Self-reported Pain and Osteoarthritis of the Hip and Spine in Retired Elite Rowers

A THESIS SUBMITTED TO THE
UNIVERSITY OF OXFORD



IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE BY RESEARCH IN MUSCULOSKELETAL SCIENCES

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Hilary Term 2018

Acknowledgements

Acknowledgements go to my supervisors, Dr Julia Newton, Dr Kirsten Leyland, and Dr Stefan Kluzek, for all their support and putting up with me over the last three years. I hope I haven't been too much trouble. Secondly, to Dr Madi Davies and Dr Betsy Jones, who have saved my bacon on multiple occasions.

To Leander Club, Dr Ann Redgrave and Dr Robert Treharne Jones for their collaboration and support. A special thank you to Robert for his excellent photographs used in this thesis.

To the Arthritis Research UK Centre for Sport, Exercise and Osteoarthritis for their funding support to get my research up and running.

Finally, to Pip and Jamie for helping me cause mischief in the lab, Christine and Ruth for taking the time to proof read my thesis, and to my friends and family for being so unbelievably supportive and encouraging throughout my time at Oxford.

Abstract

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Background and Aim: Pain in the hip and spine presents a large burden to athletes competing in rowing. Previous injury is a risk factor for the development of osteoarthritis (OA) in later life. Little research has investigated the long-term effects of rowing participation on the musculoskeletal health and risk of OA in rowers. The aim of this study was to describe the prevalence of pain at the hip and spine, as well as OA in those regions within a cohort of retired elite British rowers. A secondary objective was to identify potential rowing-specific risk factors associated with adverse health outcomes at the hip and spine, and explore the potential for a hip-spine syndrome in this population.

Methodology: A literature review was performed to identify potential risk factors for the development of pain and OA at the hip and spine joints in retired rowers. A cross-sectional analysis using retrospective questionnaires completed by retired elite British rowers was undertaken. Retired rowers were asked to report their competition history, injury history, current pain and osteoarthritis history. The rowing-specific risk factors of total rowing hours per week and the use of a hatchet type rowing blade were reported and tested for differences in those with poor health outcomes at the hip, spine and combined hip-spine.

Results: 92 participants were included in the analysis (age: 49.7 $\pm$ 17.8 years; BMI: 24.8 $\pm$ 2.7 kg/m^2). The prevalence of self-reported pain at the hip joint, and across the thoracic spine and lower back was 14.1%, 9.8% and 29.4%, respectively. Hip OA and spine OA were 2.2% and 10.9% prevalent, with total hip replacements reported by 5.4% of retired elite rowers. Poor outcomes at the hip, spine and combined hip-spine were 19.2%, 40.2% and 9.8% prevalent in the cohort. No significant differences were found between rowing training duration or hatchet blade use in retired rowers with poor outcomes at the hip, spine or combined hip-spine. However, it is likely that this study was underpowered to detect statistical differences. Over 90% of rowers reflected positively on their careers.

Conclusions: Retired elite rowers are at risk of pain at the hip and spine joints. Rowers reflected positively on their elite careers. Further research with a larger sample size is required to understand the effects of rowing-specific factors on pain and OA at the hip and spine in retired elite rowers.

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Chapter 1. Introduction, aims and research questions

1.1 Background

Osteoarthritis (OA) is a degenerative joint disease that causes damage to the articular cartilage and surrounding structures. (1) It is one of the top three conditions resulting in the greatest loss of health-related quality of life in the UK population. (1) OA affects over 8.75 million people in the UK alone. At present, 4.71 million people seek treatment for knee OA yearly, with over 8 million people predicted to seek treatment for knee OA by 2035. (1,2) Risk factors for the disease include systemic and demographic factors such as age, sex, ethnicity, bone mineral density, hormonal factors, genetics and biomechanical factors including prior joint injury, high body mass index (BMI), occupation associated with chronic joint loading, repetitive movements, and abnormal joint biomechanics. (3,4)

Hip OA is the second most commonly affected joint, with 11% (2.46 million) of England's population affected by this condition. (1) The risk of developing the disease increases from the late 40s, with women more likely than men to have sought treatment, such that 16% of women over 75 years old have sought treatment in the UK alone. (5)

Lower back pain (LBP) is also a very common complaint in the general population. Over 6 million people have chronic LBP in the UK. (6) Similarly to

OA, LBP is more common in females, with a greater prevalence in those over 40 years old. (7) The economic costs of LBP are increasing as the population expands and ages. (8,9)

LBP and OA affect the sporting population, including the rowing population. Research by Bahr *et al.* (2004) reported that up to 55% of elite rowers complained of LBP. The severity of this LBP can impact athletic performance through early retirement from sporting careers and subsequent changes in occupation due to the disability caused by pain. (9,10) Previous injury at the hip joint has been reported to increase the risk of hip OA up to four-fold in adults, identifying injury as a risk factor for future OA development at the hip. (11,12)

The different characteristics of a sport can also influence the risk of OA development in later life. Research comparing elite male athletes from different sports found 36.6% of all athletes presented some form of OA. It seems that hip OA is particularly prevalent in soccer players and skiers when compared with athletes from other sports. This could be explained by the weight bearing characteristics and increased loading at the hip joint, demanded by the movement skills of the sports. (13) Furthermore, weight bearing sports participants have been reported to have an increased risk of developing hip OA, with a 2-3-fold increased risk of radiologic OA in the hips of females competing in these sports. (14) It is therefore evident that a sport's characteristics can influence the risk of OA development in later life.

Rowing is a high-intensity and high-load sport that uses whole body movements to lever the boat using repeated flexion and extension of the lower and upper body, in addition to trunk rotation. These movements exert large forces on the

musculoskeletal (MSK) system that can lead to the development of pain, overuse (trauma is uncommon) injuries and OA. 53% of all injuries reported in rowing are to the lower back region, with athletes commonly reporting LBP as symptom. (8,9,15)

Reduced hip mobility due to abnormal bone morphology is also a common cause of pain and significantly increases the risk of developing hip OA. (16) Previous studies have described that hip impingement and subsequent reduced mobility at the joint are common complaints among rowers. (8,17) Isolated groin pain has been reported in 71% of rowers, with 81% of rowers presenting physical signs of hip impingement. (17) The presentation of anterior hip or groin pain can be a sign of femoroacetabular impingement (FAI) at the hip joint. (8,18–21) Although research has presented findings of FAI in multiple sports, no research has yet reported clinical findings of FAI in rowers. (8,19–21) In rowing, the hip and back are the most commonly affected areas presenting pain and until recently have been treated individually. Clinical practice now recognises that the hip and back pain in athletes is inexorably linked, with its pathological relationship often being referred to as 'hip-spine syndrome'. (18,22–28) Rowers could therefore be at a high risk of developing hip and spine OA in the future, something that has not yet been investigated.

Elite-level rowers experience the demands of training and competition daily throughout their sporting careers. With the popularity of rowing increasing as an activity for leisure, as well as exercise and sport, it is important to understand how the training and competition associated with the sport may influence the

MSK health of the participant, and how this can be treated. Hip and spine pain and injuries are common in rowers. These outcomes may translate into long term health problems for these athletes in later life. However, the prevalence of spine and hip OA in rowers is unknown, especially in the retired elite population. Furthermore, rowing-specific factors associated with long-term health problems are unknown. Understanding this MSK burden and its risk factors will potentially benefit current rowers.

1.2 Research aims, questions and hypotheses

The overarching aim of this study was to investigate the burden of, and the risk factors for, hip and LBP in retired elite rowers. The following were used as the key research questions for the study:

a) What is the prevalence of self-reported pain, injury and hip or thoracolumbar spine OA in retired elite rowers?
b) What rowing-specific risk factors are related to hip and LBP?

This study was the first to investigate the prevalence of self-reported hip and LBP, and hip and thoracolumbar spinal OA in retired elite rowers. I hypothesised that the prevalence of both hip and LBP, and hip and thoracolumbar spinal OA would be high in the retired-elite rowing population.

Chapter 2. Literature review

A primary literature search was performed using the databases PubMed, Medline and SPORTDiscus using the search terms outlined in Table 1. The Oxford University librarian (Catherine Hartley) based at the Nuffield Orthopaedic Centre assisted with the literature search. Studies that were not based on humans, not written in English, or did not have the full text available were excluded from the search. A total of 1089 papers were identified using the search terms outlined below.

Table 1. The search strategy used to conduct the literature review.

Search Term(s) 1		Search Term(s) 2		Search Term(s) 3
Prevalence Risk Epidemiology	AND	Pain Osteoarthritis Long-term health “OR” Back Lumbar Low back Chronic low back Spine "OR" Hip Femoroacetabular impingement	AND	Elite World class Professional High-level "OR" athlete(s) sport(s) "OR" Rowing "OR" General population

The results of the search strategy are summarised in Figure 1. The search strategy identified 1089 potential citations. From these, 405 were potentially eligible for inclusion in the literature review. After reviewing the titles and

abstracts of each study identified, 87 were deemed eligible for inclusion within the literature review and rational for the study. A full breakdown of the search strategy can be found in the appendix.

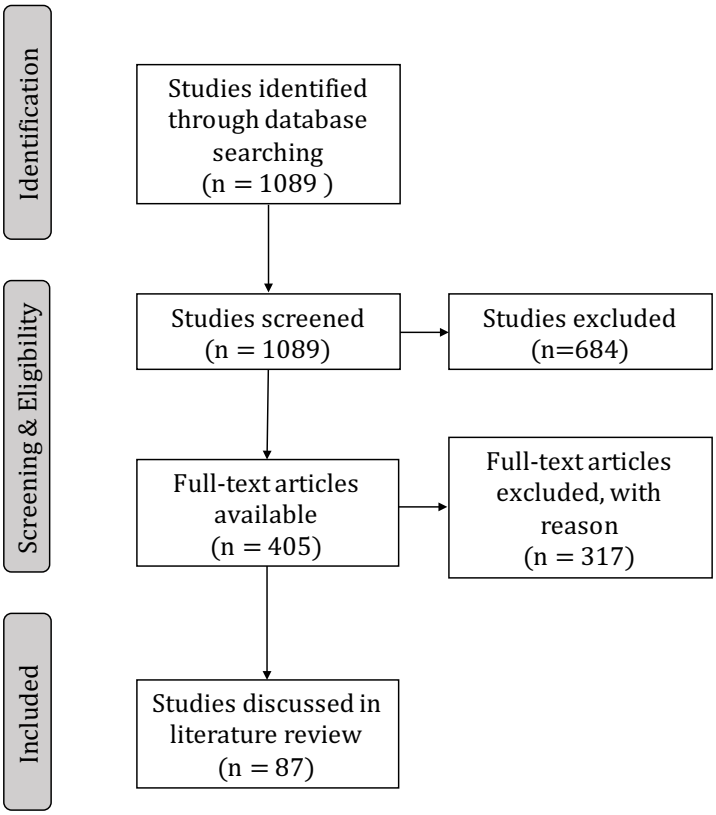

Figure 1. PRISMA flow chart describing results of the literature search strategy.

This chapter will describe the literature reviewed in the following sections:

1) Hip and thoracolumbar spinal osteoarthritis (OA)
2) Hip pain and femoroacetabular impingement (FAI)
3) Lower back pain (LBP)
    a. The relationship of hip and back pain and 'hip-spine' syndrome
4) Hip and lower back injuries, osteoarthritis and hip impingement in the rowing population

2.1 Hip and thoracolumbar spinal osteoarthritis

This section will describe the literature surrounding the epidemiology, risk factors and economic costs of osteoarthritis (OA) in the hip and spine. The pathogenesis of clinical OA will then be described, followed by its prevalence within the sporting population.

2.1.1 Epidemiology, risk factors and economic costs to society

OA is the most common joint disease in the world, with 80% of the world's population above 65 years old suffering from the disease. The number of people affected by the disease is set to increase due to the ageing population and ongoing obesity epidemic. In England alone, 11% of the population are affected by hip OA. (1) Spinal OA is less common in the general population, affecting between 8% and 12% of adults (age: 58.0 $\pm$ 13.1 years). (29) In 2004, it was reported that ~8.5 million people displayed signs of radiographic spinal OA, with back pain reported as the most common symptom. (30) Treatments for the joint disorder, such as using non-steroidal anti-inflammatory drugs (NSAIDs), costs up to £25 million alone, with the total cost of OA reported at over £850 million in the UK (31,32)

Risk factors for the disease include increased age, gender, BMI and ethnicity, systemic factors such as bone density, abnormal bone morphology, hormonal factors and genetics, and loading factors such as previous joint injuries (posttraumatic), occupation, sport and physical activity, repetitive movements, and muscle weakness. (3,4,11,14,33–36) More specifically, primary spinal OA is

more prevalent in the older population (60 years and older) due to spinal degeneration, whereas secondary spinal OA can occur in younger adults following a traumatic event. (37) Furthermore, studies have described an increased risk of hip OA development in women aged 40 years and older. (5)

2.1.2 Pathogenesis of clinical osteoarthritis

At the joint level, the disease is pathologically diverse, with the most distinct features being the loss of articular cartilage and changes in adjacent bone, demonstrating failure of the joint as an organ. OA can be defined by joint symptoms or by structural pathology, presenting as both symptomatic (with pain) or asymptomatic (X-ray radiographic morphology; no pain) in patients. (38)

Radiographic features used to define OA include joint space narrowing, osteophytosis, cyst formation, subchondral sclerosis and abnormalities of bone contour. (38) OA is clinically defined through two key areas: the symptoms associated with the condition and the degree of disability comprising its longer-term development. (39) Primary symptoms of the disease include joint pain and stiffness, with joint pain being the most dominant. Multiple studies have used such symptoms to identify self-reported OA, through the development of clinically-certified questionnaires, such as the National Health and Nutrition Examination Survey (NHANES). (40)

Molecular mechanisms that regulate biological processes within the joint are complex and include enzymatic activation associated with mechanical instability,

mitochondrial dysregulation and oxidative stress, excessive autophagy and epigenetic changes. (41) Interestingly, studies have shown that offloading the joint can result in cartilage re-growth in the knee and ankle, showing that cartilage has the capacity of self-restoration and highlighting the role of loading in OA pathogenesis. (42,43) Stressed or injured cartilage can induce a cascade of pathways leading to the formation of bony changes (osteophytes). Over-exposure of the joint to loading in sports related training may be associated with decreased recovery and disturbed joint homeostasis, further activating the pathways associated with bone formation and OA development in later life. (42,43)

2.1.3 Osteoarthritis in the sporting population

Each sport has a specific biomechanical loading profile for different joints. Describing the prevalence of OA and pain in specific sports might be helpful in identifying specific risk factors and informing future research conducted by sporting governing bodies aiming to improve participation and longevity in their sport. Two recent research groups reported the prevalence of OA in retired athletes. Jones *et al.* (2017) investigated OA in a population of retired elite cricketers. (44) The study found a prevalence of knee OA of 30% and a prevalence of hip and knee replacement of 6.2% and 4.4%, respectively. Self-reported frequent knee pain and LBP were also prevalent, with a prevalence of 30% and 22% reported for knee and spine pain, respectively. Furthermore, joint-specific injuries were significantly associated with an increased risk of joint-specific OA (odds ratio: 5.1, 7.0, 12.5 and 4.5 for the hip, knee, ankle, and shoulder, respectively), joint-specific NHANES pain (odds ratio: 6.9, 9.8, 3.1, and

2.2 for the knee, ankle, shoulder, and spine, respectively) and hip replacement surgery (odds ratio: 12.7 for the hip). This study is the first of its kind to identify long-term health outcomes associated with elite participation in cricket. A high prevalence of OA has helped to inform further research aiming to investigate preventative strategies for reducing OA and maintaining long-term joint health in sporting participation.

Similar research was conducted by Davies *et al.* (2016) into OA in former international rugby players. (45) The study aimed to describe the prevalence of OA within former elite international rugby players, and to examine whether possible rugby-related and injury-related risk factors were predictive of OA-related outcomes. 138 participants completed the questionnaire (age: 62 ± 15.5 years; BMI: 28.9 ± 3.5 kg/m^2). Physician-diagnosed OA prevalence was 61.5% and joint replacement prevalence was 27.0%. Physician-diagnosed OA at the hip joint was 19.6%, with 16.9% of these participants reporting hip replacement. Furthermore, the prevalence of OA at the knee was 38.5%, with 12.2% of these participants reporting knee replacement. Severe injuries were reported at the knee (38.5%) and hip (20.3%). Of these injuries, rugby-related injury was associated with physician-diagnosed OA. Associations were also found between joint-specific rugby injury and OA at the hip and knee, respectively.

2.2 Hip pain and femoroacetabular impingement

There is a complicated relationship between spine pathology and hip pain, as well as hip pathology and subsequent spine pain. This relationship has been

documented in the literature and will be explored in this section. The literature has suggested femoroacetabular impingement (FAI) as a potential loading related risk factor that might be related to hip pain and OA in the rowing population. Hip pain can often result due to pain referral from the lumbosacral spine and sacroiliac joints, hip OA, muscle and tendon injuries and symphysis pubis bone oedema. (46) As FAI related hip pain is particularly common in the young and sporting population, this next section will describe the clinical syndrome of hip pain and FAI, and the prevalence of both hip pain and FAI in both the general and sporting populations.

2.2.1 Epidemiology, risk factors and economic costs to society

Hip pain has been reported to affect up to 19.2% of the population aged 65 years and older. (47) Pain in the hip can be caused by a multitude of different factors. Joint specific abnormalities at the hip can be one cause of pain at the hip joint. FAI is the presence of abnormal bone morphology at the hip joint, between the acetabular rim and femoral head-neck junction. (19) This joint disorder is a risk factor for the development of hip OA in later life. (48–50) The bony abnormalities commonly seen in FAI are thought to be associated with abnormal loading in the joint in adolescence. Constant rubbing and abrasion between the acetabular rim and femoral head-neck junction causes changes to the bone shape. Long-term contact between these structures can lead to functional limitation, pain, and OA. (18,19) FAI is estimated to affect 15% to 20% of the general population. (18,19,51,52)

There are three types of FAI deformity: cam-type FAI, pincer-type FAI and mixed-type FAI. Cam-type FAI occurs when the bone morphology at the proximal femoral neck, or head-neck junction, is abnormal in a type of 'bump' (Figure 2a). This can result in impingement and abrasion of the femoral head-neck junction at the acetabular rim. (18)

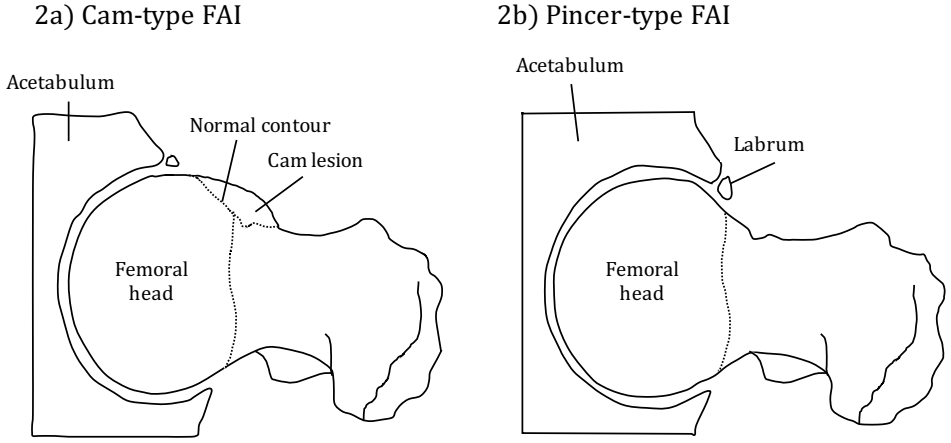

Figure 2. 2a) Cam-type FAI and 2b) Pincer-type FAI. Figure adapted from Zhang *et al.* (2015). (18)

Pincer-type FAI occurs when the acetabular rim has additional bone covering the femoral head (Figure 2b). Patients can also have mixed-type FAI where the pathomorphology of both cam-and pincer-type FAI is present. Previous research has indicated that the prevalence of cam-type FAI is lower in the general population, with only 14% of people affected, whereas mixed-type FAI is the most common. (53) In symptomatic individuals, FAI type-specific prevalences have been reported at 47.6%, 7.9% and 44.5% for cam-type FAI, pincer-type FAI, and mixed-type FAI, respectively. (54) Cam-type FAI can be diagnosed using the alpha-angle, pistol-grip deformity, or femoral head-neck offset, whilst pincer-type FAI is diagnosed from findings such as the cross-over sign, posterior wall sign, prominence of ischial spine sign, or coxa profunda. (55) Most commonly used is the alpha-angle, where 50° or 55° marks a positive finding of cam

impingement. Plain radiography, computed tomography (CT) or magnetic resonance imaging (MRI) are predominantly used to evaluate the alpha-angle. (55) Physical examinations can also be used to test for FAI, through methods such as the impingement test and the flexion-abduction-external rotation (FABER) test, however both of these tests are subject to variable reliability influenced by inter-and intra-observer bias by the physician conducting the examination. (56,57)

Established risk factors for the development of FAI include age, gender, BMI, obesity, and biomechanical factors, such as participating in physical activity and performing repetitive hip-flexion movements. (50,53,54,58–60) Research by Nepple *et al.* (2011) reported a strong association between cam-type FAI and more severe labral disease, with higher prevalences of labral tears in males compared to females. (50) This suggests a strong gender-specific characteristic as a risk factor for FAI. Furthermore, the abrasive movements typical of FAI mean that it is a risk factor for the development of hip OA in later life as the cartilage at the hip joint is exposed to wear and tear. (48–50)

The hip joint changes shape during skeletal development and adulthood, a response regulated by the effects of joint loading. (61,62) Restoration of joint homeostasis can be triggered by excessive abnormal loading and often results in remodelling, with a structurally altered, but symptom-free joint. (41) Cam-type lesions, presented as abnormal bone morphology at the femoral head neck junction, are often asymptomatic, and therefore remain undiagnosed until scanned by a doctor. However, a strong relationship between symptomatic FAI with pain on presentation and OA has been demonstrated (53,63,64)

The development of degenerative arthritis of the hip might be initiated by tears in the acetabular labrum. Research by Altenberg in 1977 found that minor hip injury or strain can cause the acetabular labrum to tear. (65) Acetabular labral tears are associated with a progressive derangement of the joint cartilage, most likely due to instability, causing disabling hip pain and degenerative arthritis in many patients. Surgical removal of torn fragments often relieves impingement symptoms and may prevent early progression of degenerative arthritis. (66–69)

The economic costs to society presents similar issues as that of OA. Direct costs of FAI through surgical and pharmacological intervention amount to thousands of pounds each year, with the indirect costs continuing to have a vast impact in the longer term. (70,71) Like OA, FAI can affect patient's quality of life. (71)

However, FAI is not the only cause of hip pain in the general population. Abnormalities in spine pathology can also present pain at the hip. Lumbosacral spine and sacroiliac joint problems have been reported to cause pain in the groin and hip regions. Research by Kurosawa et al. (2017) investigated the prevalence of groin pain in patients with spinal disorders without comorbid hip disorders. Groin pain was reported by 46.5% of patients with sacroiliac joint dysfunction, 6.8% of patients with lumbar spinal canal stenosis and 8.1% of patients with lumbar disc herniation. (72) Other rare but important causes of hip pain can include stress fracture, tumours and slipped upper femoral epiphysis (SUFE). (73,74)

2.2.2 FAI in the sporting population

Cam impingement has been reported to be significantly more common in athletes versus non-athlete controls. Ayeni *et al.* (2014) investigated FAI in elite ice hockey players and found that cam impingement was more common in elite ice hockey players when compared with non-athletes. (21) Athletes had greater alpha-angles than non-athletes (54.2 degrees versus 43.2 degrees, respectively). It is suggested that the activity-related stresses placed on the hips of athletes playing ice hockey are causative of cam-type FAI in elite ice hockey players.

More recent research by Palmer *et al.* (2017) investigated the hip morphology in a younger group of adolescent academy level soccer players (aged 9-18 years). The study reported rapid increases in alpha-angles and epiphyseal extension between 12 and 14 years of age. (61) The first signs of soft-tissue hypertrophy at the femoral head-neck junction were evident at 10 years old, preceding osseous cam morphology at the joint level. This confirms that cam-type FAI develops in early adolescence. The study showed significantly greater maximum alpha-angles (6.7° higher) in males compared to females, and significantly greater alpha-angles (4.4° higher) in individuals who play regular sport for a school or club. Furthermore, alpha-angles were 7.7° higher in individuals competing at national or international level, suggesting the level of sports participation increases the alpha-angle at the hip, and is therefore a primary risk factor for cam-type FAI.

To summarise this section, FAI is frequently a cause of joint discomfort and pain among both the general population and elite athletes. Risk factors for developing

the disorder include age, gender, BMI, obesity and biomechanical factors, with the condition itself being a risk factor for future joint-specific OA development in later life. As the disorder develops in adolescence and is affected by physical activity, it is important to understand its involvement in the prevalence of sport-specific OA and how this could be managed to encourage long-term participation in the future.

2.3 Lower back pain

This section will discuss another significant burden to the general population and to athletes, which might be relevant to the rowing population based on the literature reviewed. It will describe the epidemiology, risk factors and economic costs to society of lower back pain (LBP). The pathology and clinical understanding of LBP and its prevalence in the sporting population will then be discussed, followed by the relationship of hip and back pain and hip-spine syndrome.

2.3.1 Epidemiology, risk factors and economic costs to society

LBP is the leading cause of disability in the UK and presents a significant burden of 9.4% globally. (75) Research by Arthritis Research UK found that 1 in 6 adults (16.9%) in England were affected by some form of back pain. Their research captured those with severe back pain (lasting three or more months), with around 5.5 million people estimated to have severe back pain. (76) Risk factors for the disorder include age, sex, BMI, socioeconomic status, smoking and level of education achieved. Research has shown that obesity is a significant risk factor

for LBP, and LBP symptoms can be successfully improved if overall body mass is reduced. (77) Furthermore, the disorder has vast economic costs to society. The direct and indirect costs combined can total up £12.3 million per year. (78,79) These costs presents a huge burden to employers, tax payers and patients dealing with pain and can consequently have negative implications on mental health and lifestyle. (80,81)

2.3.2 Pathology and clinical understanding of low back pain

LBP can be diagnosed as related to specific abnormalities or idiopathic. Specific LBP describes symptoms caused by pathophysiological mechanisms, such as disc degeneration, infection or osteoporosis. Idiopathic LBP defines symptoms without clear or specific structural changes, with around 90% of all LBP presenting with non-specific symptoms. (82) More specifically, idiopathic LBP is usually classified by the duration of the complaints, with acute LBP describing pain persistent for less than six weeks, and chronic LBP as pain lasting 3 months or more. (75,83,84)

Most cases of acute LBP do not require medical treatment, with symptoms settling after a short time. In some cases, simple analgesia and non-steroidal anti-inflammatory drugs (NSAIDs) are often sufficient to relieve symptoms. However, other treatment options have been also found to have therapeutic value, such as physiotherapy, exercise, and acupuncture. (82) Spinal epidural injections can also be administered to treat chronic LBP; however, the effectiveness and safety are still debated. (84–87) Similarly, fusion surgery as a

treatment strategy for chronic LBP has been investigated in various randomised clinical trials, however the results are inconclusive. (88–90)

2.3.3 Low back pain in the sporting population

LBP presents a heavy burden to training and performance in the sporting population. Research by Bahr *et al.* (2004) investigated the prevalence of LBP in endurance sports with different loading characteristics on the lower back. (9) The study cohort included 257 cross-country skiers, 199 rowers, 278 orienteerers, and 197 non-athletic controls. The prevalence of at least one episode of LBP in the previous 12 months was reported at 63.0% in skiing, 55.3% in rowing, 49.8% in orienteering and 47.5% in the non-athletic control group. The prevalence of athletes requiring outpatient medical assistance was significantly higher in skiing and rowing (31.9% and 24.1%, respectively) than in orienteering and the control group (19.4% and 9.6%, respectively). Furthermore, athletes reported a higher prevalence of LBP during periods of high training and competition load, showing training load has a significant influence on LBP and is a risk factor for developing the symptom.

Similar cross-sectional research by Fett, Trompeter and Platen investigated the prevalence of back pain in German elite athletes using a back pain questionnaire developed from the standardized Nordic Questionnaire. (91) Over 40 sports were examined, including archery, badminton, basketball, canoeing, cycling, golf, rowing, sailing, soccer, and tennis. The lifetime prevalence of LBP was 77% across all the athletes. The lower back was the most commonly affected area and a significant positive correlation was reported between back pain prevalence

and weekly training volume; a finding consistent with the research of Bahr *et al.* (2004).

Findings of LBP have been reported in elite soccer (football) players in Belgium. Grosdent *et al.* (2016) investigated the relationship between the history of LBP and quality of lumbopelvic motor control in male elite soccer players. (92) Forty-three male soccer players (mean age: 18.2 $\pm$ 1.4 years) participated in the study. At least one episode of disabling LBP lasting more than two consecutive days was reported by 46.5% of the participants.

The underlying pathology of chronic LBP in elite athletes has also been investigated retrospectively using certified physician reports of LBP between 1988 and 2008. Malliaropoulos *et al.* (2011) reported the most common cause of chronic LBP in male and female track and field athletes was discogenic (vertebral disc) problems, followed by muscle and back injuries. (93)

The literature shows LBP presents a significant burden to the sporting community, as well as the general population. In the sporting world, performance is paramount, and disruption to training and competition can be destructive to the sport both from a performance perspective and economically in relation to funding sources.

In summary, LBP represent a significant burden in both the general population and athletes, presenting higher prevalences in the sporting population. Risk factors for the disorder include age, sex, BMI, socioeconomic status, smoking and

education, with training load in terms of hours spent training being a significant risk factors for chronic LBP in athletes.

2.4 Relationship of hip and back pain and 'hip-spine' syndrome

A relationship between hip and spine pain has been commonly reported in the literature as a 'hip-spine' syndrome. The syndrome was first reported by Offerski and Macnab in 1983. The study reported aggravation of spine pain caused by deformity of the hip in symptomatic patients. More recent research has reported improvements in spine pain following total hip replacement surgery. (22,28,94–96)

Ben-Gamlin *et al.* (2007) investigated the effects of total hip replacement (THR) on LBP. Hip and spine related symptoms were evaluated in patients with severe hip OA at 3 months and 2 years post THR. In the 25 patients examined (age range: 32-84 years), spinal and hip pain and function were significantly better after surgery. This study was the first to clinically validate the hip-spine syndrome hypothesised by Offerski and Macnab (1983).

Similar research by Stupar *et al.* (2010) examined whether self-reported back pain predicted future OA-related pain and disability in individuals with hip (and knee) OA. (94) The study used a population-based cohort of patients who were 55 years or older and reported symptomatic hip OA (n=983). 58% of the cohort reported LBP at baseline, and baseline LBP was predictive of higher hip OA-

related pain and disability at follow-up. This finding could be related to the structures shared by the hip and spine joints, presenting with anatomically and structurally shared pain. However, this could also be due to reporting bias where patients think pain is coming from different structures to its actual origin. It is therefore important to understand the location of pain and site of causality when treating injuries in sport.

2.5 Hip and spine injuries, osteoarthritis and hip impingement in the rowing population

The most common injuries in rowing are to the spine, followed by the hip, with other injuries reported to the ribs, knee, shoulder and forearms. (8,97–100) In this section, based on my literature review, I will describe the prevalence of isolated hip and spine injuries, joint specific OA of the hip and spine, and hip impingement in rowers.

2.5.1 Hip injuries, self-reported hip pain and osteoarthritis

Injuries to the hip in rowers are becoming more commonly observed in the clinical and elite sports settings, however published literature specific to this topic is still limited. (8) Boykin *et al.* (2013) researched acetabular labral pathology in school and collegiate rowers (participant mean age of 18.5 years). (17) 71% of patients had isolated groin pain, and 81% had physical findings consistent with impingement. Twenty-six percent of rowers presented catching and locking of the hip when their range of motion was examined. Most patients reported a gradual onset of pain over time (n = 20). All participants reported

that their pain worsened with physical activity. Ten of the 18 rowers who underwent surgery returned to rowing (56%), while six never returned (33%) at a mean of eight months after surgery. The repetitive hip flexion required during the rowing stroke may be a risk factor of hip injuries in rowers, however this has not yet been investigated.

2.5.2 Spinal injury, LBP and training load

The lower back is the area most commonly affected by injury in rowers of all levels. Lower back injury was reported at 32.3% in elite junior rowers (mean age of 18 years). (101) Wilson *et al.* (2010) reported that 31.8% of injuries in elite adult rowers (men: n = 12; women: n = 8age: 26.3 ± 4.2 years) were to the lower back and found that rowing performance was associated with a high risk of lower back injury. (102) The study also found that injury risk significantly increased with the volume of ergometer training the athlete completed. A mean injury rate of 3.67 per 1000 exposure hours (2.2 injuries per athlete per 12-month period) was reported.

The movements required in rowing mean that most lower back injuries are related to long term repetitive loading. Forces greater than 4.6 times that of the rowers' mass can be placed on the athletes' spines during the rowing stroke due to hyper flexion and torsional movements of the spine required in the rowing technique. (103) This presents the potential for serious burden to both quality of life and athletic performance.

Furthermore, previous injury is a significant risk factors for OA development in later life. As rowers experience high prevalences of injuries to the lower back, it is hypothesised that they have an increased risk of developing lumbar spinal OA. To date, there is no literature quantifying the prevalence of lumbar spinal OA in rowers. Other sports, such as professional football, have investigated radiographic spinal OA in retired athletes. Spinal OA has been reported at 9.2% in retired football players, with higher numbers of osteophytes reported in the retired footballers group compared to the normal population control group. (104) This shows how impact-triggered structural changes from trauma and previous injury can increase the risk of spinal OA development in later life. Rowing is a non-contact sport, so the structural changes will not be triggered due to direct impact, however it is possible that the loading generated through the rowing stroke could trigger similar structural changes in the lower back.

LBP in rowers is common and was first reported as a significant problem in rowers in 1980 by Stallard (1980). (100) This study was the first to comment on changes in rowing technique, where body movement had changed from a straight-backed swing, to flexion and rotation of the lumbar spine at the beginning of the stroke. These changes in technique could be responsible for increased spinal injury and subsequent pain as a result.

There is strong evidence to support the association between training load and LBP. (9,105–109) More recent research by Newlands *et al.* (2015) investigated the prevalence and incidence of LBP among international-level rowers in New Zealand. (106) The study reported prevalences of LBP ranging from 6% to 25%

throughout the year. The incidence of episodes of LBP was 1.67 per 1000 exposure-hours. There were 72 episodes of LBP reported by 40 rowers (53%) during 12 months, of these, 45% had an incidental effect on training. Furthermore, there were high correlations between new LBP and total training hours per month ($r = 0.83$, $P<0.01$), the number of ergometer training hours per participants per month ($r = 0.73$, $P<0.01$), the average training hours per participant per month ($r = 0.73$, $P<0.01$) and the average number of kilometres rowed per participant per month ($r = 0.71$, $P<0.01$). This shows a high correlation between training load and the development of LBP in elite rowers.

The training volume and competitive level of an athlete may affect the severity of LBP experienced. Verral and Darcey (2014) reported that national level rowers were more likely to have a lower back injury than international level rowers, in a 5 year retrospective study of Australian high-level rowers. (109) It has also been hypothesised that differences in lower limb force production could be associated with LBP in rowers. However, research by An *et al.* (2015) investigated lower limb reaction forces in rowers with and without a history of back injury and found no association between lower limb force production and LBP. (25)

As presented in section 2.5, hip and spine injuries, and pain at the hip and back, are common in rowing. It is possible that there could be an association between hip pain and spine pain, and a potential hip-spine syndrome in rowers.

To date, no research has investigated the long-term musculoskeletal (MSK) health of retired elite rowers, nor examined a potential hip-spine syndrome.

Therefore, the aim of this thesis is to describe the long-term MSK health of retired elite rowers through the prevalence of hip and back pain, and joint specific OA in the population. A secondary objective is to examine possible rowing-specific risk factors for the development of hip or thoracolumbar spine OA, and potential association between hip and spine pain in retired elite British rowers.

2.6 Chapter conclusions

The literature reviewed in this chapter has demonstrated a significant burden of hip pain and LBP in the general population. The literature on epidemiology, risk factors and economic costs of hip and spine OA, FAI, and LBP in both general and sporting populations was reviewed. The chapter then discussed how common hip and lumbar spinal injuries are in rowing and their effect on athletic performance. Furthermore, the association between LBP in patients with symptomatic hip problems was discussed. This review described potential explanations for the high prevalence of LBP in rowers with hip impingement.

Trauma and excessive loading are associated with the development of OA and subsequent pain at the hip and spine can be triggered by the loading exposed at the joint, increasing the risk of OA development. For this reason, I will explore rowing-specific risk factors potentially associated with excessive loading that could explain the hip-spine syndrome and OA development in rowers. To understand this fully, the next chapter will describe the sport of rowing, with specifics around technique, competition and equipment use, and then describe

how rowing-specific risk factors may be associated with hip and spine pain and hip and spine OA in rowers.

Chapter 3. Participation in rowing and musculoskeletal health

Rowing is one of the oldest sports in the modern day Olympic games, with participation dating back to ancient Roman and German empires with documented races since the thirteenth century in Venice. The sport's popularity continued to increase, with races between ferrymen on London's river Thames in the 1700s, and the start of the Oxford-Cambridge boat race in the 1800s. (110,111)

Great Britain was one of the top rowing nations at the Rio de Janeiro 2016 Olympic Games, qualifying twelve out of fourteen boats into the Olympic boat classes. The high-performance team displayed excellence in both men's and women's events, winning three gold and two silver medals in total. (112) Rowers are at a high risk of hip and low back pain due to increased joint loading through long training hours and heavy loading forces acting on the body. (8,102,105,106,108) However, it is unknown whether this pain translates into long term complaints such as joint-specific osteoarthritis in later life. With participation increasing, it is important to understand the long-term effects of rowing on the musculoskeletal (MSK) health of athletes, something that has not yet been investigated. To understand the potential long term problems associated with rowing, I will describe the potential risk factors leading to high loading at the lower back and hip in rowers by describing the basic rowing technique used by British rowers and the typical injury profile of the sport.

The following section will:

a) Describe the technical parameters of the rowing stroke, equipment used and the competitive events that elite rowers compete in.
b) Discuss the rowing-specific risk factors associated with hip pain and LBP.

3.1 Rowing technique

The ability to generate boat speed comes from the connection between the athlete, the boat (hull) and the blade (oar). The rower uses their physical strength and power to push the boat along the water surface using the blade as the material point of leverage; a process that is complicated by the movements of the rowers within the boat itself.

To better understand how the boat moves, it is important to understand the basic technique used to move the boat. The athletes' feet are attached to the boat in fixed shoes whilst the athlete is seated on a sliding seat. This way the athlete can move up and down inside the boat with their feet fixed, allowing them to drive against a footplate and generate leverage via the blade handle, resulting in movement of the boat. The rowing stroke itself can be broken down into four key components: the catch, the drive, the recovery, and the finish. (113,114)

The catch position describes the start of the drive phase of the stroke. The blades are first placed into the water, described as 'catching' the water, when the shins are vertically positioned at 90° to the hull deck. The seat on which the rower sits on can then be compressed tightly to their heels, facilitating a compact squat-like

position. This allows the athlete to use their gluteal and quadriceps muscles in the legs to drive the blades through the water, and move the boat forwards as a result. The drive phase is predominately leg driven but there is some involvement from the trunk and upper body to push the boat. Hip extension, from contraction of the quadriceps and hamstrings, and back extension, from contraction of the erector spinae, lengthens the drive and pushes the boat further. (113) The arms are pulled into the chest to finish off the drive sequence. Figure 3 below depicts the catch position, followed by the drive sequence in Figure 4.



Figure 3. The Catch position. Image provided by Dr Robert Treharne Jones, Clinical Director, LumiraDx Care Solutions Ltd.

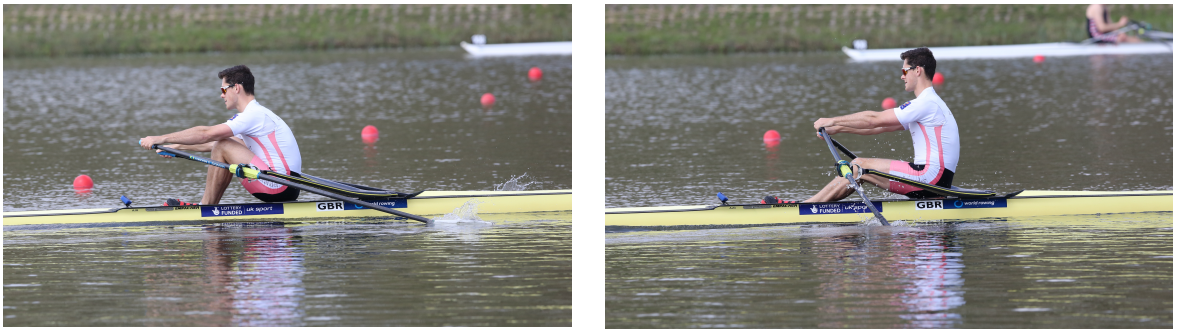

Figure 4. The drive sequence. Images provided by Dr Robert Treharne Jones, Clinical Director, LumiraDx Care Solutions Ltd.

The finish (Figure 5) describes the position in which the rowers' legs are completely flat against the hull, their arms drawn into their chest and the blade handles almost touching their lower ribs, meaning the blades are at the end of their stroke length in the water. The rower will apply downward pressure from their hands to remove the blades from the water, ending the blade propulsion part of the stroke.



Figure 5. The finish position. Image provided by Dr Robert Treharne Jones, Clinical Director, LumiraDx Care Solutions Ltd.

With the blades clear off the water, the rower can begin the recovery sequence. This is where they prepare for the next stroke, moving their body out of the finish position in the order of hands away, body swing over (hip flexion) and then bending the legs.

High levels of hamstring and hip flexibility are required to reach the compact position at the catch. A limited range of motion can hinder the ability of the athlete to reach a fully compressed position, decreasing their stroke length and limiting their physiological capacity to push on the boat. (115) The repetitive movement pattern described in the rowing technique are similar to the risk

factors for OA development (repetitive bending and squatting), therefore rowers could be at risk of hip OA in later life. (33)

3.2 Rowing equipment and competition

Rowing equipment has been developed and improved significantly over the last 100 years. Figure 6 depicts a timeline of the key changes to rowing equipment and competition over the last 180 years. Racing hulls were originally made from wood and had heavy metal riggers, making them difficult to move without a lot of force.

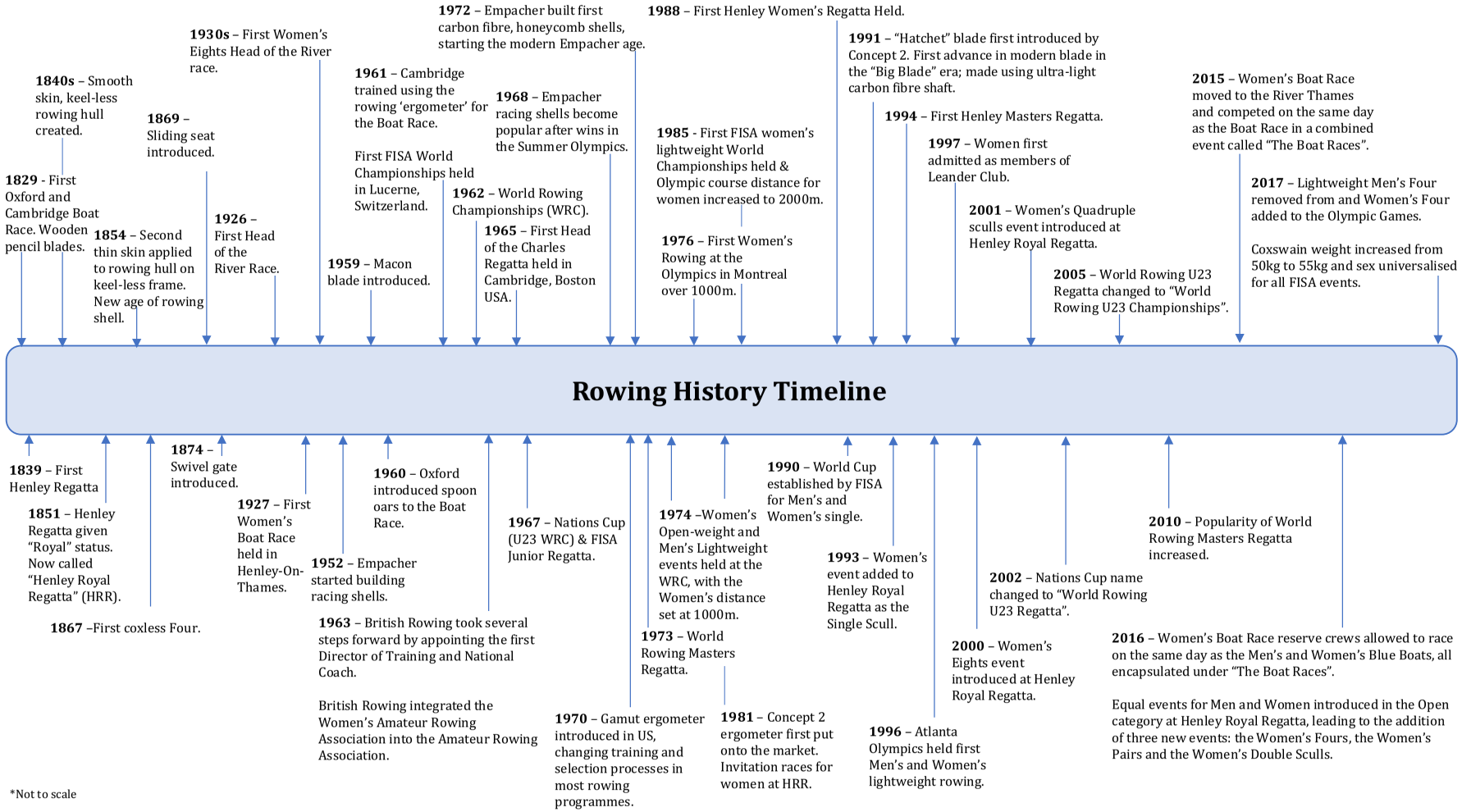

Figure 6. A timeline of rowing history, including developments in equipment and changes to competition. (110,111,161,164–166)

A rigger is the part of the boat that extends outside of the shoulders of the boat and is the point of attachment for the blade. This point of contact acts as the fixed leverage point of the blade to the boat, helping to move the boat through the water. Originally, the seats in the boats were fixed, meaning that they did not slide and the rower was limited to the capacity of the arms and back to move the boat. The sliding seat was developed and propagated in 1869, enabling the rower to use their legs as well as their arms and body, vastly lengthening their stroke and increasing boat speed. Over time, rowing hulls were made from lighter and stiffer materials: honeycomb, glass fibre and carbon fibre based materials with aluminium riggers. The modern day racing hulls are made of carbon fibre with carbon fibre riggers, making them much lighter, stiffer and therefore much faster by decreasing the weight of the whole unit but more importantly, decreasing energy-momentum dispersion. These innovations could be translating into higher musculoskeletal loading in current rowers using this equipment.

Furthermore, the mechanical design of the rowing blade has developed in conjunction with boat design developments. The first blades used were made entirely of wood with small square edged blade surfaces called 'Pencils' that were used to lever the boat (Figure 7).



Figure 7. Drawing of pencil type blade, demonstrating the small blade face surface area.

In the 1950s the 'Macon' blade, sometimes referred to as a 'tulip' or 'spoon', was introduced to the rowing scene (Figure 8). The Macon blade had a rectangular shaped blade face with rounded edges, slightly larger than the Pencil type blade, allowing for greater grip of the water because of the larger blade face surface area. The Macon blade face is shorter in length than modern blades, meaning there is less drag acting on the loom (long shaft area) whilst it is in the water. Although the early Macon blades were made of wood, there were many variations in materials used, including aluminium and plastic.

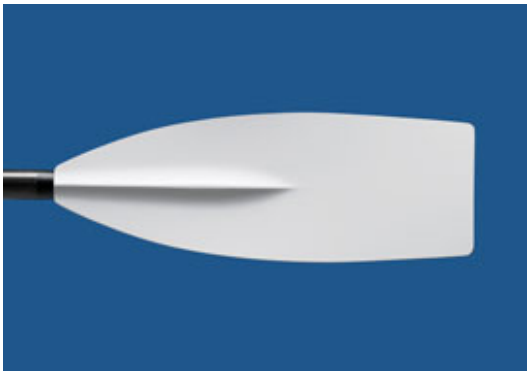

Figure 8. Macon blade. Figure from Concept2 inc. with permission. (116)

Further development of the more effective modern blade happened in the 1990's, marking the start of the 'big-blade' series. This style blade was called a 'Hatchet' blade and was made from mixed carbon fibre materials, making it much lighter and stiffer than its counter-parts (Figures 9 and 10). The blade face was much larger and squared off at the edges, reducing the slip of the blade and increasing grip of the water throughout the stroke. These modifications increase the leverage that rowers can place on the blade to move the hull. Higher loads and the ability to produce greater force per drive are two key advances achieved through this lighter and stiffer blade, leading to faster race times and new World

and Olympic records. The Concept2 Hatchet blade sparked the start of the modern-day racing blade, with many competing companies trying to develop similar blades to more efficiently convert the athlete's power into boat speed.

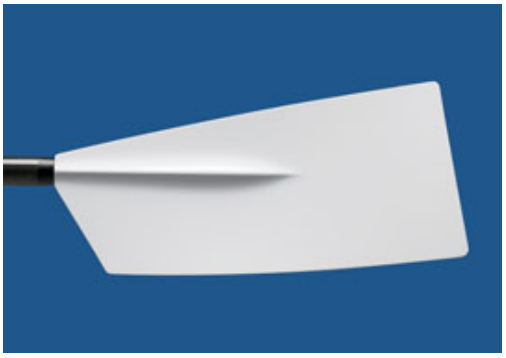

Figure 9. The Hatchet blade ('big blade'). Figure from Concept2 inc. with permission. (116)

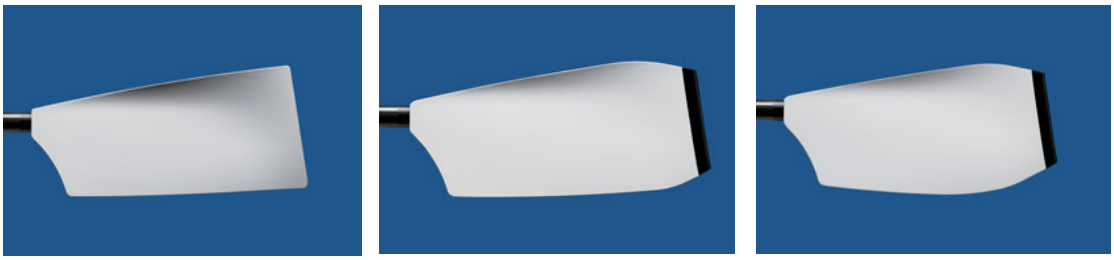

Figure 10. Modern variations of the Hatchet blade. Figure from Concept2 inc. with permission. (116)

Fluid dynamics of the rowing blade:

The blade path is complicated with multiple biomechanical determinants, including Newtons laws of physics, influencing how the blade moves through the water, the amount of slip there is on the blade face, and the resistance and load generated by the water against the rower (Figure 11).

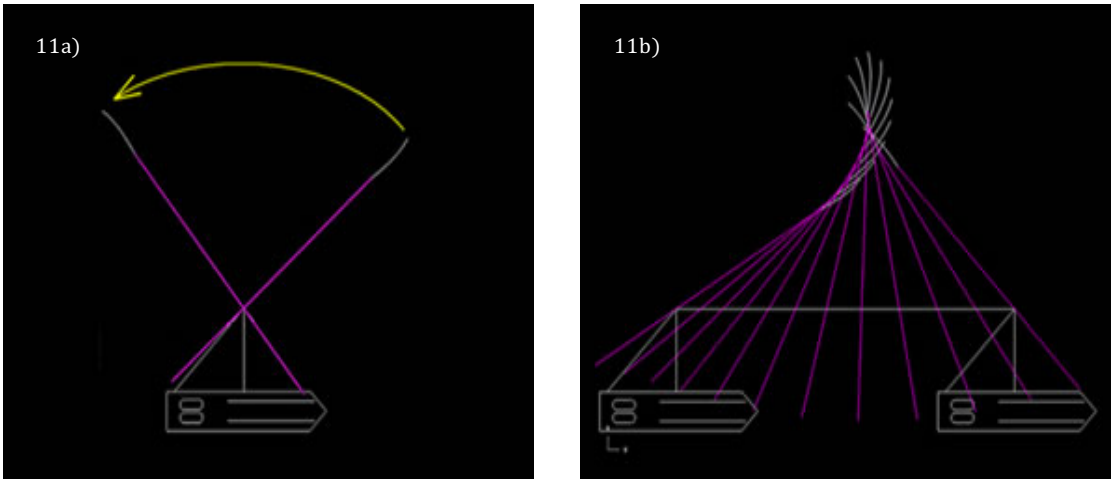

Figure 11. 11a) The assumed blade path and 11b) The actual blade path. Figure from Concept2 inc. with permission. (117)

However, in order to increase boat speed the athlete has to apply a large amount of force to the oar handle. Such forces place excessive loading on the joints and musculoskeletal system of the athlete. The increased loading achievable with the modern Hatchet blade could increase the risk of injury and OA in later life. These relationships and causalities have not yet been investigated.

3.3 Rowing-specific risk factors associated with hip pain and low back pain

Two rowing-specific risk factors for the development of hip and low back pain have been identified using evidence from the literature reviewed (chapter 2 and chapter 3, sections 3.1 to 3.2):

1) High training load and increased risk of injury and pain
2) Use of Hatchet-type rowing blade.

Therefore, the total hours spent rowing on the water and ergometer will be combined and described as one rowing-specific risk factor for training load in

this study. Furthermore, the use of a Hatchet-type blade will be used as the second rowing-specific risk factor for blade type. This is because variations in loading occur with different types of rowing blade. The Hatchet type blade is the modern style of rowing blade used and is known to facilitate faster boat speed through enhanced connection and grip through the water during the rowing stroke. With this enhanced connection, sudden increases in force generated by the muscles during the stroke cycle and an acute increase in loading through the skeleton to the shaft and blades will place greater load on the body. Therefore, the use of a Hatchet-type blade could be associated with greater injury risk, and potential pain and future OA risk at the joint level.

3.4 Chapter conclusions

Rowing is a hugely popular and relatively low risk sport that has seen huge successes to British sport over the last four Olympiads. As the popularity of the sport increases, it is important to understand the long-term effects of rowing on musculoskeletal health. Factors associated with injury rates include cumulative loading over extended periods, and acute loading, through sudden onsets of increased load. Cumulative loading can be associated with hours of training, whilst acute loading can be associated with advances in equipment used over the last few decades. The movement patterns required in rowing are similar to the risk factors for OA development (repetitive knee bending and squatting), therefore rowers could be at risk of hip OA in later life. This chapter explained the sport of rowing, the technique used and elements of competition as the sport has evolved. The equipment used in rowing is then described. Finally, potential

rowing-specific risk factors for the development of hip and back pain, and hip and back OA were identified using the literature. The next chapter will describe the methodology of the study.

Chapter 4. Materials and Methods

4.1 Background

To examine the long-term effect of rowing on the hip and lower back complaints in rowers, I designed a retrospective cross-sectional study of retired elite British rowers. Patient and Public Involvement (PPI) were used to incorporate novel elements to the study framework. This study design was partly dictated by recent experience on similar research conducted within the Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences (NDORMS) and the Arthritis Research UK Centre for Sport, Exercise and Osteoarthritis, exploring musculoskeletal health outcomes associated with long-term participation in elite sport, allowing for cross-sport data comparisons in the future. In this section I will discuss the design and methodology, as well as the rationale for this study.

4.2 Recruitment, patient cohort and group demographics

This section will describe the study design and recruitment strategy, including the inclusion and exclusion criteria for the study.

4.2.1 Study design

A retrospective, cross-sectional study design was employed to investigate long-term hip and spine problems in retired elite rowers. The study was designed to collect cross-sectional data on the prevalence of pain at the hip and spine, as well as long-term markers of musculoskeletal health such as osteoarthritis and joint replacement in retired elite British rowers, using a recall questionnaire in 2017.

The research framework followed was comparable to Davies *et al.* (2016) and Jones *et al.* (2017) to allow for future cross-sport comparisons of datasets within the Arthritis Research UK Centre for Sport, Exercise and Osteoarthritis, with novel elements designed using patient and public involvement (PPI).

4.2.2 Target population and recruitment

The target population for this study was a representative population of retired elite British rowers initially recruited from the elite British rowing club, 'Leander Club'. Leander Club is one of the most successful and highly-regarded elite rowing clubs in Great Britain. (118) An email advertisement, sent out via the clubs own online monthly newsletter 'Hippo Happenings', was used to recruit potential participants. All initial communication with participants was initiated through a study representative from Leander Club.

Study advertisements were sent only to 'full members' of the club. 'Full membership' is awarded to any distinguished past and present oarsmen and women, as well as the current world-class athletes competing on the active rowing squad at Leander. (119) An explanation of the recruitment process can be found in Figure 12 below.

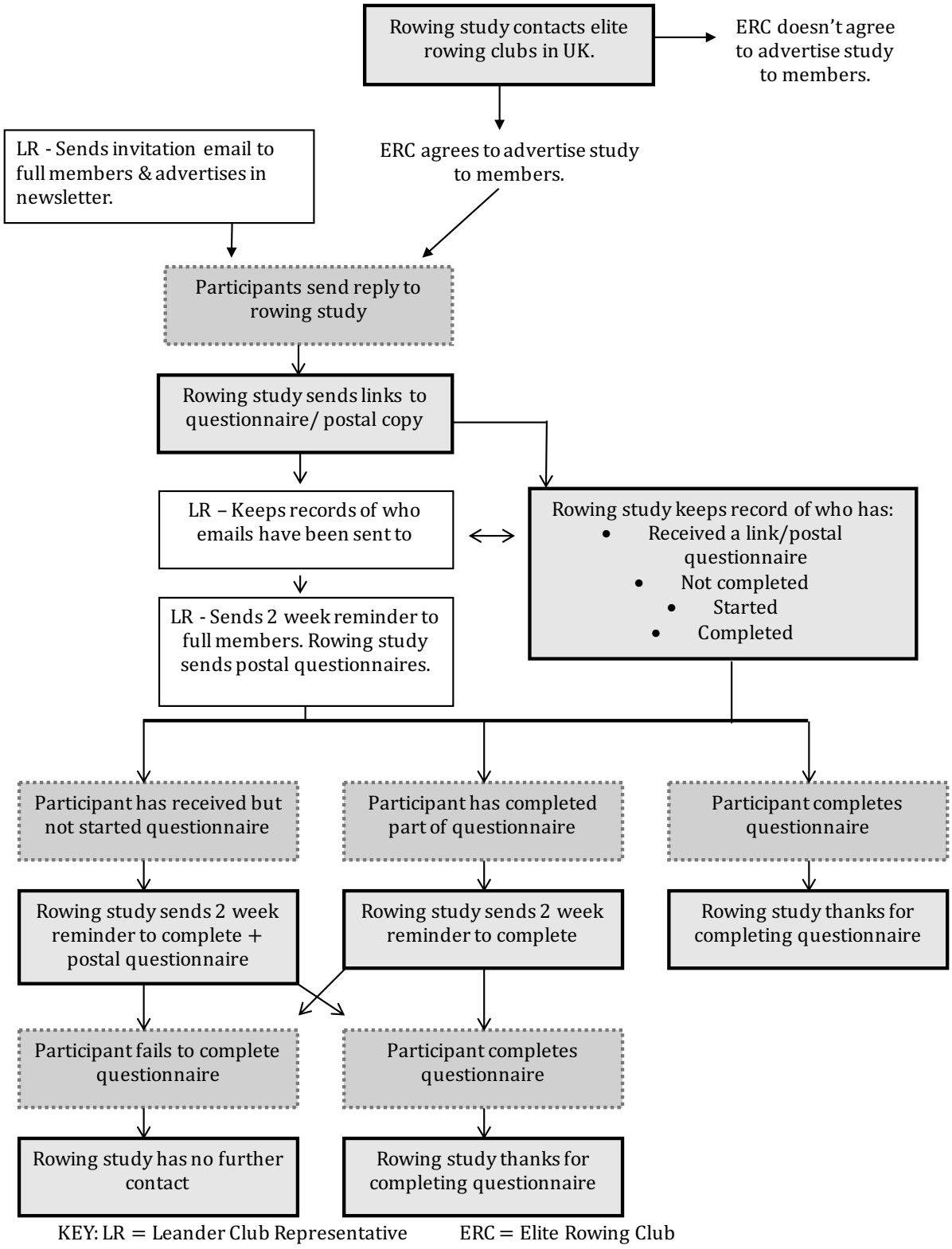

Figure 12. Flowchart of recruitment.

The study was also advertised to other high performance boat clubs within the UK, including Oxford University Men's and Women's Boat Clubs, Cambridge University Men's and Women's Boat Clubs, Molesey Boat Club, Thames Rowing Club, and Upper Thames Boat Club. Email responses were received from some participants associated with these boat clubs. To identify recruitment location all participants were asked to specify whether they were a Leander Club member and the capacity under which they had been approached to participate in the study. This allowed for the demographics of the recruitment population to be understood.

Inclusion criteria:

A flowchart of the inclusion and exclusion criteria can be found below (Figure 13). From the cohort contacted, only retired elite British rowers were eligible to participate in the study. For this research, retired elite British rowers were defined as anyone who had previously raced in a Henley Royal Regatta final, the Boat Race for Oxford or Cambridge, at Home Internationals for England, Scotland, Ireland or Wales as a Junior or Senior, or Internationally for Great Britain at Junior, under 23 or Senior level in any event, but who no longer trains or competes at this level. Participants could still be rowing and racing at recreational, club or Masters level. All participants had to be over 18 years of age and able to provide informed consent on their own accord.

Within the rowing community, Masters rowing (previously known as Veteran rowing) is age-categorised racing from 27 to 90+ years old and can be raced at standards from local club level to the World Rowing Masters Regatta. Although

the World Rowing Masters Regatta is the highest standard of competition at Masters level, it is not regarded as an elite level in this study.

Exclusion criteria:

Any athlete still competing at an elite level, those that had never competed at an elite level, or athletes that were not British were excluded from the study. The criteria excluded any potential participant that was unable to provide informed consent to the study.

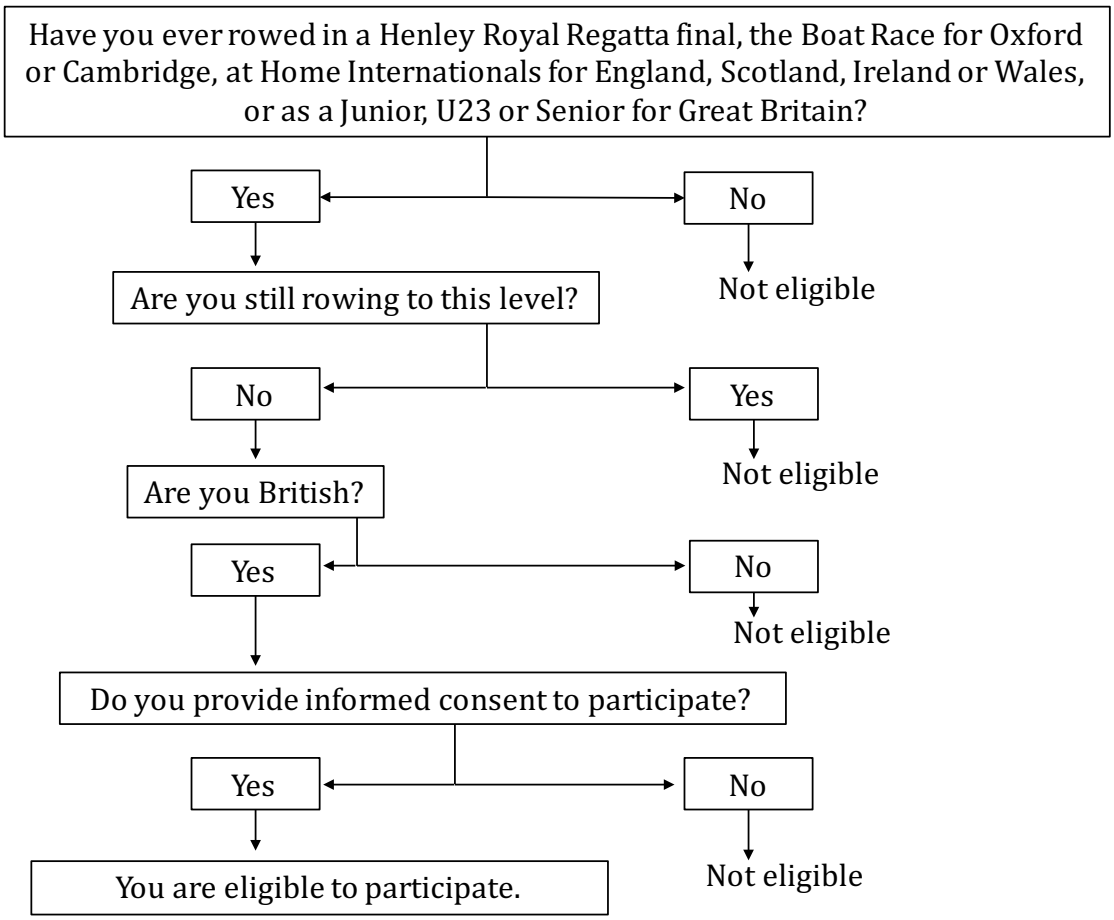

Figure 13. Flowchart summarising the eligibility questions used in the study questionniare.

Leander Club cohort:

Of the two-thousand full members of Leander Club contacted, at least 50% were still competing at an elite level, 30% were non-rowing members but had committed significantly to the sport through umpiring, coaching and other non-competitive means, leaving 20% eligible potential participants ($n = 400$). All full members were contacted because it was thought that this would help to increase the public knowledge of the study and encourage more people to participate.

Advertisement and social media:

A total of one hundred flyers and information cards for the study were distributed at different rowing events throughout the year. Hardcopy items were distributed at Henley Masters Regatta and the World Masters Rowing Championships in the summer of 2016. It was difficult to keep a record of how many people had been reached by the study advertisement as the internet sources and flyer information could easily be shared. Social media accounts were set up to advertise the study and to interact with potential participants and Olympians as means of study promotion. All adverts were pre-approved by the university ethics committee.

4.3 Patient and Public Involvement

4.3.1 Overview

The questionnaire for the study was designed in two parts. Firstly, questions that had been developed for cricket and rugby as part of a core-questionnaire to investigate injury, OA and pain were used in the rowing study questionnaire to

provide continuity between other sport-specific questionnaires. This consistency of questions allowed for the option of cross-sport comparisons between data sets for future research. The core questions had been developed by two DPhil students working for the Arthritis Research UK Centre for Sport, Exercise and Osteoarthritis from clinically verified questions to ensure self-reported, clinically meaningful data would be collected. (120–123)

The second part of the questionnaire I developed through a process of reviewing the current literature and incorporating Patient and Public Involvement (PPI) to identify novel rowing-specific questions that had not yet been investigated. These questions included questions comparable to other rowing related research, and novel questions such as what type of blade athletes used when rowing.

INVOLVE is a Government-funded initiative to support active public involvement in NHS, public health, and social care research. (124) Recent research has involved rugby players across the research cycle of a player health study, ensuring the study was player-centred and that the design and questionnaire of the study were approved by the players. (122) For our study, PPI was used in a similar manner to achieve rower-centred research.

This section will outline the PPI recruitment strategy, group demographics, suggestions made by the PPI group and action for changes to the questionnaire. All organisational requirements, participant recruitment, and reviewing

materials were organised by myself and facilities were co-ordinated through the help of Leander Club.

4.3.2 PPI recruitment and group demographics

This sub-section will be split into two parts: PPI recruitment and PPI group demographics.

4.3.2.1 PPI Recruitment

Participants for the PPI group were recruited through an email that was sent to all full members of Leander Club via the study representative. The email asked for any current elite rowers in the Great British national team and retired elite British rowers who were either no longer rowing, or currently competing at a Masters level and who were interested in helping the development of a questionnaire for research into the musculoskeletal health of retired elite rowers. All participation was completely voluntary and participants were free to withdraw or leave the meeting when they wanted. Any potential participants were asked to email the rowing study directly to ask for details of the requirements of the PPI group and a meeting venue and date was set that worked unanimously for the group.

4.3.2.2 Group demographics

The PPI group consisted of rowers who were current Olympic medallists, World champions, retired World Champions, and retired GB Rowing Team athletes who were still competing in Masters rowing. There was a total of 10 participants (8 males and 2 females) with an age range of 26 to 80 years old.

4.3.3 Procedure and Questionnaire Development through PPI

This sub-section will be split into three descriptive parts: the reviewing process, descriptions of the suggestions made by the PPI group, and descriptions of how changes to the study questionnaire were actioned using the suggestions of the PPI group.

4.3.3.1 Reviewing process

A guide was written pre-meeting and used as a structure for the reviewing process (see Appendix). The reviewing process was conducted in an informal manner with open discussions. Each participant was given the opportunity to speak freely about the questionnaire and could write comments on paper if they had not had a chance to voice their opinion. Questions were reviewed individually and feedback was provided by the group on terminology, appropriateness of the questions, understanding of what the question was asking, and ordering in the questionnaire. Any notes on Post-its or questionnaires were reviewed for key points and themes by myself before being stored securely. Furthermore, a full recording of the informal discussion was taken and transcribed into text. Key quotes, themes and suggestions were noted and used to modify the questionnaire. Both the recording and transcribed script are stored securely on a password protected hard-drive at the University of Oxford.

4.3.3.2 Suggestions made by the PPI group

1) Blade type:

Following transcription of the audio recording, any key suggestions were noted and used to influence the development of novel questions for the questionnaire. For example, one participant stated:

"I never rowed with one of these funny blades which I think cause an awful lot of these injures. Even the pencils, well actually you couldn't get a lot on the pencils, but even the spades were relatively benign to the body. Whereas nowadays because you can get the catch so quickly and so hard, that's when you damage yourself."

This statement reflects upon some of the changes to blade biomechanics over the years and potential concerns over such changes. It is apparent that although allowing the athletes to build more boat speed, the newer blades could be causing more injuries because of the increased load that it is possible to generate on the blade face. This contributed to the development of questions asking about the type of blade athletes rowed with before, during and after their elite rowing career, and for how long they used that type of blade. This was something that had not been investigated in other rowing literature.

2) Masters rowing:

The second most influential suggestion was to include athletes who were still competing in the questionnaire. The PPI group were concerned that Masters rowers would not complete the questionnaire because they would feel like they weren't classified as elite enough for the study, despite having previously competed internationally for Great Britain. To accommodate the increasing Masters rowing scene, questions were added that asked about current

competition levels and any key Masters events that athletes had recently competed at. This information could be useful in investigating why some athletes have carried on rowing after retirement from elite racing, and why others have stopped competing. For governing bodies such as British Rowing, this could be helpful in encouraging participation and longevity in the sport following elite careers.

3) Training equipment:

Some of the older members of the PPI group suggested adding in different training options for the rowing-specific questions investigating training load. This suggestion was helpful because during their elite careers rowing ergometers had not yet been invented, or were only just starting to be introduced, meaning training was either completed on the water in boats, or through cross-training activities such as running and cycling. Furthermore, it was also suggested to incorporate a question that would identify whether athletes completed some form of core-strength or flexibility training.

4) Sculling vs Sweep Oar rowing:

One of the most common interests of the PPI group was whether it was possible to investigate differences between the type of rowing that the athlete did and their long term MSK health. Participants suggested it was important to understand all the rowing that the participants had done, including sculling or sweep oar, because this is how some of them had first become injured in their careers:

"All my career I'd done sculling. Done a couple of sweep races, but nothing to an elite level. Do you still want to know the training I've done in sweep boats because I mean, that would still have an implication to injury considering that's how I injured myself in the first place but I never actually raced internationally or to an elite level in sweep."

For this reason, participants were asked if they had ever rowed in sculling or sweep oared boats, and to what level they had rowed in those boat classes.

4.3.3.3 Actions of changes to questionnaire

Changes to the questionnaire were put into place to incorporate the suggestions made by the PPI group. The questionnaire already contained the 'Blade biomechanics' section, detailing different blade types as well as asking how long and during which career phase they had rowed with this type of blade for. The PPI group confirmed the importance of this question, and therefore the section remained in the questionnaire.

Questions for Masters competitors were added to the 'Racing history' section to ensure that data around their current participation and racing was captured. Different boat classifications were added so that the boat classifications and level at which the athletes had competed could be captured.

Furthermore, questions asking about hours trained per day and days of training per week were added in three sections: on the water, on the rowing ergometer and in the gym. This change allowed athletes who were in the older portion of the cohort to complete the training load section even if rowing-specific equipment had not yet been introduced. A core-strength, flexibility and mobility

question was added to identify whether some method of prehabitation had been incorporated into their elite training programmes.

4.4 Questionnaire

4.4.1 Clinically validated questions

The National Health and Nutrition Examination Survey (NHANES) is a program of studies designed to assess the health and nutritional status of adults and children in the United States. NHANES questions were used to identify current pain as these questions have been shown to be closely correlated with predicting current OA. In the study questionnaire, the NHANES specific terminology of 'pain on most days of the last month' was used to capture both severity of pain and as a clinically validated self-reported predictor of OA at the joint level. (40,125,126)

The accuracy in the anatomical location of pain is a limitation of the questionnaire. It is possible that participants could recall pain to what they thought was the hip joint, when it could have been originating elsewhere, such as the sacroiliac joint. To reduce the chances of participants recalling pain to the incorrect anatomical location, special attention was given to the wording of the questions used in the core questionnaire. Each NHANES pain question was provided with a brief description of the pain location being targeted in the question. For example, when asking about pain at the hip joint, participants were asked whether they had pain at the 'hip(s) or the groin', as patients regularly recall hip pain to the groin area. This is something that will be discussed further in chapter 7.

4.4.2 Core questions

The term ‘core’ is used to describe a specific set of questions which can be used to compare basic demographics and musculoskeletal complaints between different sports groups. These questions were developed by two DPhil candidates at the University of Oxford within the Arthritis Research UK Centre of Excellence as part of cross-sectional research into the musculoskeletal health of athletes in cricket and rugby. The original study was in rugby, and the original questionnaire was then adapted for different sports, including cricket, football, jockeys, ballet and rowing. The ‘core questions’ describe the questions that are consistent between all questionnaires, regardless of what sport was investigated. This design was implemented to allow for cross-sport comparison between data sets and to maintain consistency within the research.

4.4.3 Novel questions

At present, all the literature has studied current elite rowers, neglecting to investigate the retired population of elite rowers, and therefore the long-term outcomes of participating in elite level rowing.

Following a review of the current literature around elite rowing, training, and biomechanics, combined with a personal history of competing as an elite athlete in rowing, the following novel questions were designed to target areas of elite rowing not yet investigated:

Racing history:

3.1 Are you currently rowing?

3.2 If yes, at which level?

3.3 If yes, are you still racing?

3.4 If you are a Masters (Veteran) competitor, which Masters competitions have you competed at?

3.5 Please provide either the date or age you retired from elite rowing.

3.6 Reasons for retirement from elite rowing?

3.7 Age at first ever race?

3.8 Age at last race?

3.9 Age at first elite race?

3.10 Age at last elite race?

3.33 How many years did you race before your elite career?

3.34 How many years did you race at an elite level?

3.35 How many years did you race after your elite career?

3.36 How many medals did you win throughout your elite career?

Boat classes:

3.12 Did you ever row in sculling boats?

3.13 If yes, what age did you learn to scull?

3.14 If yes, please select all the sculling boat classes you have sculled in.

3.15 If yes, what levels have you sculled in that boat class?

3.16 Did you ever row in sweep oar boats?

3.17 If yes, what age did you learn to row sweep?

3.18 If yes, please select all the sweep rowing boat classes you have rowed in.

3.19 If yes, what levels have you rowed in that sweep boat class?

Rowing related hip and spine injuries:

6.6 If yes, were these spine injuries rowing or non-rowing related?

6.13 If yes, were these hip or groin injuries rowing or non-rowing related?

Blade biomechanics:

3.26 Before rowing at an elite level, what type of blade did you row with?

3.27 How long did you row with this type of blade for?

3.28 At an elite level, what type of blade did you row with?

3.29 How long did you row with this type of blade for?

3.30 Did you continue rowing after your elite career?

3.31 If yes, what type of blade did you row with after your elite career?

3.32 how long did you row with this type of blade for?

Training load:

Before your elite rowing career, on average, how many hours per day and days per week did you spend training:

3.63 On the water?

3.64 On the rowing ergometer?

3.65 In the gym (free, machine or body weights)?

During your time as an elite athlete, on average, how many hours per day and days per week did you spend training:

3.66 On the water?

3.67 On the rowing ergometer?

3.68 In the gym (free, machine or body weights)?

After your elite rowing career, on average, how many hours per day and days per week did you spend training:

3.69 On the water?

3.70 On the rowing ergometer?

3.71 In the gym (free, machine or body weights)?

Currently, on average, how many hours per day and days per week do you spend training:

3.72 On the water?

3.73 On the rowing ergometer?

3.74 In the gym (free, machine or body weights)?

3.75 In sport, exercise or physical activity other than rowing?

3.76 Did you regularly complete core strength and stability, mobility or flexibility training as part of your elite rowing training programme?

Current pain:

4.10 Have you ever rowed with back pain?

4.11 If yes, did you ever row with back pain during your elite career without receiving medical or physiotherapy treatment?

4.12 If yes, how long did you row with back pain without receiving treatment?

4.21 Have you ever rowed with hip or groin pain?

4.22 If yes, did you ever row with hip or groin pain during your elite career without receiving medical or physiotherapy treatment?

4.23 If yes, how long did you row with hip or groin pain without receiving treatment?

A full list of all questions asked can be found in the appendices.

4.4.4 Data entry

Online platform - REDCap:

The online platform 'REDCap' (Research Electronic Data Capture) was used to host the online version of the questionnaire. Study data were collected and managed using REDCap electronic data capture tools hosted at the University of Oxford. (127) REDCap is a secure, web-based application designed to support data capture for research studies. All participants were given the option of completing the questionnaire either electronically (online) or by hand (paper copy via post). All questions, answer choices, font, and formatting for the online questionnaire was consistent with the paper version. Formatting and access of the online platform was controlled by a departmental data manager to ensure appropriate practices were followed. Each variable for the questionnaire was entered manually and was unique to the question.

When participants contacted the rowing study to participate in the research, a unique link to the REDCap study page was sent to each participant. Participants were given a unique code identifier that anonymised them and allowed for the researchers to identify that they had completed the questionnaire online. The

participants could then complete the questionnaire in their own time, and had the option to take a break from it and return when they wanted. During the set-up of the invitation to complete email, a two-week reminder email to complete the questionnaire was scheduled for mailing if participants had not completed their questionnaire already. Further reminder emails could be sent from the platform if participants had questions or needed their unique questionnaire codes re-sent to them.

Paper responses – data entry into REDCap:

Responses completed on the paper questionnaire were sent via post to the Botnar Research Centre to be entered manually into the REDCap database. As the principle researcher, I completed all the data entry of the 13 paper questionnaires into the database. Each participant was uniquely coded to show that they had completed a paper version of the questionnaire and anonymised. Following completion of data entry, all responses were marked as unverified. This allowed for a second researcher to verify the data entered into the server and check that all was correct, before marking each response as complete.

4.5 Ethics and study approval

Ethical approval was received through the Central University Research Ethics Committee (CUREC) at the University of Oxford and was given the IDREC approval number: R44491/RE001. A copy of the study approval letter is appended.

4.6 Statistical analysis

This section will be split into four parts. The study risk factors and outcome variables will be explained first, followed by descriptions of variable development in the statistical platform, study analysis protocol and statistical tests used.

4.6.1 Defining risk factors and outcome variables

Rowing-specific risk factors:

Rowing-specific risk factors were a priori selected and obtained in the questionnaire. Below, I describe variables based on the questionnaire used for the analysis in this these.

1) Blade type (binary variable):

Macon and Spoon blade types were grouped together as one blade type for analysis called 'Macon/Spoon'. The variable 'Ever used Hatchet?' was generated to investigate potential differences between the use of a Hatchet blade and those with hip and/or back pain and OA. It is hypothesised that this type of blade will be associated with a greater risk of current pain, OA and injury due to the enhanced loading. It is hypothesised that the blade types Pencil and Macon/Spoon will have a significantly lower risk of current pain, OA and injury due to lower loading forces biomechanically.

2) Hours trained per week (continuous variable):

The total hours trained per week was identified as a risk factor as the literature supports the hypothesis that greater hours spent training on the water and ergometer are associated with a greater injury risk.

In this study, we will look at training load in two ways. Firstly, individual training load per week in each training discipline (on water, ergometer, and gym) will be calculated as total hours per week. Secondly, water and ergometer hours will be combined to give a weekly total of 'rowing hours' to be compared to 'gym' hours. This is because we hypothesise that hours spent training in the gym, completing body weight, free weight, and machine weight training, may provide a preventative mechanism against injury due to better physiological conditioning of the athlete; the more robust an athlete is, the less susceptible to injury they will be.

Outcome variables:

Outcomes to investigate the prevalence of self-reported severe joint pain and self-reported OA at the joint level were derived from the following variables:

Self-reported NHANES hip (binary variable):

NHANES hip pain was developed using responses from question 4.15 'Have you had any pain in your hip(s) or groin on most days of the last month?'. Patient responses were coded in a binary format, ready to be analyses in logistic regression to identify possible relationships between rowing-specific risk factors and the outcome.

Self-reported NHANES back (binary variable):

NHANES back pain was developed using responses from questions 4.3, 4.4 and 4.5. These questions asked for joint specific pain at the cervical spine, thoracic spine or lower back on most days of the last month. As with NHANES hip, patient responses were coded in a binary format, ready to be analysed in logistic regression to identify possible relationships between rowing-specific risk factors and the outcome.

This variable was then used to generate joint specific NHANES back pain variables:

a) Self-reported NHANES thoracic spine (binary variable)

b) Self-reported NHANES lower back (binary variable)

Physician-diagnosed hip osteoarthritis (binary variable):

Physician-diagnosed (self-reported) OA was used to identify whether patients had OA of the hip. Patients were asked 'Have you ever been told you have wear and tear, degeneration or Osteoarthritis by a Doctor?' in the questionnaire and to indicate which joints this was specific to. This was used as the method of Physician-diagnosed OA. Patients were also asked 'Have you ever had joint replacement surgery?' and to identify which joints they had had surgery on. This was used as a parameter to identify the number of patients that had had a total hip replacement (THR).

Physician-diagnosed thoracolumbar spine osteoarthritis (binary variable):

Physician-diagnosed (self-reported) OA was used to identify whether patients had spinal OA. Patients were asked 'Have you ever been told you have wear and

tear, degeneration or Osteoarthritis by a Doctor?' in the questionnaire and to indicate which joints this was specific to. If they indicated any part of the lumbar or thoracic spine they were coded into the variable for physician-diagnosed thoracolumbar spine OA.

Total hip replacement (binary variable):

A new variable for THR was generated from responses to the question 'Have you ever had joint replacement surgery?' (binary variable) and the follow-up question 'If yes, please indicate the number below for each affected joint/side' (categorical variable). If a participant had entered '≥1' for the number of joint replacements they had received at the hip joint, they were coded as a '1'. Anyone who had not indicated any joint replacement at the hip was coded as '0'. If a participant was entered as 'missing' to the original question 'Have you ever had joint replacement surgery?', they were coded as 'missing'.

The THR variable was then broken down into the following new variables so that the hip(s) that underwent surgery could be identified:

3a) Left THR

3b) Right THR

3c) Both hips replaced

Poor hip outcome (binary variable):

A poor hip outcome (PHO) was developed into a binary variable to outline any participants that had answered 'yes' to any of the three individual poor hip outcomes (Self-reported NHANES hip pain, Physician diagnosed hip OA and total

hip replacement). This allowed for an understanding of the overall health of the hip joint within the population studied and demonstrated the level of disability caused. A PHO variable has been used in previous research, therefore this outcome will be consistent with other literature. (44,122,128,129)

Poor spine outcome (binary variable):

A poor spine outcome (PSO) was developed into a binary variable to outline any participants that had answered 'yes' to any of the three individual poor spine outcomes (self-reported NHANES thoracic spine pain, NHANES LBP, and Physician-diagnosed spine OA). This allowed for an understanding of the overall health of the spine within the population studied and demonstrated the level of disability caused.

Hip-spine outcome (binary variable):

A hip-spine outcome (HSO) was developed into a binary variable to capture participants that had both the PHO and PSO. Those with both outcomes were coded as '1', and those with one or neither were coded as '0'. This variable was designed to describe the potential for hip-spine syndrome within retired elite rowers, and allow for differences to be investigated between those with PHOs and PSOs.

Outcomes to investigate the prevalence of self-reported injury at the joint level were derived from the following variables:

Any spine injury (binary):

Participants were asked 'Have you ever had any severe injury in your spine, leading to more than four weeks of reduced participation in exercise, training or sport?'. The terminology 'more than four weeks of reduced participation in exercise, training or sport' was used to identify severe injuries, as four weeks was deemed to be a significant memorable event that participants would have found easier to recall. This time frame is also used in previous publications researching pain and OA and is therefore consistent with the literature, which also helps to reduce recall bias within the population. (40,44,128,129) Furthermore, severe injuries are associated with OA development in later life, so capturing these injuries could help to identify joints at risk within the population. Participants that answered 'Yes' were coded as '1' or 'No' as '0'. Any participants that had answered 'Don't know' were coded as 'missing'. All missing participants were also coded as 'missing'.

Any spine injury was then split into rowers reporting rowing related spine injuries, and those reporting non-rowing related spine injuries. If a participant had reported at least one or more spine injury and reported that one of these spine injuries were rowing related, they were coded with a '1' and marked as having a rowing related spine injury. If participants had responded yes to a spine injury but no to having a rowing related spine injury, they were coded with a '0' and marked as having a non-rowing related spine injury. Participants that had reported having more than one injury to the spine but reported these injuries as one non-rowing and one rowing related, were coded into both the rowing related spine injuries and non-rowing related spine injuries variables. Any rower

who didn't specify whether they had a rowing- or non-rowing related injury were excluded from the analysis.

These variables were used to explain whether previous injuries were associated with joint-specific OA development in later life, and whether the pain or injuries experienced by the rowers were directly related to their rowing participation or not.

Any hip injury (binary variable):

As with spine injury, participants were asked 'Have you ever had any severe injury in your hip(s) or groin, leading to more than four weeks of reduced participation in exercise, training or sport?'. Participants that answered 'Yes' were coded as '1' and 'No' as '0'. Any participants that had answered 'Don't know' were coded as missing. All missing participants were also coded as 'missing'.

The variable any hip injury was broken down into those reporting having rowing related hip injuries and non-rowing related hip injuries. The variable generation was the same as in rowing and non-rowing related spine injuries, outlined above.

4.6.2 Variable development - designing and cleaning variables for analysis

All variables to be used for analysis were individually identified and cleaned. New variables were created when cleaning practices such as editing, combining or unit conversion were required.

Missing data:

All missing responses to variables were treated as 'missing'. Any participant missing any of the key variables for analysis were removed from the study to conduct a complete-case analysis. Missing participant characteristics were collected before any analysis and compared to those with participants of the non-missing cohort to check for any significant differences between groups and limit any selection bias. This also allowed for the generalisability of the results to be tested.

Don't know responses:

All variables that were entered as 'Don't know' were coded as 'missing'. This was because the response 'Don't know' is neither a 'Yes' nor a 'No'. The response could have been treated conservatively and re-coded as a 'No', however I did not want to assume that the participants meant 'no', and therefore treated the response as 'missing'.

BMI (continuous variable):

The following variables were used to create BMI:

- Current bodyweight in stones and pounds
- Current bodyweight in kilograms
- Height in centimetres
- Height in feet and inches

The following equation was used to calculate BMI:

$$BMI = \frac{Weight\ (kg)}{Height\ (m)^2}$$

Therefore, all measures of body weight needed to be converted into pounds and then to kilograms and all height measurements converted from feet and inches (or centimetres) to metres. Once the conversions were completed, BMI could be calculated. If patient data for either height or weight was missing, they were removed from the study.

Number of rowers still rowing (binary variable):

A binary variable was created to show the number of rowers still rowing to a level below elite in the questionnaire. Anyone who answered 'Yes' to "Are you still rowing?" was coded as a '1', and those who answered 'No' were coded as '0'.

Number of rowers still racing (binary variable):

If participants were still rowing they were asked "Are you still racing?". Participants who answered 'Yes' were coded as '1', and those who answered 'No' to this question, or answered 'No' to "Are you still rowing?", were coded as '0'. This showed the number of retired rowers who were still racing at a Masters, club or recreational level for the love of the sport, but were no longer racing or training to an elite standard.

Number of rowers who raced at a Senior World Championships (binary variable):

Participants were asked to select all the elite competitions in which they had competed. Those who selected 'Senior World Championships' were coded as a '1', and those that did not select the event were coded as '0'. This variable was used to illustrate the elite standard of the retired rowers who participated in the questionnaire.

Number of rowers who raced at an Olympic Games (binary variable):

This variable was created in the same way as the 'number of athletes who competed at a Senior World Championships' variable. This described the number of retired rowers who had competed to the highest standard in their elite rowing careers.

Blade type - Hatchet blade use (binary variable):

The questionnaire allowed for multiple blade types to be selected for use pre-elite, elite and post-elite career. New variables were generated for each career phase to show whether they had rowed with a Hatchet blade at any point in that phase. If participants had recorded a 'Yes' for Hatchet during their career phase, the variable was coded as '1'. If participants had answered 'No', the variable was coded as '0'.

Training load (continuous variable):

Training load data was captured for three training categories: on water, on the ergometer, and in the gym during each career phase. The original data set

provided data for hours trained per day, minutes trained per day and days trained per week. The hours were converted to minutes and then added to the minute's dataset in a new variable for 'hour + minutes'. The combined value of hours and minutes was then multiplied by the number of days per week trained, and then divided by 60 to give total hours trained per week.

Any participants who had provided hours or minutes per day, but not days per week, were given a day per week value of '1 day' entered. This value was chosen because this is the minimum number of days per week that the athlete could have trained. Any participants who had provided a value for days per week, but not hours or minutes per day, were given a minutes per day value of '30 minutes'. This value was awarded based on both professional opinion on elite rowing, and from a study by Gates *et al.* (2017) who reported the value of '30 minutes' for the minimum time spent rowing from existing population cohorts in the UK and USA. (35)

New variables for training load were created so that the load could be investigated in two ways:

1) Training hours in each training discipline, per career phase:

Total weekly hours trained in each training discipline were calculated specific to each career phase. For example, 'total_hours_water_belite_MBW' describes the total number of hours of training completed per week on the water before their elite rowing career. This process of variable generation was followed for before elite water, ergometer, and gym; elite water, ergometer, and gym, and post-elite water, ergometer, and gym.

2) Rowing hours per week versus gym hours per week, for each career phase:

The weekly hours for water and ergometer training were combined to give a new variable demonstrating the total 'rowing hours' trained before elite, whilst elite, or after elite. As the gym hours per week, specific to each career phase, were already generated, a new variable was not required.

Wellbeing (categorical variable):

Participants were asked to what extent they agreed with the statement: "Considering the benefits and risk of my previous participation in rowing, I would do the same again". 91 out of 92 participants answered this question. The one missing response was re-coded to be 'Undecided' in a new variable called 'wellbeing_rowing_again'. This was decided to be the most neutral response the participant could have said, and allowed for the data to be tested in the complete-case cohort.

Reasons for retirement from rowing (categorical variable):

Participants were asked to select all reasons for retirement from their elite rowing careers. Each selection was then coded into a binary variable, such that a selection of a reason for retirement was coded as '1' for that variable, and no selection coded as '0'. This process was completed for each of the 'reasons for retirement'.

Health status using EQ5D-5L (categorical variable):

The EQ5D-5L questionnaire was used to assess the health status of the participants. Permission was received from the EuroQol Research Foundation to use the EQ5D-5L questionnaire in the study. (130,131)

4.6.3 Complete case analysis

A complete-case analysis was conducted on the dataset. To check for generalisability bias within the missing participants, a missing vs non-missing analysis was conducted. Significant differences were conducted between the two groups using t-tests at a statistical significance of $p<0.05$.

The complete-case cohort was used to describe characteristics and potential risk factors associated with hip and spine problems in retired elite rowers. The missing data group describes any participant that failed to answer all questions used for analysis in the study. Analysing the missing data group allows us to understand the characteristics of those participants in the missing population and whether there are any differences between those who are included in the complete-case group and those who are in the missing data group. This allowed me to check for bias in selection and generalisability, and to understand how these differences may affect the results of the study. (132,133)

4.6.4 Statistical tests

Statistical analysis was conducted using the statistical software Stata 14.1. Descriptive statistics of the population demographics were reported as mean ± standard deviation, where variables were normally distributed. Where variables

were not normally distributed, data were reported as median and range. Rowing-specific demographics were reported in the same way. All outcome variables were reported as prevalences within the complete-case analysis group. Where variables were normally distributed and continuous, t-tests were used to test for differences between groups. Mann-Whitney U tests were used to test for differences in continuous variables with skewed distributions. Chi squared tests were used to test for statistical differences between normally distrusted binary variables. A statistical significance was set at $p<0.05$ for all tests. Post-hoc power calculations were used to calculate the power of the sample size of used to test for differences between rowing-specific risk factors and primary outcomes.

Chapter 5. Descriptive analyses of hip and spine problems in retired elite rowers

5.1 Background

Pain presents a significant burden to athletes in the sporting arena. Hip and spine injuries have a negative impact on the training and performance of elite rowers and are described as two of the most common injuries in rowing. (8,17,102,106,109) The severity of pain caused from these injuries and its associations with training specific factors have been investigated and are understood to be associated with the load that the athlete is exposed to. (106,107) Factors associated with injury rates include cumulative loading over extended periods, and acute loading, through sudden onsets of increased load. Cumulative loading can be associated with hours of training, whilst acute loading can be associated with advances in equipment used over the last few decades. However, it is unknown whether these rowing factors are associated with long-term health problems such as hip and spinal osteoarthritis in retired elite rowers (Figure 14). Furthermore, there is a growing body of research suggesting that there are instances where spinal pain may be a result of abnormal hip pathology, and therefore a 'hip-spine syndrome'. (95,134,135)

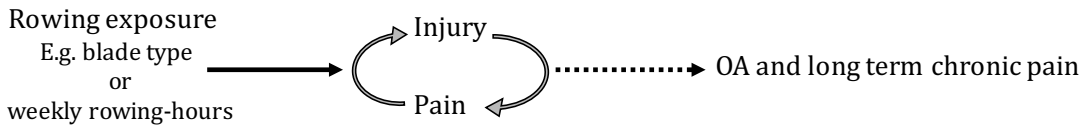

Figure 14. Schematic association between rowing-specific risk factors and hip and spinal injuries and pain, and potential long-term MSK health problems.

To improve the understanding of the relationship between rowing training and hip and spinal pain in retired elite rowers, I will describe the size of this problem and compare self-reported training characteristics in affected and unaffected individuals. This analysis can potentially help to identify important rowing-specific risk factors associated with spinal and hip problems in retired elite British rowers. The overall aim of this chapter is to describe the prevalence of long-term hip and spine problems in the retired rowing population, and potential rowing-specific risk factors associated with those problems.

To achieve this, I will take the specific steps described in the objectives below:

1) Describe the demographic characteristics of the elite rowers in the study and those excluded from analysis
2) Describe the prevalence of rowing-specific risk factors
3) Describe the prevalence of hip pain/OA, thoracolumbar spine pain/OA and hip-spine syndrome.

5.1.1 Complete-case sample

A complete-case analysis structure was used to analyse the data. The final study cohort included only participants who had answered specific questions to provide all the key variables for analysis including hip and thoracolumbar spinal

outcomes and exploratory variables. The complete-case sample (Figure 15) excluded any participant who was missing key demographic variables, self-reported hip and spine problems, and specific self-reported rowing factors.

Thirty-four participants did not have complete data and could not be included in the complete case analysis (Table 2). Figure 15 (below) describes how the complete-case sample was determined and where participants were lost. Following the implementation of the complete-case criteria, 92 participants remained (23% response rate) and were used as the complete-case cohort for the study analysis.

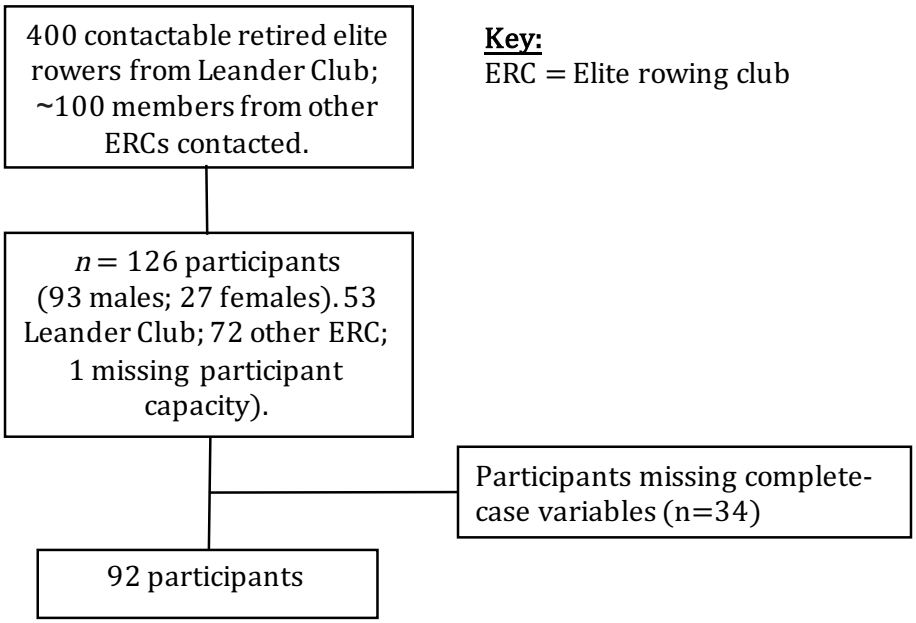

Figure 15. A flow diagram of participants' eligibility for the complete-case study analysis.

In the next section the demographic characteristics of the missing group are compared to the complete-case group to test for significant differences between groups. Any significant differences will be described and their potential effect on the results outlined.

5.1.2 Characteristics of participants not included in the analysis due to missing data:

Demographic characteristics of the complete-case group and the missing group are compared in Table 2 below (page 82). There were no significant differences between groups in age, BMI, height, weight, any NHANES pain in the hip or spine, physician-diagnosed OA of the hip or thoracolumbar spine, THR, any hip injury, Hatchet blade use or rowing hours in each career phase. However, a significant difference was found in the percentage of retired elite rowers that rowed with a Hatchet-type blade after their elite career; participants in the complete-case group reported a significantly higher hatchet blade exposure than participants in the missing group (56.5% vs 26.9%; p=0.008).

Table 2. Missing vs non-missing analysis

Characteristic	Participants included in the analysis n=92	Participants not included (missing cc variables n=38)	p-value*
Age, years, mean (SD)	49.7 (17.8)	44.7 (19.1)	0.18
BMI, kg/m^2, mean (SD)	24.8 (2.7)	25.2 (5.4)	0.64
Height, m, mean (SD)	1.9 (0.1)	1.9 (0.1)	0.61
Weight, kg, mean (SD)	86.4 (12.8)	87.7 (21.8)	0.69
NHANES hip, n (%)	13 (14.1)	8 (28.6)	0.08
NHANES thoracic spine, n (%)	9 (9.8)	1 (4.4)	0.41
NHANES lower back, n (%)	27 (29.4)	11 (39.3)	0.32
Physician diagnosed hip OA, n (%)	2 (2.2)	2 (7.4)	0.19
Physician diagnosed spine OA, n (%)	10 (10.9)	2 (6.9)	0.53
Total Hip Replacement (THR), n (%)	5 (5.4)	0 (0)	0.22
Any hip injury, n (%)	6 (6.5)	4 (14.8)	0.17
Any spine injury, n (%)	34 (37.0)	13 (34.2)	0.76
Rowed with Hatchet - Belite, n (%)	44 (47.8)	15 (48.4)	0.96
Rowed with Hatchet - Elite, n (%)	55 (59.8)	19 (61.3)	0.88
Rowed with Hatchet - Aelite, n (%)	52 (56.5)	7 (26.9)	0.008*
Belite Rowing-Hours, hours, mean (SD)	8.6 (5.1)	11.0 (6.1)	0.07
Elite Rowing-Hours, hours, mean (SD)	16.0 (8.1)	17.6 (9.2)	0.38

Key: SD = standard deviation; cc = complete-case; *p=<0.05; Belite = before elite; Aelite = after elite

The characteristics of participants stratified by sex are described in Table 3, below. As the sample size for females is so low, males and females will be grouped together for the analyses.

Table 3. Descriptive characteristics of males and females in the complete-case cohort.

Characteristic	Males (n=75)	Females (n=17)	All (n=92)
Age, years, mean (SD)	51.1 (17.0)	43.6 (20.5)	49.7 (17.8)
BMI, kg/m^2, mean (SD)	25.2 (17.8)	23.3 (2.7)	24.8 (2.7)
Height, m, mean (SD)	1.9 (0.1)	1.8 (0.1)	1.9 (0.1)
Weight, kg, mean (SD)	89.5 (10.9)	72.8 (11.7)	86.4 (12.8)
NHANES hip, n (%)	8 (10.7)	5 (29.4)	13 (14.1)
NHANES thoracic spine, n (%)	7 (9.3)	2 (11.8)	9 (9.8)
NHANES lower back, n (%)	24 (32.0)	3 (17.7)	27 (29.4)
Physician diagnosed hip OA, n (%)	2 (2.7)	0 (0)	2 (2.2)
Physician diagnosed spine OA, n (%)	8 (10.8)	2 (11.8)	10 (10.9)
Total Hip Replacement (THR) n (%)	4 (5.3)	1 (5.8)	5 (5.4)
Any hip injury, n (%)	5 (6.7)	1 (5.9)	6 (6.5)
-Rowing related hip injury, n (%)	1 (20.0)	1 (100.0)	2 (33.3)
-Non-rowing related hip injury, n (%)	4 (80.0)	0 (0.0)	4 (66.6)
Any spine injury, n (%)	27 (36.0)	7 (41.2)	34 (37.0)
-Rowing related spine injury, n (%)	22 (81.5)	6 (35.3)	28 (82.4)
-Non-rowing related spine injury, n (%)	4 (14.8)	1 (14.2)	5 (14.7)
Rowers still rowing, n (%)	32 (42.6)	4 (23.5)	36 (39.1)
Rowers still racing, n (%)	25 (33.3)	3 (17.6)	28 (30.4)
Rowed at a Senior World Championships, n (%)	24 (32.0)	10 (58.8)	34 (36.9)
Rowed at an Olympic Games, n (%)	16 (21.3)	8 (47.1)	24 (26.1)
Rowed with Hatchet - Belite, n (%)	31 (41.3)	13 (76.4)	44 (47.8)
Rowed with Hatchet - Elite, n (%)	42 (56.0)	13 (76.5)	55 (59.8)
Rowed with Hatchet - Aelite, n (%)	42 (56.0)	10 (58.8)	52 (56.5)
Belite Rowing-Hours, hours, mean (SD)	8.6 (5.2)	8.6 (4.8)	8.6 (5.1)
Elite Rowing-Hours, hours, mean (SD)	15.7 (8.6)	17.1 (5.0)	16.0 (8.1)

Key: SD = standard deviation; *p=<0.05; Belite = before elite; Aelite = after elite

Hip pain (on most days of the last month; NHANES) was reported at a prevalence of 14.1%. The prevalence of thoracic spine pain and LBP was 9.8% and 29.4%, respectively. The prevalence of pain in the lower back was significantly higher than that of the hip (29.4% and 14.1%, respectively; p=0.03). Physician-diagnosed OA of the hip and spine was reported at 2.2% and 10.9%, respectively. Only 5.4% of participants reported having a THR of any hip. The prevalence of injury to the spine was higher than injury to the hip joint (37.0% vs 6.5%, respectively). Of the severe hip injuries reported, 33.0% were rowing related, whilst the remaining 66.0% were non-rowing related hip injuries. 10 out of 27 rowers that reported LBP also reported having a severe spine injury (37.0%). 7 of the 9 participants who reported having thoracic spine pain reported having a severe spine injury. Furthermore, of the 34 rowers (37.0%) who reported having a severe spine injury, 28 (82.4%) reported having a severe rowing related spinal injury.

30.4% of the retired rowers included in the complete-case analysis were still completing some type of rowing activity, but not racing to an elite standard. Of the retired rowers still rowing 77% (28 out of 36) were still racing at a level below elite, either at Masters, club, or recreationally at fun regattas. Moreover, 36.9% of rowers had raced at a Senior World Championships, whilst 26.1% of rowers were retired Olympians. The mean rowing hours before rowers' elite careers were 8.6 $\pm$ 5.1 hours and 16.0 $\pm$ 8.1 hours during their elite careers. 47.8% of rowers used a Hatchet blade before their elite career, with 59.8% and 56.5% using a hatchet blade during and after their elite careers, respectively.

5.2 Description of potential rowing-specific risk factors

The existing literature and information gained through the PPI group of participants with elite rowing experience was used to identify two rowing-specific risk factors for pain and OA in retired elite rowers**.** These rowing-specific risk factors are training load and type of rowing blade used. (106,108,136,137) Ergometer training load is associated with increased injury risk and LBP in rowers. (108) For our study, we wanted to investigate the effects of combined water and ergometer hours on the long-term pain and OA prevalence in retired elite rowers, therefore ergometer and water training hours were combined to give the variable 'rowing hours'. This is presented in before, during and after athletes' elite rowing careers.

In addition to training load, developments in equipment and technology used during training and racing have resulted in enhanced boat speed. These developments have increased the physical demands on the athletes' bodies by increasing the leverage force between the athlete, the oar and the water. This increased loading could be a risk factor for pain, injury and OA. (116,138) Therefore, Hatchet blade use will define the second rowing-specific risk factor for pain and OA in the study.

5.2.1 Self-reported training load:

To define training load, as described in chapter 4, participants were asked:

"Before, during and after your elite rowing career, how many hours per day and days per week did you spend training on:

a) The water?

b) The ergometer?"

To capture the total rowing hours that rowers trained during each career phase, hours and days per week for water and ergometer training were grouped together to form a new variable called 'rowing hours'. The total rowing hours was calculated by multiplying the hours rowed per day by the days per week for water and ergometer separately, and then adding them together to give one total weekly rowing hours.

The isolated water and ergometer training hours per week are presented in Figure 16a. The mean water training hours before an athletes' elite career was 7.6 ± 4.6 hours and 13.3 ± 6.3 hours during their elite career. The mean ergometer training hours before athletes' elite careers was 1.4 ± 1.5 hours, and 3.1 ± 4.8 hours whilst elite. Therefore, the weekly water training hours were longer than ergometer hours before and during rowers' elite careers. Mean rowing hours after athletes' elite careers were not included in the analysis as the sample size of participants that answered the questions for training hours after elite was too small.

Figure 16b presents the overall loading per week that athletes underwent before and during their elite careers. It is expected that rowers would train for longer durations whilst in their elite career phase than before becoming elite athletes. In this study, the total rowing-hours during rowers' elite careers was

significantly greater than before rowers' elite careers ($p<0.05$; Figure 16b). This was calculated using a non-parametric method (two-samples Mann-Whitney U test). This demonstrates that the physical demands placed on athletes through training and racing are substantially greater whilst in their elite career phase.

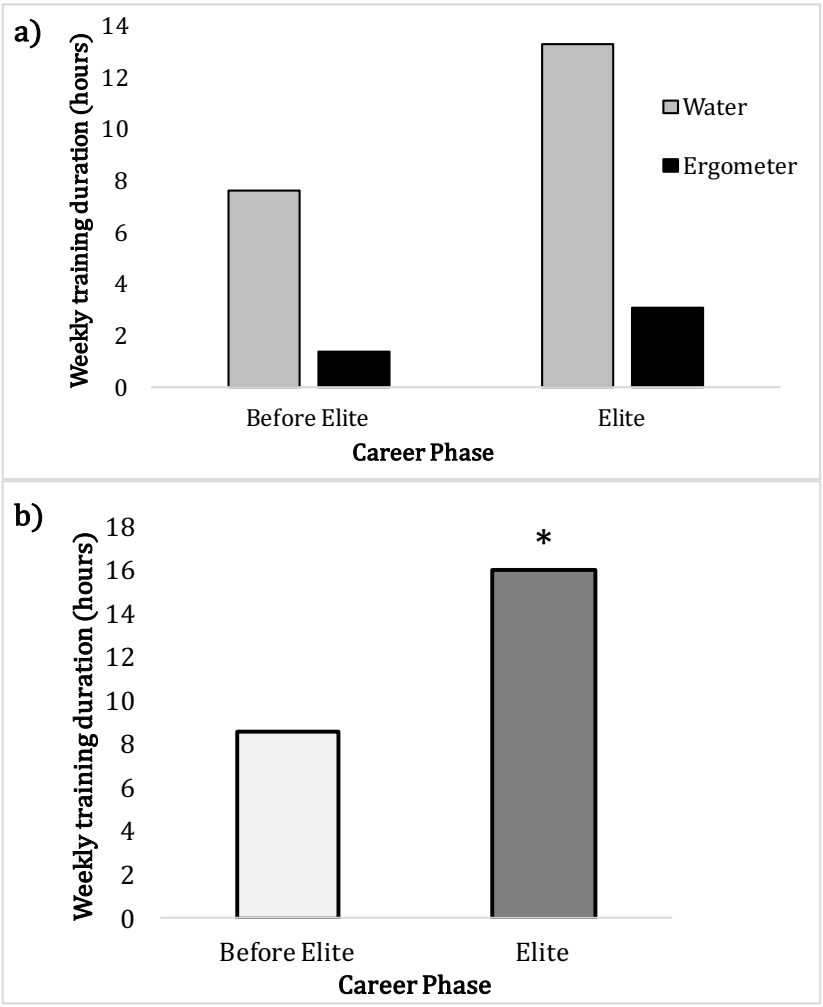

Figure 16: 16a) The mean weekly training hours during each career phase per training discipline. **16b)** The mean total 'rowing hours' trained per week before and during an athletes' elite rowing career.
* = $p<0.05$

5.2.2 Self-reported type of blade used

I hypothesised that the Hatchet blade is associated with a greater prevalence of pain, OA and injury within retired elite rowers by increasing acute loading during training. Therefore, the binary variable of 'ever rowed with hatchet' was used to quantify Hatchet blade use before elite, during elite and after elite in the analysis. Figure 17 describes the percentage of rowers that used a Hatchet blade before, during and after their elite career. Those risk factors were analysed against hip and spine outcomes to test for differences between them. The Hatchet blade was used most during rowers' elite careers (59.8%), followed by after their elite career (56.5%).

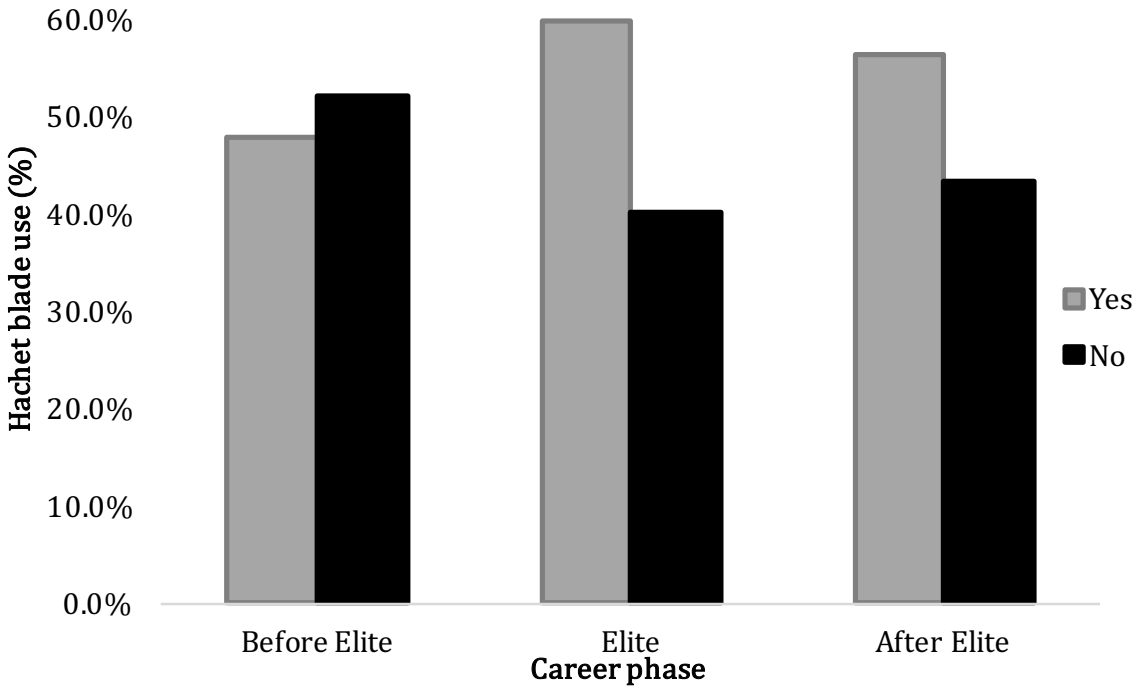

Figure 17. The prevalence of Hatchet blade use during each career phase of former elite rowers.

5.3 Prevalence of hip and spine problems in retired elite rowers

Self-reported hip, spine and combined hip-spine groups will be described in the following outcomes:

1) Hip specific outcomes
2) Spine specific outcomes
3) Combined hip-spine outcome.

Poor joint outcomes for hip, spine, and hip-spine were generated to describe the severity of pain and disorder of the population studied. For the purpose of this study, the hip-spine outcome (HSO) will describe retired rowers who reported having at least one poor hip outcome and one poor spine outcome. The definitions and grouping of the poor hip outcome and poor spine outcome will be explained in sections 4.4.1 and 4.4.2 to follow.

5.3.1 Hip outcomes

Three variables were used to generate one agglomerate hip outcome called the 'poor hip outcome' (PHO):

1. NHANES hip pain
2. Physician-diagnosed hip OA
3. Total hip replacement (THR)

The PHO demonstrates the severity of pain and disorder experienced by the retired elite rowers. The most common complaint was NHANES hip pain (14%) and Table 4 below describes the prevalence of each poor hip variable that make

up the poor hip outcome. Figure 18 shows a visual representation of the grouping of poor hip outcomes reported by former elite rowers.

Table 4. Components of the poor hip outcome agglomerate measure.

	Yes, n (%)	No, n (%)
NHANES Hip Pain	13 (14.1)	79 (85.9)
Physician Diagnosed Hip OA	2 (2.2)	90 (97.8)
Total Hip Replacement	5 (5.4)	87 (94.6)

A Venn diagram has been used to illustrate the overlapping of NHANES hip pain, physician-diagnosed hip OA and total hip replacement (THR) which were used to generate PHO. Figure 18 shows that a total of 18 participants reported one or more variables used to generate PHO in this study. Twelve of these participants reported pain (on most days of the last month) at the hip joint. One participant reported pain at the hip joint and physician diagnosed OA of the hip, demonstrating how the NHANES pain question can capture hip OA through severe pain at the joint level. A total of five participants reported having a THR at some point in their lifetime, however only one of these five participants reported having physician diagnosed hip OA.

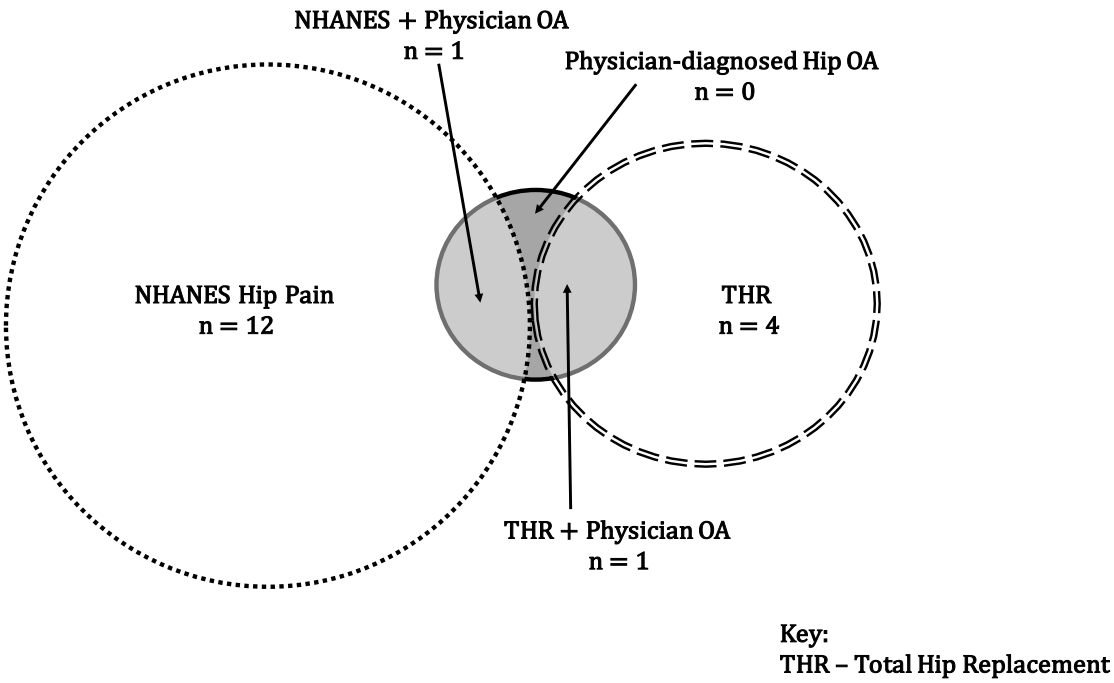

Figure 18. Venn-diagram showing the cross-over between Poor Hip Outcome (PHO) variables. N.B. Not to scale.

The prevalence of reported hip problems, using the PHO, in retired elite rowers was 19.6%. The statistical power to recognise a statistical difference in means for continuous variables in those with and without PHO was 35%, 11%, 97% and 5% for age, BMI, height and weight, respectively. There were no significant differences between those with and without PHOs for any of the key participant characteristics (Table 5).

Table 5. Characteristics of participants with and without poor hip outcome (PHO).

Characteristics	Participants with PHO (n=18)	Participants without PHO (n=74)	p-value*
Age, years, median (range)	56.0 (26.0-88.0)	47.5 (22.0-91.0)	0.13
Gender: male, n (percentage)	12.0 (66.7)	63.0 (85.1)	0.07
Gender: female, n (percentage)	6.0 (33.3)	11.0 (14.9)	0.07
BMI, kg/m^2, median (range)	24.9 (21.3-30.0)	24.5 (20.0-32.9)	0.35
Height, m, median (range)	1.8 (1.5-2.0)	1.9 (1.6-2.0)	0.25
Weight, kg, median (range)	85.5 (50.0-116.6)	87.5 (55.0-122.0)	0.78

*p-value set at a significance of p=<0.05

Distribution of those characteristics are graphically presented using kernel-density plots below (Figure 19). Age, BMI, and height were not normally distributed, therefore non-parametric Mann-Whitney U tests were used to test for statistical differences between those with and without PHOs. Participants with PHO's were slightly older than those without PHOs, although no significant differences were found. This trend in age is expected as it is well known that the risk of OA develops with age, and therefore the long-term health of an athletes' hip joint is likely to worsen in those that are older, thus supporting the finding of more PHO's in the older participants. BMI and height followed similar trends across the groups, as shown in the kernel-density plots below. No significant differences were reported between those with and those without poor hip outcomes for current BMI or height, respectively.

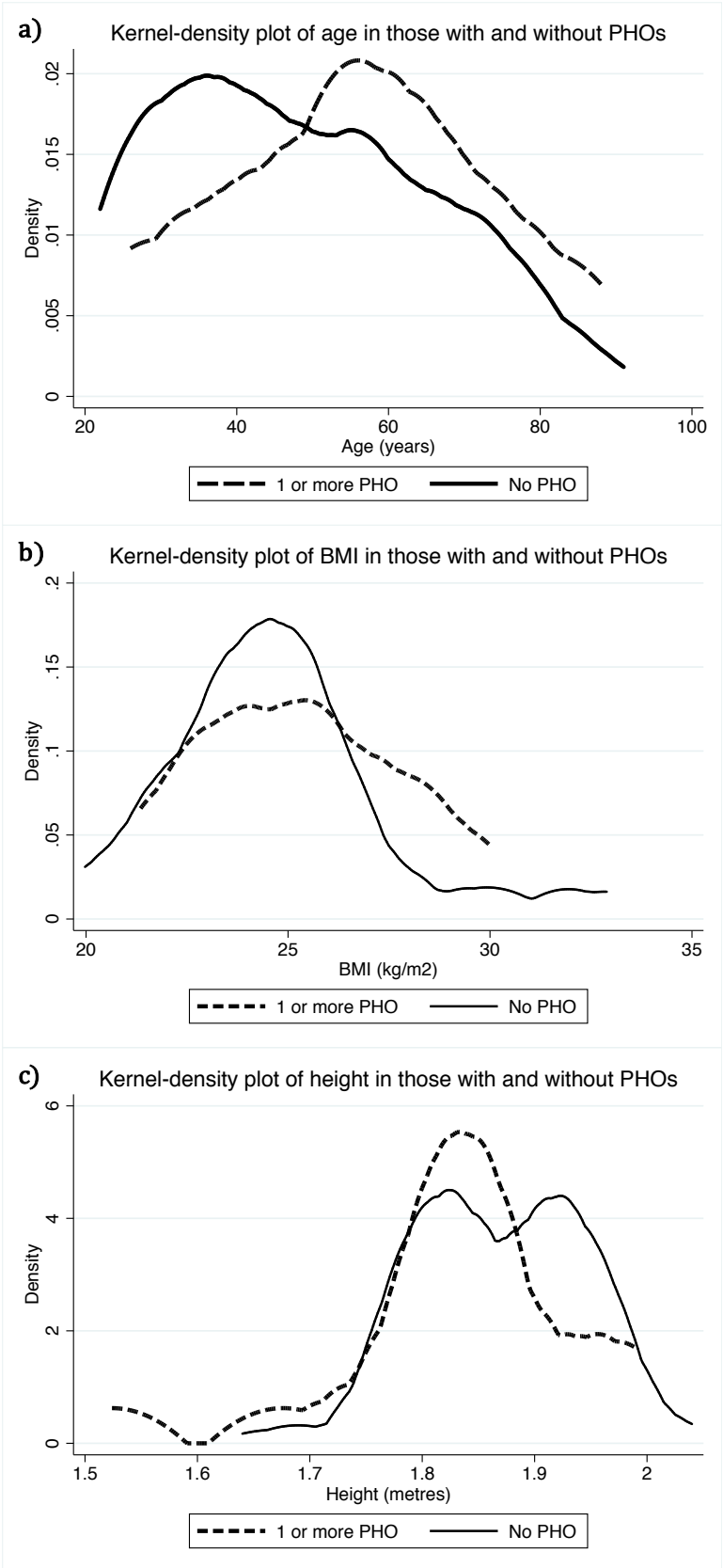

Figure 19. Kernel-density plots of a) age, b) BMI and c) height for participants with and without poor hip outcomes.

5.3.2 Spine outcomes

Three variables were used to generate one agglomerate spine outcome called 'poor spine outcome' (PSO):

1. NHANES thoracic spine pain
2. NHANES lower back pain (NHANES LBP)
3. Physician-diagnosed thoracolumbar spine OA.

The most common complaint was NHANES LBP with 29% of rowers reporting the outcome (Table 6). There was some overlap between participants with the poor spine variables. This overlap is represented in Figure 20.

Table 6. Make up of PSO.

	Yes, n (%)	**No, n (%)**
NHANES thoracic spine pain	9 (9.8)	83 (90.2)
NHANES lower back pain	27 (29.4)	65 (70.7)
Physician-diagnosed thoracolumbar spine OA	10 (10.9)	82 (89.1)

The Venn-diagram below describes the overlap between the spine variables to form the PSO. Figure 20 shows that a total of 37 participants reported one or more spinal specific variable in the study. Three participants reported only NHANES thoracic spine pain, while 18 reported only NHANES LBP. Six participants reported both NHANES thoracic and LBP. Furthermore, seven participants reported having thoracolumbar spine OA diagnosed by a physician, with a further three participants reported both NHANES LBP and physician diagnosed thoracolumbar spine OA.

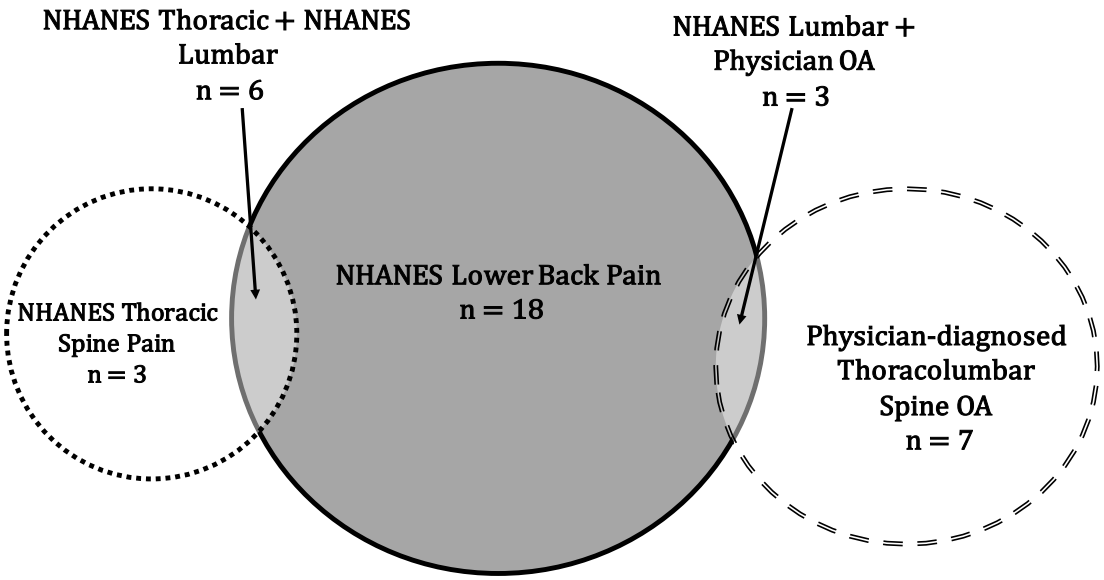

Figure 20. Venn-diagram showing the cross-over between Poor Spine Outcome (PSO) variables. N.B. Not to scale.

The prevalence of poor spine outcomes (PSO) was 40.2% in retied elite rowers. No significant differences were reported between those with and those without PSO for any of the participant characteristics. Table 7 describes the characteristic of the participations with and without the PSO. Mean age for participants with at least one of the three PSO was 49.2 years' vs 50.0 years for those without a PSO. Furthermore, the mean BMI for participants with at least one PSO was 25.3 kg/m^2 compared to 24.6 kg/m^2 in those without a PSO. Figure 21 presents kernel-density plots of these participant characteristics. Age for both those with and those without PSO is skewed right, showing a young participant cohort, with more participants in the 50-60 years' age range with PSOs compared to 40 years of age in those without PSO. This difference is the same for the PHO variable. BMI follows a similar trend for both with and without PSO. Density of height is skewed left in those with and without PSO, and although

trends are slightly different in the modal range, there were no significant differences.

Table 7. Characteristics of participants with and without Poor Spine Outcome (PSO).

Characteristics	Participants with PSO (n=37)	Participants without PSO (n=55)	p-value*
Age, years, mean (SD)	49.2 (16.5)	50.0 (18.8)	0.83
BMI, kg/m^2, mean (SD)	25.3 (20.0)	24.6 (20.0)	0.22
Gender: Male, n (percentage)	31 (83.9)	44 (80.0)	0.65
Gender: Female, n (percentage)	6 (16.2)	11 (20.0)	0.65
Height, m, m, mean (SD)	1.9 (0.1)	1.9 (0.1)	0.51
Weight, kg, mean (SD)	88.8 (16.1)	84.8 (9.7)	0.14

***p-value set at a significance of p=<0.05**

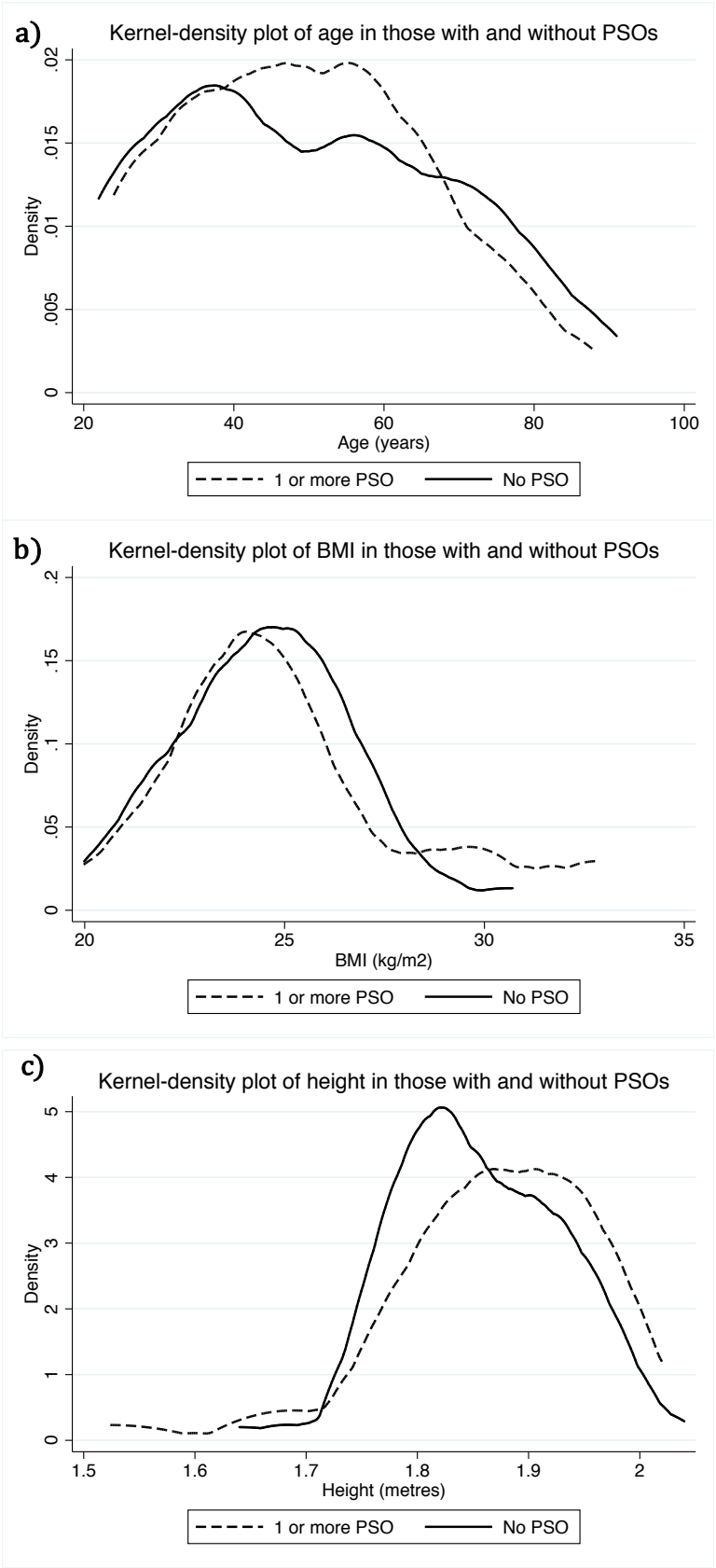

Figure 21. Kernel-density of age, BMI and height for participants with and without poor spine outcomes.

5.3.3 Combined hip-spine outcome (HSO)

PHO and PSO were combined to generate a combined hip-spine outcome (HSO). Figure 22 shows the Venn diagram of how hip and spine outcomes overlap to form the HSO outcome. Nine participants out of 55 (18 PHO and 37 PSO) reported having HSO, leaving a total of 37 participants of the remaining cohort who had no PHO, PSO or HSO.

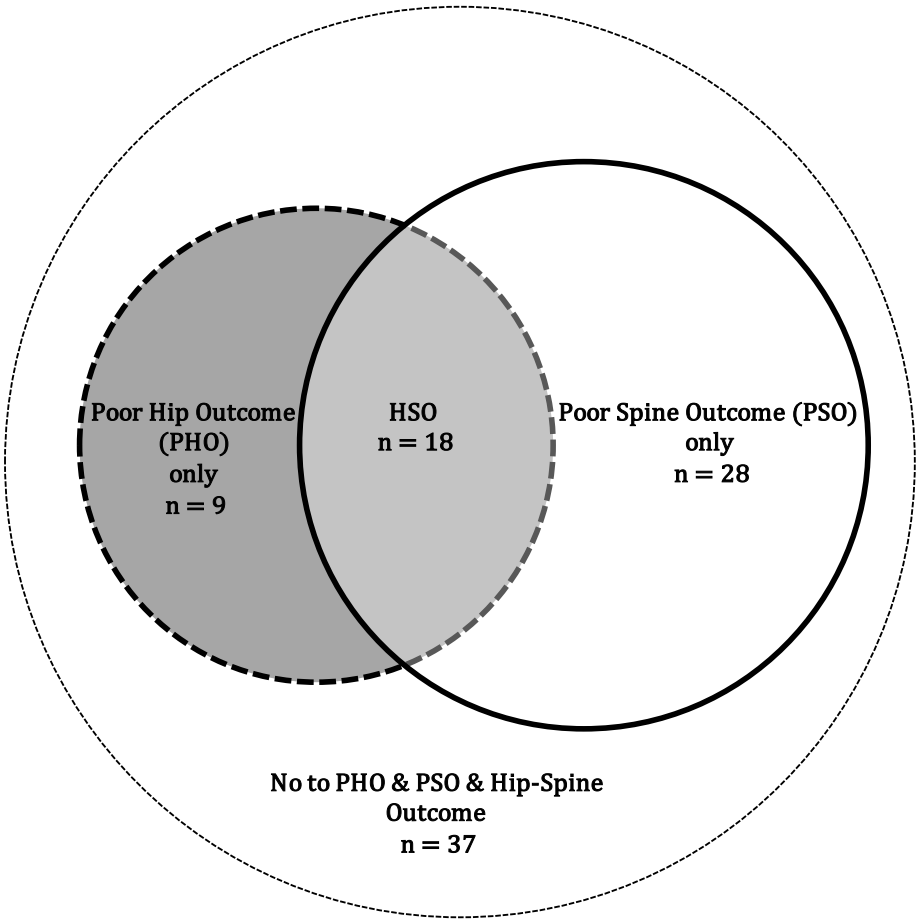

Figure 22. The Venn diagram showing the cross-over between the variables Poor Hip Outcome and Poor Spine Outcome (PSO) to form the outcome Hip-Spine Outcome (HSO). N.B. Not to scale.

The prevalence of HSO was 9.8% in retired elite rowers. No significant differences were found between any participant characteristics. The characteristics of the participants with and without the HSO are described in

Table 8 (below). Mean age for participants with HSO was 48.9 years compared to 49.8 years for those without HSO, however no significant differences were observed. BMI was similar for both groups (24.8 kg/m^2 and 24.9 kg/m^2 for those with and without HSO). The distribution of these characteristics is outlined in Figure 23 below. Both age and BMI were skewed right in both groups, whilst height was skewed leftwards. The modal age for those with and without HSO was similar for both groups.

Table 8. Characteristics of participants with and without Hip-Spine Outcome (HSO).

Characteristics	Participants with HSO (n=9)	Participants without HSO (n=83)	p-value*
Age, years, mean (SD)	48.9 (18.6)	49.8 (17.9)	0.88
BMI, kg/m^2, mean (SD)	24.8 (3.3)	24.9 (2.7)	0.95
Gender: Male, n (percentage)	6 (66.7)	69 (83.3)	0.23
Gender: Female, n (percentage)	3 (33.3)	14 (16.9)	0.23
Height, m, mean (SD)	1.8 (0.2)	1.9 (0.1)	0.43
Weight, kg, mean (SD)	85.9 (22.9)	86.5 (11.4)	0.86

Key: SD = standard deviation; *p-value set at a significance of p=<0.05

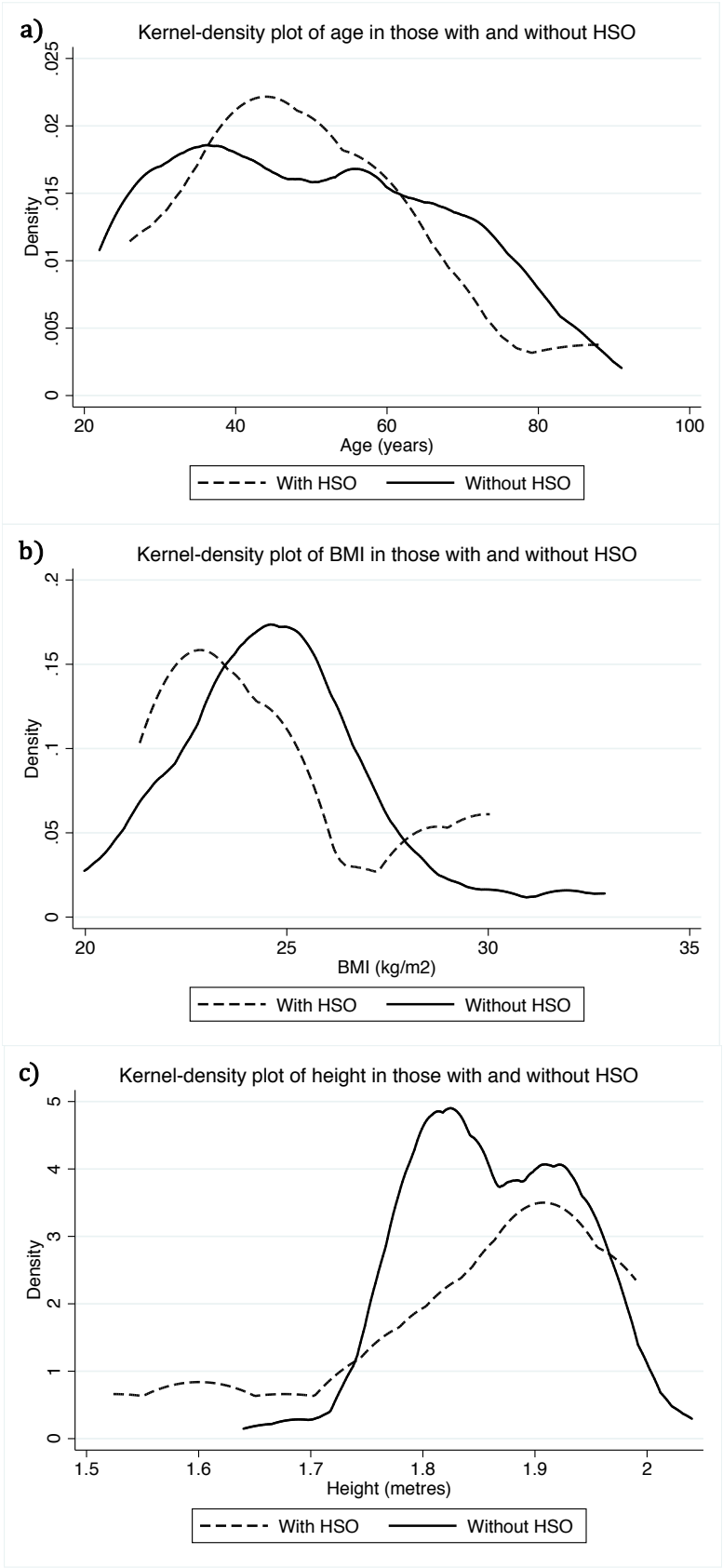

Figure 23. Kernel-density plots of age, BMI and height in participants with and without the hip-spine outcome (HSO).

5.4 Wellbeing

Retired rowers were asked questions to identify their overall wellbeing and the effect that rowing participation had had on their lives (Figure 24).

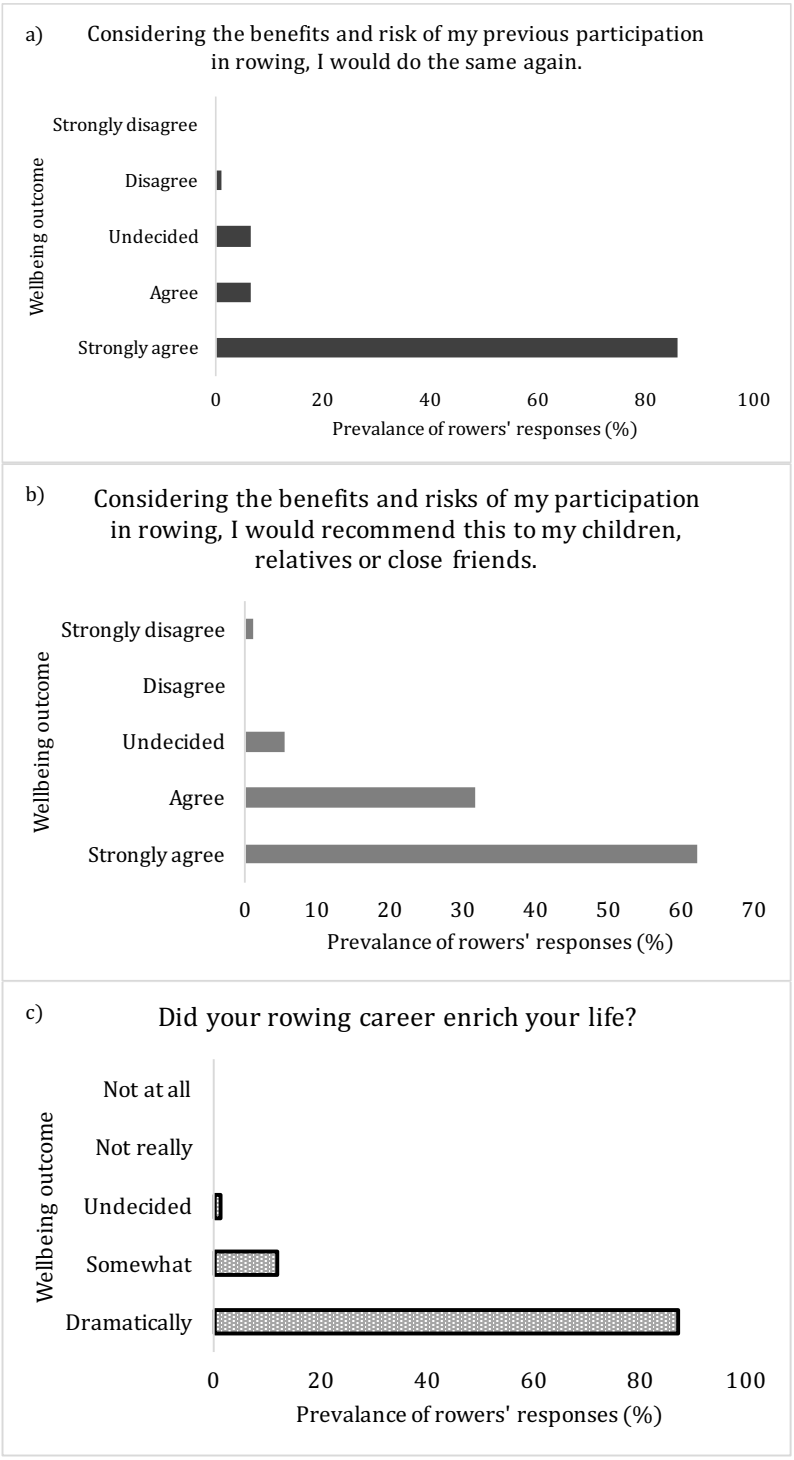

Figure 24. Participants responses to the wellbeing questions included in the questionnaire.

Eighty-nine percent of participants strongly agreed that they would participate in rowing again (Figure 24a). Similarly, 62% strongly agreed that they would recommend rowing to their children, relatives or close friends (Figure 24b). Finally, 87% reported that rowing dramatically enriched their life, followed by 12% who agreed that it somewhat enriched their life (Figure 24c).

Reasons for retirement

Rowers were also asked the reasons they retired from elite rowing. As there could be more than one reason, rowers were free to select all reasons that applied. Figure 25 outlines the responses of the rowers.

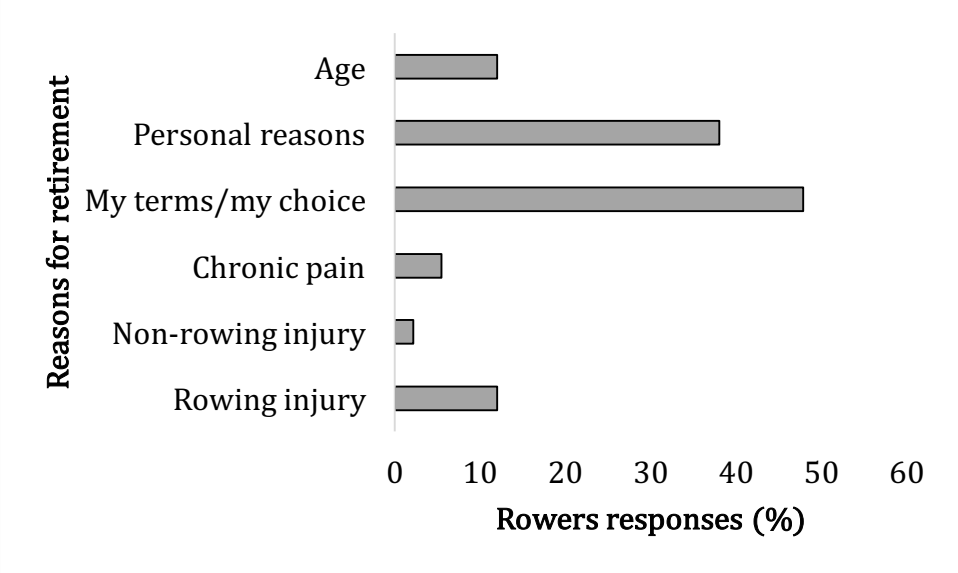

Figure 25. Reasons for retirement from elite rowing.

The most commonly reported reason for retirement from elite rowing was 'my terms/ my choice' at 47.8%, followed by personal reasons at 38.0%. Both age and rowing-related injury were reported by 12.0% of the rowers, whilst chronic pain and non-rowing related injury were the least commonly reported at 5.4% and 2.2%, respectively.

Health-related quality of life using EQ5D-5L

A health status assessment using the EQ5D-5L questionnaire was taken to describe retired rowers' health-related quality of life (HrQoL). The mean results of the EQ5D-5L health status assessment are shown in Figure 26.

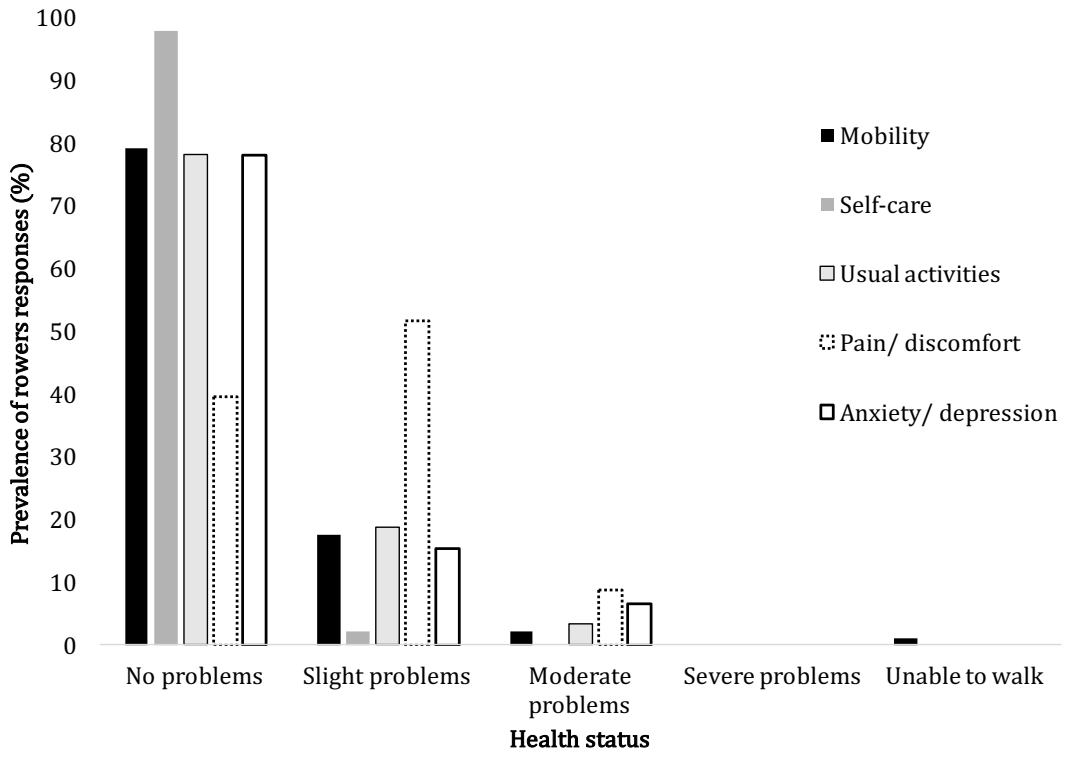

Figure 26. Participant responses to the EQ5D-5L health status assessment of their health 'today'.

Retired rowers reported having minimal disturbance of their health today, with over 70% of all rowers reporting no problems with mobility, self-care, usual activities, or anxiety/depression. Slightly fewer rowers reported no problems with pain/discomfort (39.6%), with 51.6% reporting slight problems with pain/discomfort. Only 1% of the participants showed signs of extreme disruption to their quality of life, such that they were unable to walk at all. A small portion of participations reported moderate problems with mobility, usual activates, pain/discomfort, or anxiety/depression (<9%). Table 9 describes the

mean EQ VAS scores of the participants taken on the day that they completed the study questionnaire.

Table 9. EQ VAS scores of retired rowers' health on day of questionnaire.

	EQ VAS (n=92)
Mean	80.4
-SD	15.1
Median	85.0
-25th	76.0
-27th	90.0

Participants scored from 0 to 100, with 0 being the worst health they could imagine, and 100 being the best health they could imagine being in. The mean EQ VAS score was 80.4 ± 15.1, with an inter-quartile range of 14.

5.5 Chapter summary

The prevalence of self-reported hip pain, thoracic spine pain, and LBP were reported at 14.1%, 9.8%, and 29.4%, respectively. Hip OA and thoracolumbar spine OA were 2.2% and 10.9% prevalent, with THR reported by 5.4% of retired elite rowers examined (Table 3). Severe hip 6.5% and spine injuries were and 37.0% prevalent, respectively. Poor outcomes at the hip, spine, and combined hip-spine were present in 19.6%, 40.2% and 9.8% of the cohort.

Rowers trained on average 7.4 hours longer per week during their elite career than before their elite careers (Figure 16). The Hatchet blade was used most during rower's elite careers (59.8%). However, this was not statistically different between career phases (Figure 17). Retired rowers reflected positively on their

elite rowing careers and would recommend the sport to their close relatives and friends. Retired rowers' responses to the health status assessment were high, further supporting a positive lifestyle and reflection of their careers.

To the best of my knowledge, this is the first study to describe the prevalence of poor outcomes and combined hip and spine problems, in retired elite British rowers. Pain in the hips and spine presents a burden to retired rowers in their lives long after elite training has ended. Furthermore, this is the first study to describe the prevalence of rowing-specific factors presented as Hatchet blade use and weekly rowing hours in retired elite rowers. Until now, rowing blade type had not been investigated as a potential risk factor for pain in retired elite rowers.

Chapter 6. Differences in rowing factors and joint-specific pain and osteoarthritis

6.1 Background

It is well described that training load is associated with an increased risk of injury in rowing. (8,106,107) In this study training hours spent rowing on the water and rowing on the ergometer were combined to give the total rowing hours per week. This chapter will describe any differences between rowing hours and joint specific pain and OA in retired elite British rowers. Furthermore, advances in technology and the equipment used in rowing have meant that the speeds and performance parameters of elite rowers have improved over the last ten years. (116,117,139) Acute loading during training associated with modern rowing blades might be associated with a greater prevalence of OA and hip and spinal pain in retired elite rowers. This chapter will also discuss any differences explored between Hatchet blade use and pain and OA outcomes at the hip and spine, and its relationship with a potential hip-spine syndrome.

The following objectives will be described in the chapter:

1) Describe the association between rowing factors and hip pain and OA
2) Describe the association between rowing factors and thoracic spine pain and LBP, and thoracolumbar OA

3) Describe the association between rowing factors and combined hip and spine pain and OA
4) Rowing-specific risk factors in those with and without poor hip outcome, poor spine outcome or hip-spine outcome.

6.2 The differences between rowing-specific risk factors and hip pain and osteoarthritis.

This section will describe the differences between rowing-specific risk factors in rowers with and without hip pain and OA.

6.2.1 Rowing hours

The total rowing hours per week were lower in those with PHO compared to those without PHO, both before and during rowers' elite careers (before elite: 7.5 ± 3.5 hours vs 8.9 ± 5.3 hours, respectively; during elite: 15.1 ± 6.8 hours vs 16.2 ± 8.4 hours, respectively). However, no significant differences were found between rowing hours before or during rowers' elite careers and those with or without PHOs ($p>0.05$). Table 10 below shows the rowing hours trained in each career phase for participants with and without PHO. The distribution of rowing hours in those with and without PHO is graphically presented below in Figure 27. However, this study was underpowered to detect those differences. The statistical power to recognise a statistical difference in means for rowing hours in those with and without PHO was 4% before rowers' elite careers and 3% during rowers' elite careers (post-hoc calculation; alpha risk = 0.05; two-sided test).

Table 10. Weekly rowing training duration in participants with and without Poor Hip Outcome (PHO).

Characteristics	Participants with PHO (n=18)	Participants without PHO (n=74)	p-value*
Belite Rowing-Hours, hours, mean (SD)	7.5 (3.4)	8.9 (5.4)	0.29
Elite Rowing-Hours, hours, mean (SD)	15.1 (6.8)	16.2 (8.4)	0.60

Key: SD = standard deviation; *p-value set at a significance of p=<0.05; Belite = before elite

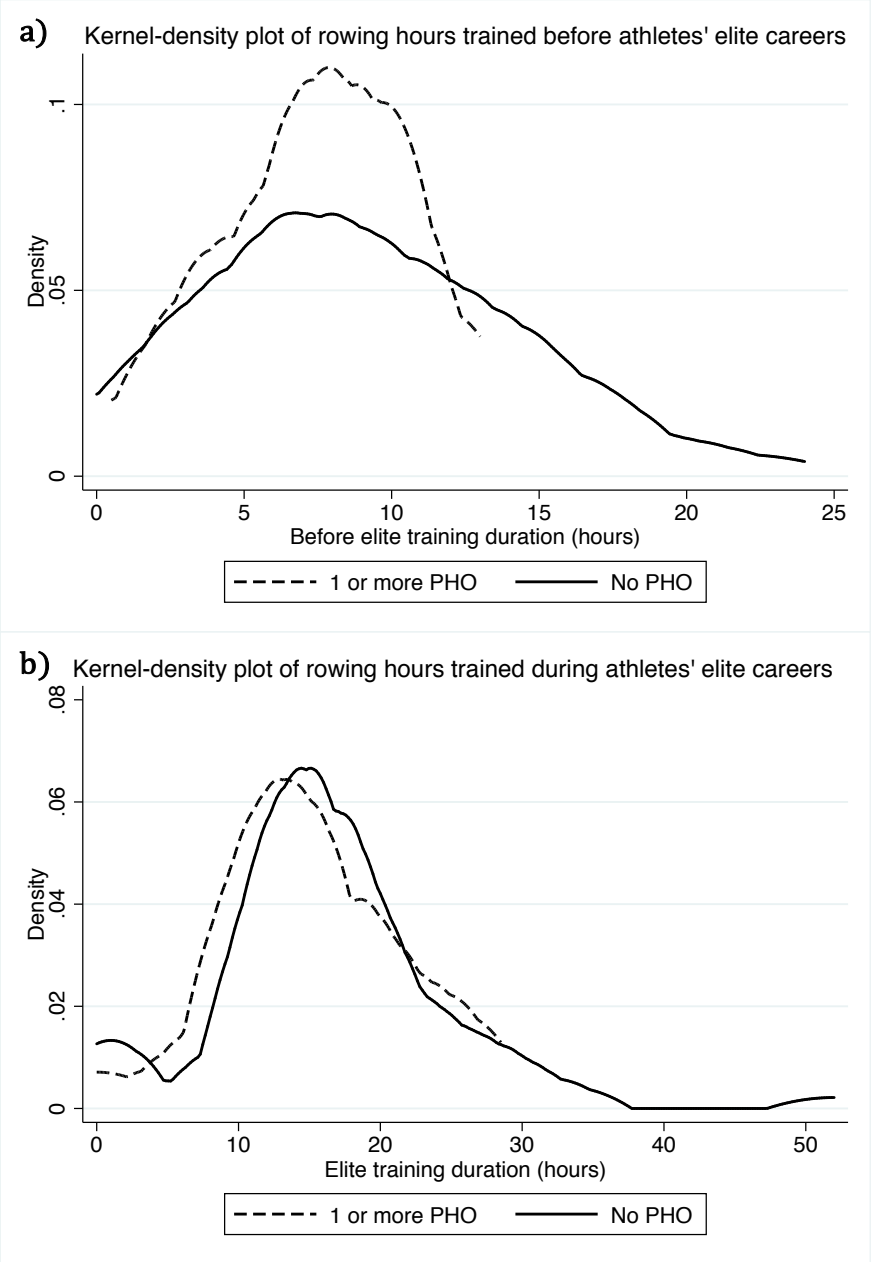

Figure 27. Kernel-density of total rowing hours a) before and b) during athletes elite rowing careers for those with and without poor hip outcomes.

6.2.2 Hatchet blade use

Table 11 shows the prevalence of Hatchet blade use in those with and without PHO. Hatchet blade use was lower in those with PHO compared to those without PHO. Before rowers' elite careers, 4.2% fewer rowers in the PHO group reported using a Hatchet blade compared to rowers without PHO, however this result was

not statistically significant. During rowers' elite careers, Hatchet blade use was 12.2% lower in those with PHO compared to those without. Again, this difference was not statistically significant. Finally, after rowers' elite careers, hatchet blade use was 8.1% lower in those with PHO compared to those without PHO. This difference was not statistically significant. Overall, no significant differences were observed between groups for Hatchet blade use during each career phase. However, this study was underpowered to detect those differences. The statistical power to recognise a statistical difference in those with and without PHO was 6%, 16% and 10% for Hatchet blade use before elite, during elite and after rowers' elite careers, respectively (post-hoc calculation; alpha risk = 0.05; two-sided test), demonstrating the statistical tests were underpowered.

Table 11. Hatchet blade use in participants with and without Poor Hip Outcome (PHO).

Characteristics	Participants with PHO (n=18)	Participants without PHO (n=74)	p-value*
Hatchet blade - Belite, n (%)	8 (44.4)	36 (48.65)	0.75
Hatchet blade - Elite, n (%)	9 (50.0)	46 (62.2)	0.35
Hatchet blade - Aelite, n (%)	9 (50.0)	43 (58.1)	0.53

Key: *p-value set at a significance of p=<0.05; Belite = before elite; Aelite = after elite

In conclusion, none of the demographic or selected rowing-specific characteristics were different in those with or without PHO in the sampled retired elite rowing population.

6.3. The differences between rowing-specific risk factors and thoracic spine and LBP, and thoracolumbar osteoarthritis.

This section will describe the differences between rowing-specific risk factors in rowers with and without spine pain and OA.

6.3.1 Rowing hours

Rowing hours before rowers' elite careers were 1.2 hours lower in those with PSO compared to those without PSO. This difference failed to reach statistical significance. Rowing hours during rowers' elite careers were 2.2 hours longer in retired rowers with PSO compared to those wtihout PSO, however this difference was not statistically significant. The weekly rowing hours are described in Table 12 and the distribution of rowing hours presented in Figure 26.

Overall, no significant differences were found between rowing hours in each career phase and those with and without PSO. Unfortunately, this study was underpowered. The statistical power to recognise a statistical difference in means for rowing hours in those with and without PSO was 6% and 9% for before and during rowers' elite careers, respectively (post-hoc calculation; alpha risk = 0.05; two-sided test).

Table 12. Weekly rowing duration in participants with and without Poor Spine Outcome (PSO).

Characteristics	Participants with PSO (n=37)	Participants without PSO (n=55)	p-value*
Belite Rowing-Hours, hours, mean (SD)	7.9 (4.4)	9.1 (5.5)	0.27
Elite Rowing-Hours, hours, mean (SD)	17.3 (9.5)	15.1 (6.9)	0.19

Key: SD = standard deviation; *p-value set at a significance of p=<0.05;
Belite = before elite

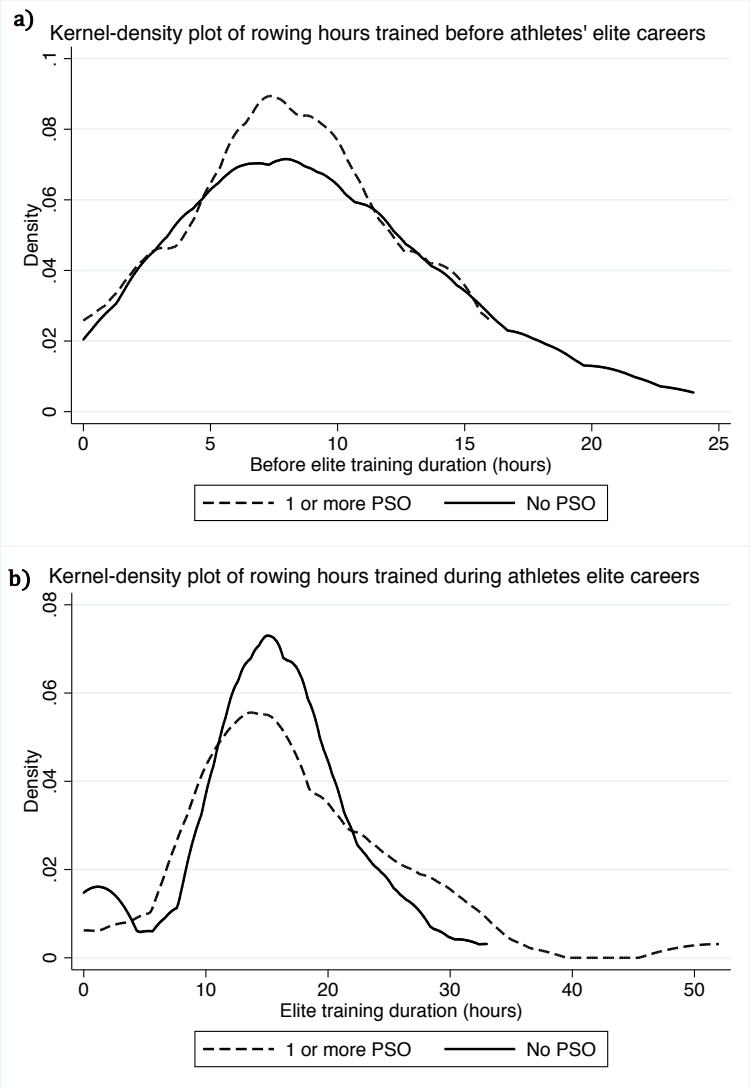

Figure 28. Kernel-density of total rowing hours a) before and b) during athletes elite rowing careers for those with and without poor spine outcomes.

6.3.2 Hatchet blade use

Hatchet blade use was lower in those with PSO before and during rowers' elite careers. Retired rowers reported a 7.7% lower usage of Hatchet blade in retired rowers with PSO compared to retired rowers without PSO before their elite careers, however this difference was not statistically significant. During rowers' elite careers, Hatchet blade use was 5% lower in retired rowers with PSO compared to retired rowers without PSO. However, this difference did not reach statistical significance. Finally, after rowers' elite careers, Hatchet blade use was 4.9% higher in retired rowers with PSO compared to retired rowers without PSO. Again, this finding did not reach statistical significance. Table 13 describes Hatchet blade use in those with and without PSOs. Overall, no significant differences were found between Hatchet blade use and those with or without PSO. Again, this study was underpowered to detect statistical differences. The statistical power to recognise a statistical difference in those with and without PSO was 12%, 7% and 7% for Hatchet blade use before, during and after rowers' elite careers (post-hoc calculation; alpha risk = 0.05; two-sided test).

Table 13. Hatchet blade use in participants with and without Poor Spine Outcome (PSO).

Characteristics	Participants with PSO (n=37)	Participants without PSO (n=55)	p-value*
Hatchet blade - Belite, n (%)	16 (43.2)	28 (50.9)	0.47
Hatchet blade - Elite, n (%)	21 (56.8)	34 (61.8)	0.63
Hatchet blade - Aelite, n (%)	22 (59.5)	30 (54.6)	0.64

Key: *p-value set at a significance of p=<0.05; Belite = before elite; Aelite = after elite

To conclude, no significant differences were observed in demographic characteristics and rowing-specific factors between retired rowers with PSO and retired rowers without PSO.

6.4. The differences between rowing-specific risk factors and hip-spine outcomes.

This section will describe the differences between rowing-specific risk factors in rowers with and without HSO.

6.4.1 Rowing hours

Rowing hours before rowers' elite careers were 0.8 hours lower in those with HSO compared to those without HSO. As this difference was small it was not statistically significant. Rowing hours during rowers' elite careers were similar between those with and without HSO, with no significant differences found between the two groups. Weekly rowing hours of those with and without HSO are reported in Table 14. The distribution of the rowing hours during each career phase is presented in Figure 27. Overall, no significant differences were found in rowing hours between retired rowers with HSO compared to retired rowers without HSO. As with PHO and PSO, this study was underpowered to detect differences in those with and without HSO. The statistical power to recognise a statistical difference in means for rowing hours in those with and without HSO was 3% and 4% for before and during rowers' elite careers, respectively (post-hoc calculation; alpha risk = 0.05; two-sided test).

Table 14. Weekly rowing duration in participants with and without Hip-Spine Outcome (HSO).

Characteristics	Participants with HSO (n=9)	Participants without HSO (n=83)	p-value*
Belite Rowing-Hours, hours, mean (SD)	7.8 (3.7)	8.7 (5.2)	0.57
Elite Rowing-Hours, hours, mean (SD)	16.0 (8.7)	16.0 (8.1)	0.98

Key: SD = standard deviation; *p-value set at a significance of p=<0.05; Belite = before elite

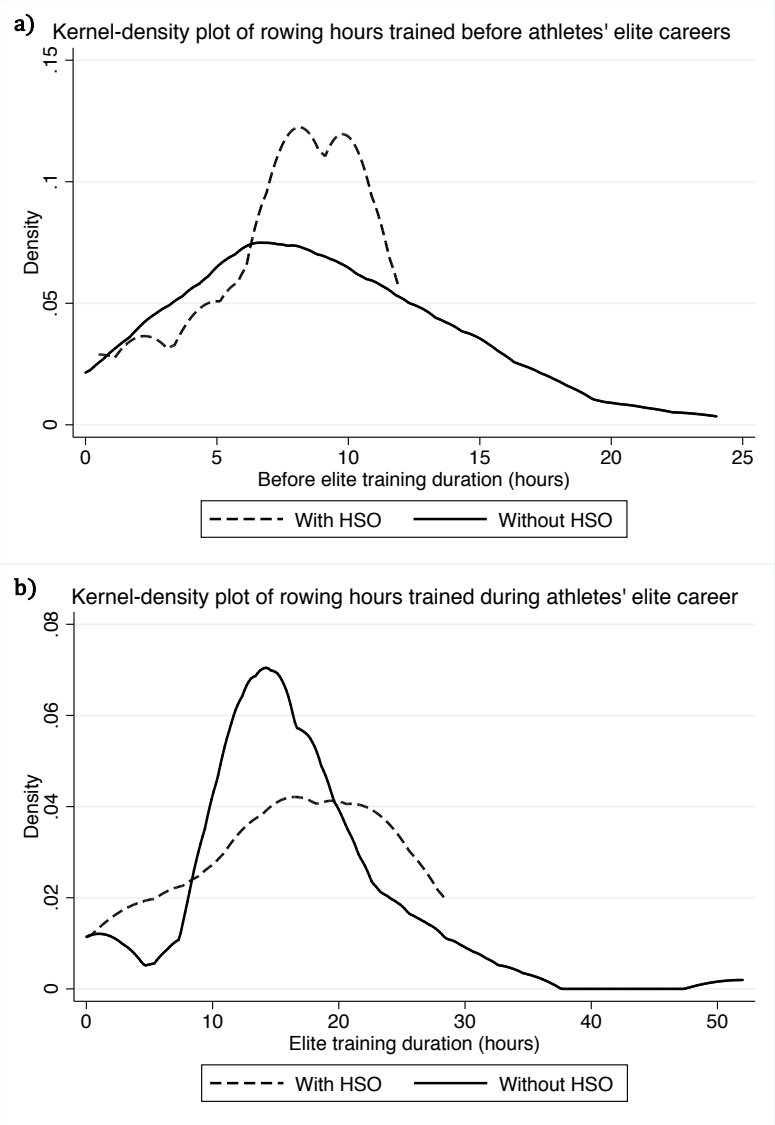

Figure 29. Kernel-density of total rowing hours before and during participants elite rowing careers for those with and without HSO.

6.4.2 Hatchet blade use

Before rowers' elite careers, Hatchet blade use was 3.9% lower in retired rowers with HSO compared to retired rowers without HSO, however this finding was not statistically significant. During rowers' elite careers, Hatchet blade use was 7.7% higher in retired rowers with HSO compared to retired rowers without HSO. This difference failed to reach statistical significance. Finally, after rowers' elite careers, Hatchet blade use was very similar between retired rowers with HSO

compared to retired rowers without HSO, with only a 1% difference in Hatchet blade use. Hatchet blade use in retired rowers with HSO compared to retired rowers without HSO is presented in Table 15. Overall, no significant differences were found between groups for any career phase of Hatchet blade use. Again, the study was underpowered. The statistical power to recognise a statistical difference in those with and without HSO was 4%, 7%, and 3% for Hatchet blade use before, during and after rowers' elite careers (post-hoc calculation; alpha risk = 0.05; two-sided test).

Table 15. Hatchet blade use in participants with and without HSO.

Characteristics	Participants with HSO (n=9)	Participants without HSO (n=83)	p-value*
Hatchet blade - Belite, n (%)	4 (44.4)	40 (48.2)	0.83
Hatchet blade - Elite, n (%)	6 (66.7)	49 (59.0)	0.66
Hatchet blade - Aelite, n (%)	5 (55.6)	47 (56.6)	0.95

Key: *p-value set at a significance of p=<0.05; Belite = before elite; Aelite = after elite

In conclusion, no significant differences were observed between rowing hours in retired rowers with HSO compared to retired rowers without HSO. Furthermore, no significant differences were found between Hatchet blade use at any career phase in retired rowers with HSO compared to retired rowers without HSO.

6.5 Rowing-specific risk factors in those with poor outcomes at the hip, spine, or combined hip-spine.

This section will describe the differences between rowers with hip, spine and combined hip-spine outcomes. This will be presented through:

1) Differences in demographic characteristics between those with PHO, PSO or HSO
2) Differences in rowing hours between those with PHO, PSO or HSO.

The descriptive measure of differences in Hatchet blade use between those with PHO, PSO, or HSO was not undertaken because the test was severely underpowered by the small sample sizes of the groups.

6.5.1 Demographic characteristics of those with poor outcomes at the hip, spine or combined hip and spine

The characteristics of those with poor outcome of the hip, spine or combined hip and spine are presented in Table 16. The mean age in the PHO group was ~6 years older than in the PSO or HSO groups, although the difference was not statistically significant. BMI was the same in the PHO and PSO groups, but lower in the HSO group (25.3 ± 2.6 kg/m^2, 25.3 ± 3.4 kg/m^2 and 24.8 ± 3.3 kg/m^2, respectively), with no significant differences found in BMI between groups. Height was the same across all three groups, whilst those in the PSO were ~2.9kg heavier than those with PHO or HSO. Overall, no significant differences were found between any demographic characteristics and those in the PHO, PSO or HSO groups.

Table 16. Basic characteristics of those with PHO vs those with PSO.

Characteristics	PHO (n=18)	PSO (n=37)	HSO (n=18)
Age, years, mean (SD)	55.6 (18.3)	49.2 (16.5)	48.9 (18.6)
BMI, kg/m^2, mean (SD)	25.3 (2.6)	25.3 (3.4)	24.8 (3.3)
Height, m, mean (SD)	1.8 (0.1)	1.9 (0.1)	1.8 (0.2)
Weight, kg, mean (SD)	85.7 (16.6)	88.8 (16.1)	85.9 (22.9)

6.5.2 Rowing hours in those with poor outcomes at the hip, spine or combined hip and spine

The weekly rowing hours (on the water and the ergometer combined) athletes rowed during each phase of their elite career are described in Table 17. Weekly rowing hours before rowers' elite careers were 0.8-1.5 hours longer in those with HSO compared to only PHO or PSO. This difference was not statistically significant. During rowers' elite careers, rowing hours were 2.2 hours longer in those with only PSO than those with only PHO, and 1.3 hour hours longer in the PSO group than those in the HSO group. However, these differences did not reach statistical significance ($P>0.05$). The statistical power to recognise a statistical difference in rowing hours in those with PHO, PSO or HSO was <5% (post-hoc calculation; alpha risk = 0.05; two-sided test).

Table 17. Rowing hours of those with PHO, PSO or HSO.

Characteristics	PHO (n=18)	PSO (n=37)	HSO (n=18)
Belite Rowing-Hours, hours, mean (SD)	7.5 (3.4)	7.9 (4.4)	8.7 (3.7)
Elite Rowing-Hours, hours, mean (SD)	15.1 (6.8)	17.3 (9.5)	16.0 (8.7)

Key: SD = standard deviation; *p-value set at a significance of p=<0.05; Belite = before elite

6.6 Chapter summary

To understand the potential rowing related exposures that could affect the long-term joint health of elite rowers, I evaluated differences between retired rowers complaining of hip and/or spine problems and rowing-specific risk factors. Overall, no significant differences were found in demographic characteristics between retired rowers reporting PHO and no PHO, retired rowers reporting PSO and no PSO, and retired rowers reporting HSO and no HSO.

In summary, participants complaining of hip, spine or both hip-spine problems were not different in terms of their demographic characteristics and potential rowing-specific risk factors to those without complaints. However, this study is underpowered to detect significant differences in potential rowing-specific risk factors.

Chapter 7. Discussion

This chapter will discuss the results of the last two chapters, specifically it will concentrate on these three sections:

1. The prevalence of self-reported NHANES pain and OA of the hip and thoracolumbar spine.
2. Potential rowing-specific risk factors.
3. The differences between rowing-specific factors and poor hip, poor spine and poor hip-spine outcomes.

The complete-case cohort used in the analysis (n=92) did not present any significant differences in demographic characteristics (age, BMI, height) to those who were not included in the analysis. This would suggest that responder bias in these two groups was unlikely. (140) However, a significant difference was found in Hatchet blade use after rowers' elite careers between the complete-case and missing groups.

7.1 Prevalence of self-reported pain and osteoarthritis of the hip and thoracolumbar spine

This study is the first to describe the long-term health of retired elite rowers. Hip pain (on most days of the last month; NHANES) was reported at a prevalence of 14.1% in the retired elite rowers. At present, there is no literature reporting the prevalence of hip pain in retired or current elite rowers. Therefore, our findings cannot be compared directly to current elite rowers. The prevalence of self-

reported hip pain in the general population has been previously reported at 63.7% in those aged 65-75 years. (141) However, only 15.2% of participants in our study were in this age range, with most participants being much younger. This could explain the lower hip pain prevalence as OA may have been yet to present symptomatically (3,14,33–36)

Recent research conducted into Great Britain's retired Olympians found a hip pain prevalence of 22.4%. (142) This is slightly higher than in our study. Cooper et al.'s research included Olympians from 11 Winter Olympic sport disciplines and 25 Summer Olympic sport disciplines, including rowing. The Olympians were slightly older than in our study (age: 63.6 $\pm$ 13.3; BMI: 24.8 $\pm$ 3.7), therefore the higher hip pain prevalence in these Olympians could be due to age-related pathology, such as OA development, and both primary and/or post traumatic secondary hip OA. The study found an association between weight bearing sport and hip pain when adjusted for age, sex and BMI, providing some explanation to the higher prevalence of hip pain compared to our study.

A limitation of our study is the accuracy of the participants to accurately recall the anatomical site of pain. Self-reporting pain questionnaires are limited in this area, however specific terminology that had been reviewed by the PPI group and was consistent with terminology in the NHANES questionnaire was chosen to reduce the risk of an incorrect pain location being reported.

Physician-diagnosed OA of the hip was 2.2% in our study. This is comparable to former professional footballers (1.7% to 4% for right and left hip OA,

respectively; age: 47.6 ±13.2 years). (143) Hip OA prevalence has also been investigated in former elite rugby players. (45) Physician-diagnosed OA at the hip was reported by 19.6% participants. This is much higher than in our study and could be explained by the older participants and higher BMI reported in former elite rugby players (age: 62.0 ± 15.5 years and 49.7 ± 17.8 years; BMI: 28.9 ± 3.5 kg/m^2, and 24.8 ± 17.8 kg/m^2, for former rugby players and retire rowers, respectively). These are known important risk factors for hip OA.

Similar research into British Olympians found hip OA was 11.1% prevalent across a cohort of winter and summer Olympic sports (142) The study found a significant association between previous injury at the hip joint and both pain and OA at the hip. Risk factors for the development of hip OA were also reported, with older age, obesity, injury and previous participation in impact or weight bearing exercise as some of the significant risk factors reported. (34)

The impact component of the rugby could also explain the higher prevalence of hip OA in former rugby players compared to retired rowers. Previous research comparing OA in former elite athletes from impact and non-impact sports has reported 50% to 75% higher risks of hip OA in impact sports compared to non-impact sports. (144) The overall prevalence of hip OA in all former elite athletes (impact and non-impact combined) was 14.2%. The general population also have higher prevalence's of hip OA than in our study. (1,60,65,145,146) The findings of a lower prevalence of hip OA in our study compared to other sports and the general population are likely due to the young age of the retired rowers in the cohort. However, it could also be suggested that rowing may be supportive

of positive long-term health at the hip joint. The study did not have a large enough sample size to be able to conduct age-matched comparisons with normal population data or other retired athlete data, therefore this statement cannot be confirmed by our study.

THR prevalence in the retired elite rowers was reported at 5.4%. This is inconsistent with our finding of physician-diagnosed hip OA of 2.2%, as those that have had a hip replacement will most commonly been previously diagnosed with hip OA. It is possible that participants forgot they had been previously diagnosed with OA, for reasons such as time or no longer experiencing pain, showing potential recall bias in the results of our study. Hip replacement in former professional rugby players was reported at 16.9% by Davies *et al.* (2016), who also reported a hip OA prevalence of 19.6%, which demonstrates a more expected relationship between the two results. A similar prevalence of THR was reported for former elite cricketers (5.4% versus 7.3% for rowing and cricket, respectively). (128) BMI was also higher in former rugby players compared to former cricketers (27.6 ± 3.6 kg/m^2). This could explain a higher THR prevalence in former elite rugby players. Moreover, the torsional nature of multidirectional sports, such as rugby, could increase the risk of hip OA and need for THR in comparison for more unidirectional sports like cricket and rowing. (145)

Despite having a lower prevalence of hip OA in retired elite rowers than the general population, the prevalence of THR is similar between groups. Age and

sex matched non-athletic controls taken from the ELSA cohort were used in the research of both Davies *et al.* (2016) and Jones *et al.* (2017). Both studies reported similar figures for THR prevalence in the general population (4.0% and 3.6%, respectively). (45,128) Although we cannot statistically compare these figures, from a raw comparative, the prevalence of THR in retired rowers is similar to the general population. This would suggest that THR is therefore going to be higher in rowers once they reach comparable ages to those in the ELSA cohort, as age is the greatest risk factors for THR and OA development. (147,148)

Research has shown that 74% of athletes from various sports can successfully return to sport at the same level or above following femoroacetabular impingement (FAI) surgery. (149) However, professional athletes were 9% more likely to return to sport at a lower level post-surgery. Elite athletes are more likely to endure the pain and continue with their injury over the risk of being unable to return to performing at an elite level. This could further explain a low prevalence of THR in retired elite rowers.

The prevalence of thoracic and LBP was 9.8% and 29.4%, respectively. These findings of LBP are lower than those reported in current elite rowers, where LBP prevalence has been reported from 32% to 53%. (102,106) Thoracic spine pain is much less commonly reported in the literature. Research has reported thoracic spine pain prevalence of up to 19% in male and female international rowers. (150) However, rowing technique has changed significantly since this research

was conducted. (100) This could explain why thoracic spine pain prevalence was comparatively lower in our study.

As our study does not have matched controls from the general population, only raw reported prevalences can be considered between the retired rowers and the general population. A prevalence of ~17% for LBP have been reported in the general population. It could therefore be suggested that retired elite rowers have a higher raw prevalence's of LBP. (76) The training duration is one explanation for this finding. The duration that rowers spend rowing on the ergometer as part of the weekly training hours may be one explanation for the higher prevalence of LBP in retired elite rowers. (9,105–109) A mechanical explanation for this higher prevalence of LBP in rowers spending long hours on the ergometer is that rowers have a ~5% longer stroke length on the ergometer than on the water. (151) This means that the rowers are exposed to loading at the lower back for longer. Furthermore, the leverage on the oar handle is greater on the ergometer than on the water. (152) Therefore, lumbar flexion is increased in ergometer rowing and results in spinal creep, where the lumbar extensor muscles fatigue and the risk of injury increases. (153,154) Despite being retired, the participants in this study still trained for one to eight hours per day. This amounts to significant loading on the spine, however, this finding could not be described in the main results of the study as the sample size was too small for statistical validity.

In addition, these finding of higher LBP prevalence in retired elite rowers could also be due to asymptomatic FAI causing increased loading to the back due to loss of range of hip motion. Palmer *et al.* (unpublished) has demonstrated that

90-100% of current elite rowers examined presented some form of cam-type FAI in their preliminary data. (155) The prevalence of cam-type FAI in our population of retired elite rowers is not known, however this research suggests cam-type FAI is likely to be highly prevalent in the retired elite population, supporting a potential hip-spine pain complex resulting from asymptomatic cam-FAI.

Physician-diagnosed OA of the thoracolumbar spine was reported at 10.9% in our study. This is lower than in former professional footballers, where a prevalence of 18.8% has been reported. (156) The former football players mean age was 56.1 ± 11.8 years, slightly older than that of the retired rowers. This could explain the higher prevalence of spine OA in the footballers. Interestingly, spine OA was reported at 5% in the British Olympians study. This is much lower than was found in our study of retired rowers. Only 26.1% of the retired rowers in our study were Olympians, whereas the Olympians study is comprised entirely of former Olympic athletes. Of the 24 retired Olympic rowers included in our study, 4.2% reported having thoracolumbar spine OA (n=1). It is possible that the standard to which rowers competed could play some role in the development of spinal OA, however the sample size limited the ability to investigate this further within this thesis.

Our findings of physician-diagnosed thoracolumbar spine OA are similar to the general population. Lumbar facet joint OA has been reported at 8-12% amongst community-dwelling adults in the Framingham Heart Study. (29) These participants were older than those in our study (57.0 ± 13.0 years versus 49.7

± 17.8 years, respectively). Furthermore, the mean BMI of the retired rowers was slightly lower than in the adults of the Framingham Heart Study (24.8 ± 2.7 and 28.0 ± 5.1, respectively). This could support the higher prevalence of spinal OA in the general population, as increased adipose tissue has been described as a risk factor for OA. (157,158)

The prevalence of injury to the spine was higher than injury to the hip joint (37.0% vs 6.5%, respectively). Furthermore, our study also found that 82.4% severe spinal injuries reported were rowing related. This suggests rowing has a significant impact on the MSK health of the spinal joint both functionally and pathologically. This is similar to lower back injuries reported in current elite rowers. Research by Wilson *et al.* (2010) reported a lower back injury prevalence of 31.8% in elite adult rowers (men: n = 12; women: n = 8; age: 26.3 ± 4.2 years). (102) The study also found that rowing performance was associated with a high risk of lower back injury. The prevalence of spine OA in our study supports injury as a significant risk factor for the development of OA in later life. (14,33–36)

The prevalence of pain in the lower back was significantly higher than that of the hip (29.4% and 14.1%, respectively; p=0.03). One explanation for this is that the injuries to the joints may not be causing the pain experienced at the joint level by the athlete. Injury prevalence may have been under-reported, as the injury might not be severe enough to be captured by the questionnaire. It is unlikely that minor injuries or transient overloading of the spine would be recalled by retired rowers. The questionnaire used in our study asked participants to recall any

severe injury they had that lead to more than four weeks of reduced participation in exercise, training or sport. Severe injuries tend to be more memorable and therefore easier for participants to recall, however there is still the potential for recall bias to have influenced the reported figures for injury at the hip and spine in our study. It is more likely that participants would have under-reported injury as they were asked to recall something that may have happened a long time ago (10+ years). (159,160) Hip injury could not be compared to current elite rowers as there is no research documenting this.

Of the retired rowers included in our study, 39.1% were still rowing, despite no longer completing or training to an elite level. This could have influenced our results on pain and injury prevalence, such that rowers that continued rowing after their elite careers may have been more likely to participate in the questionnaire. The remaining 60.9% of retired rowers included in the study had stopped rowing completely, therefore the results should predominantly describe the prevalence of pain, injury and OA in those who are 'fully' retired. The most common reason for retirement from rowing was due to rowers own terms or choice (47.8%), whereas 14.1% and 5.4% retired because of injury and chronic pain, respectively. This suggests that pain and injury were not the main reasons for many rowers' retirement from rowing. The study could be limited by responder bias where rowers who had retired because of pain and injury may have decided not to participate.

7.1.1 Section summary

In this section, the prevalence of self-reported pain, physician-diagnosed OA, THR and injury at the spine and hip were discussed. Self-reported hip pain was lower in retired elite rowers than in the general population. No figures for hip pain in current rowers could be found, and therefore this finding was not compared. Physician-diagnosed hip OA was similar to that of former professional footballers but lower than that of former professional rugby players and the general population. Our findings of THR were not consistent with our findings of hip OA, demonstrating under-reporting in the population. However, THR prevalence was similar to that of former elite cricketers and the general population. Self-reported pain at the spine was lower in retired rowers than in current elite rowers, but higher than in the general population. Physician-diagnosed OA of the spine was higher in other sports and the general population than in retired elite rowers. However, our study is limited by the young age of our participants in comparison to OA research in the general population, whereby OA at the hip or spine may be yet to be diagnosed in our participants. Finally, hip injury could not be compared to current elite rowers as there is no research documenting this, however, the prevalence of spine injuries in retired rowers was similar to that of current elite rowers.

7.2 Rowing-specific risk factors in retired elite British rowers.

The total rowing hours reported in our study are consistent with those reported by literature on current elite athletes (8.6 $\pm$ 5.1 hours and 16.0 $\pm$ 8.1 hours,

before and during elite careers, respectively). (102,106) This confirms the previous elite standard of the athletes included in the complete-case cohort. Training duration averaged 1.2 ± 0.7 hours per day before rowers' elite careers, and 2.3 ± 1.2 hours during rowers' elite careers. Both exposures have been reported to be associated with an increased risk of LBP, with training durations of more than 30 minutes in one extended exercise bout on the rowing ergometer associated with a greater risk of pain in the lower back. (15,106,108)

This is the first study to describe the prevalence of Hatchet type blade use in any rowers. Hatchet blade use was 47.8% prevalent before rowers' elite career, 59.8% during rowers' elite careers, and 56.5% after rowers' elite careers. As no other studies have investigated Hatchet blade use, or any rowing blade use within the current or retired elite rowing populations, we cannot compare these findings to other literature. The prevalence of Hatchet blade use in our study was higher during and after rowers' elite careers. This could be explained by both the standard of the athlete at the time point, such that better equipment is used at a higher level because of greater funding opportunities and higher performance requirements, and that Hatchet blades were introduced in 1991, therefore any athletes rowing before this period would not have been able to use this blade type. (110,161) As the age of the study cohort is relatively young in comparison to other osteoarthritis and retired athlete literature, it is likely to have captured athletes' elite and post-elite careers around the time when the Hatchet blade was introduced, further supporting higher Hatchet blade use during these career phases. Using knowledge gained from current elite British rowers, Hatchet-type blade usage would be ~100% within current elite British rowers, with variations

in the shaft weight (making blades even stiffer and lighter) and blade tip (such as the vortex edge) being introduced as equipment improves. (161)

7.3 Potential rowing-specific risk factors

I evaluated differences between potential rowing-specific risk factors in two groups of retired elite rowers. Those with hip and/or spinal outcomes and those without.

7.3.1 Rowing hours

The total rowing hours per week were lower in retired rowers with PHO compared to those without PHO in both career phases examined (before elite: 7.5 ± 3.5 hours vs 8.9 ± 5.3 hours, respectively; during elite: 15.1 ± 6.8 hours vs 16.2 ± 8.4 hours, respectively). However, these differences failed to reach statistical significance. It could be suggested that those experiencing PHO (pain, OA and joint replacement) may have reduced their training hours before and during their elite careers because they were experiencing early symptoms of these outcomes, such as pain and early injury. It may also be that athletes were not robust enough to handle longer rowing hours in training, and subsequently presented worse long-term health later on in life.

Before rowers elite careers, weekly rowing hours were lower in those with PSO compared to those without PSO (7.9 ± 4.4 hours vs 9.1 ± 5.5 hours, respectively). However, unlike PHO, rowing hours during rowers' elite careers were higher in retired rowers reporting PSO compared to retired rowers without

PSO (17.3 ± 9.5 hours vs 15.1 ± 6.9 hours, respectively), although this difference did not reach statistical significance. Lower training hours, specifically on the rowing ergometer, before athletes' elite careers could have some association with positive health outcomes at the spine in the long term due to reduced spinal loading from rowing-related movements. (102,162) One way to explore this further would be to investigate how long rowers' careers lasted before they were elite and what specific training they completed. Associations could then be tested between these factors to see whether this period effected the longevity of their elite career and joint health.

Finally, rowing hours were compared in retired rowers with HSO and retired rowers without HSO. Before rowers' elite careers, rowing hours were lower in those with HSO compared to those without HSO (7.8 ± 3.7 hours vs 8.7 ± 5.2 hours, respectively). However, this difference was not statistically significant. Rowing hours were the same during rowers' elite careers in those with and without HSO (16.0± 8.7 hours and 16.0 ± 8.1 hours, respectively). No research has investigated rowing hours and the presence of hip and spine pain or OA in retired rowers, although research has shown that longer training durations are associated with LBP in rowers. (102,106,108,163) Our findings of longer rowing hours in those without HSO before their elite career, and equal rowing hours in those with and without HSO during their elite career, do not support this.

It is important to consider that the sample sizes used to test for differences significantly underpowered the statistical tests, making it difficult to detect any

statistically meaningful differences between groups. All groups had a power of <9% to detect a statistical difference (post-hoc calculation; alpha risk = 0.05; two-sided test). As this is the first study investigating these potential risk factors in retired rowers, we were unable to estimate a priori adequate sample size.

7.3.2 Hatchet blade use

Retired rowers presenting poor outcomes at the hip used the Hatchet blade less during each career phase than rowers with no poor outcomes at the hip. Hatchet blade use was lower in retired rowers with PHO compared to retired rowers without PHO before, during and after their elite careers (before elite: 44.4% vs 48.7%; elite: 50.0% vs 62.2%; after elite: 50.0% vs 8.1%, for retired rowers with and without PHO, respectively). This could suggest that rowers who were prone to pain or injury at the hip used blades with reduced loading characteristics to allow them to continue rowing at their level, however these differences did not reach statistical significance. It is also difficult to understand whether Hatchet blade use during their careers was causing pain or injury specific to that time, as this information was not captured by the questionnaire.

Although statistically insignificant, retired rowers with PSO also reported a lower use of the Hatchet blade before and during their elite careers (before elite: 43.2% vs 50.9%; elite: 56.8% vs 61.8% for retired rowers with and with PSO, respectively). However, retired rowers with PSO reported a 4.9% higher usage of the Hatchet blade after their elite career than retired rowers with no PSO (59.95% vs 54.6% for retired rowers with PSO and without PSO, respectively; P>0.05). This could be due to two reasons. Firstly, rowers presenting long-term

spine pain and spinal OA, could have these outcomes because of their Hatchet blade use in later life. However, this cannot be confirmed by our results. Secondly, and the most probable explanation, is that the differences in hatchet blade use may be due to the era of rowing the participants were invovled in. The Hatchet blade was not introduced until 1991, therefore anyone rowing as an elite athlete before then will not have used a hatchet blade. (110,111,161,164–166)

Finally, the Hatchet blade was used less by retired rowers with HSO than retired rowers without HSO before and after their elite careers (before elite: 44.4% vs 48.2%; after elite: 55.6% vs 56.6%, for retired rowers with and with HSO, respectively). As with Hatchet blade use and retired rowers with and without PHO or PSO, no significant differences were observed. More retired rowers reported having a HSO whilst using a Hatchet blade in their elite careers than retired rowers that did not have an HSO (66.7% vs 59.0%, respectively). This difference failed to reach statistical significance, however a larger sample size could have increased the power to detect such differences, and allowed for the possibility of hip-spine syndrome to have been explored further.

As with rowing hours, it is important to understand that sample sizes used to test for differences in Hatchet blade use between poor outcomes at the hip, spine, and combined hip-spine were statistically underpowered, making it unlikely to detect statistical differences between groups.

To summarise, our study found no statistical differences between any rowing-specific risk factors and adverse outcomes at the hip, spine or hip and spine combined. However, results are limited by small sample size. Therefore, larger sample sizes are required to further investigate differences between rowing hours and Hatchet blade use, and poor outcomes at the hip, spine, or combined hip-spine. The next section will discuss potential differences in rowing-specific risk factors between the joint-specific poor outcome groups.

7.4 Comparing rowing-specific risk factors between those with poor outcomes at the hip, spine or combined hip-spine

7.4.1 Demographic characteristics

Retired rowers in the PHO group were ~6 years older than in the PSO or HSO groups, however age was not statistically different between groups. BMI was lower in the HSO group (24.8 ± 3.3 kg/m^2) group compared to the PHO (25.3 ± 2.6 kg/m^2) and PSO (25.3 ± 3.4 kg/m^2) groups, however these differences were not statistically significant. Furthermore, no differences were observed in height or weight between the three groups. These findings demonstrate that there are no striking differences in demographic characteristics that could cause rowers to be more at risk of poor outcomes at the hip, spine or combined hip-spine.

Research has suggested an increased risk of chronic LBP in women >1.7m in height, reflecting potential mechanical issues in LBP development. (167) As the mean height in this study was greater than 1.7m, it is possible that rowers could have been predisposed to LBP, and therefore at an increased risk of poor spine

outcomes in the long term. As our study did not find any significant differences between height and those with PHO, PSO or HSO, our results do not support this suggestion.

7.4.2 Rowing Hours

Rowing hours before athletes' elite careers were longer in retired rowers with HSO compared to those with only PHO or PSO (8.7 ± 3.7 hours, 7.9 ± 4.4 hours and 7.5 ± 3.4 hours for HSO, PSO and PHO, respectively). This difference was not statistically significant, however, increasing the sample size in the tested groups could present enough power to explore this finding further. Rowers rowing for longer periods of time could be at a greater risk of both pain and OA at the hip and spine due to increased loading from longer training hours. As this is the first study to investigate long-term health risk of rowing participation, this finding cannot be compared to other literature.

During rowers' elite careers, rowing hours were longer in those with PSO compared to those with PHO or HSO (17.3 ± 9.5 hours, 15.1 ± 6.8 hours and 16.0 ± 8.7 hours for PSO, PHO and HSO, respectively), however this finding did not reach statistical significance. This can be affected by the small sample size. The intensity of the rowing training completed whilst rowers were elite could have influenced the severity of pain or OA experienced at the spine in later life. The questionnaire used in our study did not capture the intensity of the training completed by the rowers, therefore we cannot present evidence for this. The literature shows that training load, in terms of duration, does increase the risk of

injury to the lower back in rowers, therefore we would have expected to see some differences between rowing hours and PSO. (102,106,108)

7.4.3 Hatchet blade use

The sample sizes were underpowered to find any statistically significant differences in the Hatchet blade use of retired rowers with poor outcomes at the hip, spine, or combined hip-spine. Future research should increase the number of participants in each group to generate enough power to find a statistical difference, and be able to test for differences between Hatchet blade use and joint-specific poor health outcomes.

7.5 Wellbeing in retired elite rowers

The overall wellbeing reported in the study was very positive, with most rowers reporting they would participate in rowing again (92.4%), recommend the sport to their children, relatives or close friends (93.5%), and stating that rowing dramatically enhanced their life (93.5%). This shows that despite pain, injuries, and potential long-term health risks being associated with rowing participation, the rowers reflected positively on their participation. This is similar to the responses of former professional rugby players, who reflected positively on their playing careers. Ninety percent of players agreed that they would participate in rugby again, 74% would recommend rugby to their relatives, and 90% felt that rugby had enriched their lives. (45) This shows that sports participation regarded as a positive and beneficial experience, and is supportive of longevity in both mental and physical health. (128,129,168,169)

Health-related quality of life (EQ5D-5L)

The health-related quality of life (HrQoL) reported by the rowers in the study was high. Retired rowers reported having minimal disturbance of their health today, with over 70% of all rowers reporting no problems with mobility, self-care, usual activities, or anxiety/depression. This supports the wellbeing results of the study, where rowers reflected positively on their elite careers. The mean EQ VAS score was 80.4 $\pm$ 15.1, illustrating that retired rowers felt that they were close to being in the optimum health (EQ VAS score of 100 = best possible health). There is a potential selection bias for those with a higher QoL by recruiting through Leander club.

The most commonly reported problem by the rowers was slight to moderate pain/discomfort (60.4%). This is understandable from the high prevalence of participants reporting pain on most days of the last month to the lower back (29.4%). These HrQoL findings are similar to that of former elite rugby players, where 78.3% of rugby players reported problems with pain and discomfort. (129)

Less than 9% of retired rowers reported moderate problems with mobility, usual activates, pain/discomfort, or anxiety/depression (<9%), with 1% of the participants showing signs of extreme disruption to their quality of life, such that they were unable to walk at all. It is important to design strategies to reduce these disruptions to patients' quality of life.

7.6 Limitations

The study is limited by recall bias as participants were asked to retrospectively recall their previous injuries, medical history and previous medical diagnosis by physicians. (159,160) In order to reduce this bias, questions were worded to capture significant memorable events for injury (four weeks or more of reduce participation in sport, exercise or physical activity) and pain (pain on most days of the last month). (40) This could also be due to recall bias such that patients could either be experiencing referred pain or have a lack of understanding of where, anatomically, the pain was located. Furthermore, the study is limited by response bias, where those that did not respond to the questionnaire may have experienced more problems or been unhealthier than those that did respond. (170,171) Rowers may have under-reported the severity of their injuries and pain to present the sport in a positive light. Patient and Public Involvement (PPI) was one element used to try to reduce this bias. Keeping the study rower-focused and questions guided by retired and current rowers allowed for questions to be included that would collect information on rowing performance and experience, not just injury and pain.

It is also possible that the number of non-rowing related injuries to the hip and spine could artificially inflate the pain and OA data collected in this study. The study found that 82.4% of spine injuries and 33.0% of hip injuries reported by retired rowers were rowing related. This helps us to understand that some of the pain and OA captured in the questionnaire may be caused by other activates and sports than rowing. However, it is common for athletes to participate in other

sports as methods of cross-training to facilitate their elite performance, therefore it was considered important to include participants pain and OA responses even if they had a non-rowing related injury.

Furthermore, as highlighted in the results and discussion, this study was underpowered to detect potential differences in rowing-specific risk factors between those who complained of hip and/or spinal problems. The sample size of the study was dependent on the convenience of access to the Member's database at Leander Club, and the approachability of retired elite rowers. This research had never been conducted before in retired elite rowers, therefore it was unknown what the response rate would be, and whether there would be enough retired rowers contactable that would be eligible for the study. The response rate for the study was 23%. For sports-specific research, this is quite a high response, as similar studies researching the long-term health of retired rugby and cricket players have reported response rates of 20% and 13%, respectively. (128,129)

Finally, the study may have been subject to selection bias in participant recruitment. Retired rowers that had pain and injuries may have been more inclined to complete the questionnaire than those without. (172) Retired rowers may have been persuaded or dissuaded to volunteer to participate in the research based on their personal reflections of both their own rowing careers and of Leander Club. It is also possible that retired rowers may have been put off from participating for fear of presenting their sport in a negative light. The recruitment may have also been limited by accessibility to the study information.

Most participants were recruited using the advert sent out in the Leander Club online newsletter. Those without access to this email may have missed the study advertisement. However, paper flyers and study information sheets were distributed in the Leander Club entrance to help minimise this selection bias. It is difficult to quantify how much this selection bias may have influenced the recruitment and overall sample size of the study. We would need to know the entire population of retired elite rowers in the UK and compare those with the characteristics of our complete-case cohort to understand how this may have affected the generalisability of the study results.

Chapter 8. Conclusions

Basic prevalences were reported for hip and spine pain, OA, THR, and injury. The prevalence of self-reported pain at the hip and lower back was reported at 14.1% and 29.4%, respectively. Self-reported thoracic spine pain was present in 9.8% of retired elite rowers examined. Physician-diagnosed hip OA was 2.2% prevalent in the retired elite rowers, whilst THR was reported by 5.4%. Physician-diagnosed spine OA was present in 10.9% of the cohort. Furthermore, injury prevalences were 6.5% and 37.0% at the hip and spine, respectively. Findings of rower wellbeing were high, with over 90% of rowers reflecting positively on their careers.

No significant differences were found between rowing training duration and poor outcomes at the hip, spine or combined hip and spine. This finding is inconsistent with the literature, where longer training durations have been reported to increase the risk of injury and pain in rowers. However, this study was the first to test this in retired elite British rowers, and therefore no direct comparison can be made.

Finally, no differences were found between Hatchet blade use and poor outcomes at the hip, spine, or combined hip and spine. This study was the first to test for differences between rowing blade use and adverse outcomes at the hip or spine. However, a small sample size meant that we did not have enough

statistical power to detect a significant difference between groups, therefore we cannot confirm this finding.

Future research

Future research should reinvestigate rowing equipment and aspects of technique that could be associated with injury, pain, and OA in retired elite rowers. Using a larger sample size, which can now be estimated based on this research, might increase the statistical power to be able to test for these differences. This research would improve the understanding of the causes of injury and pain in rowing, and help to facilitate longevity in the sport. Furthermore, inter-sport comparisons between rugby, cricket and rowing could be conducted to test for common parameters across sports and their associations with the long-term health of former elite athletes. This research could help to improve the understanding of risks associated with sports participation and create strategies to mitigate these risks.

Appendices

Appendix 1: Search strategy for literature review

The OVID Medline search strategy is detailed below. The same search strategy was employed for Pubmed and SPORTDiscuss.

Database: Journals@Ovid Full Text <April 17, 2018>, Your Journals@Ovid, Ovid MEDLINE(R) Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily, Ovid MEDLINE and Versions(R) <1946 to April 11 2018>

Search Strategy:

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1 (prevalence or risk or epidemiology).m_titl. (856864)

2 (femoroacetabular impingement or impingement).m_titl. (4660)

3 limit 2 to english language [Limit not valid in Journals@Ovid,Your Journals@Ovid; records were retained] (4453)

4 limit 3 to full text [Limit not valid in Your Journals@Ovid; records were retained] (1355)

5 limit 4 to yr="1990 - 2018" (1294)

6 limit 5 to humans [Limit not valid in Journals@Ovid,Your Journals@Ovid; records were retained] (1197)

7 (rower* or rowing).m_titl. (1702)

8 limit 7 to english language [Limit not valid in Journals@Ovid,Your Journals@Ovid; records were retained] (1656)

9 limit 8 to full text [Limit not valid in Your Journals@Ovid; records were retained] (898)

10 limit 9 to yr="1990 - 2018" (785)

11 limit 10 to humans [Limit not valid in Journals@Ovid,Your Journals@Ovid; records were retained] (761)

12 osteoarthritis.m_titl. (35423)

13 limit 12 to english language [Limit not valid in Journals@Ovid,Your Journals@Ovid; records were retained] (33750)

14 limit 13 to full text [Limit not valid in Your Journals@Ovid; records were retained] (8915)

15 limit 14 to yr="1990 - 2018" (8231)

16 limit 15 to humans [Limit not valid in Journals@Ovid,Your Journals@Ovid; records were retained] (7062)

17 (back or spine or spinal).m_titl. (289096)

18 limit 17 to english language [Limit not valid in Journals@Ovid,Your Journals@Ovid; records were retained] (264305)

19 limit 18 to full text [Limit not valid in Your Journals@Ovid; records were retained] (124711)

20 limit 19 to yr="1990 - 2018" (96639)

21 limit 20 to humans [Limit not valid in Journals@Ovid,Your Journals@Ovid; records were retained] (83365)

22 "hip*".m_titl. (182484)

23 limit 22 to english language [Limit not valid in Journals@Ovid,Your Journals@Ovid; records were retained] (166766)

24 limit 23 to full text [Limit not valid in Your Journals@Ovid; records were retained] (58440)

25 limit 24 to yr="1990 - 2018" (46597)

26 limit 25 to humans [Limit not valid in Journals@Ovid,Your Journals@Ovid; records were retained] (32533)

27 (athlete* or sport*).m_titl. (61048)

28 limit 27 to english language [Limit not valid in Journals@Ovid,Your Journals@Ovid; records were retained] (55489)

29 limit 28 to full text [Limit not valid in Your Journals@Ovid; records were retained] (22827)

30 limit 29 to yr="1990 - 2018" (20393)

31 limit 30 to humans [Limit not valid in Journals@Ovid,Your Journals@Ovid; records were retained] (19334)

32 pain.m_titl. (280689)

33 limit 32 to english language [Limit not valid in Journals@Ovid,Your Journals@Ovid; records were retained] (259564)

34 limit 33 to full text [Limit not valid in Your Journals@Ovid; records were retained] (108592)

35 limit 34 to yr="1990 - 2018" (91370)

36 limit 35 to humans [Limit not valid in Journals@Ovid,Your Journals@Ovid; records were retained] (84065)

37 (back or low back or lower back or chronic low back).m_titl. (64018)

38 limit 37 to english language [Limit not valid in Journals@Ovid,Your Journals@Ovid; records were retained] (60911)

39 limit 38 to full text [Limit not valid in Your Journals@Ovid; records were retained] (25056)

40 limit 39 to yr="1990 - 2018" (21013)

41 limit 40 to humans [Limit not valid in Journals@Ovid,Your Journals@Ovid; records were retained] (19471)

42 (hip* or groin).m_titl. (186250)

43 limit 42 to english language [Limit not valid in Journals@Ovid,Your Journals@Ovid; records were retained] (170347)

44 limit 43 to full text [Limit not valid in Your Journals@Ovid; records were retained] (60032)

45 limit 44 to yr="1990 - 2018" (47781)

46 limit 45 to humans [Limit not valid in Journals@Ovid,Your Journals@Ovid; records were retained] (33647)

47 36 and 41 (12342)

48 27 and 47 (170)

49 7 and 47 (9)

50 36 and 46 (1408)

51 31 and 50 (99)

52 11 and 50 (0)

53 1 and 16 and 21 (12)

54 31 and 53 (0)

55 11 and 53 (0)

56 16 and 31 (34)

57 26 and 56 (7)

58 11 and 16 and 26 (0)

59 1 and 6 (46)

60 31 and 59 (0)

61 6 and 31 (36)

62 (elite or world class or professional or high-level).m_titl. (68582)

63 limit 62 to english language [Limit not valid in Journals@Ovid,Your Journals@Ovid; records were retained] (61254)

64 limit 63 to full text [Limit not valid in Your Journals@Ovid; records were retained] (23065)

65 limit 64 to yr="1990 - 2018" (17281)

66 limit 65 to humans [Limit not valid in Journals@Ovid,Your Journals@Ovid; records were retained] (15230)

67 6 and 66 (8)

68 hip-spine syndrome.m_titl. (23)

69 limit 68 to english language [Limit not valid in Journals@Ovid,Your Journals@Ovid; records were retained] (22)

70 limit 69 to full text [Limit not valid in Your Journals@Ovid; records were retained] (16)

71 limit 70 to yr="1990 - 2018" (13)

72 limit 71 to humans [Limit not valid in Journals@Ovid,Your Journals@Ovid; records were retained] (13)

73 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55 or 56 or 57 or 58 or 59 or 60 or 61 or 67 or 72 (13792)

74 1 and 47 (680)

75 1 and 50 (16)

76 48 or 49 or 51 or 52 or 53 or 54 or 55 or 56 or 57 or 58 or 59 or 60 or 61 or 67 or 72 or 74 or 75 (1089)

77 48 or 49 or 51 or 52 or 53 or 54 or 55 or 56 or 57 or 58 or 59 or 60 or 61 or 67 or 72 (405)

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Appendix 2: Ethical approval letters

MEDICAL SCIENCES
INTER-DIVISIONAL 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

CONFIDENTIAL

Ref: R44491/RE001

Ms Morgan Baynham-Williams
NDORMS
University of Oxford
Botnar Research Centre
Old Road
Oxford

4th March 2016

Dear Morgan

Research Ethics Approval - CUREC 1

Project title: The Rowing Study

The above application has been considered on behalf of the Medical Sciences Inter-divisional 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 **1 year**, commencing on **4th March 2016**. The reference number for this project is **R44491/RE001**.

This is **subject to:**

a) **your following the BPS guidelines for online research**

b) **it is your responsibility 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) **if new staff are engaged MS IDREC should be informed of their names, status and ethics training.**

Please may I remind you that your project may be reviewed at some stage during an annual audit of projects.

Amendments

Should there be any subsequent changes to the project, which raise ethical issues not covered in the original application, you should submit details to the IDREC for consideration and approval.

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

MEDICAL SCIENCES
INTER-DIVISIONAL RESEARCH ETHICS COMMITTEE

Research Services, University of Oxford, Wellington Square, Oxford, OX1 2JD
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ethics@medsci.ox.ac.uk

CONFIDENTIAL

30th March 2016

Ms Morgan Baynham-Williams
NDORMS
University of Oxford
Botnar Research Centre
Old Road
Oxford

Dear Morgan

Amendment of Research Ethics Application

Ref No: R44491/RE002

Project Title: The Rowing Study

Thank you for submitting a request for an amendment to the above project, which has been reviewed on behalf of the Medical Sciences Inter-Divisional Research Ethics Committee (IDREC).

I am pleased to inform you that your requests to:

- make changes to the Participant Information Sheet - change the telephone number and remove the British Rowing logo
- make a change to the Consent Form – remove the British Rowing logo

have been judged as meeting appropriate ethical standards, on the basis of the information provided to the IDREC.

Please do not hesitate to contact me if you have any queries about this.

Yours Sincerely

H. Barnby-Porritt

Dr. Helen Barnby-Porritt
Research Ethics Manager, Medical Sciences

MEDICAL SCIENCES
INTER-DIVISIONAL RESEARCH ETHICS COMMITTEE

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CONFIDENTIAL

1st June 2016

Ms Morgan Baynham-Williams
NDORMS
University of Oxford
Botnar Research Centre
Old Road
Oxford

Dear Morgan

Amendment of Research Ethics Application

Ref No: R44491/RE003

Project Title: The Rowing Study

Thank you for submitting a request for an amendment to the above project, which has been reviewed on behalf of the Medical Sciences Inter-Divisional Research Ethics Committee (IDREC).

I am pleased to inform you that your request to:

- add and remove questions on the questionnaire, as well as formatting and grammar changes

has been judged as meeting appropriate ethical standards, on the basis of the information provided to the IDREC.

Please do not hesitate to contact me if you have any queries about this.

Yours Sincerely

H. Barnby-Porritt

Dr. Helen Barnby-Porritt
Research Ethics Manager, Medical Sciences

Appendix 3: Topic guide for the Patient and Public Involvement group



Focus Group – Topic Guide

The Rowing Study

This study aims to investigate the long-term health effects of elite rowing on the musculoskeletal health of retired rowers. It is the first of it's kind in rowing and is designed to work in collaboration with British Rowing and Leander Club to inform policy within the sport. The questionnaire is being designed with your help to gather relevant information about the careers of elite rowers and the effects of high level rowing on their health.

You have been invited to participate in the review process of the questionnaire because you are a retired elite rower, current elite rower, or elite coach. Your feedback on the questionnaire will be used to inform and amend the questionnaire, improving the overall quality and relevance of this research.

This review process will take no more than two hours. The process will involve a brief introduction, individual reading of the paper questionnaire (approx. 30 minutes), a group open discussion of the questionnaire and a final closure to wrap up the review.

1) Introduction:
- Welcome – thank you for agreeing to participate
- Explanation of study/questionnaire
- Explanation of focus group
- Discussion guidelines for participants
- Data protection
- Group members introduction – name and previous/current role in elite rowing.

2) Paper format Questionnaire (~30 minutes)
- Time to read through the questionnaire independently and form/note initial thoughts, questions and suggestions.

3) Opening Questions
- Initial thoughts?
- Likelihood of under- or –over reporting?
- Any questions you would feel uncomfortable answering?
- Any topics that you would not want to discuss surrounding rowing?

4) The Questionnaire Review
- Review and of each of the sections.

5) Research Methods
- What would be the most appropriate way of contacting participants?
- How should the questionnaire be distributed (online, postal or phone)?

6) Closure (~5 minutes)
- Thank you for your time
- Any questions?

Appendix 4: The Rowing Study questionnaire









Rowing Study Questionnaire

Thank you for agreeing to complete this questionnaire. Please ensure you have completed the enclosed consent form. For open text boxes, please write your answer. For multiple choice answers, please select the box of the answer to indicate which response is most relevant to you.

For the purpose of this study we are recruiting retired elite rowers. Retired elite includes anyone who has previously raced in a Henley Royal Regatta Final, the Boat Race, at Home Internationals for England, Scotland, Ireland or Wales as a Junior or Senior, or Internationally for Great Britain at junior, U23 or senior level in any event, but who no longer trains or competes at this level. Participants may still be rowing and racing at Masters, club or recreational levels.

1. Registration	
1.1. First Name(s):	
1.2. Surname:	
1.3. Email Address:	
1.4. Postal Address (including postcode):	
1.5. Phone number:	

1.6. In what capacity were you approached to participate in the study? Please select one.					
Leander Club Member		Other, please specify:		Don't know	

2. Personal Details: We request these details as they may relate to risk of developing osteoarthritis.									
2.1. Gender	Male						Female		
2.2. Month/Year of Birth	MM/YYYY								
2.3. Current Body Weight (either Kg or Stone/Pounds)	____Kg		____ Stone ____ Pounds				Don't know		
2.4. Height (either Cm or Feet/Inches)	____Cm		____ Feet ____ Inches				Don't know		
2.5. Are you right handed, left handed or both?	Left		Right		Both		Don't know		
2.6. Do you smoke?	Yes		No		Ex-smoker		Don't know		

2.7. What is your current marital status? Please select the most appropriate.							
Married		Widowed		Divorced		Separated	
Never Married		Long-term relationship		Other		Don't know	

2.8. Please select the ethnicity that is most applicable to you:									
White		Mixed		Black		Asian		Other	
Do not wish to answer				Don't know					





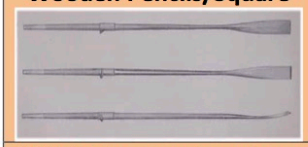




3. Racing History: We are interested in how your sporting career may relate to your current health.												
3.1. Are you currently rowing?			Yes			No (go to 3.5)			Don't know			
3.2. If yes, at which level?	Club		Masters (Veteran) competitor						Recreational			
	Other, please specify:								Don't know			
3.3 If yes, are you still racing?			Yes			No			Don't Know			
3.4. If you are a Masters (Veteran) competitor, which Masters competitions have you competed at? Select all that apply.												
Veterans Head of the River Race			Henley Masters Regatta						British Rowing Masters Championships			
FISA World Rowing Masters Regatta									Don't know			
3.5. Please provide either the date or age you retired from elite rowing:												
MM/YYYY			_____Years						Don't know			
3.6. Reasons for retirement from elite rowing (please select all that apply):												
Rowing related injury			Non-rowing related injury						Personal reasons			
Age		My terms/My choice		Chronic pain					Other, please specify:			
3.7. Age at **first** ever race:			_____ Years						Don't know			
3.8. Age at **last** race: (Can be age at last race if still racing)			_____ Years						Don't know			
3.9. Age at **first elite** race:			_____ Years						Don't know			
3.10. Age at **last elite** race:			_____ Years						Don't know			
3.11. Average racing weight during elite racing career? Please select only one.												
____Kg			____Stones ____Pounds						Don't know			
3.12. Did you ever row in **sculling** boats?												
Yes			No (go to 3.16)						Don't know			
3.13. If yes, what age did you learn to scull?			____ Years						Don't know			
3.14. If yes, please select all the **sculling** boat classes you have sculled in.												
1X		2X		4X		8X			Don't know			
3.15. If yes, what levels have **sculled** in that boat class? Select all that apply.												
1X	Recreational		Training		Club competition		Elite competition		Don't know			
2X	Recreational		Training		Club competition		Elite competition		Don't know			
4X	Recreational		Training		Club competition		Elite competition		Don't know			
8X	Recreational		Training		Club competition		Elite competition		Don't know			
3.16. Did you ever row in **sweep oar** boats?												
Yes			No (go to 3.26).						Don't know			
3.17. If yes, what age did you learn to row sweep?			____ Years						Don't know			

3.18. If yes, please select all the **sweep** rowing boat classes you have rowed in.											
2-		2+		4-		4+		8+		Don't know	
3.19. If yes, what levels have rowed in that **sweep** boat class? Select all that apply.											
2-	Recreational		Training		Club competition		Elite competition			Don't know	
2+	Recreational		Training		Club competition		Elite competition			Don't know	
4-	Recreational		Training		Club competition		Elite competition			Don't know	
4+	Recreational		Training		Club competition		Elite competition			Don't know	
8+	Recreational		Training		Club competition		Elite competition			Don't know	
3.20. Did you ever row on **Bowside** in sweep rowing?											
Yes					No (go to 3.23)					Don' t know	
3.21. If yes, what **levels** have you rowed on **Bowside**? Select all that apply.											
Recreational		Training			Club competitions		Elite competitions			Don't know	
3.22. If yes, how many **years** did you row on **Bowside**?					_____Years					Don't know	
3.23. Did you ever row on **Strokeside** in sweep rowing?											
Yes					No (go to 3.26)					Don' t know	
3.24. If yes, what **levels** have you rowed on **Strokeside**? Select all that apply.											
Recreational		Training			Club competitions		Elite competitions			Don't know	
3.25. If yes, how many **years** did you row on **Strokeside**?					_____Years					Don't know	

Blade biomechanics: We are interested in what types of blade you have rowed with throughout your rowing career.

Wooden Pencils/Square	**Macon/Spoon**	**Big Blade (modern blade, first edition called "Hatchet")**
		

3.26. **Before rowing at an elite level**, what type of blade did you row with? Select all that apply.					
Pencils		Macon/Spoon		Big Blade (Hatchet)	
Other, please specify:				Don't know	
3.27. How long did you row with this type of blade for?					
Pencils			_____Years	Don't know	
Macon/Spoon			_____Years	Don't know	
Big Blade (Hatchet)			_____Years	Don't know	
Other			_____Years	Don't know	

3.28. **At an elite level**, what type of blade did you row with? Select all that apply.					
Pencils		Macon/Spoon		Big Blade (Hatchet)	
Other, please specify:				Don't know	
3.29. How long did you row with this type of blade for?					
Pencils			_____Years	Don't know	
Macon/Spoon			_____Years	Don't know	
Big Blade (Hatchet)			_____Years	Don't know	
Other			_____Years	Don't know	
3.30. Did you continue rowing **after** your elite career?					
Yes		No (go to 3.33).		Don't know	
3.31. If yes, what type of blade did you row with **after** your elite career? Select all that apply.					
Pencils		Macon/Spoon		Big Blade (Hatchet)	
Other, please specify:				Don't know	
3.32. How long did you row with this type of blade for?					
Pencils			_____Years	Don't know	
Macon/Spoon			_____Years	Don't know	
Big Blade (Hatchet)			_____Years	Don't know	
Other			_____Years	Don't know	

3.33. How many **years** did you race **before** your elite career?	_____ Years	Don't know	
3.34. How many **years** did you race at an **elite level**?	_____ Years	Don't know	
3.35. How many **years** did you race **after** your elite career?	_____ Years	Don't know	
3.36. How many **medals** did you win throughout your **elite career**?	_____ Medals	Don't know	
3.37. Have you ever competed at the Head of the River Race (Can be either Men's or Women's)?			
Yes	No (go to 3.39)	Don't know	
3.38. If yes, what was your highest overall ranking at the Head of the River Race?			
Highest overall ranking:		Don't know	
3.39. Have you ever competed at the Head of the Charles?			
Yes	No (go to 3.41)	Don't know	
3.40. If yes, what was your highest overall ranking at the Head of the Charles?			
Highest overall ranking:		Don't know	

Did you compete in any of these **elite competitions**?						
3.41. Home-internationals	Yes		No		Don't know	
3.42. Junior World Championships	Yes		No		Don't know	
3.43. U23 World Championships	Yes		No		Don't know	
3.44. Boat Race	Yes		No		Don't know	
3.45. Henley Royal Regatta Final	Yes		No		Don't know	
3.46. Commonwealth Games	Yes		No		Don't know	
3.47. European Championships	Yes		No		Don't know	
3.48. World Cups	Yes		No		Don't know	
3.49. Senior World Championships	Yes		No		Don't know	
3.50. Olympic games	Yes		No		Don't know	
3.51. Other equivalent competition, please specify:	Yes		No		Don't know	
If yes, how **many times** did you compete in any of these **elite competitions**? (E.g. Senior World Championships in 2010 and 2011 = 2 times).						
3.52. Home-internationals					Don't know	
3.53. Junior World Championships					Don't know	
3.54. U23 World Championships					Don't know	
3.55. Boat Race					Don't know	
3.56. Henley Royal Regatta Final					Don't know	
3.57. Commonwealth Games					Don't know	
3.58. European Championships					Don't know	
3.59. World Cups					Don't know	
3.60. Senior World Championships					Don't know	
3.61. Olympic games					Don't know	
3.62. Other equivalent competition					Don't know	
Before your elite rowing career, on average, how many **hours per day** and **days per week** did you spend training:						
3.63. On the water?	____Hours ____ Minutes per day ____Days per week				Don't know	
3.64. On the rowing ergometer?	____Hours ____ Minutes per day ____Days per week				Don't know	
3.65. In the gym (free, machine or body weights)?	____Hours ____ Minutes per day ____Days per week				Don't know	
During your time **as an elite athlete**, on average, how many **hours per day** and **days per week** did you spend training:						
3.66. On the water?	____Hours ____ Minutes per day ____Days per week				Don't know	
3.67. On the rowing ergometer?	____Hours ____ Minutes per day ____Days per week				Don't know	
3.68. In the gym (free, machine or body weights)?	____Hours ____ Minutes per day ____Days per week				Don't know	

After your elite rowing career, on average, how many **hours per day** and **days per week** did you spend training:			
3.69. On the water?	____Hours ____ Minutes per day ____Days per week	Don't know	
3.70. On the rowing ergometer?	____Hours ____ Minutes per day ____Days per week	Don't know	
3.71. In the gym (free, machine or body weights)?	____Hours ____ Minutes per day ____Days per week	Don't know	
Currently, on average, how many **hours per day** and **days per week** do you spend training:			
3.72. On the water?	____Hours ____ Minutes per day ____Days per week	Don't know	
3.73. On the rowing ergometer?	____Hours ____ Minutes per day ____Days per week	Don't know	
3.74. In the gym (free, machine or body weights)?	____Hours ____ Minutes per day ____Days per week	Don't know	
3.75. In sport, exercise or physical activity **other than rowing**?	____Hours ____ Minutes per day ____Days per week	Don't know	

3.76. Did you regularly complete **core strength and stability, mobility or flexibility** training as part of your elite rowing training programme?					
Yes		No		Don't know	
3.77. Did you use any **practitioner support** as an elite athlete?					
Yes		No (go to 4.1)		Don't know	
3.78. If yes, what practitioner support did you use as an elite athlete? Select all that apply.					
Team Doctor		Physiotherapist		Strength and Conditioning Coach	
Massage Therapist		Chiropractor		Don't know	
Other, please specify:					

4. Joint Pain: We are interested in understanding how common joint pain is in rowers.							
SPINE:							
4.1. Do you experience pain, discomfort, or have a problem with your spine (back or neck)?							
Yes		No (go to 4.3)				Don't know	
4.2. If yes, have you had to alter your activities as a result of this spinal pain?							
Yes		No				Don't know	
4.3. Have you had any pain in your cervical spine (neck) on most days of the last month?							
Yes		No				Don't know	
4.4. Have you had any pain in your thoracic spine (mid-back) on most days of the last month?							
Yes		No				Don't know	
4.5. Have you had any pain in your lumbar spine (lower back) on most days of the last month?							
Yes		No (if no to 4.3, 4.4 and 4.5, go to 4.8)				Don't know	
4.6. If yes to 4.3, 4.4 or 4.5, when does this spinal pain occur? Select all that apply.							
At rest		During exercise		After exercise		Don't know	

4.7. If yes to 4.3, 4.4 or 4.5, at what age did the first onset of back pain occur?					____ Years		Don't know	
4.8. Do you currently have any pain in your spine?								
Yes		No (go to 4.10)					Don't know	
4.9. If yes, where is the pain? Select all that apply.								
Cervical (neck)		Thoracic (mid-back)		Lumbar (lower)			Don't know	
4.10. Have you ever rowed with back pain?								
Yes		No (go to 4.13)					Don't know	
4.11. If yes, did you ever row with back pain during your **elite career** without receiving medical or physiotherapy treatment?								
Yes		No (go to 4.13)					Don't know	
4.12. If yes, how long did you row with back pain without receiving treatment?								
No. of sessions:							Don't know	

HIP:								
4.13. Do you experience pain, discomfort, or have a problem with your hip(s) or groin?								
Yes		No (go to 4.15)					Don't know	
4.14. If yes, have you had to alter your activities as a result of this hip or groin pain?								
Yes		No					Don't know	
4.15. Have you had any pain in your hip(s) or groin on most days of the last month?								
Yes		No (go to 4.19)					Don't know	
4.16. If yes, which side has this hip or groin pain been on?								
Left		Right		Both			Don't know	
4.17. If yes, when does this hip or groin pain occur? Select all that apply.								
At rest		During exercise		After exercise			Don't know	
4.18. If yes, at what age did the first onset of hip or groin pain occur?					____ Years		Don't know	
4.19. Do you currently have any pain in your hip(s) or groin?								
Yes		No (go to 4.21)					Don't know	
4.20. If yes, which side is this pain on?								
Left		Right		Both			Don't know	
4.21. Have you ever rowed with hip or groin pain?								
Yes		No (go to 4.24)					Don't know	
4.22. If yes, did you ever row with hip or groin pain during your **elite career** without receiving medical or physiotherapy treatment?								
Yes		No (go to 4.24)					Don't know	
4.23. If yes, how long did you row with hip or groin pain without receiving treatment?								
No. of sessions:							Don't know	

KNEE:							
4.24. Have you had any pain in your knee(s) on most days of the last month?							
Yes		No (go to 4.26)				Don't know	
4.25. If yes, which side has this knee pain been on?							
Left		Right		Both		Don't know	
4.26. Do you currently have any pain in your knee(s)?							
Yes		No (go to 4.28)				Don't know	
4.27. If yes, which side is this knee pain on?							
Left		Right		Both		Don't know	

SHOULDER:							
4.28. Have you had any pain in your shoulder(s) on most days of the last month?							
Yes		No (go to 4.30)				Don't know	
4.29. If yes, which side has this shoulder pain been on?							
Left		Right		Both		Don't know	
4.30. Do you currently have any pain in your shoulder(s)?							
Yes		No (go to 4.32)				Don't know	
4.31. If yes, which side has this shoulder pain been on?							
Left		Right		Both		Don't know	

ANKLE:							
4.32. Have you had any pain in your ankle(s) on most days of the last month?							
Yes		No (go to 4.34)				Don't know	
4.33. If yes, which side has the ankle pain been on?							
Left		Right		Both		Don't know	
4.34. Do you currently have any pain in your ankle(s)?							
Yes		No (go to 5.1)				Don't know	
4.35. If yes, which side is this ankle pain on?							
Left		Right		Both		Don't know	









5. Medical History: We request these details as they may relate to outcomes we want to understand. If you are unsure about or unfamiliar with a term, you may provide your best answer or "Don't know".

5.1. During your teenage years, did you physically develop earlier, on average, or later compared to your peers?							
Early		On average		Late		Don't know	
Have you ever been told you have any of the following by a Doctor?							
5.2. Asthma		Yes		No		Don't know	
5.3. Diabetes		Yes		No		Don't know	
5.4. Dementia		Yes		No		Don't know	
5.5. Epilepsy		Yes		No		Don't know	
5.6. High blood pressure		Yes		No		Don't know	
5.7. Depression		Yes		No		Don't know	
5.8. Heart problems (e.g. heart attack or angina)		Yes		No		Don't know	
5.9. Stroke		Yes		No		Don't know	
5.10. Osteoporosis		Yes		No		Don't know	
5.11. Anxiety		Yes		No		Don't know	
5.12. Kidney problems		Yes		No		Don't know	
5.13. Memory impairment		Yes		No		Don't know	
5.14. Any other medical problems?		Yes		No (go to 5.16)		Don't know	
5.15. If yes, please give details:							
5.16. Have you ever had a slipped growth plate (SUFE) in your hip, Perthes' Disease or Avascular Necrosis?							
Yes		No (go to 5.18)				Don't know	
5.17. If yes, which side?	Left		Right		Both	Don't know	
5.18. Did you ever have clicking hips, dislocated hips or hip dysplasia at birth?							
Yes		No (go to 5.20)				Don't know	
5.19. If yes, which side?	Left		Right		Both	Don't know	
5.20. Have you ever had inflammatory Arthritis (Rheumatoid Arthritis, Ankylosing Spondylitis, Psoriatic Arthritis, Juvenile Idiopathic Arthritis)?							
Yes		No				Don't know	
5.21. Have you ever been told you have wear and tear, degeneration or Osteoarthritis by a Doctor?							
Yes		No (go to 5.24)				Don't know	

5.22. If yes, where? Please circle which joint(s)/side(s), or specify 'other': (Select all that apply).

Hip		**Knee**		**Ankle**		**Shoulder**		**Wrist**		**Hand**		**Other joint:**
Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	

5.23. If yes, please indicate at what age you were told this, below the affected joint(s)/side(s):

Hip		**Knee**		**Ankle**		**Shoulder**		**Wrist**		**Hand**		**Other joint:**
Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	

5.24. Have you ever had keyhole surgery/arthroscopy?													
Yes		No (Continue to 5.26)								Don't know			
5.25. If yes, please indicate the number below for each effected joint/side:													
Hip		**Knee**		**Ankle**		**Shoulder**		**Wrist**		**Hand**		**Other joint:**	
Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right		
5.26. Have you ever had joint replacement surgery?													
Yes		No (go to 5.29)								Don't know			
5.27. If yes, please indicate the number below for each effected joint/side:													
Hip		**Knee**		**Ankle**		**Shoulder**		**Wrist**		**Hand**		**Other joint:**	
Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right		
5.28. If yes, please indicate the age you were when you had this surgery, below the affected joint(s)/side(s):													
Hip		**Knee**		**Ankle**		**Shoulder**		**Wrist**		**Hand**		**Other joint:**	
Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right		
5.29. Have you ever had any broken bones or fractures?													
Yes		No (go to 5.32)								Don't know			
5.30. If yes, please indicate the number below for each effected joint/side:													
Hip		**Knee**		**Ankle**		**Shoulder**		**Wrist**		**Hand**		**Other joint:**	
Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right		
5.31. If yes, please write 'R' if rowing related or 'NR' for non-rowing related, below each affected joint(s)/side(s):													
Hip		**Knee**		**Ankle**		**Shoulder**		**Wrist**		**Hand**		**Other joint:**	
Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right		
5.32. Have you taken any medications in the last 12 months?													
Yes		No (go to 5.34)								Don't know			

5.33. If yes, please complete the following information as accurately as possible.
What medications have you taken in the last 12 months (please identify all painkillers, anti-inflammatory medications, vitamins, supplements and contraception)?

Medication name	*Strength*	*Formulation (e.g. tablets, capsules, drops etc.)*	*Dose*	*Times*	*Frequency (i.e. daily, weekly, monthly, yearly, as needed)*	*Date started (MM/YYYY)*	*Date finished (MM/YYYY)*

5.34. Have you ever had any injections in the spine?

Yes		No (go to 5.39)		Don't know	

5.35. If yes, how many?

		Don't know	

5.36. If yes, what types of injections have you in the spine? Select all that apply.

Epidural		Facet Joint Injection		Prolotherapy (Definition at bottom of section 5*)	

Other, please specify:		Don't know	

5.37. If yes, how many **courses of each** of the following treatments have you had?

Epidural		Facet Joint Injection		Prolotherapy		Other	

5.38. If yes, during which phase of your rowing career did you have these injections? Select all that apply.

Before elite rowing		During elite rowing career		After elite rowing career – still rowing	

After elite rowing career – no longer rowing		Don't know	

5.39. Have you ever had a spinal fusion?

Yes		No		Don't know	

5.40. Have you ever had any injections in your hip(s)?

Yes		No (go to 6.1)		Don't know	

5.41. If yes, what type of injections of the hip(s) did you have? Select all that apply.

Steroid		Artificial Lubricant		Other, please specify:		Don't know	

5.42. If yes, what side(s) were the injections on?

Steroid				Artificial Lubricant				Other				Unknown			
Left		Right		Left		Right		Left		Right		Left		Right	

5.43. If yes, how many injections did you have?

Steroid				Artificial Lubricant				Other				Unknown			
Left		Right		Left		Right		Left		Right		Left		Right	

5.44. If yes, during which phase of your rowing career did you have these injections? Select all that apply.

Before elite rowing		During elite rowing career		After elite rowing career – still rowing	

After elite rowing career – no longer rowing		Don't know	

*Prolotherapy – repeated injections of dextrose solution or other irritating substances into the joint, tendon, or painful tissue in order to provoke a regenerative tissue response.

6. Past Injuries: We are interested in how past injuries relate to current joint health.							
6.1. Have you ever had **any** severe injury leading to more than four weeks of reduced participation in exercise, training or sport?							
Yes		No (go to 7.1)				Don't know	
6.2. Have you ever had any severe injury in your **spine**, leading to more than four weeks of reduced participation in exercise, training or sport?							
Yes		No (go to 6.10)				Don't know	
6.3. If yes, which part of the spine was affected? Please select all that apply.							
Neck (cervical spine)		Mid-back (thoracic spine)					
Lower back (lumbar spine)		Don't know					
6.4. If yes, **how many** spine injuries?							
Neck (cervical spine)		Mid-back (thoracic spine)					
Lower back (lumbar spine)		Don't know					
6.5. If yes, **how many** of each of the following types of spine injuries have you had? Please specify.							
Fracture		Prolapsed disc		Facet Joint Problem		Sciatica	
Other, please specify type and number:						Don't know	
6.6. If yes, were these spine injuries rowing or non-rowing related? Select all that apply.							
Rowing		Non-rowing (go to 6.8)				Don't know	
6.7. If these spine injuries were rowing related, **how many** of these spine injuries were related to the following types of training? Please specify the number of injuries to all that apply.							
On water - Training		Ergometer training		Weight training		On water - Racing	
Cross training, please specify type and number:						Don't know	
6.8. If yes, did you ever miss an elite competition due to a severe injury in your spine (more than four weeks of reduced participation in exercise, training or sport)?							
Yes		No (go to 6.10)				Don't know	
6.9. If yes, **how many** elite competitions did you miss?						Don't know	

6.10. Have you ever had any severe injury in your **hip(s) or groin**, leading to more than four weeks of reduced participation in exercise, training or sport?							
Yes		No (go to 6.17)				Don't know	
6.11. If yes, **how many** hip or groin injuries?		Left:		Right:		Don't know	
6.12. If yes, **how many** of each of the following types of hip or groin injuries have you had? Please specify.							
Fracture		Stress Fracture				Impingement	
Muscle tear/injury		Other, please specify:				Don't know	
6.13. If yes, were these hip or groin injuries rowing or non-rowing related? Select all that apply.							
Rowing		Non-rowing (go to 6.15)				Don't know	

6.14. If these hip or groin injuries were rowing related, **how many** of these hip or groin injuries were related to the following types of training? Please specify the number of injuries to all that apply.							
On water - Training		Ergometer training		Weight training		On water - Racing	
Cross training, please specify type and number:						Don't know	
6.15. If yes, did you ever miss an elite competition due to a severe injury in your hip(s) or groin (more than four weeks of reduced participation in exercise, training or sport)?							
Yes		No (go to 6.17)				Don't know	
6.16. If yes, **how many** elite competitions did you miss for your hip/groin injuries?						Don't know	

6.17. Have you ever had any severe injury in your **knee(s)**, leading to more than four weeks of reduced participation in exercise, training or sport?							
Yes		No (go to 6.21)				Don't know	
6.18. If yes, **how many** knee injuries?		Left:		Right:		Don't know	
6.19. If yes, were these knee injuries rowing or non-rowing related? Select all that apply.							
Rowing		Non-rowing (go to 6.21)				Don't know	
6.20. If these knee injuries were rowing related, **how many** of these knee injuries were related to the following types of training? Please specify the number of injuries to all that apply.							
On water - Training		Ergometer training		Weight training		On water - Racing	
Cross training, please specify type and number:						Don't know	

6.21. Have you ever had any severe injury in your **shoulder(s)**, leading to more than four weeks of reduced participation in exercise, training or sport?							
Yes		No (go to 6.25)				Don't know	
6.22. If yes, **how many** shoulder injuries?		Left:		Right:		Don't know	
6.23. If yes, were these shoulder injuries rowing or non-rowing related? Select all that apply.							
Rowing		Non-rowing (go to 6.25)				Don't know	
6.24. If these shoulder injuries were rowing related, **how many** of these shoulder injuries were related to the following types of training? Please specify the number of injuries to all that apply.							
On water - Training		Ergometer training		Weight training		On water - Racing	
Cross training, please specify type and number:						Don't know	

6.25. Have you ever had any severe injury in your **ankle(s)**, leading to more than four weeks of reduced participation in exercise, training or sport?							
Yes		No (go to 7.1)				Don't know	
6.26. If yes, **how many** ankle injuries?		Left:		Right:		Don't know	
6.27. If yes, were these ankle injuries rowing or non-rowing related? Select all that apply.							
Rowing		Non-rowing (go to 7.1)				Don't know	

6.28. If these ankle injuries were rowing related, **how many** of these ankle injuries were related to the following types of training? Please specify the number of injuries to all that apply.							
On water - training		Ergometer training		Weight training		On water - Racing	
Cross training, please specify type and number:						Don't know	

7. Family history: We request these details as they may be related to the risk of developing osteoarthritis.					
Have your parents or any brothers or sisters ever had any of the following?					
7.1. Been told by a Doctor that they have wear and tear/degeneration of the joints or been diagnosed with osteoarthritis?					
Yes		No (go to 7.3)		Don't know	
7.2. If yes, where? Please select all the joints that apply and/or specify "other":					
Hip		Knee		Shoulder	
Hand		Other, please specify:		Don't know	
7.3. Joint replacement surgery?					
Yes		No (go to 8.1)		Don't know	
7.4. If yes, where? Please specify all the joints that apply and/or specify "other":					
Hip		Knee		Shoulder	
Hand		Other, please specify:		Don't know	

8. Wellbeing- For each question, please select the most relevant answer for you:				
8.1. Considering the benefits and risks of my previous participation in rowing, I would do the same again.				
1 Strongly agree	2 Agree	3 Undecided	4 Disagree	5 Strongly disagree
8.2. Considering the benefits and risks of my previous participation in rowing, I would recommend this to my children, relatives or close friends.				
1 Strongly agree	2 Agree	3 Undecided	4 Disagree	5 Strongly disagree
8.3. Did your rowing career enrich your life?				
1 Dramatically	2 Somewhat	3 Undecided	4 Not really	5 Not at all
8.4. My previous participation in rowing has resulted in an **increase** in my **current** physical activity level.				
1 Strongly agree	2 Agree	3 Undecided	4 Disagree	5 Strongly disagree
8.5. My previous participation in rowing has resulted in a **decrease** in my **current** physical activity level.				
1 Strongly agree	2 Agree	3 Undecided	4 Disagree	5 Strongly disagree

Thank you for your time. Please return the questionnaire in the enclosed envelope.

Appendix 5: EQ5D Questionnaire included at the end of the rowing study questionnaire.

Under each heading, please tick the ONE box that best describes your health TODAY.

MOBILITY

I have no problems in walking about ❑
I have slight problems in walking about ❑
I have moderate problems in walking about ❑
I have severe problems in walking about ❑
I am unable to walk about ❑

SELF-CARE

I have no problems washing or dressing myself ❑
I have slight problems washing or dressing myself ❑
I have moderate problems washing or dressing myself ❑
I have severe problems washing or dressing myself ❑
I am unable to wash or dress myself ❑

USUAL ACTIVITIES *(e.g. work, study, housework, family or leisure activities)*

I have no problems doing my usual activities ❑
I have slight problems doing my usual activities ❑
I have moderate problems doing my usual activities ❑
I have severe problems doing my usual activities ❑
I am unable to do my usual activities ❑

PAIN / DISCOMFORT

I have no pain or discomfort ❑
I have slight pain or discomfort ❑
I have moderate pain or discomfort ❑
I have severe pain or discomfort ❑
I have extreme pain or discomfort ❑

ANXIETY / DEPRESSION

I am not anxious or depressed ❑
I am slightly anxious or depressed ❑
I am moderately anxious or depressed ❑
I am severely anxious or depressed ❑
I am extremely anxious or depressed ❑

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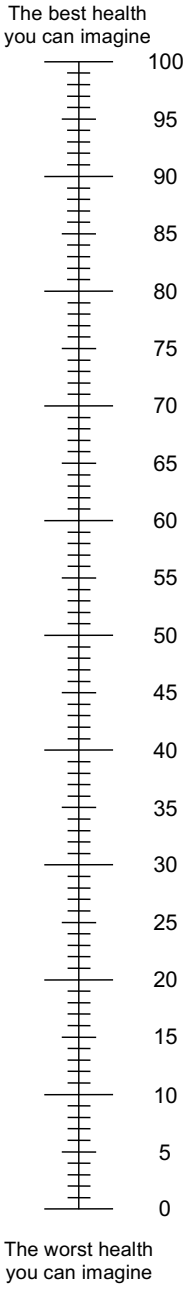
- We would like to know how good or bad your health is TODAY.
- This scale is numbered from 0 to 100.
- 100 means the <u>best</u> health you can imagine.
  0 means the <u>worst</u> health you can imagine.
- Mark an X on the scale to indicate how your health is TODAY.
- Now, please write the number you marked on the scale in the box below.

YOUR HEALTH TODAY = ☐



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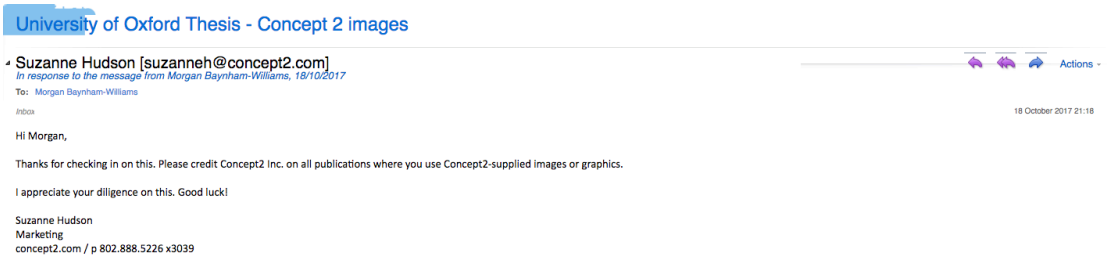

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Suzanne Hudson [suzanneh@concept2.com]
In response to the message from Morgan Baynham-Williams, 18/10/2017

Actions

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Inbox

18 October 2017 21:18

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