
- Too early to provide any relevant feedback. 1st Webinar was an introduction to the whole course and i m looking forward to the upcoming webinars to have a better judgement.
- Clear & concise well delivered.
- Generally very clear webinar.

Participants joined live from 21 countries: Australia, Austria, Belgium, Canada, Denmark, France, Greece, Hungary, Iceland, Ireland, Italy, Jordan, Latvia, Netherlands, Portugal, Qatar, Serbia, Switzerland, UAE, UK, USA
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<tr><td>Webinar 2</td><td>

- It would have been useful to discuss the role of arthrography, particularly in relation to labral tears
- I'm very enthusiastic of this webinar series. All these knowledge will give me a deep perspective of the hip anatomy and primary cam morphology for my forthcoming thesis.
- Great content - looking forward to the next!
- Thanks for the invitation to follow the webinar.
- Thank you
- Excellent webinar
- As a clinical researcher primary focused on PROMS, clinical examinations and assessment of hip muscle strength and performance-based function, my knowledge on radiology is a bit limited. However, I did learn a lot even though some of the specific measures were challenging to understand and remember.
- Some overlap between speakers was noted
- Very helpful to have insight that data collected in research projects is not always realistic to be collected or assessed to the same degree in every day clinical practice, yet research data is highly valuable to guide clinical practice. Good to gain insight into pro's and cons of different imaging- important to gain different angles of view. The parent's perspective made the athlete more 'real' and not just a trial subject.
- Thanks
- This is a very interesting and informative webinar
- As a PT that does not do research, this was a good introduction to higher level thinking regarding imaging, but it is not something I feel I have a good understanding of yet. I think I will have to read and reread the course documents to begin to grasp this topic.
- excellent clarity provided with respect to imaging clinical measures, supported by relevant and clear images
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	• as a nq physiotherapist this was a bit more technical that I expected • Great work! Thanks Paul and others. • very well run technically - speakers on multiple contitnets and all went smoothly - great! • Very well delivered. • Good webinar. As a lay person I did not quite manage to follow all the content. Participants joined live from 22 countries: Australia, Austria, Bangladesh, Belgium, Denmark, France, Greece, Hungary, Iceland, Ireland, Italy, Jordan, Kuwait, Netherlands, Portugal, Qatar, Serbia, Switzerland, Turkey, UAE, UK, USA
Webinar 3	• Really enjoyed all these talks- thank you. • Thank you for all the material and effort to provide this astonishing webinar series. • Thank you • Thank you for this really high quality webinar • Thanks • Very nice figures - however, I already answered these questions. I think there is a mistake as I should have been aswering questions from webinar 3 and not 2. • Excellent. • Great speakers and chairs. Right length of time for the session. Short break works well. Great to have slides to refer back to on canvas. Overall IT has been good allowing for slick presentations. Really enjoying this series of talks. • Thanks • As a physiotherapist I am finding the content is more for radiographers/consultants so far • I like that it is made clear that the majority of studies in this field is on male athletes, and maybe especially male football players. Makes me wonder if being male is a real risk factor, or if it is more related to load. That if girls would train as much as boys between the age of 10 and 13 - we would see the same development of cam morphology? Just a thought. • Some of the measuring parts feel less relevant to me and changing my practise... especially the MRI measurements. I appreciate the audience may disagree... the load management part I think is crucial Participants joined live from 20 countries: Australia, Austria, Bangladesh, Denmark, France, Hungary, Iceland, Italy, Jordan, Latvia, Netherlands, Portugal, Qatar, Serbia, Spain, Switzerland, Turkey, UAE, UK, USA
Webinar 4	• Voice recordings of Jason was lacking quality. • The session was huge. Dr. Agricola is as always top notch clinical representative. And the overdiagnosis topic was so relevant. Can’t wait for the next webinar. • Interesting presentations • Thank you • Great presentation • It was great Clare involved the participants from the chat. • Excellent webinar! • go on, very interesting • Another great webinar, thank-you! • thanks

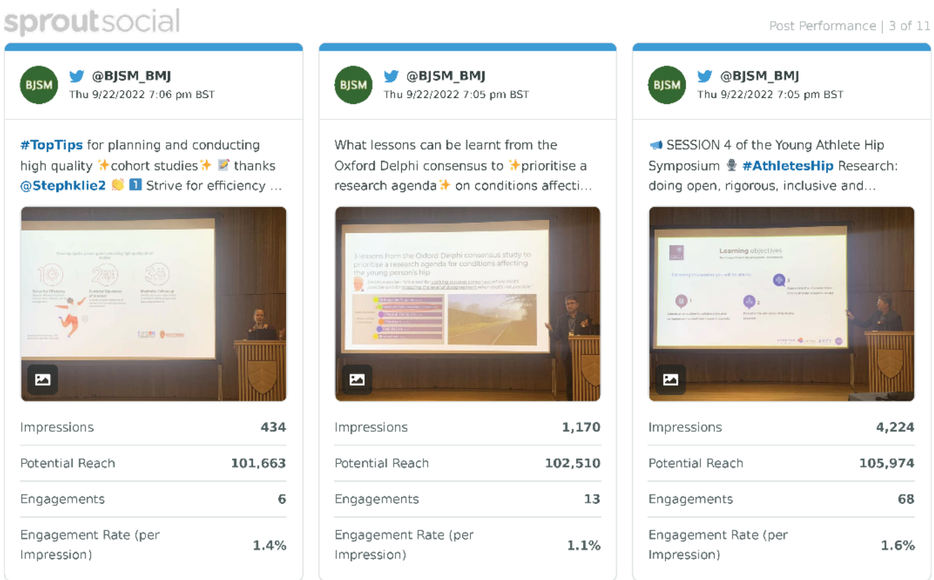
	• Can I check as screening to me does not mean imaging...? As I screen and notice any restrictions but do not image... Participants joined live from 21 countries: Australia, Austria, Bangladesh, Belgium, Canada, Denmark, France, Hungary, Iceland, Ireland, Italy, Japan, Jordan, Latvia, Netherlands, Portugal, Qatar, Serbia, Switzerland, UK, USA
Webinar 5	• No further comment • Thank you and can't wait for the new session, Kind Regards • Great interventions, the presenters are really competent. • Thank you • I may be biased as I was the first presenter. • Failing the questions is my bad, not the speakers' fault! Thanks for the webinar! • Thanks Participants joined live from 20 countries: Australia, Austria, Bangladesh, Canada, Egypt, France, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Netherlands, Norway, Portugal, Qatar, Serbia, Switzerland, UK, UAE
Webinar 6	• Given the increasing evidence of horrendous human rights abuses and the huge number of avoidable deaths in Qatar, I think it's very insensitive to be promoting anything in the country (even if you argue that academia and medicine are not directly involved). • Please consider cutting ties with Qatar institutions. Footballers themselves have had the guts to call it out. Health professionals should do the same. " • Thank you for this great session • Thank you • Thank you • I struggle to understand the need to answer specific questions regarding reported findings from studies. Is the questionnarie designed to give feedback to you or the presenters or something else? • I am looking at the recording, therefor my comment may not be relevant. However, the webinar series is great and the presentations are outstanding. However, at this time the same content seems to be repeated between presenters and sessions. • Great talk , enjoyed the presentation • Great presentations.. • unable to answer last few questions due to missing presentation • The webinar was very good. Research is very important to present. I do wonder if perhaps it would also be useful to look at some case studies to demonstrate points made because these usually teach us more about what is going on in the real world as compared to clinical studies. • I think the survey should come after the webinar not before, to enable us to answer the questions Participants joined live from 19 countries: Australia, Bangladesh, Egypt, France, Hungary, Ireland, Japan, Jordan, Latvia, Netherlands, Norway, Portugal, Qatar, Serbia, South Africa, Switzerland, UAE, UK, USA
Webinar 7	• Well planned and chaired webinar • Thank You • Thank you • Thank you, this is an excellent series! • Great talk

	• Thank you for an excellent webinar • The discussion with Marc Philippon was interesting, however, a bit long then followed by the panel discussion. • There seemed to be a push for early surgery (after only 6 weeks of rehab) by the surgeons on the panel which seemed to contradict a lot of the evidence which indicated that only after 3 months can we expect significant change. Participants joined live from 15 countries: Austria, Bangladesh, Egypt, France, Hungary, Jordan, Netherlands, Norway, Portugal, Qatar, South Africa, Switzerland, UAE, UK, USA
Webinar 8	• Thank you for getting me involved in this study. • Thank you • Great presentation by Dr. Bekker Participants joined live from 13 countries: Australia, Denmark, France, Hungary, Ireland, Italy, Japan, Kuwait, Qatar, South Africa, Turkey, UAE, UK
Webinar 9	• This was an enlightening webinar. Thank you. • Thank you • Really nice and excellent webinar that opened my eyes to see how important patients perspective is. • Great presentation on PPI in the development of PROMs. • NA • V good webinar. Quite accessible even for a lay person like me. Participants joined live from 16 countries: Bangladesh, Brazil, Canada, France, Ireland, Italy, Jordan, Kuwait, Netherlands, Qatar, Serbia, South Africa, Turkey, UAE, UK, USA What words would you use to describe successful & meaningful partnerships with patients and the public in research? ✓ Fruitful and insightful ✓ REWARDING, RESPECTFUL ✓ Health expectations, cost effective ✓ committed to working in partnership; connect and share; inclusion & diversity ✓ Creating confidence ✓ imperative ✓ Share - cooperation. - a must ✓ More openness and need information have to provide clear word for better understanding ✓ Empathy in digits ✓ Accuracy ✓ mutual benefit ✓ Respect, collaboration, understanding ✓ Collaboration ✓ communication, flexibility, honesty, understanding ✓ Shared, informed ✓ optimizing relevance of research projects and reducing research waste. ✓ excellent collaboration, engagement ✓ trust, empathy, patience, transparency ✓ Commitment ✓ Collaborative, cooperative, trust, productive
Webinar 10	• Thank You

	• Thank you • Great work! • Excellent webinars and disussions. • I prefer to use the term "cam morphology" and not divide it into primary and secondary. I am affraid treatment for patients with FAIS with secondary cam morphology may be to aggressive. • Very interesting! Thank you Participants joined live from 18 countries: Australia, Austria, Belgium, Canada, Egypt, Greece, Ireland, Japan, Netherlands, Norway, Portugal, Qatar, Serbia, South Africa, Switzerland, UAE, UK, USA
Webinar 11	• thanks for this great webinar series • Thank you for this incredible year at Yahir at Oxford. • Thank you • I couldn't watch the recording of this webinar, although I tried in Oxford website. Please let me know how to see in Oxford website. • Excellent series! Participants joined live from 18 countries: Australia, Austria, Belgium, Canada, Egypt, France, Greece, Ireland, Jordan, Netherlands, Portugal, Qatar, Serbia, South Africa, Spain, Switzerland, UK, USA

E.3 Young Athlete's Hip Symposium

Social Media Impact – example of Tweet report received from BJSM social media



Appendix figure E-9. Social media impact – Young Athlete's Hip Symposium

Symposium endorsement – International Federation of Sports Medicine

FÉDÉRATION INTERNATIONALE DE MÉDECINE DU SPORT
INTERNATIONAL FEDERATION OF SPORTS MEDICINE

THE PRESIDENT

Our ref Pres. 07-2022FP/fp

Lausanne, 7 September 2022

Dr. Hendrik Paulus Dijkstra
Chairman
Oxford Young Athlete's Hip Symposium

via e-mail: hendrik.dijkstra@conted.ox.ac.uk

Re: Oxford Young Athlete's Hip Symposium: request of the FIMS Patronage

Dear Dr. Dijkstra, Dear Colleague,

Following your request I am pleased to grant the patronage of the International Federation of Sports Medicine (FIMS) to the Oxford Young Athlete's Hip Symposium and Research meeting, which will be held from 22 to 23 September 2022 in Worcester College, Oxford and send you my best wishes for the success of this initiative.

Yours sincerely,

Prof. Fabio Pigozzi

Fédération Internationale de Médecine du Sport
International Federation of Sports Medicine
Maison du Sport Internationale
Av.de Rhodanie 54 CH-1007 Lausanne
e-mail: headquarters-ch@fims.org

Appendix figure E-10. Official letter from the president of the International Federation of Sports Medicine (FIMS) endorsing the *Young Athlete's Hip Symposium*

E.3.1 Qualitative feedback

<table>
<tr><td>Symposium</td><td>

- I would prefer fewer presentations of longer duration.
- Practical “hands-on” sessions prior to the main symposium :
  - - how to read a pelvis and hip radiograph
  - - 5 top tips on PT in FAI
- 5 minute presentations were perhaps a little TOO concise! I’d prefer slightly longer and felt this was feasible as there was occasionally a little overlap. Fantastic event though.
- Not yet, need to view am session
- VERY WELL-ORGANISED AND COMPREHENSIVE. ALSO EXCELLENT VARIETY OF REFRESHMENTS.
- N/A
- Make sure the presenters are speaking into the microphone as well as repeating the questions, so the people listening online can hear.
  - I liked the one slide presentations to a certain extent but I think these should be mixed into traditional didactic lectures at times as well...
- Maybe a session led by clinicians dealing with immature athletes would prompt research ideas relevant to the clinical setting
- Use of slido or something similar would potentially allow for more interactivity from online attendees
- Very well organised
- It was a very interesting subject
- Nil
- Perfectly ogranised. No comments.
- Watching on-line I felt (5 minute) presentations followed by interactive discussions worked very poor. It was a stressfull presentation of some cases leading up to the different presentations in each session. However, there was no follow-up on these cases or specific discussion regarding those cases.
- I enjoyed the fact that everyone's questions were addressed. Great to see everyone is open to feedback - massive learning opportunity. Very good to include a topic about leadership skills / team work, something that I didn't had during my physician education."
- N/A
- No
- I was quite pleased with the symposium.
- Great selection of speakers and good discussions
- An introductory keynote on the topic can be considered.
- I cannot praise enough the event. It is very difficult to find something to suggest as it was very well balanced. The scientific level exceptional and at the same time everyone felt valued and I believe that the audience recognized this and hence there were lively interactions and many questions. (the moderators played important role for this)
  - The more diverse scientific event I have attended by far and a model for all to follow.
  - From the new concept (5 Min 1 slide) as suggested by Prof Greenhalgh was the perfect way to get the pearls from all the speakers and enough time for discussion and interactions. I have

</td></tr>
</table>

	already discussed this pattern and model within my organisation referring to the Young Athlete's Hip Symposium. o I haven't used the Canvas for the symposium but I have used the canvas planform frequently for previously for the YAHIR webinars o For the last question i cannot comment as I was FTF audience • A thoroughly enjoyable and dynamic day. Was very disappointed that I am unable to attend in person due to covid but thought the ability to watch on line was brilliant. I enjoyed the 1 slide slide presentation, as this allowed time for relevant discussions with the audience members - which were high-level considering the small in-person audience of mainly the faculty • It was great • Might be helpful to include more athletes especially from sports which have a high incidence of cam morphology. • 5 minutes format worked well for those present in person. I heard from on-line participants that it did not work equally well online. • I really enjoyed this symposium and would like to see it become a regular event (perhaps biannual). It would be good to attract more clinicians working in this field from both the UK as well as other countries since key researchers were in attendance but there are more people involved in research and practice in this field who could be included and supported to contribute further. COUNTRIES (online: n=21): Australia, Austria, Belgium, Brazil, Canada, Denmark, France, Greece, Hungary, Ireland, Italy, Jordan, Netherlands, New Zealand, Norway, Qatar, South Africa, Switzerland, Taiwan, UK, USA

F Chapter 6 Appendices

F.1 Research ethics: University of Oxford and Qatar University

MEDICAL SCIENCES INTERDIVISIONAL RESEARCH ETHICS COMMITTEE
Research Services, University of Oxford, Wellington Square, Oxford, OX1 2JD
Tel: +44(0)1865 616577 Fax: +44(0)1865 280467
ethics@medsci.ox.ac.uk

UNIVERSITY OF OXFORD

CONFIDENTIAL

Ref: R66281/RE001

10th December 2019

Dr Hendrik Dijkstra
Department of Continuing Education
University of Oxford
Rewley House, 1 Wellington Square
Oxford

Dear Dr Dijkstra

Research Ethics Approval - CUREC 1

Study title: Stakeholder perspectives on factors contributing to high quality research on how primary cam morphology develops – a qualitative interview study and framework analysis

Short title: Factors that contribute to high quality research on how primary cam morphology develops

The above application has been considered on behalf of the Medical Sciences Interdivisional Research Ethics Committee (IDREC) in accordance with the procedures laid down by the University for Ethical Approval of all research involving human participants.

I am pleased to inform you that, on the basis of the information provided to the IDREC, the proposed research has been judged as meeting appropriate ethical standards, and approval has been granted for a period of **20 months**, commencing on **1st January 2020**. The reference number for this study is **R66281/RE001**.

This is **subject to:**

- **a) you following the BPS guidelines for online research**
- **b) the PI agreeing to comply with the requirements for administering any tests or questionnaires and, if in doubt, to contact the publisher of those tests or questionnaires**
- **c) the PI ensuring that, where new research staff are engaged, they are suitably qualified by training and/or experience.**

I would like to remind you that your study may be selected for review by the MS IDREC for the purposes of monitoring and/or audit.

Amendments

Should there be any subsequent changes to the study, you should submit details to the MS IDREC for consideration and approval. Details of changes must be listed on an amendment form.

Please do not hesitate to contact me if you have any queries.

Yours Sincerely

H. Barnby-Porritt

Dr. Helen Barnby-Porritt
Research Ethics Manager, Medical Sciences

Qatar University Institutional Review Board **QU-IRB**

QU-IRB Registration: IRB-QU-2020-006, QU-IRB, Assurance: IRB-A-QU-2019-0009

February 20th, 2020

Dr. Sean Michael Auliffe
College of Health Sciences
Qatar University
Phone: 4403 6028
Email: Sean@qu.edu.qa

Dear Dr. Sean Michael Auliffe,

Sub.: Research Ethics Expedited Approval
Project Title: "Stakeholder perspectives on factors contributing to high quality research on how primary cam morphology develops – a qualitative interview study and framework analysis"

We would like to inform you that your application along with the supporting documents provided for the above project, has been reviewed by the QU-IRB, and having met all the requirements, has been granted research ethics **Expedited Approval** based on the following category(ies) listed in the Policies, Regulations and Guidelines provided by MOPH for Research Involving Human Subjects. Your approval is for one year effective from February 20th, 2020 till February 19th, 2021.

1) present no more than minimal risk to human subject, and
2) involve only procedures listed in the following category(ies).
Category 6: Collection of data from voice, video, digital, or image recording made for research purposes.
Category 7: Research on individual or group characteristics or behavior (including but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

Documents Reviewed: QU-IRB Application Human Subject- Ver 2_Bilingual Dr PAUL DIJKSTRA V3 JANUARY2020 (3), QU-IRB Application Material Check List Dr PAUL DIJKSTRA 12January2020, R66281_RE001_Dijkstra_CUREC 1 Approval_10 Dec 2019.docx, Paul Dijkstra Research Protocol, signed Jan 2020 (1), INTERVIEW GUIDE Stakeholder perspectives on factors contributing to high quality research on how primary cam morphology develops, DIJKSTRA_researcher_record_of_oral_consent, DIJKSTRA_oral_consent_script FINAL, DIJKSTRA Written consent form JANUARY2020FINAL (1), DIJKSTRA Participant information sheet JAN2020FINAL (2), DIJKSTRA Email invitation patient Nov2019FINAL, DIJKSTRA Email invitation parent or coach Nov2019FINAL, DIJKSTRA Email invitation clician researchers Nov2019FINAL, QU-IRB Review Forms, responses to IRB queries and updated documents.

Also note that expedited approvals are valid for a period of **one year** and renewal should be sought one month prior to the expiry date to ensure timely processing and continuity. Moreover, any changes/modifications to the original submitted protocol should be reported to the committee to seek approval prior to continuation.

Your Research Ethics Expedited Approval Number is: **QU-IRB 1239-EA/20**. Kindly state this number in all your future correspondence to us pertaining to this project. In addition, please submit a closure report to the QU-IRB upon completion of the project.

Best wishes,

Dr. Ahmed Awaisu
Chairperson, QU-IRB

Institutional Review Board
(IRB)
Office Of Academic Research

G Chapter 7 appendices

G.1 IOC World Conference on Prevention of Injury & Illness in Sport

From: Hendrik Dijkstra
To: Clare Ardern; Andrea Mosler; Sion Glyn-Jones
Cc: [redacted]
Subject: IOC Symposium 49 on Primary Cam Morphology
Date: 11 October 2021 17:24:28

Dear Clare, Andrea, and Sion,

Hope you are all well

Below is a "screenshot" of our IOC Symposium - 15 30-16 30 on 27 November

The benefit of a delayed conference is more evidence to support our Primary Cam Morphology (PCM) symposium Clare and I will share the results of the PCM concept analysis and Delphi study Andrea's focus is screening for PCM and (possible) intervention(s) to prevent it while Sion's focus is on current evidence on prediction & prognosis - can we (yet) predict (and therefore protect) the athlete with PCM from developing FAI syndrome and OA

I suggest we go beyond IPD meta-analysis in the panel discussion and focus on research collaboration in general - high quality qualitative and quantitative research to answer some of the many unanswered questions

C. SYMPOSIUM 49 - PREVENTING PRIMARY CAM MORPHOLOGY AND FEMOROACETABULAR IMPINGEMENT SYNDROME IN THE YOUNG ATHLETE: IS THE 'HOP' REALLY THE HIP'S DEMISE?

27/11/2021	15:30 16:30	Symposium	SESSION C - Room Camille Blanc

Chairmen:
Clare Ardern,
University of British Columbia
- Australia
Paul Dijkstra, Chair Person
Aspetar, Qatar Orthopaedic and Sports Medicine Hospital - Department of Medical Education
Doha - Qatar

Time	Title	Speakers
15:30	Our confusing hip language is undermining prevention and protection	Clare Ardern
15:42	To prevent and protect the hip, we have to understand primary cam morphology, its cause and prognosis – but can we yet?	Paul Dijkstra
15:54	Screening and intervention to prevent primary cam morphology – is too much sports medicine creating a mountain out of a molehill?	Andrea Mosler
16:06	Protecting the athlete with primary cam morphology from developing femoroacetabular impingement syndrome and osteoarthritis	Sion Glyn-Jones
16:18	Panel Discussion : This discussion will focus on the current state of evidence on protecting athletes from developing cam morphology, femoroacetabular impingement syndrome and early hip osteoarthritis. The importance of multi-center collaboration for clinical research, to reach consensus on sharing data and experiences, and develop the foundations for a prospective Individual Patient Data Meta-analysis will also be discussed	Clare Ardern; Paul Dijkstra; Andrea Mosler; Sion Glyn-Jones;

I don't think we need to meet online as a group but happy to do if you feel we should In the meantime, I will arrange to meet with you individually to discuss and finalise

Best wishes,

Paul

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