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ORIGINAL ARTICLE

Bridging the knowledge gap in rare bone disorders: insights from the APCO Asia-Pacific Rare Bone Disorders Engagement (ASPIRE) survey

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Abstract

Summary This first-of-its-kind survey reveals deep gaps in awareness, diagnostic confidence, and access to resources for rare bone disorders across the Asia-Pacific. It calls for urgent action to improve care, diagnosis, and transition across the lifespan for those living with these diseases.

Purpose Rare bone disorders (RBDs) are often misdiagnosed or diagnosed late, causing irreversible complications that could have been prevented by early identification and intervention. This survey assessed awareness among healthcare providers across various specialties with the goals of identifying knowledge gaps as well as barriers in education, clinical practice, and health policy regarding RBDs.

Methods The ASPIRE survey was designed by a steering committee of international experts and administered to attendees of an Asia-Pacific musculoskeletal congress held in Singapore. It included multiple-choice questions, short answers, and situational case studies.

Results Of 106 clinician attendees, 96 completed the survey. While 71.9% of respondents had some knowledge of RBDs, only 36.5% had ever managed a patient with a RBD. Overall, 76.0% of respondents indicated not feeling qualified to diagnose or treat RBDs; 74.0% were unaware of any RBD national or international guidelines, and 66.7% were unaware of any new specific medications available in the last 5−10 years to treat any RBD. Among those who attempted diagnosis of two clinical vignettes, only 46.3% correctly identified X-linked hypophosphatemia, and only 32.4% correctly identified hypophosphatasia. The survey also highlighted substantial barriers to effective RBD care, including gaps in medical education and training, and limited access to diagnostic tools and RBD specialists.

Conclusion This first of a kind survey provides evidence of the stark lack of awareness of RBDs in the Asia-Pacific region. Urgent attention is needed from educators, clinicians, and policymakers to address the educational, structural, and policy gaps identified.

Keywords Adult · Asia · Asia-Pacific · Awareness · Pediatric · Rare bone disorders

Introduction

Genetic disorders affecting the skeletal system account for a large proportion of recognized rare diseases, with hundreds of skeletal dysplasia phenotypes identified [1]. Examples range from well characterized conditions such as osteogenesis imperfecta, X-linked hypophosphatemia, and hypophosphatasia to lesser-studied entities including melorheostosis, pycnodysostosis, fibrodysplasia ossificans progressiva, etc., reflecting the clinical and biological heterogeneity of RBDs [2]. Many RBDs are characterized by short stature, skeletal dysmorphology, and identifiable genetic mutations. RBDs can cause a substantial detrimental impact on patients through diagnostic delays and mismanagement compounded by the limited availability of treatment options and barriers to appropriate and timely healthcare faced by pediatric patients living with RBDs while transitioning from childhood and adolescence to adulthood [3, 4]. In general, RBDs are underrecognized and undertreated worldwide. This is

Extended author information available on the last page of the article

particularly true in the Asia-Pacific (AP) region, where over 250 million individuals are estimated to be living with a rare disease [5].

The Asia-Pacific Consortium on Osteoporosis (APCO) was established in 2019 as an apolitical and nonpartisan organization of musculoskeletal health experts working in various healthcare systems and clinical settings, who are dedicated to reducing the burden of musculoskeletal disorders, including osteoporosis and other metabolic bone diseases, including RBDs in the region[6]. The vision of APCO is to enhance awareness, diagnosis, and treatment pathways for these diseases by engaging with relevant stakeholders, including healthcare providers, policymakers, patients, and the public.

The APCO Asia-Pacific Rare Bone Disorders Engagement (APCO ASPIRE) survey was developed by a steering committee comprised of international RBD experts. The goal of the survey was to assess baseline awareness of RBDs among healthcare providers across various specialties in the AP region. By understanding knowledge gaps and barriers regarding RBDs, it is hoped that the survey results can contribute to a framework for improving education and clinical practice, with the goal of contributing to health policy decisions and improving patient outcomes.

Methods

Survey design and structure

The ASPIRE survey was designed by the lead investigator and author (MC) and approved by a steering committee comprised of international experts in adult/pediatric metabolic and rare bone disorders. The purpose of the survey was to assess the baseline awareness of RBDs among clinicians and allied healthcare providers across the AP region. Basic science and technical researchers were excluded.

The survey, intended to be completed within approximately 10 min, included multiple choice questions, short answers, and situational case studies (Online Resource 1 is a table outlining the survey questions). The survey assessed respondents' knowledge of RBDs, including their familiarity with national and international guidelines, perceived challenges in RBD care, awareness of access to specialists and resources, knowledge of treatment options, and competence in the diagnosis and management of specific RBDs. Section I of the survey collected demographic information, Section II focused on general awareness of RBDs (genetic or acquired), and Section III assessed awareness and knowledge of specific RBDs through two hypothetical situational case studies on XLH and hypophosphatasia. These two conditions were chosen as examples because they are distinct mineralization disorders with overlapping features that can make diagnosis challenging, and because effective targeted therapies are already available or expected to become available in parts of Asia, making timely recognition particularly relevant for clinicians in the region. The concluding section of the survey asked for potential barriers, as perceived by respondents, to the timely diagnosis and management of RBDs within their respective countries or regions as free-text responses.

Survey administration

The survey was administered at the APCO Singapore Osteoporosis and Other Metabolic Bone Disorders Summit (APCO SOOMBODS), which was held in Singapore from May 17 to 19, 2024. Participants were not aware beforehand that a survey would be conducted during the conference. To gauge *baseline* knowledge of RBDs before participation in the congress, the program of which included sessions on RBDs, the survey was completed before participants attended the conference sessions. Participants were also requested to complete the survey independently, without consulting external sources or colleagues. Surveys were administered in person at the registration desk to support this approach. Participation in the survey was entirely voluntary, and informed consent was obtained. No collection of personally identifiable data was obtained, except voluntarily provided contact details. The survey was administered in English.

Results

All analyses and reporting are descriptive as the survey was not powered for statistical analyses.

Respondents

The meeting was attended by 106 clinical care providers. Of these, 96 completed the survey. These survey responders were from 12 different AP countries and across a variety of specialties, with the most common being adult endocrinology (34.4%) and allied healthcare (13.5%; Table 1). Overall, 68.8% of the survey responders worked in a university or teaching hospital or specialized center. The majority (80.2%) of survey respondents reported spending over half of their time on direct patient care.

Awareness of rare bone disorders

When questioned about their awareness of RBDs (genetic or acquired), 71.9% (69/96) of respondents replied that they had some knowledge of RBDs. Conditions most frequently mentioned (demonstrating variable familiarity with diagnostic

Table 1 Demographics of survey participants

Characteristic	*N* = 96 *n* (%)
Specialty	
Adult endocrinologist	33 (34.4)
Allied healthcare provider	13 (13.5)
Other	12 (12.5)
Adult rheumatologist	8 (8.3)
Orthopedic surgeon	8 (8.3)
Geriatrician	7 (7.3)
Family physician	6 (6.3)
Internist	4 (4.2)
Adult and pediatric endocrinologist	3 (3.1)
Nephrologist	2 (2.1)
Age group of patients managed	
Adult only	79 (82.3)
Both adult and pediatric	16 (16.7)
Pediatric only	1 (1.0)
Number of years of clinical practice	
< 5	14 (14.6)
6–10	18 (18.8)
11–20	35 (36.5)
21–30	14 (14.6)
31–40	13 (13.5)
> 40	2 (2.1)
Current designation in clinical practice	
Senior consultant[a]	37 (38.5)
Consultant[a]	19 (19.8)
Junior/associate consultant[a]	13 (13.5)
Specialty trainee[b]	14 (14.6)
Retired and no longer seeing patients	1 (1.0)
Non-specialty trainee	10 (10.4)
Medical student	2 (2.1)
Clinical practice	
University or teaching hospital or specialized center (tertiary-level care)	66 (68.8)
District or community hospital (non-teaching)	4 (4.2)
Private specialist practice (group or sole)	16 (16.7)
Polyclinic	4 (4.2)
Private primary care (GP) practice	1 (1.0)
Other[c]	5 (5.2)
Time spent on direct patient care	
0–25% of time	11 (11.5)
26–50% of time	8 (8.3)
51–75% of time	33 (34.4)
76–100% of time	44 (45.8)
Country	
Australia	6 (6.3)
Brunei	1 (1.0)
India	5 (5.2)
Indonesia	9 (9.4)
Japan	1 (1.0)
Malaysia	7 (7.3)
Myanmar	8 (8.3)
Philippines	2 (2.1)
Singapore	41 (42.7)
Taiwan	1 (1.0)
Thailand	13 (13.5)
Vietnam	2 (2.1)

GP, general practitioner

[a]Or equivalent grade

[b]Including senior resident or fellow equivalent grade

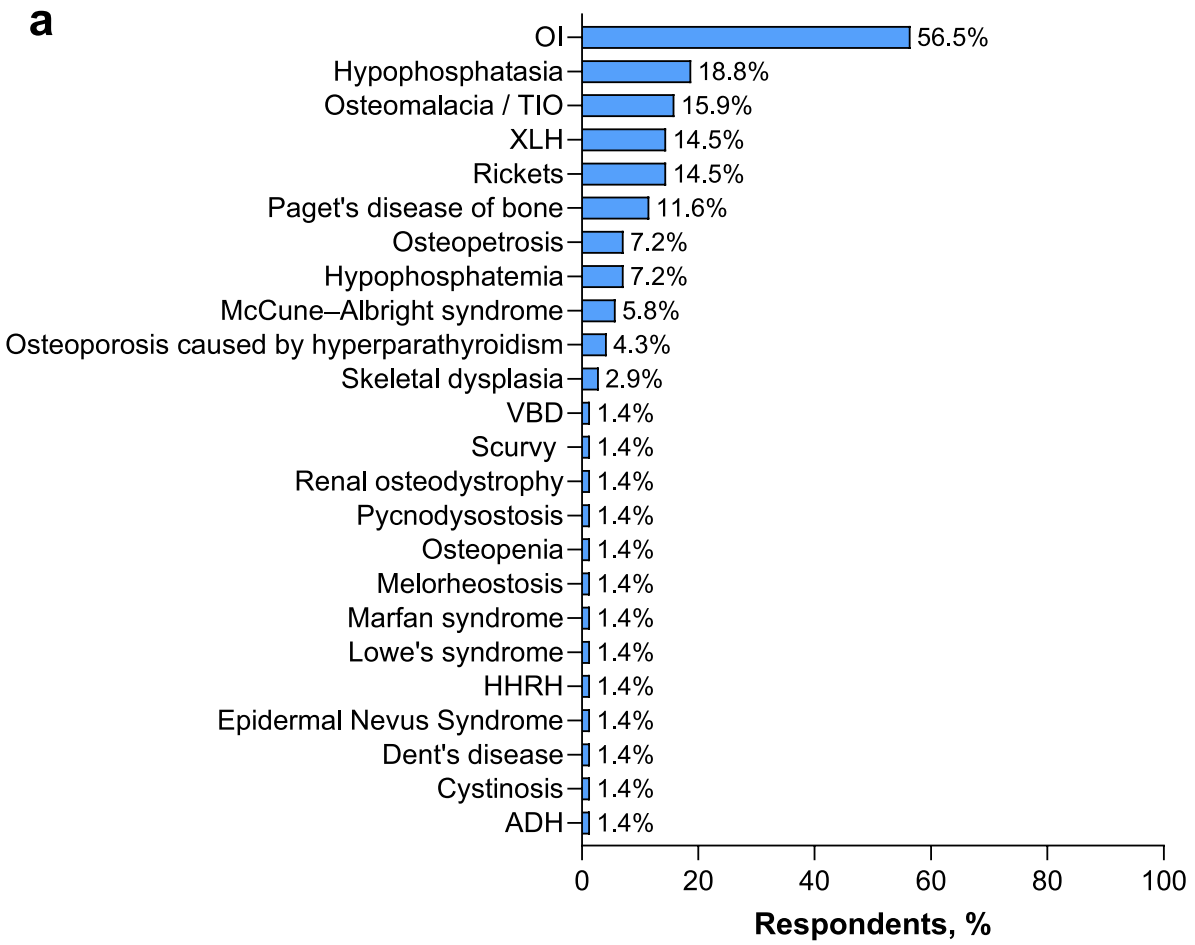
[c]Including army hospital, community teaching hospital

distinctions) were OI (56.5% [39/69]), hypophosphatasia (18.8% [13/69]), "osteomalacia/tumor-induced osteomalacia (TIO)" (15.9% [11/69]), rickets (14.5% [10/69]), XLH (14.5% [10/69]), and Paget's disease of bone (11.6% [8/69]) (Fig. 1a). Of respondents who could think of some specific RBDs, 52.1% ($n = 50$) replied that they had heard about RBDs for the first time from their reading, medical school, or specialty training, while only 36.5% ($n = 35$) had cared for a patient with a confirmed or suspected diagnosis of RBD (Fig. 1b).

Competency in diagnosis and management

The majority (76.0%; $n = 73$) of respondents reported not feeling qualified or knowledgeable enough to diagnose (i.e., able to identify signs and symptoms), evaluate, and manage a patient with RBD. Overall, 61.5% ($n = 59$) of respondents reported having access to or knowledge of specialists and resources in their geographical area for referring patients with RBDs (Fig. 2a). The most frequently cited resources were laboratories (39.0% [23/59]), genetic testing (35.6% [21/59]), and "equipped hospitals" (28.8% [17/59]) (Fig. 2b). Among respondents who felt they lacked access to such resources, the most identified need was for laboratory facilities (40.5% [15/37]), while 35.1% (13/37) were uncertain about which resources would be most beneficial.

When asked about awareness of national, regional, or international consensus guidelines on any RBD, 74.0% (71/96) of respondents answered they were not aware of such consensus guidelines. When the respondents who described awareness of such guidelines were asked to name these guidelines, the most common responses were XLH guidelines (32.0% [8/25]). Notably, 16.0% (4/25) of respondents could not name such guidelines, and a further 16.0% (4/25) listed *osteoporosis* guidelines rather than those for RBDs (Fig. 3a).


a
OI
Hypophosphatasia
Osteomalacia / TIO
XLH
Rickets
Paget's disease of bone
Osteopetrosis
Hypophosphatemia
McCune–Albright syndrome
Osteoporosis caused by hyperparathyroidism
Skeletal dysplasia
VBD
Scurvy
Renal osteodystrophy
Pycnodysostosis
Osteopenia
Melorheostosis
Marfan syndrome
Lowe's syndrome
HHRH
Epidermal Nevus Syndrome
Dent's disease
Cystinosis
ADH
56.5%
18.8%
15.9%
14.5%
14.5%
11.6%
7.2%
7.2%
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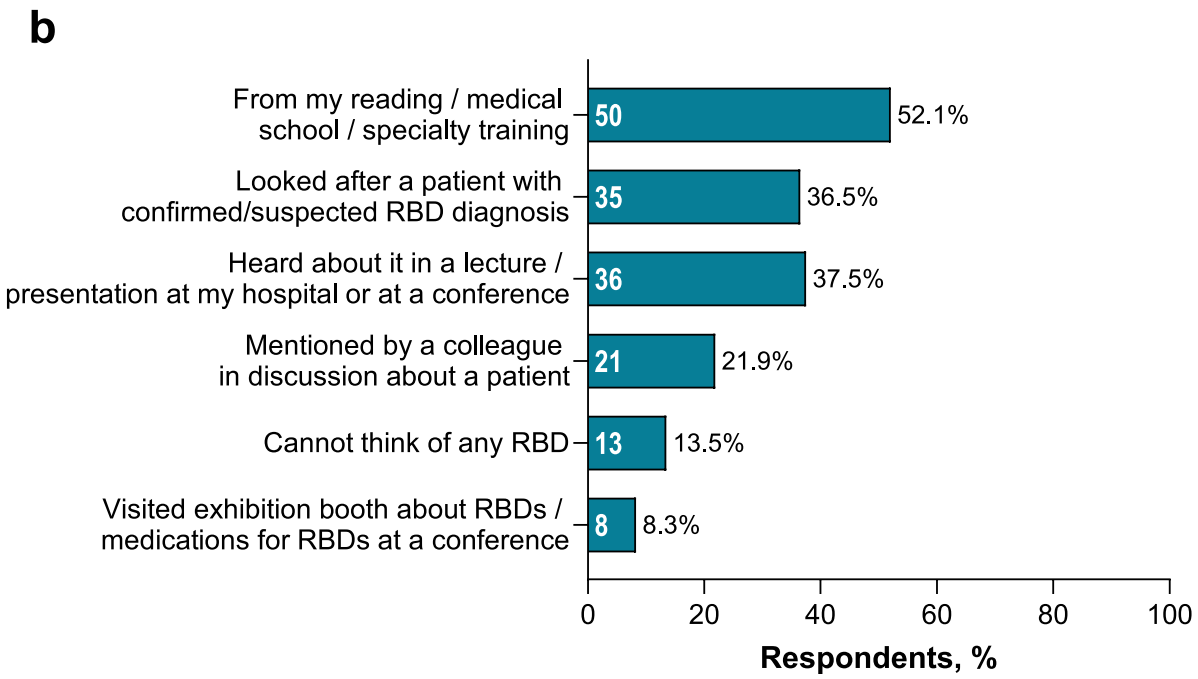
0
20
40
60
80
100
Respondents, %


b
From my reading / medical school / specialty training
Looked after a patient with confirmed/suspected RBD diagnosis
Heard about it in a lecture / presentation at my hospital or at a conference
Mentioned by a colleague in discussion about a patient
Cannot think of any RBD
Visited exhibition booth about RBDs / medications for RBDs at a conference
50
35
36
21
13
8
52.1%
36.5%
37.5%
21.9%
13.5%
8.3%
0
20
40
60
80
100
Respondents, %

◂**Fig. 1** Awareness of RBDs including **a** their naming and **b** where knowledge was first acquired. **a** shows response from participants when asked to note as many RBD(s) immediately coming to mind. **b** shows responses from participants when asked how they heard about RBD(s) for the first time. The total number of respondents was 96 (respondents could provide >1 response to the question). In **a**, 69 respondents could recall the name of RBD(s). In **b**, the values in the bar are the number of responses for that category. ADH, autosomal dominant hypophosphatemia; HHRH, hypophosphatemic rickets with hypercalciuria; OI, osteogenesis imperfecta; RBD, rare bone disorder; TIO, tumor-induced osteomalacia; VBD, Van Buchem disease; XLH, X-linked hypophosphatemia

The majority (66.7% [64/96]) of respondents were not aware of any recently available specific medication (i.e., available within the last 5−10 years) to treat any RBD (Fig. 3b). When those who responded that they were aware of such a treatment for RBDs were asked to list these treatment names, the most common responses were burosumab (40.6% [13/32]) and "cannot recall" (31.3% [10/32]). Notably, four respondents named medications used to treat osteoporosis rather than RBDs. Only 18% (17/96) of respondents were aware of any specific or new medications to treat any RBD that were available in their country, with burosumab (64.7% [11/17]) being the most listed (Fig. 3c). Notably again, four respondents listed a medicine used to treat osteoporosis rather than RBDs.

Two brief case studies were presented to assess participants' awareness and knowledge of specific RBDs. The first case described an inherited disorder characterized by low levels of phosphate in the blood due to loss of phosphate in the urine (phosphate wasting/phosphaturia) and leading to poorly mineralized bones and osteomalacia. The symptoms of this inherited disorder in children were described as rickets, delayed/disproportionate growth, craniosynostosis, delayed motor development, and gait abnormalities. Symptoms specifically in adults were described as fractures, osteoarthritis, enthesopathy, spinal stenosis, and hearing loss. Across all ages, symptoms were described as short stature, deformity of weight-bearing limbs, osteomalacia, bone and joint pain, stiffness, dental complications, muscle pain and weakness, Chiari malformation, and gait disturbance. Overall, 56.3% (54/96) of respondents thought they knew what this condition was. When those 54 respondents were asked to provide a diagnosis, only 46.3% ($n=25$) correctly diagnosed this condition as XLH rickets (Fig SI1 in Online Resource 2).

The second case described an inherited disorder that often has as its first sign early loss of primary teeth in a child. The affected child may have a short stature with an abnormally shaped skull, bowed legs or knock knees, and enlarged wrist and ankle joints characteristic of rickets. Adults may present with fractures including atypical femur fractures and have other signs of osteomalacia. Diagnosis may be made by finding low levels of an enzyme in the blood as well as elevated levels of vitamin B6 or its metabolites in the blood. Overall, 35.4% (34/96) of respondents thought they knew what this condition was (Fig SI2 in Online Resource 2). Among those respondents, only 32.4% (11/34) correctly diagnosed this condition as hypophosphatasia.

In exploring potential predictors of diagnostic accuracy for the two clinical vignettes (XLH and hypophosphatasia), we examined respondent characteristics including specialty, designation, clinical setting, and years in clinical practice. Formal statistical comparisons were limited by small or uneven subgroup sizes and showed considerable variability in diagnostic acumen. For XLH, consultants with 11−20 years of experience working in university or teaching hospitals had a 20.0% success rate (1/5), while the same designation in private specialist practice showed 100% accuracy (1/1), though limited by small numbers. Senior consultants in teaching hospitals had similarly modest performance, with only 1 of 5 respondents (20.0%) correctly identifying XLH. For hypophosphatasia, patterns were similar, with correct responses scattered across different settings and designations, without a consistent trend. Overall, correct identification of both conditions remained suboptimal across all subgroups.

Challenges in rare bone disorders care

When asked to describe the major obstacles to the timely diagnosis and treatment of RBDs in their country or region, the most common barrier cited was lack of awareness of the conditions among healthcare providers (77.1% [74/96]) and among patients and caregivers (57.3% [55/96]). Other barriers identified were inadequate training in medical school and specialty training curricula (53.1% [51/96]) and lack of resources such as advanced imaging, genetic testing, or specialized laboratory testing (50.0% [48/96]) (Fig. 4).

Discussion

A notable gap in surveys that capture healthcare provider perspectives across the full spectrum of RBDs exists. In a modest but meaningful step towards closing that gap, the APCO survey offers a cross-sectional glimpse into the realities of clinical practice across diverse health systems in the AP region. The results of our survey highlight an alarming lack of awareness regarding RBDs among skilled healthcare providers in the AP region. This emphasizes the urgent need to educate and raise awareness about RBDs among clinicians across all medical specialties as well as allied healthcare providers. Our intent in conducting the survey and publishing its findings is not to suggest that all clinicians should have comprehensive knowledge of all the disorders that are encompassed within the RBD spectrum, but rather to assess baseline awareness and identify opportunities to improve recognition of atypical cases and strengthen referral

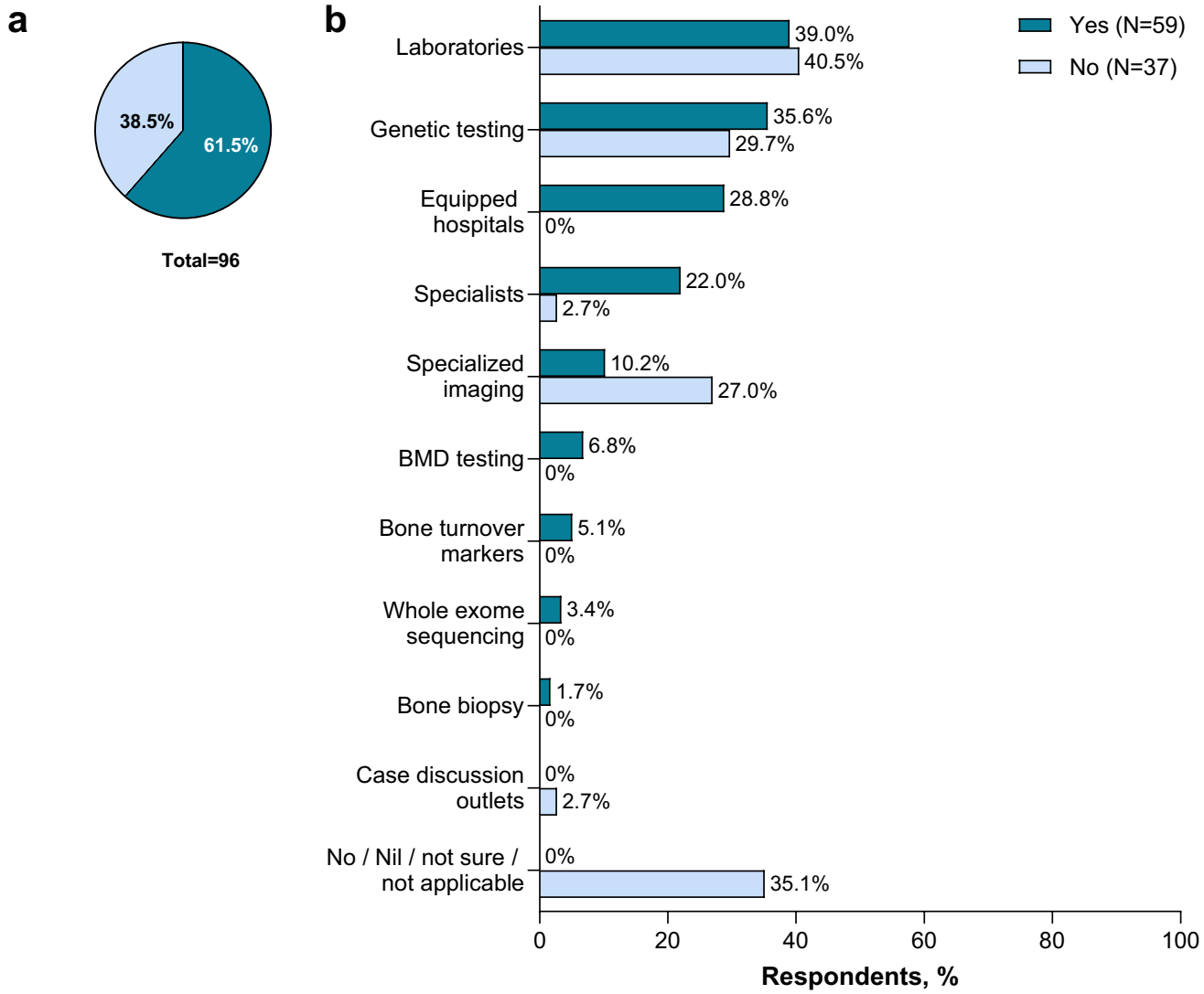


Fig. 2 Access to or knowledge of specialist resources to refer patients with RBDs. (**a**) shows responses from participants when asked whether they feel sufficiently qualified or knowledgeable to diagnose (identify signs and symptoms), evaluate, and manage a patient with an RBD. (**b**) shows responses when asked whether they feel they have access to or know of specialists or resources to refer their patients with RBDs. As responses were open-ended and multiple answers were allowed, percentages represent the proportion of the 59 applicable respondents mentioning each resource and do not sum to 100%. BMD, bone mineral density; RBD, rare bone disorder

pathways. The survey identified barriers to effective RBD care including lack of awareness and knowledge among healthcare providers, gaps in medical education and training, and limited access to diagnostic tools and specialists.

The European Commission's European Reference Networks (ERNs) focuses on complex and rare diseases necessitating specialized treatment and concentrated resources. ERN ReCONNECT directs its attention towards rare and complex connective tissue and musculoskeletal diseases [7]. In contrast to our broader survey, the latter entity conducted a survey in 2020 with a narrow focus on adherence to clinical practice guidelines among a small number of healthcare providers ($n = 56$). The healthcare providers noted that improved patient care is reliant on well-constructed and relevant guidelines; however, the general response then was that few, if any, guidelines were available to providers, and barriers to their use included local legislative restrictions and time constraints in studying them [7]. Suggested strategies then to counter these barriers included improving the practicality of existing guidelines, increasing knowledge and education on guidelines, and government support in minimizing legislative restrictions. The wider dissemination of guidelines to patients, families, and caregivers, as well as their adaptation to regional healthcare systems, was proposed.

In our survey, some responses, such as "Osteomalacia/TIO," indicated that respondents were conflating a general clinical syndrome with a specific diagnosis. This example

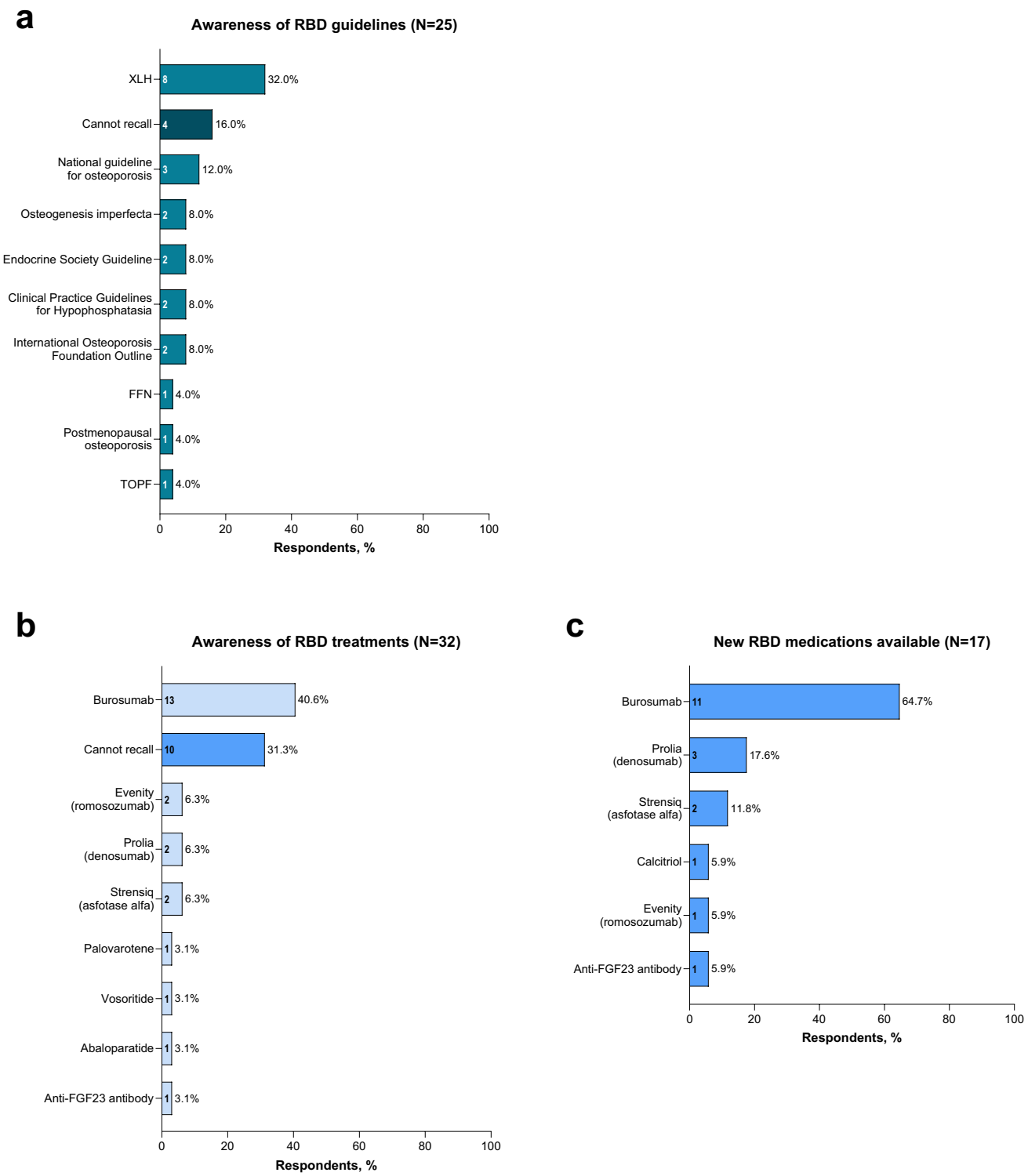


Fig. 3 Participants awareness of RBD guidelines and treatments. In (**a**), respondents were asked to name any national, regional, or international consensus guidelines on any RBD. In (**b**), respondents were asked to name specific new medications (i.e., available in the last 5–10 years) to treat any RBDs. In (**c**), respondents were asked to name any specific and new medications for any RBD available in their country. The numbers in the bars are the number of responses for that category. *N* is the total number of yes responses (respondents could provide > 1 response to the question). FFN, Fragility Fracture Network; FGF23, fibroblast growth factor 23; RBD, rare bone disease; TOPF, Thai Osteoporosis Foundation; XLH, X-linked hypophosphatemia

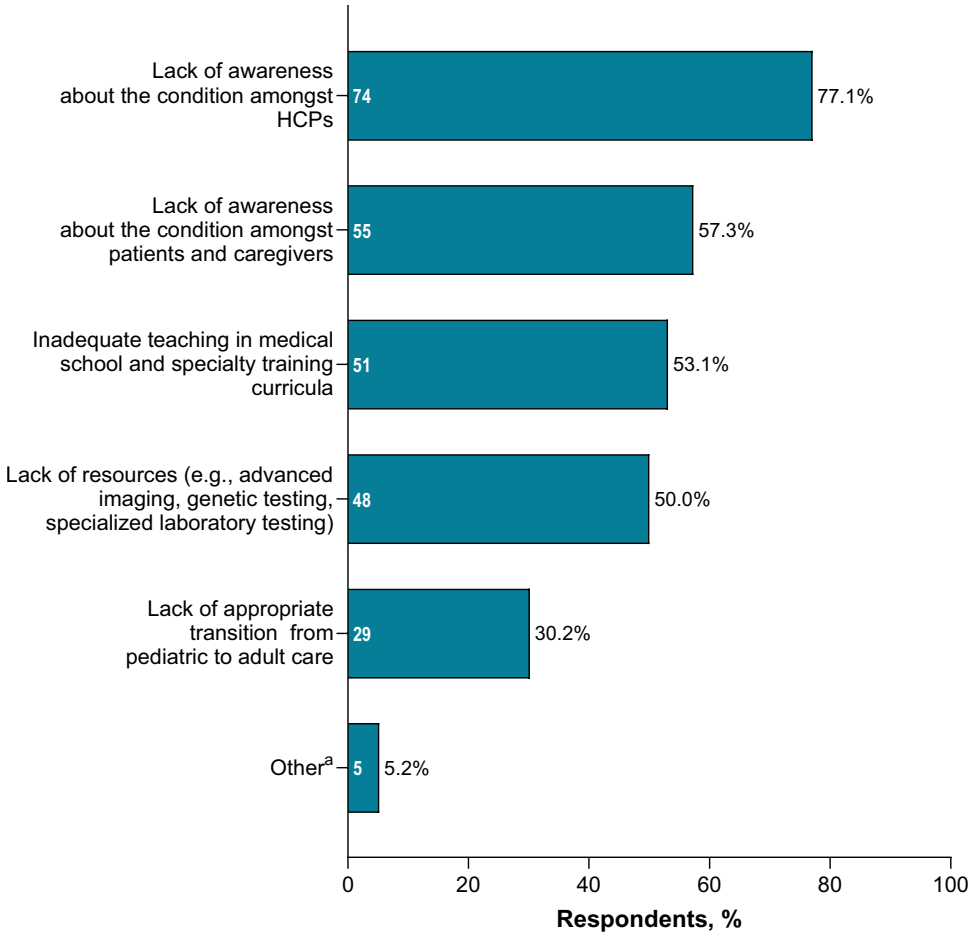


Fig. 4 Obstacles to timely diagnosis and treatment of RBDs. Respondents were asked to identify the major obstacles to the timely diagnosis and treatment of RBDs in their country or region. The total number of respondents was 96 (respondents could provide > 1 response to the question). The numbers in the bars are the number of responses for that category. [a]Included unspecified ($n = 4$) and patients do not care about their clinical conditions ($n = 1$). HCP, healthcare provider; RBD, rare bone disorder

suggested that the respondents had a surface-level awareness of phosphate-wasting disorders, but limited ability to distinguish between a specific condition such as "tumor-induced osteomalacia" from "osteomalacia," which is a broader descriptive term encompassing various underlying causes, including nutritional deficiencies, renal losses, and hereditary disorders. This diagnostic blurring points to a broader gap in understanding the classification and etiology of RBDs and underscores the need for more structured educational initiatives focused on disease mechanisms, nosology, and clinical differentiation. To support clinicians in recognizing bone disorders that do not fit the profile of typical osteoporosis, we suggest using elements from the set of key clinical "red flags" described in our previously published report from the Global Rare Bone Disorders Summit [3] This summit had brought together international experts to share best practices and improve diagnostic and management pathways for these conditions. These "red flags" include an unusual frequency of fractures, joint pain, family history of RBDs, disproportionate growth or developmental delay, skeletal or facial dysmorphology, dental abnormalities, functional impairment, fatigue, and diagnostic uncertainty (e.g., multiple referrals, unexplained test results, or treatments failing to work as expected). The presence of these features should prompt early referral to a clinician experienced in RBDs. Ultimately, however, confirmation of a suspected RBD often requires genetic testing, and improving access to such diagnostics in the Asia-Pacific remains a key priority.

Among the free-text responses describing available referral resources (Fig. 2b), several respondents listed "equipped hospitals" rather than naming specific diagnostic services such as laboratories or genetic testing. This phrasing likely reflects a more general perception of institutional readiness, namely, that certain hospitals are seen as better able to manage complex or rare conditions, rather than a reference to specific resources like personnel or diagnostics. It highlights the need both to define what truly is meant by comprehensive RBD care and to delineate what constitutes a center capable of managing RBDs.

The scattered pattern of correct responses across distinct experience levels, designations, and clinical settings to the case vignettes included in the survey suggests that exposure to RBDs remains inconsistent, even within academic institutions. RBDs like XLH and hypophosphatasia are uncommon in routine clinical practice, even in university hospitals. Exposure may be inconsistent, depending on

local subspecialty interest or referral patterns. Most medical training programs (including endocrinology, rheumatology, or internal medicine) do not systematically include RBDs. Hence, recognition often depends on personal reading, chance exposure, or interest, rather than seniority or the setting of clinical practice. Because participants were attending a musculoskeletal conference, some respondents may have had niche interest or prior exposure that improved their recognition of the two disorders that were set as clinical case vignettes, regardless of designation or career stage. Seniority does not always correlate with up-to-date knowledge of rare conditions, especially if the practice is not bone-focused or if the clinician has not encountered such cases in recent years. Even within university hospitals, the subspecialty infrastructure (e.g., metabolic bone clinics, genetics laboratories) may vary widely across countries in the region. Some clinicians in private practice may be subspecialists in bone disorders or hold dual affiliations with academic institutions, potentially affording them greater diagnostic familiarity than their counterparts in university or teaching hospitals.

Clinical practice guidelines and consensus statements for diagnosis, treatment, and management provide standardized approaches and the best possible knowledge for treating rare diseases, highly impacting patient care by delivering improved and positive outcomes [7]. However, the development of evidence-based guidelines remains particularly challenging in the field of rare diseases due to limited patient numbers, heterogeneous clinical presentations, and a scarcity of high-quality trial data to inform standardized recommendations [8]. Further challenges in developing and applying guidelines for rare diseases include limited clinical experience among healthcare providers, low awareness of existing recommendations, and a lack of adaptation to local healthcare system contexts [9]. To address these gaps, where formal guidelines are lacking, some advocacy groups are partnering with medical experts to develop care recommendations, aiming to provide clinicians with at least a baseline framework informed by the best available evidence.

Our survey identified a lack of awareness and familiarity with existing consensus guidelines for the diagnosis and management of RBDs, despite the publication of several international and regional guidelines in recent years [10–20]. Most of these guidelines are condition-specific, addressing individual RBDs in isolation rather than offering cross-cutting or universally applicable recommendations that span multiple conditions. Whether this highly focused approach enhances clinical utility by providing detailed, tailored guidance, or conversely limits applicability in settings where diagnostic uncertainty or resource constraints exist remains uncertain. We identified a clear need for the development and dissemination of regional guidelines through collaboration with local medical societies. Standardized diagnostic and treatment protocols should be adapted to regional healthcare systems and made widely accessible via open-access publications and targeted training. Though our survey participants came from professional backgrounds, language barriers may still have influenced their understanding of the survey questions or recognition of international guidelines, many of which are available only in English. This highlights a potential barrier to guideline adoption in the AP region, where linguistic diversity is high. Translating key guidelines into native languages could improve both awareness and implementation, particularly in non-anglophone or resource-limited settings.

Encouragingly, consensus recommendations tailored to specific regions and healthcare systems such as those developed for XLH in the AP region are beginning to emerge, offering more practical, context-sensitive strategies for implementation [10]. Critical to the implementation of guideline recommendations is the leveraging of experts and opinion leaders, who can improve healthcare providers' knowledge and compliance to rare disease guidelines. Similarly, it is critical to engage patient advocacy groups and patients who can assist with disseminating reliable information and raising public understanding [9]. Future studies on factors influencing guideline implementation in rare diseases, including in low-resource regions where the lack of associated research is notable, are also needed.

Lack of specialized management for rare diseases may be associated with worse patient outcomes. However, the care of individuals with rare diseases typically falls under the purview of specialist healthcare providers, and there are often only a limited number of experts within a given region for any specific rare condition [9]. This poses a particularly formidable barrier for patients residing in rural areas or smaller towns, where local clinicians may not have the requisite expertise. Initiatives such as the APCO Collective Intellect Clinical Case Discussion Platform (CICCDP) help bridge this gap by enabling these clinicians to tap into a pool of expert knowledge [21]. Through this platform, they can present and collaboratively deliberate on complex metabolic bone disease cases, including rare bone disorders (RBDs) with experienced colleagues across the Asia-Pacific region, thereby expanding access to specialist-level input regardless of geographic location.

Another issue not specifically identified in our survey but is apparent in our clinical practices and in the literature is the difficulty for pediatric patients living with rare diseases in their transition into adulthood. For instance, a study of 77 centers of the ERN for Hereditary Metabolic Disorders (MetabERN) found that only 67% of centers had a dedicated transition coordinator for pediatric patients with inherited metabolic diseases, and only about half provided written transition protocols, of which less than one quarter were standardized [22]. Transitioning from pediatric to adult care is particularly challenging for individuals with rare diseases who, due to severe disabilities or complex medical comorbidities, may be unable to participate in decisions about their own

healthcare. Their care often requires highly specialized treatment, but the scarcity of relevant expertise and the narrow window for coordinated transition make this process especially difficult [4, 22]. Other barriers to this transition include limited awareness among healthcare providers, as well as among patients and families, who may also face financial and access challenges, and may be less likely to seek timely or specialized care, especially if past experiences have shaped limited expectations about what is available to them [4, 23]. Healthcare disparities among children living with rare diseases are also barriers into adulthood care for their condition. A recent international consensus statement by the ECTS Rare Bone Disease Action Group reinforces these concerns, calling for structured, multidisciplinary transition pathways specifically tailored for young persons with rare bone mineral conditions [23]. Their recommendations emphasize the urgent need for formalized coordination, shared-care models, and age-appropriate education to ensure continuity of care and equitable health outcomes into adulthood.

Initiatives such as those spearheaded by APCO are emerging to address limitations in RBD diagnosis and management in the AP region [6]. APCO would like to coordinate the development of a database of reputed medical centers of excellence in the AP region equipped to manage patients with RBDs. APCO would also like to organize a conference in 2026 specifically devoted to RBDs, collaborating with other organizations and entities such as the Global Rare Bone Disease Summit (a virtual event held previously in December 2021) [3]. Beyond case-by-case support, APCO CICCDP aims to foster long-term skill transfer. By exposing participating clinicians to expert reasoning and evolving best practices, the platform serves as a tool for capacity building, enhancing local clinical competence over time and contributing to a broader, more resilient regional network of bone health expertise.

Recognizing the potential for alignment with global efforts, APCO sees value in future collaborations with international initiatives focused on rare bone disorder (RBD) advocacy, diagnosis, and management. These include programs such as the Rare Bone Disease TeleECHO, which brings together a core faculty of global specialists and frontline clinicians in case-based learning to improve clinical outcomes [24]. Another ERN, European Conference Network on Rare Bone Diseases (ERN BOND), also focuses on RBDs and aims to enhance patient care through multidisciplinary, patient-centered approaches, expedited diagnosis and treatment, and rapid information exchange [25]. Specific activities include facilitating data pooling and sharing, public health surveillance, and communication among healthcare teams, which include patients. Challenges in these efforts include complex and fragmented governance structures, along with limited awareness of the network's existence and purpose, and low participation by both clinicians and patients. These gaps can reduce transparency, hinder the inclusion of key stakeholders especially patients, and constrain opportunities for meaningful collaboration.

Collectively, the results of our survey and review of existing literature have implications for clinical practice and health policy. Identified barriers to effective RBD care (Fig. 5) include (1) lack of awareness among healthcare providers and patients, (2) gaps in medical education and training, (3) limited access to diagnostic tools and specialists, (4) pediatric-to-adult care transition challenges, (5) language and cultural barriers in guideline comprehension and dissemination, and (6) lack of targeted education and training on specific rare bone disease entities and their classification.

There is a need to leverage digital platforms for wider dissemination of RBD knowledge, as well as make efforts targeted at increasing participation in RBD-focused conferences and workshops. These unfortunately are still seen as "too niche" by even specialists in metabolic bone diseases and remain poorly attended and publicized. Also critical is improving access to diagnostics and treatment by expanding availability of specialized diagnostic tests at tertiary care centers, encouraging pharmaceutical and biotechnology partnerships to improve drug accessibility, and promoting advocacy efforts to include RBD treatments in national healthcare coverage plans. Approaches for enhancing referral networks and multidisciplinary care include establishing clearer referral pathways between primary care, endocrinologists, rheumatologists, and geneticists. Encouraging interdisciplinary collaboration for comprehensive RBD management is also critical.

Strengths of our survey study are notable. To our knowledge, this is the first study of its kind not only conducted across a broad region such as the Asia-Pacific, but also explores multiple domains such as healthcare provider awareness, diagnostic confidence, and perceived system-level needs related to RBDs. Its breadth—spanning multiple countries, healthcare settings, and professional roles—offers a valuable regional perspective that has been absent from the literature to date. Participants were unaware about the survey, it was anonymized, and collaboration during its completion was not allowed. Therefore, it revealed a contemporary snapshot of the knowledge regarding RBDs in the AP region among individual clinicians and allied clinical healthcare providers. Our survey was intentionally designed to enable meaningful assessment of baseline awareness of RBDs within the constraints of survey length and respondent burden. While not exhaustive, this approach allowed us to capture clinically relevant insights that can serve as a foundation for expanding future surveys to encompass a broader range of these disorders. To facilitate such future work, we have included the full survey instrument in Online Resource 4, which we hope will be a useful resource for other investigators designing studies in this area. Although the survey

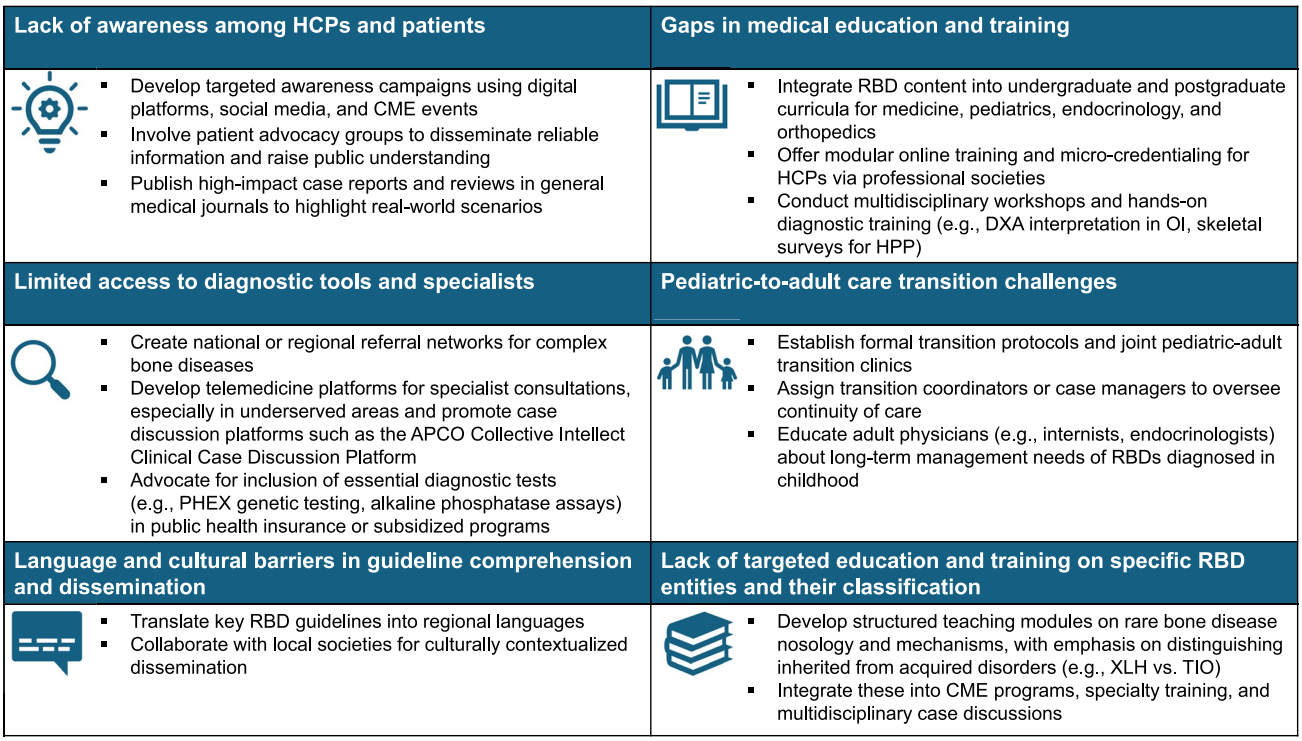


Fig. 5 Approaches to break down barriers in RBD knowledge, diagnosis, and management. APCO, Asia-Pacific Consortium on Osteoporosis; CME, continuing medical education; DXA, dual-energy X-ray absorptiometry; HCP, healthcare provider; HPP, hypophosphatasia; OI, osteogenesis imperfecta; PHEX, phosphate regulating gene; RBD, rare bone disorders; TIO, tumor-induced osteomalacia; XLH, X-linked hypophosphatemia

was conducted in the Asia-Pacific, the gaps in awareness, diagnostic access, and referral pathways we identified likely reflect challenges shared across many healthcare systems worldwide. As such, the insights generated may inform educational and policy strategies beyond our region.

Our survey had limitations. The participant number was obtained from a convenience sample of healthcare providers. However, the completion rate (96/106 attendees) was high, indicating an elevated level of engagement. The survey was not powered to perform statistical comparisons among specialties, seniority levels, clinical settings, or years in clinical practice, and therefore the ability to draw causal inferences was limited. Further studies employing random sampling and appropriate statistical controls are required to strengthen the evidence base for decision-making. Another limitation of our survey is that over 40% of our respondents were from Singapore. This reflects the location of the conference where the survey was administered. While this may somewhat limit generalizability across the Asia-Pacific region, the findings are nonetheless concerning, given that they reflect the lack of knowledge about RBDs among health care practitioners even within a relatively well-resourced healthcare system. It is conceivable that similar surveys conducted in lower-resource settings could reveal even wider gaps in awareness and preparedness to manage RBDs, underscoring the urgency of regional capacity-building efforts.

The merging of diagnostic and management-related questions in the survey may have limited more granular insights into where the greatest deficits lie. However, this combined framing aligns with the real-world complexity of managing RBDs, where diagnosis and treatment decisions are often intertwined. Although all respondents were highly educated healthcare professionals, language limitations, given that the survey was conducted in English, may still have affected comprehension of some questions. Our study had low representation from pediatricians, a group crucial for early recognition and long-term management of RBDs that present in childhood. Future surveys should prioritize targeted engagement of this community to ensure their perspectives are adequately captured.

Conclusion

This survey highlights substantial gaps in knowledge, diagnostic acumen, and accessibility to resources related to RBDs among frontline clinicians in the Asia-Pacific region. The low rates of correct case identification, unfamiliarity with guidelines, and lack of confidence in managing RBDs

even among clinicians attending a musculoskeletal conference point to a systemic neglect of these conditions across the broader healthcare system.

Though based on an exploratory, descriptively analyzed dataset, the findings highlight important gaps that merit attention. Strengthening RBD-focused content in medical education, specialist training, and continuing professional development should be priority undertakings so that recognition and appropriate management of these disorders are improved. Regional clinical guidelines adapted to local healthcare structures, alongside clearer referral pathways and expanded access to essential diagnostic tools, particularly in under-resourced settings, could also help address some of the gaps identified. In addition, formalizing the transition of care from pediatric to adult services remains a critical but often overlooked element of rare disease management. Addressing these priorities will require coordinated, cross-sectoral strategies linking education, clinical infrastructure, and policy. Our survey provides an important starting point and a regional evidence base to inform future, more robust studies and guide global capacity-building in RBD care.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00198-025-07706-8.

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Declarations

Conflict of interest MC has received honoraria for speaking engagements from Kyowa Kirin and Amgen and travel grants from Amgen. She is Chairperson of the Asia Pacific Consortium on Osteoporosis (APCO).
MKJ has received paid consultancy or sponsorship for external talks from Amgen, UCB, Sanofi, Kyowa Kirin, Nanox-AI, Naitive Technologies, Thornton Ross, and Theramex. His Institution—NDORMS, University of Oxford—has received unrestricted research grants from UCB, Amgen, and Kyowa Kirin.
TN works for inVIVO Academy.
SK is Project Manager for APCO.
RCB has had speaker honoraria and/or advisory boards for Amgen, Ipsen, Lilly, Specialized Therapeutics, and Kyowa Kirin.
CM has received research funding from Amgen and Kyowa Kirin, consultancy fees from Kyowa Kirin and Amgen, and speaker fees from Kyowa Kirin.
AT has received paid consultancy from Kyowa Kirin, Ascendis pharma, Alexion, and Pharmacosmos.
SKB is an Executive Committee Member of APCO.
PRE has had research funding from Alexion and honoraria from Alexion and Kyowa Kirin. He is an Executive Committee Member of APCO.
AM is a Scientific Advisory Member of APCO.
M-LB has received honoraria from Calcilytix and Kyowa Kirin, received grants and/or served as a speaker for Alexion and Kyowa Kirin, and is a consultant for Alexion, Amolyt, Calcilytix, and Kyowa Kirin.

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