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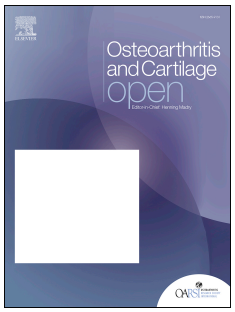

International multispecialty consensus on how to image, define, and grade ultrasound imaging features of first metatarsophalangeal joint osteoarthritis, a Delphi consensus study

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Title: International multispecialty consensus on how to image, define, and grade ultrasound imaging features of first metatarsophalangeal joint osteoarthritis, a Delphi consensus study

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Abstract

Objective

To reach consensus concerning which ultrasound imaging features should be assessed and graded, and what ultrasound imaging procedure should be performed when examining osteoarthritic change in the first metatarsophalangeal joint.

Design

An online Delphi study was conducted over four iterative rounds with 16 expert health professionals. Items were scored from 0-100 (0 = not at all important; 100 = extremely important). Consensus was defined based upon an item receiving a median score of ≥70% acceptance. Items receiving median score of ≤50% were rejected. Items considered ambiguous (median score 51% - 69% of acceptance) were assessed in an additional round. A final round determined the content validity of items through calculation of the content validity ratio and content validity index.

Results

Sixteen items were deemed essential, which included osteophytes graded dichotomously, cartilage damage graded continuously, synovitis and joint space narrowing graded on a semiquantitative scale. The panel deemed essential that the first metatarsophalangeal joint start in a neutral position, then move through range of motion for both dorsal and plantar scanning, orientating the probe in longitudinal and in transverse, whilst using first metatarsal head and proximal phalanx as anatomical landmarks. A supine body position was only deemed essential for a dorsal scan and a neutral foot/ankle position was only rated essential for a plantar scan. The content validity index of the 16 essential items was 0.19.

Conclusion

The consensus exercise has identified the essential components the ultrasound imaging acquisition procedure should encompass when examining first metatarsophalangeal joint osteoarthritis.

Keywords

Osteoarthritis

Metatarsophalangeal Joint

Ultrasound imaging

Foot

Introduction

Osteoarthritis (OA) is a global health burden and leading cause of chronic pain, joint stiffness, functional limitation, and disability among older adults [1, 2]. Within the foot, the first metatarsophalangeal joint (MTPJ) is the most commonly affected joint with a prevalence of 8% for individuals aged over 50 years [3]. By age 60 years, radiographic first MTPJ OA is present in approximately 46% of women and 32% of men [4].

There has been a fundamental shift in our understanding of OA, from a cartilage-only disease to a whole organ disease, recognising the heterogeneous involvement of multiple joint tissues, including cartilage damage, subchondral bone remodelling, synovial inflammation, and osteophyte development [5-7]. OA is not simply a process of wear and tear, but rather abnormal remodelling of joint tissues driven by a host of inflammatory mediators [7, 8]. Attention has now turned to the prognostic value and role of inflammatory markers [7-9], with several studies reporting an association between active synovitis and structural OA progression [10-12]. Despite this advancement in knowledge our current method of diagnosing foot OA is governed by the findings of conventional radiography [13, 14], which captures OA later in the disease process when irreversible structural damage has already occurred.

Ultrasound (US) imaging potentially affords inherent advantages for the diagnosis of first MTPJ OA, providing a whole organ assessment with multiplanar acquisitions, enabling a more detailed assessment of pathology [15, 16]. US has gained recognition due to its ability to detect inflammatory joint pathology that is otherwise not detected by clinical examination [5, 17], and reliably quantify both bone and soft-tissue abnormalities [15]. Given the ability of US to depict tissue-specific morphological changes before the onset of pain and before the point of irreversible structural damage, US may play a fundamental role in the earlier detection and assessment of foot OA [18, 19], thus enabling more targeted and timely interventions that may

provide capacity to alter disease progression. However, the role of US imaging for OA diagnosis in foot joints has not been clearly defined.

Currently, the use of US to categorise OA-related joint changes has several limitations: Firstly, it is not known what US features are specific to and representative of first MTPJ OA. Secondly, there is no clear consensus as to which type of grading system (e.g. dichotomous or on a semiquantitative scale) should be applied to determine degree of severity for each US feature. Finally, it is unclear what US imaging acquisition procedure should be used to examine the first MTPJ. Therefore, the objective of this research was to adopt a Delphi study design to reach consensus concerning US imaging of first MTPJ OA.

Methods

Design

An online four-round Delphi study design was undertaken to achieve consensus on which US features are indicative of first MTPJ OA, how features should be graded, and what US imaging acquisition procedure is preferable when examining the first MTPJ. The Delphi method is an iterative series of structured rounds that surveys experts to achieve a convergence of opinion in order to gain group consensus [20]. Subsequent survey rounds refine and define the items, gauging their accuracy or support from the participants [21]. This method is considered an appropriate means of dealing with an absence of guidelines [20]. Conducting and REporting of DElphi Studies (CREDES) recommendations were adopted to provide guidance on a reporting standard [22]. Details of how our study reporting aligned with the CREDES recommendations are detailed in Supplementary Data 1. The study was approved by *Auckland University of Technology Ethics Committee (AUTEC) (21/117*).

Participants

Study recruitment occurred via one of two pathways: (1) potential participants were recruited via their association with the Osteoarthritis Research Society International (OARSI) Foot and Ankle OA discussion group, the United Kingdom (UK) Podiatry US group or the European League Against Rheumatism (EULAR) US network group. The three network groups consist of expert health professionals from either a clinical and/or academic background: rheumatologists, sonographers, radiologists, podiatrists, physiotherapists, epidemiologist, academics, researchers, and orthopaedic surgeons. Geographically, members were located in New Zealand, Australia, United Kingdom, United States of America, Canada, Spain, Brazil, Italy, Netherlands, and Japan. Therefore, the three groups were diverse, and a representative group of clinicians and researchers involved in the investigation of foot and ankle OA [23]. Alternatively, (2) participants were identified through snowball sampling, in which potential participants were invited to participate through a known contact of the primary researcher (PM). All participants were anonymised to each other, enabling them to share their own thoughts without judgement [24].

Survey format

The Delphi survey was implemented using online survey platform Qualtrics© (Qualtric Research Suite Provo. UT 2013). Each round of the Delphi was piloted among co-authors (MC, CB, RE and KR) who were not participants, to refine the format and question design. Participants were requested to consider each question in terms of developing an US atlas to grade the degree of osteoarthritic related change in the first MTPJ. Consent was obtained prior to the commencement of each round and there was no intra-panel communication. Participants were given a four-week deadline to complete each Delphi round. Reminders were sent via email two weeks following the opening of each round, and participants were given an additional two weeks to complete the round before being classified as a non-responder. After the deadline, the surveys were collated.

Procedure

Delphi Round 1

The Delphi was developed using an evidence driven approach with findings from a systematic review [25] and scoping review [26] used to inform Round 1 open-ended questions. The systematic review investigated what US features are associated with OA in peripheral joints and how US features in peripheral joints are defined and graded [25]. The scoping review investigated US imaging acquisition procedures and guidelines used to assess the first MTPJ [26]. Round 1 included participant information, online consent, instructions, and the Round 1 survey (Supplementary Data 1). Round 1 was divided into two sections: (i) participant characteristic questions and (ii) open-ended questions concerning US imaging of first MTPJ OA. Due to the inconsistencies reported in both reviews and the dearth of knowledge specific to first MTPJ OA, open-ended questions were specifically aimed to encourage alternative views to determine which US features are indicative of first MTPJ OA, how should those features be graded, and what US imaging acquisition procedure should be used to evaluate the first MTPJ.

Survey responses were exported and analysed in Microsoft® Excel®, version 2205 with responses collated into the following sections: Part A: First MTPJ OA US features; Part B: Grading US features and Part C: US imaging acquisition procedure. The US imaging acquisition procedure was further broken down into two components (I) Patient body and lower limb positioning (dorsal and plantar) and (II) Probe position (longitudinal and transverse). Data were presented as medians and interquartile range unless otherwise noted.

All Round 1 responses were collated with similar responses amalgamated to ensure that the subsequent round was not repetitive and easy to complete. A set of themes were established that mapped US features, grading systems and US imaging acquisition procedure; to create items for Round 2 [27]. Themes were developed through qualitative

descriptive analysis [28, 29] and reviewed by a second author (MC). Open-ended responses from Round 1 were combined with additional items generated from the systematic and scoping reviews [25, 26], that were not identified by participants in Round 1.

Delphi Round 2

Due to reduced uptake of Round 1, linked to timing in the midst of the COVID pandemic, Round 2 was redistributed to all three network groups, via pathway one and to those that were invited to participate through snowballing method. Potential participants were sent an invitation email containing the Round 2 survey link. Participants were required to rate their level of agreement for each item using a sliding scale from 0-100 (0 = not at all important; 100 = extremely important). The Round 2 survey is detailed in Supplementary Data 2. Consensus was defined based upon items receiving a median score of ≥70% of acceptance [30]. Items receiving a median score of ≤50% were rejected. Items where there was disagreement, were considered as being ambiguous (answers receiving a median score between 51% - 69% of acceptance) and were taken back to participants for further consideration in Round 3 [21].

Delphi Round 3

An invitation to participate in Round 3 was only sent to those participants who responded to Round 2. In Round 3, participants were asked to accept or reject ambiguous items generated in Round 2 (answers receiving a median score of between 51% - 69% of acceptance). Round 3 provided participants the opportunity to change their answers considering the group's median. To aid in consensus decision making, participants were provided the results from Round 2, which included the group median score and interquartile range (IQR). For Round 3, consensus was defined based upon item statements receiving a median score of ≥70% of acceptance. Statements receiving a median score of <70% were rejected [30, 31]. The Round 3 survey is outlined in Supplementary Data 3.

Delphi Round 4: Content validity

Evaluating content validity is a critical step in the development process, which demonstrates the final items are representative of the entire domain the assessment seeks to measure [32], thus ensuring the US atlas contains the appropriate content to diagnose and grade first MTPJ OA. To determine the content validity of items to be included in the atlas, all participants who participated in Round 3 were asked to rate all accepted items into one of three categories: “essential,” “useful, but not essential,” or “not necessary.” The Round 4 survey is detailed in Supplementary Data 4. The content validity ratio (CVR) was used to determine the content validity of each item included in Round 4, using the formula proposed by Lawshe [33]. The CVR is a widely applied statistic when quantifying content validity of instruments which involves a panel of 'experts' [32]. Items perceived as "essential" by ≥50% of the panel members, provides assurance of content validity[33]. A positive CVR indicates more than 50% of the panel members rate the item as essential. Items deemed not essential by ≥50% of panel members were discarded. The content validity index (CVI) was calculated. The CVI is the mean of the CVR values of the retained items and is an indicator of overall content validity [32, 33].

Results

Participant characteristics

Round 1 of the Delphi exercise received 10 responses. Table 1 details the characteristics of the 10 participants who completed Round 1. Round 2 received 20 responses. Sixteen participants completed Round 3, of which all 16 participants completed Round 4 (content validity round). Although the invited participants varied with regard to demographics and experience, the respondents were researchers, podiatrists, physiotherapists, sonographers, radiographers and a physiatrist. The characteristics of the 16 participants who completed Rounds 2, 3 and 4 are detailed in Table 2. Participants were predominantly female (6 male:

10 female), aged over 40 years old (81%), White British ethnicity (44%) and currently living in the UK (50%). Participants were predominantly podiatrists and/or researchers (44%). Two thirds of the participants reported to have between 0-10 years of musculoskeletal US experience. Half the participants reported they held no formal qualification relating to musculoskeletal US.

Insert Table 1 near here.

Insert Table 2 near here.

Delphi findings

Figure 1 details the number of participants involved in each round and the number of items developed, accepted, and/or rejected from each round. Authors identified 50 open-ended items based on the participants free-text responses in Round 1. These items were combined with an additional 12 items generated from the authors' recent systematic [25] and scoping reviews [26] to be considered in Round 2. Participants rated 62 items in Round 2, 23 items reached consensus (medians score of ≥ 70%), 21 items were considered ambiguous (achieved a median score between 51–69% agreement), and 18 items were excluded (median score ≤ 50%). As a result of two features (tenosynovitis and capsulitis) being excluded their associated grading systems, which were rated as ambiguous were also excluded. In Round 3, participants rated the 21 ambiguous items, three items achieved ≥ 70% agreement and 18 items were excluded. Of the 18 items that were excluded, three were features (synovial hypertrophy, joint effusion and joint erosion) that had previously accepted grading systems from Round 2. For that reason, their associated grading system were now excluded. All accepted items and the round they were accepted are displayed in Table 3. Subsequently, 23 accepted items were included in the content validly round (Round 4). Sixteen items were deemed essential by ≥50% of the participants with a CVI of 0.19 (Table 4).

Insert Figure 1 near here.

Insert Table 3 near here.

Insert Table 4 near here.

Discussion

The Delphi study design sought to generate consensus between experts to inform the methodological development of an US atlas to grade the degree of osteoarthritic related change in the first MTPJ. Through applying a Delphi study design, the panel rated 16 items as 'essential' across three domains: first MTPJ OA US features, grading US features, and US imaging acquisition procedure.

OA is characterised by both structural damage and inflammatory abnormalities [34]. Four US features rated as essential to be included in the US atlas were synovitis, osteophytes, joint space narrowing, and cartilage damage/thickness. It is well understood that inflammation is an important driver of the disease and contributes to the pain experienced and the structural progression of the disease [10-12]. Given the prognostic value of inflammatory features and the sensitivity US possesses in detecting subclinical inflammatory change [5, 17], the inclusion of multiple inflammatory features may be more helpful in elucidating the role of inflammation in foot OA. In contrast, a recent US consensus-based study, conducted by Outcome Measures in Rheumatology (OMERACT), for grading hand OA [35], scored greyscale inflammatory abnormalities for synovial hypertrophy and joint effusion separately in addition to power Doppler signal (flow signal detected within synovial hypertrophy to be considered a sign of synovitis) [35, 36]. Furthermore, the OMERACT hand OA study reported marked variation in prevalence between greyscale and Doppler detected inflammatory features [35]. Greyscale inflammatory features, joint effusion and synovial hypertrophy were frequently observed (40% and 45% respectively). In contrast power doppler signals (considered a sign of

213 synovitis) were reported in 6% of interphalangeal joints [35]. Therefore, the exclusion of
214 greyscale features indicative of inflammation may result in OA being underestimated.

215

216 The inclusion of synovitis as the only marker of inflammation may be reflective of the
217 inconsistencies in the different entities of synovial pathology indicative of inflammation [25].
218 There has been marked variations across studies in terms of how synovitis, synovial
219 hypertrophy and joint effusion are defined and categorised as US features [25]. The inclusion
220 of synovitis as a core element for the US evaluation of first MTPJ OA aligns with a
221 preliminary US grading system for hand OA, that combined synovial hypertrophy and joint
222 effusion into one greyscale synovitis score [37]. Whilst the recent OMERACT definition
223 encompasses the whole concept of synovitis being the "presence of a hypoechoic synovial
224 hypertrophy regardless of the presence of effusion or any grade of Doppler signal" [38], it does
225 necessitate the inclusion of Doppler signal as part of image acquisition when examining
226 synovitis.

227

228 To date, one of the most notable imaging advancements specific to foot OA was the
229 development of the La Trobe Radiographic Foot Atlas in 2007 [13]. This atlas incorporates
230 both osteophytes and joint space narrowing to provide a quantitative means of assessing
231 foot OA. For that reason, the acceptance of both structural features (osteophytes and joint
232 space narrowing) may have been influenced by their role in the radiographic foot atlas [13].
233 Regardless, US imaging has been shown to detect more joints with osteophytes than
234 conventional radiography [39, 40]. The inclusion of osteophytes and joint space narrowing will
235 allow for comparison between radiographic and sonographic detection and grading,
236 consequently enabling the construct validity between imaging modalities to be determined.

237

Although the heterogeneous involvement of multiple joint tissues is now well recognised, cartilage damage remains the cornerstone in the pathophysiology of OA [41], this was reflected by its acceptance as an essential US feature. Unlike radiography, US can directly visualise some parts of articular cartilage [42]. Cartilage damage may not be uniform across the entire joint [43, 44]. Therefore, the ability to consistently examine the exact same part of cartilage, with US, will influence the reliability and validity of this measure. Given the general opinion that US imaging is heavily operator dependent for image acquisition and interpretation [45, 46], investigating the reliability of grading cartilage damage would be critical before inclusion into the US atlas. This reinforces the need for further refinement of anatomical landmarks to guide probe positioning to ensure a standardised US imaging acquisition procedure.

Current US grading systems applied to OA have been largely extrapolated from those originally designed and validated to quantify inflammatory change in rheumatoid arthritis (RA) [25]. Inflammation associated with OA is fundamentally different from that in RA, with OA having lower levels of inflammatory proteins [47], less pronounced synovitis [48, 49], no response to biologic drugs used in RA, and mediated primarily by the innate immune system [8]. The distinct difference of inflammation experienced in OA compared to RA[11, 50], reinforces the need for OA-specific grading systems that truly depict the disease progression of first MTPJ OA.

Both dichotomous and semiquantitative grading systems were accepted for osteophytes. However, a dichotomous grading system was deemed essential by the panel members. While dichotomous scoring may be viewed as a simpler method to distinguish between the absence or presence of a feature, it presents no mechanism to determine the progression of first MTPJ OA over time. Alternatively, a semiquantitative grading system was accepted for

synovitis and joint space narrowing. A semiquantitative system enables quantification of disease progression and provides insight into the degree of osteoarthritic change [25]. Issues related to the subjectivity of semiquantitative systems have been highlighted, with challenges in interpretation and differentiation between grading of disease severity [50]. This may be reflective of the lack of consensus to guide grading and/or studies which have extrapolated RA grading systems to OA. The acceptance of cartilage damage/thickness to be graded using a continuous measure will mitigate issues with distinguishing between grades of severity.

An US imaging acquisition procedure involves numerous variables that need to be considered as part of examination, these include patient positioning, transducer orientation and surfaces scanned. As it stands only two consensus-based guidelines exist to inform the US imaging acquisition procedure to assess the first MTPJ [16, 51]. Despite this, there has been marked inconsistency in the application of guidelines across studies [26]. The 2001 EULAR guidelines included limited instructions on body position, transducer orientation and surfaces of the first MTPJ to scan (supine position for the dorsal scans and prone position for the plantar scans) [51]. In 2017 a new EULAR-endorsed task force revised the standardised procedures for US imaging in rheumatology [16]. The updated EULAR guidelines for performing US imaging of the first MTPJ addressed patient positioning, transducer orientation, probe position (starting point) and, scanning technique [16]. Despite this enhancement, the revised guidelines still lack sufficient detail outlining specific anatomical reference points to ensure a standardised US imaging acquisition procedure.

The Delphi panel considered both patient and lower limb positioning for scanning the dorsal, plantar and medial surface of the first MTPJ. Although accepted, scanning the medial aspect of the first metatarsal head and proximal phalanx, was not rated as an essential item. Eight

items were deemed essential when scanning both dorsal and plantar surfaces of the first MTPJ. Unlike previous guidelines, the Delphi panel included first MTPJ positioning. Wherein it was deemed essential that the first MTPJ should start in a neutral position (the position where the foot is neither pronated nor supinated), then move through full range of motion during the scanning procedure for both a dorsal and plantar scans. Consistent with both 2001[51] and 2017 guidelines [16], a supine body position was deemed essential, however only when performing a dorsal scan. Positioning the ankle/foot in neutral was deemed essential, although only for a plantar scan. This is inconsistent with the 2017 guidelines which reported a dorsiflexed foot position [16]. The 2001 guideline [51] provided no further detail on how the lower limb should be positioned. Regarding knee positioning, a flexed and extended knee were accepted items for both dorsal and plantar scans respectively. Both knee positions are consistent with the 2017 guidelines [16], however neither item were rated as essential.

The Delphi panel also deemed essential that the probe be orientated both longitudinally and transverse when scanning the dorsal and plantar aspect of the first MTPJ. Specifically, for a longitudinal scan the probe should be positioned on the plantar/dorsal aspect of the forefoot, parallel to the first metatarsal head and proximal phalanx, joint line central to the image. In conjunction with a transverse scan, where the probe should be positioned on the plantar/dorsal aspect of the foot, perpendicular to the diaphysis of the first metatarsal then move distally to the diaphysis of first proximal phalanx, joint line central to the image. Previous guidelines provide limited descriptions of anatomical landmarks to guide probe positioning. The revised 2017 guidelines only reported performing a transverse scan when examining articular cartilage [16]. The findings of the Delphi support the application of a multiplanar technique when examining the first MTPJ. A multiplanar technique is crucial in cases where one feature (e.g. joint effusion or osteophyte) is obstructing the view of another feature under examination, or when there is severe structural changes, often associated with rheumatic diseases.

A strength of the current study was the inclusion of content validity. Evaluating content validity is a critical step in the development process of instruments used to measure constructs in research [32]. Content validity provides evidence to the extent at which items of an assessment instrument are representative of the entire domain the assessment seeks to measure [32]. Our findings need to be viewed in the context of several limitations. Firstly, the exercise was primarily dependent upon an expert consensus based approach [52]. Therefore, it needs to be acknowledged that it is based on the subjective opinion of the participants, which in the context of evidence-based practice constitutes low level evidence [53]. Secondly, the low sample obtained, and level of professional experience may have limited the potential for ideas as well as the number of generated items. The low number of participants maybe reflective of participant recruitment proceeding during the midst of the COVID-19 pandemic. Thirdly, author bias may have been introduced during the amalgamation of Delphi items. However, the authors have attempted to minimise this with transparency of the implemented process. Fourthly, anonymity and confidentiality are suggested requirements of participants in Delphi surveys to minimise the effects, if any, of collusion [20]. It cannot be guaranteed that participants remained anonymous to their colleagues, however there was no instance where the authors believed anonymity was not maintained. All participants were asked to keep both their responses and participation confidential to minimise this bias risk. Finally, the term 'expert' and its application to health practitioners is controversial [24]. By inviting members from three different groups (OARSI, UK Podiatry US, and EULAR US network), it is expected that the relevant knowledge, experience, and diversity was reflected in the expert panel members.

Implications for further research

The outcomes of the Delphi study will inform future studies into the methodological development of an US atlas to grade the degree of osteoarthritic change in the first MTPJ. Ongoing research is crucial in determining the capacity of US to detect early inflammatory changes that precede osseous involvement, therefore informing more timely management approaches that aim to prevent further structural progression.

Conclusion

Sixteen items were accepted as essential for the US examination of first MTPJ OA. This included osteophytes graded dichotomously, cartilage damage graded on a continuous scale, synovitis and joint space narrowing graded on a semiquantitative scale. The first MTPJ imaged in both dorsal and plantar orientation with the body supine for a dorsal scan and a neutral ankle position for a plantar scan. This data will be the catalyst in developing a US classification criterion, specific for first MTPJ OA.

List of Abbreviations

Osteoarthritis: OA

Metatarsophalangeal Joint: MTPJ

Ultrasound: US

Osteoarthritis Research Society International: OARSI

United Kingdom: UK

European League Against Rheumatism: EULAR

Content Validity Ratio: CVR

Content Validity Index: CVI

Outcome Measures in Rheumatology: OMERACT

Rheumatoid Arthritis: RA

Declarations

Ethical approval and consent to participate

The study was approved by Auckland University of Technology Ethics Committee (AUTEC) (21/117).

Consent for publication

Not applicable

Competing interests

All authors declare they have no competing interests.

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Authors' contributions

All authors (PM, CB, RE, KR and MC) were responsible for the conception and design of the research. PM was responsible for the initial development of the survey, with all authors providing critical review of each round. Analysis and management of the data were undertaken by PM and MC. PM, CB, RE, KR and MC were responsible for the preparation and review of the manuscript prior to submission for publication. PM, CB, RE, KR and MC read and approved the final manuscript.

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Availability of data and materials

All available data is provided within the manuscript

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Table 1 Demographics of participants who completed Round 1

		n (%)
Gender	Male	4 (40)
	Female	6 (60)
Age range	20-29 years old	1 (10)
	30-39 years old	1 (10)
	40-49 years old	5 (50)
	50-59 years old	2 (20)
	Over 60 years old	1 (10)
Ethnicity	Caucasian	1 (10)
	Hispanic	1 (10)
	NZ European	1 (10)
	White British	7 (70)
Country	Australia	1 (10)
	New Zealand	1 (10)
	Spain	1 (10)
	United Kingdom	7 (70)
Profession	Physiotherapist	1 (8.3)
	Podiatrist	6 (50)
	Sonographer	1 (8.3)
	Radiographer	1 (8.3)
	Researcher	3 (25)
Clinical or Academic	Clinical	1 (10)
	Academic	3 (30)
	Both Clinical: Academic	6 (60)
MSK USI experience (years)	0-5 years	4 (40)
	6-10 years	3 (30)
	11-15 years	2 (20)
	Over 20 years	1 (10)
Highest qualification relating to MSK USI	MSc Medical Ultrasound	2 (20)
	PGDip Medical Ultrasound	1 (10)
	PGCert Medical Ultrasound	2 (20)
	Continued Professional Development course	1 (10)
	No formal USI qualifications	4 (40)

*Some participants selected more than one academic and/or professional background

Table 2 Demographics of participants who completed Round 4

		n (%)
Gender	Male	6 (38)
	Female	10 (62)
Age range	Under 20 years old	0 (0)
	20-29 years old	2 (13)
	30-39 years old	1 (6)
	40-49 years old	6 (40)
	50-59 years old	3 (19)
	Over 60 years old	4 (25)
Ethnicity	Caucasian	3 (19)
	Hispanic	1 (6)
	Irish	1 (6)
	Italian	1 (6)
	NZ European	1 (6)
	White British	7 (44)
	White	2 (13)
Country	Australia	2 (14)
	Canada	1 (6)
	Italy	1 (6)
	Netherlands	1 (6)
	New Zealand	1 (6)
	Spain	1 (6)
	United Kingdom	8 (50)
	United States of America	1 (6)
Profession	Physiatrist	1 (6)
	Physiotherapist	3 (19)
	Podiatrist	7 (44)
	Sonographer	1 (6)
	Radiographer	1 (6)
	Researcher	7 (44)
Clinical or Academic	Clinical	2 (12)
	Academic	6 (38)
	Both Clinical: Academic	8 (50)
MSK USI experience (years)	0-5 years	7 (44)
	6-10 years	4 (24)
	11-15 years	2 (13)
	16-20 years	2 (13)
	Over 20 years	1 (6)
Highest qualification relating to MSK USI	MSc Medical Ultrasound	2 (13)
	PGDip Medical Ultrasound	1 (6)
	PGCert Medical Ultrasound	4 (25)
	Continued Professional Development course	1 (6)
	No formal USI qualifications	8 (50)

*Some participants selected more than one academic and/or professional background

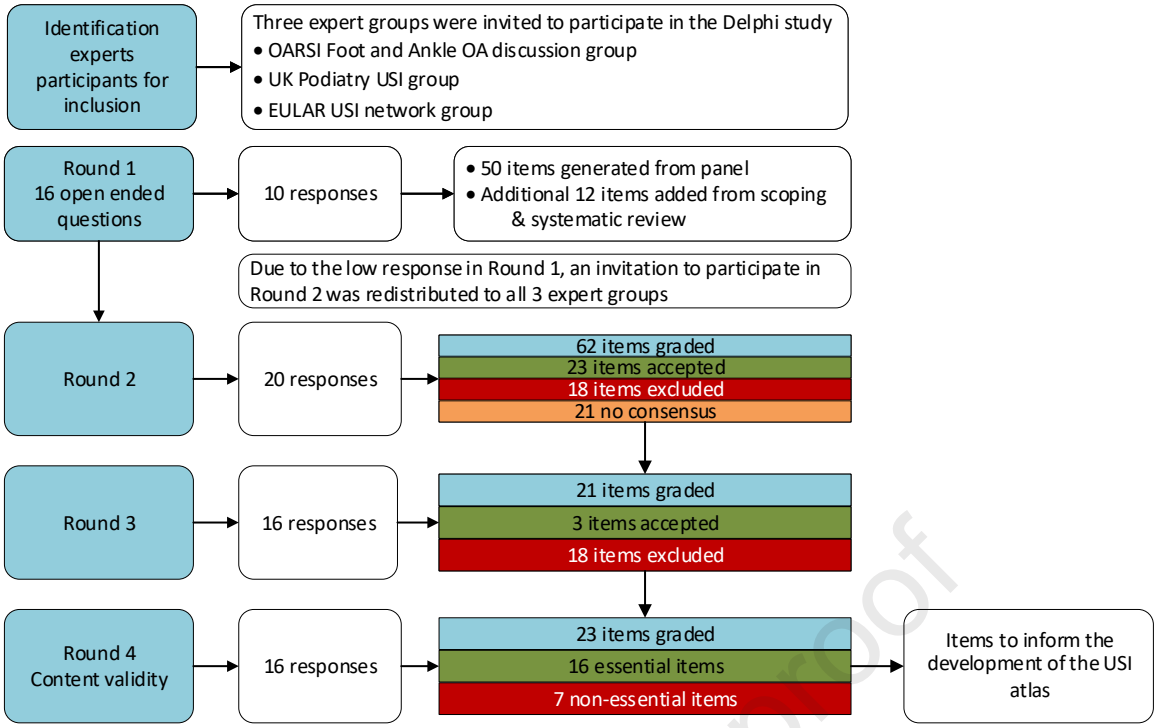
Table 3 All accepted items from the Delphi survey used to inform the methodological development of an US atlas to grade the degree of osteoarthritic change in the first MTPJ.

Item category	Item (round accepted)	Percentage score median (IQR)
PART A: First MTPJ OA ultrasound imaging features	Synovitis (2)	70 (42-80)
	Osteophytes (2)	81 (65-100)
	Cartilage damage (2)	89 (73-94)
	Joint space narrowing (2)	79 (71-93)
PART B: Grading ultrasound imaging features	Synovitis Semiquantitative (3)	74 (55-80)
	Osteophytes Dichotomous (2)	78 (29-84)
	Osteophytes Semiquantitative (3)	70 (51-80)
	Cartilage damage/thickness Cont (mm) (2)	78 (35-84)
	Joint space narrowing Semiquantitative (3)	75 (63-80)
PART C: US Imaging acquisition protocol Patient positioning (Dorsal)	Body position – Supine (2)	86 (73-90)
	Knee position – Flexed (2)	82 (27-87)
	Ankle/foot position – neutral (2)	75 (58-91
	Ankle/foot position - Foot flat on plinth (2)	72 (46-84)
	First MTPJ position -Start in neutral then move through ROM during scanning (2)	84 (67-90
Patient positioning (Plantar)	Knee position - extended	74 (60-92)
	Ankle/foot position – neutral (2)	80 (69-82
	First MTPJ position -Start in neutral then move through ROM during scanning (2)	79 (66-87)
Probe position (Longitudinal)	Dorsal aspect of the forefoot, parallel to the first metatarsal head and proximal phalanx, joint line central to the image (2)	79 (75-90)
	Plantar aspect of the forefoot, parallel to the first metatarsal head and proximal phalanx, joint line central to the image (2)	76 (67-80)
	Medial aspect of metatarsal head and proximal phalanx, joint line central to the image (2)	79 (78-87)
Probe position (Transverse)	Dorsal aspect of the foot, perpendicular to diaphysis of the first metatarsal then move distally to the diaphysis of first proximal phalanx, joint line central to the image (2)	82 (78-92)
	Plantar aspect of the foot, perpendicular to diaphysis of the first metatarsal then move distally to the diaphysis of first proximal phalanx, joint line central to the image (2)	77 (56-90)
	Medial aspect of metatarsal head and proximal phalanx, joint line central to the image (2)	72 (60-76)

Table 4 The content validity ratio (CVR) of each item included in Round 4

Round 4 items	CVR Value	
PART A: FIRST MTPJ OA ULTRASOUND IMAGING FEATURES		
Synovitis	0	
Osteophytes	0.25	
Cartilage damage	0.13	
Joint space narrowing	0.5	
PART B: GRADING ULTRASOUND IMAGING FEATURES		
Synovitis Semiquantitative	0	
Osteophytes Dichotomous	0.25	
Osteophytes Semiquantitative		-0.38
Cartilage damage/thickness Cont (mm)	0	
Joint space narrowing Semiquantitative	0.5	
PART C: US IMAGING ACQUISITION PROTOCOL (Dorsal)		
Body position - Supine	0.13	
Knee position - Flexed		-0.38
Ankle/foot position - neutral		-0.38
Ankle/foot position - Foot flat on plinth		-0.13
First MTPJ position -Start in neutral then move through ROM during scanning	0	
PART C: US IMAGING ACQUISITION PROTOCOL (Plantar)		
Knee position - extended		-0.13
Ankle/foot position - neutral	0.13	
First MTPJ position -Start in neutral then move through ROM during scanning	0.13	
Probe position (Longitudinal)		
Dorsal aspect of the forefoot, parallel to the first metatarsal head and proximal phalanx, joint line central to the image	0.5	
Plantar aspect of the forefoot, parallel to the first metatarsal head and proximal phalanx, joint line central to the image	0	
Medial aspect of metatarsal head and proximal phalanx, joint line central to the image		-0.25
Probe position (Transverse)		
Dorsal aspect of the foot, perpendicular to diaphysis of the first metatarsal then move distally to the diaphysis of first proximal phalanx, joint line central to the image	0.5	
Plantar aspect of the foot, perpendicular to diaphysis of the first metatarsal then move distally to the diaphysis of first proximal phalanx, joint line central to the image	0	
Medial aspect of metatarsal head and proximal phalanx, joint line central to the image		-0.38
CVI	**0.19**	

Positive values in green shading indicate the items that were deemed essential by ≥50% of the participants. Negative values in red shading indicate items that were not deemed essential by ≥50% of panel members and were discarded.



Note
In Round 3, three features (synovial hypertrophy, joint effusion and joint erosion) were all excluded. However, their grading systems had previously been accepted in Round 2. As a result of the feature being excluded the associated grading systems that had previously been accepted were also now excluded. Accepted items were as follows; 23 (Round 2) + 3 (Round 3) - 3 (grading systems from Round 2).

OSTEOARTHRITIS AND CARTILAGE

AUTHORS' DISCLOSURE

Manuscript title: International multispecialty consensus on how to image, define, and grade ultrasound imaging features of first metatarsophalangeal joint osteoarthritis, a Delphi consensus study

Corresponding author: Prue Molyneux

Authorship
All authors should have made substantial contributions to all of the following: (1) the conception and design of the study, or acquisition of data, or analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content, (3) final approval of the version to be submitted. By signing below each author also verifies that he (she) confirms that neither this manuscript, nor one with substantially similar content, has been submitted, accepted or published elsewhere (except as an abstract). Each manuscript must be accompanied by a declaration of contributions relating to sections (1), (2) and (3) above. This declaration should also name one or more authors who take responsibility for the integrity of the work as a whole, from inception to finished article. These declarations will be included in the published manuscript.

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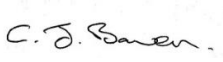	29/07/2022
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