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● *Review Article*

ULTRASOUND IMAGING ACQUISITION PROCEDURES FOR EVALUATING THE FIRST METATARSOPHALANGEAL JOINT: A SCOPING REVIEW

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Abstract——The aim of this scoping review was to investigate ultrasound imaging (USI) acquisition procedures and guidelines used to assess the first metatarsophalangeal joint (MTPJ). MEDLINE, CINAHL, AMED and SPORTDiscus were systematically searched in May 2021. Studies were included if they used grey-scale USI or power Doppler and reported a USI procedure to assess the first MTPJ. Screening and data extraction were performed by two independent assessors. The scoping review was reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses extension for scoping reviews (PRISMA-ScR). A total of 403 citations were identified for screening, with 36 articles included in the final analysis. There was wide variation in USI acquisition procedures used to evaluate the first MTPJ. Inconsistencies in reporting may be attributable to the number of elements the USI acquisition procedure encompasses, which include the model of the USI device, the type of transducer, USI modalities and settings, patient position, transducer orientation, surfaces scanned and the scanning technique used. The review found inconsistencies against international guidelines and limited implementation of consensus-based recommendations to guide image acquisition. Current guidelines require further refinement of anatomical reference points to establish a standardised USI acquisition procedure, subsequently improving interpretability and reproducibility between USI studies that evaluate the first MTPJ. (E-mail: prue.susan.molyneux@aut.ac.nz)

Key Words: **Ultrasound imaging, Acquisition procedure, First metatarsophalangeal joint.**

INTRODUCTION

Foot pain is one of the most common presenting complaints in adults (Hart and Spector 1993; Dufour et al. 2009; Grant et al. 2009; Roddy et al. 2011; Jordan 2015), with a prevalence estimated between 13% and 36% across several international population-based cohorts (Gates et al. 2019). Foot pain adversely affects physical function and quality of life and places a significant burden on both individuals and health care systems (Peat et al. 2006; Mickle et al. 2011). Within the foot, the prevalence of degenerative disease in the first metatarsophalangeal joint (MTPJ) is second to that of knee osteoarthritis (OA) (Benvenuti et al. 1995; Dawson et al. 2002). The first MTPJ is the most commonly affected joint in the foot in people with gout and OA (Rathod et al. 2016; Stewart et al. 2016), and epidemiological data suggest that its incidence is increasing (McQueen et al. 2013; Liu et al. 2015; Van der Merwe et al. 2018). People with gout and first MTPJ OA exhibit localised joint pain and structural and functional changes and experience a significant negative impact on physical mobility and health-related quality of life (Bergin et al. 2012; Rome et al. 2012; Roddy et al. 2015).

Musculoskeletal ultrasound imaging (USI) has gained notable recognition in the assessment of rheumatic diseases such as gout, rheumatoid arthritis and OA because of its ability to detect subclinical (absence of

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clinical symptoms) inflammatory joint pathology (Wakefield et al. 2004; Wright et al. 2007; Pineda et al. 2011; Filippucci et al. 2019) and reliably quantify both bone and soft-tissue abnormalities (Grassi et al. 1999, 2000; Iagnocco et al. 2005; Messina et al. 2017; Sakellariou et al. 2017). USI enables real-time, dynamic and multiplanar assessment of joint pathology, giving the examiner the unique advantage of immediate and direct correlations between the clinical picture and sonographic findings (Smith and Finnoff 2009; Möller et al. 2017).

Ultrasound imaging is a rapidly evolving field and has been increasingly incorporated into clinical practice as a valuable diagnostic and monitoring tool (Grassi and Cervini 1998; Karim et al. 2001; Naredo et al. 2010a). Developments in USI software and transducers have advanced the resolution to better identify structures, such as the first MTPJ, allowing more detailed assessment of pathology (Grassi and Cervini 1998; Grassi et al. 1999; Smith and Finnoff 2009; Messina et al. 2017; Möller et al. 2017; Sakellariou et al. 2017). High-resolution USI with power Doppler capability has further enhanced the diagnostic capabilities of USI by allowing quantification of inflammatory joint activity (Wright et al. 2007). However, numerous variables need to be considered as part of the USI acquisition procedure; these include the brand and model of the USI device (including transducer[s]), USI modalities and settings, patient positioning, transducer orientation, surfaces scanned and scanning technique. The number of components involved in image acquisition raises the need for evidence-based guidelines to outline a standardised USI acquisition procedure to evaluate the first MTPJ. A standardised procedure will increase reliability and validity and enable comparison amongst studies (Klauser et al. 2012).

The European League Against Rheumatism (EULAR) task force of world leading rheumatologists, experts in musculoskeletal USI, developed the first guidelines for the use of USI in rheumatology in 2001. The EULAR guidelines included vague instructions on body position, transducer orientation and surfaces of the first MTPJ to scan (Backhaus et al. 2001). These guidelines set the technical standards for the use of USI. The widespread uptake of USI, and technological advancements and the need for evidence-based imaging necessitated an update of these guidelines. Consequently, in 2017, a new EULAR-endorsed task force revised the standardised procedures for USI in rheumatology (Möller et al. 2017). The updated EULAR guidelines for performing USI of the first MTPJ address transducer orientation and position (starting point), surfaces scanned and scanning technique (Möller et al. 2017). Despite this enhancement, the revised guidelines still lack sufficient detail outlining specific anatomical reference points to ensure a standardised USI acquisition procedure. Further refinement of anatomical landmarks to guide probe positioning is still required to improve interpretability and reproducibility between studies. Current guidelines have overlooked how the USI acquisition procedure may need to be adapted to accommodate severe structural changes often associated with rheumatic diseases.

The successful reproducibility and validity of USI studies evaluating pathologies affecting the first MTPJ requires a standardised acquisition procedure that is comprehensively reported. Despite the well-recognised susceptibility and burden of first MTPJ pathologies, a published synthesis of an USI acquisition procedure has yet to be undertaken. The aims of this review were to analyse components of USI acquisition procedures used to assess the first MTPJ, determine if published guidelines were reported to inform procedures and ascertain if guidelines were followed.

METHODS

The framework proposed by Arksey and O'Malley (2005) was used to guide the scoping review methodology. This method involves five stages: identifying the research question; identifying relevant studies; selecting studies; charting the data; and collating, summarising and reporting the results (Arksey and O'Malley 2005). To ensure methodological quality and transparent reporting, this scoping review has been reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for scoping reviews (PRISMA-ScR; see Supplementary File S1) (Tricco et al. 2018).

Search strategy

The identification of articles for the scoping review was completed with a comprehensive search of titles and abstracts of key electronic databases (Table 1). The

Table 1. Search strategy: MEDLINE, CINAHL, Cochrane and SPORTDiscus

1	Subject term	Ultrasonography
2	Key words	Ultrasonograph* or Sonograph* or Ultrasound or US or MSUS or Doppler or Power Doppler or PDUS or Colour Doppler or Elastograph*
3	Subject term	‘Metatarsophalangeal joint’
4	Keywords	‘Metatarsophalangeal joint’ OR MTP* OR Hallux OR Toe
5	Keywords	Protocol OR acquisition OR procedure OR process OR exam* OR Position OR Scanning OR technique* OR guideline* OR Recommendation* OR approach
6	Combine	1 OR 2
7	Combine	3 OR 4
8	Combine	5 AND 6
9	Combine	6 AND 7 AND 8

search was conducted between April 14 and May 10, 2021. The electronic databases MEDLINE, CINAHL, AMED and SPORTDiscus were systematically searched from their earliest record (1955) to 2021. Broad-ranging search terms were agreed on by two of the authors (P.M. and M.C.). All titles and abstracts identified from the search were downloaded into EndNote Version X8 (Thomson Reuters, Philadelphia, PA, USA). The articles were cross-referenced, with duplicates removed.

Selection criteria

Original articles that included USI of the first MTPJ that detailed the acquisition procedure were included. In the first stage of selection, the titles and abstracts were independently screened by two authors (P.M. and A.J.). The full texts of the selected articles were retrieved and assessed against the eligibility criteria. Articles were included if they used grey-scale USI or power Doppler to assess the first MTPJ and reported the USI procedure used to acquire images of the first MTPJ and if participants were aged >18 y. Articles were excluded if they were not published in English and if they were opinion articles, commentary letters, review articles or non-human studies. Case reports and case series were also excluded because of potential issues with selection bias. Relevant articles were assessed according to the selection criteria with conflicts discussed between two authors (P.M. and A.J.) until consensus was achieved. In cases of non-consensus, a third author (M.C.) would be consulted; however, this was not required. Reference lists of all articles that met the inclusion criteria were hand searched for further potentially relevant articles. When the included articles referred to a previous paper for methodology or reliability, that article was accessed and appraised for inclusion against the eligibility criteria.

Data extraction

The following information was extracted from all included articles: study characteristics, author's name, year of publication, study design and aim(s). Participant characteristics including sample size, gender, mean age (years), mean body mass index (BMI, kg/m^2), ethnicity and pathology were also extracted (Supplementary File S2). Additionally, the following components of the USI acquisition procedure were extracted: anatomical region, patient position, USI mode and settings, transducer orientation, surfaces scanned and the scanning technique (Supplementary File S3).

RESULTS

Selection and characteristics of studies

The study aims, the participant characteristics and the pathology examined of all included studies are summarized in Supplementary File S2. A total of 403 citations were identified for screening, with 36 articles included for final analysis (Fig. 1). All 36 studies used USI to evaluate the first MTPJ. The combined sample size from the included studies was 3921 (2736 male, 1182 female). The mean age was 55.5 y, and the mean BMI was 28.5 kg/m^2. Ethnicity of the study population was reported by four studies (Howard et al. 2011; Stewart et al. 2017a, 2017b; Tan et al. 2020). Ethnicities that were reported included white American, African American, Hispanic, Asian, European, Māori, Pasifika and Chinese.

USI guidelines

This review found that three USI acquisition guidelines were reported to assess the first MTPJ. In terms of application, 10 studies (28%) reported their USI acquisition procedure was in accordance with the 2001 EULAR guidelines (Scire et al. 2009, 2011; Delle Sedie et al. 2011; Filippucci et al. 2011; Iagnocco et al. 2011; Pineda et al. 2011; Roddy et al. 2013; Elsaman et al. 2016; Tan et al. 2020; Zhang et al. 2020). No studies applied the updated 2017 EULAR guidelines (Möller et al. 2017). Zhang et al. (2020) reported their scanning procedure was in accordance with the European Society of Musculoskeletal Radiology (ESSR) guidelines, although these guidelines do not include the first MTPJ (Martinoli 2010).

USI acquisition procedure for evaluating the first MTPJ

Patient positioning. Descriptions of the various procedures that report evaluation of the first MTPJ include how the body and lower limb joints were positioned. The position in which the patient during the scanning procedure was reported by 17 (47%) studies. Details of body and joint position reported by each study are outlined in Supplementary File S3. Components of patient positioning included how the body was positioned (*e.g.,* supine or prone) and how each lower limb joint was positioned (*e.g.,* first MTPJ dorsiflexed, ankle neutral and/or knee extended) for the imaging procedure. Body positioning was reported by 7 studies, all of which reported supine positioning (Delle Sedie et al. 2011; Iagnocco et al. 2011; Pineda et al. 2011; Huppertz et al. 2014, Hiraga et al. 2015, Stewart et al. 2017a, Stewart et al. 2017b). When assessing the first MTPJ, there was no standardisation across studies as to which lower limb joints were included as part of the USI acquisition procedure description. Of the studies that included the same joint in their procedure description, there was considerable variation as to how that joint was positioned (*e.g.,* variation in knee flexion angle or extended). It was unclear from all included

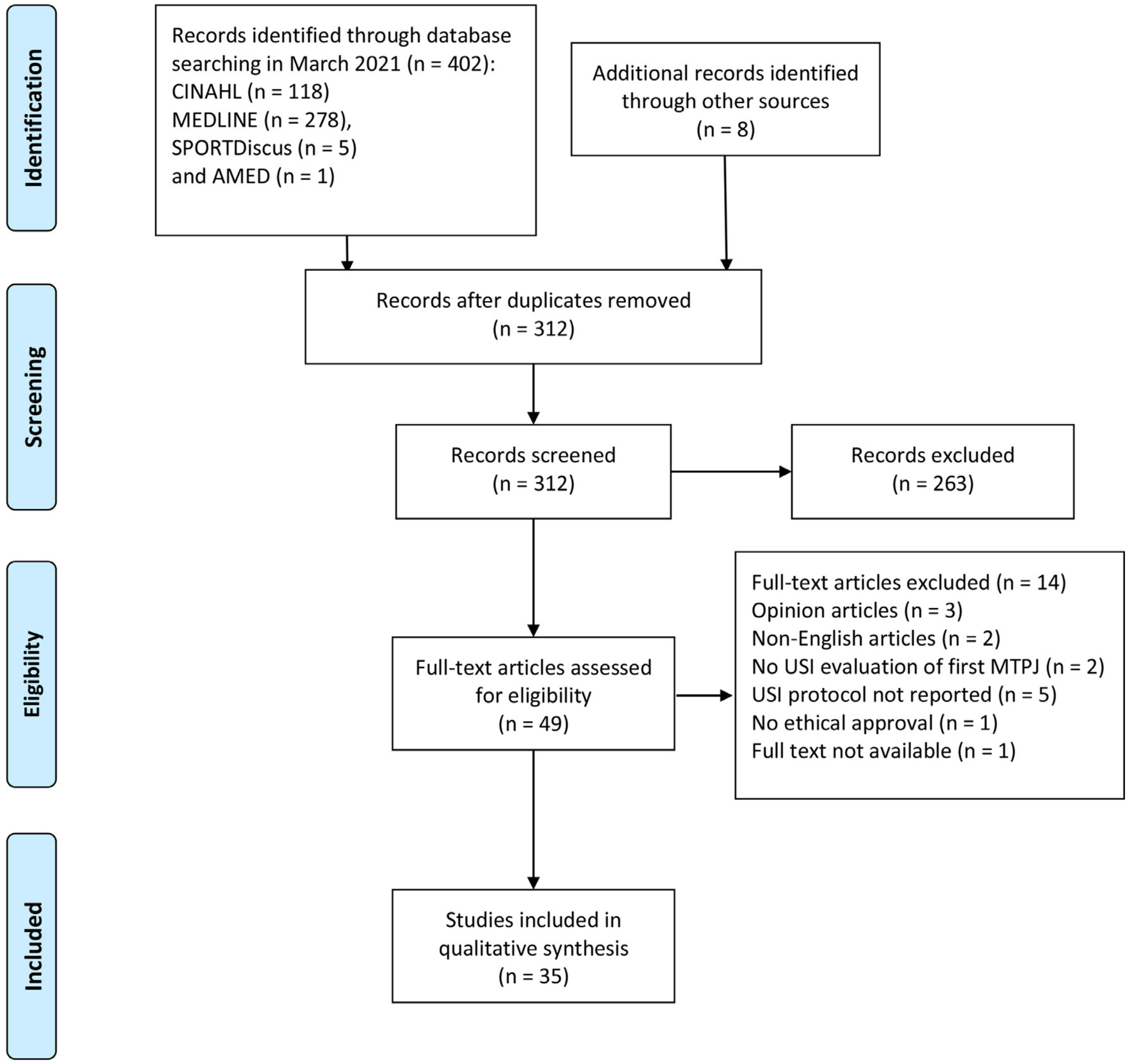

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) flow diagram.

studies if body and/or joint position changed during the USI acquisition procedure depending on the surface of the first MTPJ scanned. Of the 10 studies that reported their USI acquisition procedure was in accordance with the 2001 EULAR guidelines, only 3 studies' positioning descriptions aligned with the 2001 guidelines (supine position for the dorsal scans and prone position for the plantar scans) (Delle Sedie et al. 2011; Iagnocco et al. 2011; Pineda et al. 2011).

USI modalities and machine settings. All included studies detailed the brand and model of USI device, type and model of the transducer and USI modalities used. Details of USI mode and settings reported by each study are outlined in Supplementary File S3. The USI technique, grey-scale mode (B-mode), was reported by all 36 studies. Doppler (colour, power and pulse) was reported by 18 studies (Wiell et al. 2007; Wright et al. 2007; Scire et al. 2009, 2011; Delle Sedie et al. 2011; Iagnocco et al. 2011; Keen et al. 2011; Pineda et al. 2011; Peiteado et al. 2012; Le Boedec et al. 2013; Naredo et al. 2013; Roddy et al. 2013; Reuss-Borst et al. 2014; Das et al. 2017; Machado et al. 2017; Stewart et al. 2017a, 2017b; Tan et al. 2020). Most studies specified a linear array transducer with a multifrequency ranging between 8 and 18 MHz. Nine studies reported a set transducer frequency between 10 and 18 MHz (Delle Sedie et al. 2011; Filippucci et al. 2011; Howard et al. 2011; Iagnocco et al. 2011; Roddy et al. 2013; Yin et al. 2014; Norkuviene et al. 2017; Stewart et al. 2017a, 2017b). A hockey stick probe with a multifrequency of 7−15 MHz was employed by one study (Keen et al. 2011). One study performed volumetric PD acquisitions using 3-D) USI (Naredo et al. 2013). USI settings that were reported included dynamic range, which ranged between 40 and

70 dB, and grey-scale gain, which ranged between 17 and 60 dB. Of the 18 studies that reported using power Doppler, the pulse repetition frequency ranged from 400 to 1000 Hz and Doppler frequency ranged between 5 and 10 MHz. Additional settings reported by several studies included a low to medium wall filter with the Doppler gain adjusted to a level just below the disappearance of the colour signs within the bony cortex.

Transducer orientation and surfaces scanned. Details of the transducer orientation and surfaces scanned for the included studies are outlined in Supplementary File S3. Studies varied in terms of transducer orientation (*e.g.,* transverse or longitudinal) and which surface(s) of the first MTPJ was scanned (*e.g.,* dorsal, plantar, lateral or medial). Of the 10 studies that reported their USI acquisition procedure was in accordance with the 2001 EULAR guidelines, only Elsaman et al.'s (2016) description of transducer orientation and surfaces scanned clearly adhered to the guidelines. Naredo et al. (2013) used a 3-D volumetric USI technique, which allows examination in the longitudinal, transverse and coronal planes by producing a 3-D reconstruction of the anatomic area. The different descriptions of transducer orientation and surfaces scanned of the first MTPJ led to 12 different variations in reported procedures across studies. Le Boedec et al. (2013) and Pineda et al. (2011) described a multiplanar technique with no further clarification of what their scanning procedure entailed. Only one study did not delineate the specific scanning method (Reuss-Borst et al. 2014).

Scanning technique. Details of the scanning techniques used by included studies are outlined in Supplementary File S3. The scanning technique (static or dynamic) was not commonly reported. In a dynamic procedure, the transducer is moved along the anatomical region (first MTPJ) or the anatomical region is moved during the USI examination (Costantino et al. 2021). Three studies reported their scanning procedure involved a dynamic technique in which the probe was manoeuvred to investigate the first MTPJ (Peiteado et al. 2012; Reuss-Borst et al. 2014; Stewart et al. 2017a). Dynamic examination involving flexion−extension of the first MTPJ was reported by one study (Pineda et al. 2011). Roddy et al. (2013) and Terslev et al. (2015) reported dynamic manoeuvres but failed to report if it was the transducer or the first MTPJ that was dynamic during the USI examination. With respect to 3-D USI, the acquisition of the USI volume consists of an automatic sweeping scan movement of the piezoelectric crystals located inside the transducer, not a sweep of the transducer over the joint surface (Naredo et al. 2013). Naredo et al. (2013) reported that the volumetric probe was placed over the central part of the joint and a volumetric sweeping on the longitudinal plane was performed.

DISCUSSION

This review found a wide variation in USI acquisition procedures used to evaluate the first MTPJ. The variation between studies may be attributable to the number of elements the USI acquisition procedure encompasses. Technological developments coupled with the expansion of USI research have led to the development of consensus-based guidelines (Möller et al. 2017). However, as it stands, only two consensus-based guidelines exist to inform the USI acquisition procedure used to assess the first MTPJ (Backhaus et al. 2001; Möller et al. 2017). As most studies in this review were published prior to publication of the revised EULAR guidelines (Möller et al. 2017), no study included in this review had applied the updated EULAR guidelines.

The reporting of rheumatic and musculoskeletal USI research has also been enhanced by the recent publication of the EULAR recommendation checklist (Costantino et al. 2021). The checklist encompasses 23 items, 4 of which specifically relate to the USI acquisition procedure. The checklist was developed to ensure transparent and comprehensive reporting of USI research and procedures. It has been suggested that the global uptake of this checklist may considerably improve interpretability, reproducibility and generalisability of study results (Costantino et al. 2021). Therefore, 2 mechanisms need to be considered by USI research: the acquisition guidelines and the reporting of USI studies.

Numerous studies referred to adherence to the 2001 EULAR guidelines, despite their description of patient and joint positioning not aligning with the standardised procedure (supine position for the dorsal scans and prone position for the plantar scans) (Backhaus et al. 2001). Of the 12 studies that stated they examined both the dorsal and plantar aspects of the first MTPJ, no study indicated whether they modified patient position based on the surfaces scanned. The USI procedure description for assessing the first MTPJ often included how the body, knee, ankle and foot were positioned in conjunction with the positioning of the first MTPJ. However, there was inconsistent reporting of which lower limb joints should be included as part of the USI acquisition procedure. Of the studies that included the same joint in their procedure description, there was wide variation as to how that joint was positioned. Previous USI researchers have confirmed the importance of a standardised joint position for the reliability and generalisability of the results (Koenig et al. 2007; Hong et al. 2010; Mandl et al. 2012;

Terslev et al. 2012; Zayat et al. 2012; Zappia et al. 2016). Data from previous studies have revealed that variations in joint position can influence USI outcomes, irrespective of the anatomical site under investigation (Koenig et al. 2007; Hong et al. 2010; Mandl et al. 2012; Terslev et al. 2012; Zayat et al. 2012; Zappia et al. 2016). The updated 2017 EULAR guidelines for performing USI of the first MTPJ address both joint and patient positioning (Möller et al. 2017). To comply with the recently developed EULAR recommendation checklist for reporting USI (Costantino et al. 2021), it is recommended that both patient position (item 9a) and anatomical region position (item 9b) be implemented in future studies. A further enhancement of the updated EULAR guidelines is the accompanying electronic illustrated manual (*i.e.,* app), which clearly depicts the USI technique and procedures. The downloadable EULAR USI scanning app (http://ultrasound.eular.org/#/home) contains images detailing foot positioning and transducer orientation (longitudinal and transverse) for examining the first MTPJ. No study included images demonstrating how they acquired the ultrasound image to support their protocol description. Given the number of studies that inadequately described or failed to report patient and/or joint position, supporting images would ensure correct interpretation and allow subsequent studies to correctly replicate their procedure. Consequently, the inclusion of images may have revealed similarities between studies or adherence to cited guidelines that were unclear based on the descriptions of patient position alone.

The reporting of the USI device, type and model of the transducer, whether the software was changed during the study and USI mode and settings varied between studies. Technical characteristics of the imaging device such as USI modalities and settings used may affect the reliability and generalisability of the results (Koski et al. 2006, 2010; Ten Cate et al. 2013). One study employed 3-D USI, enabling automatic image acquisition. Three-dimensional USI has been reported to reduce operator dependence in assessing synovitis and bone erosions compared with conventional 2-D USI (Filippucci et al. 2009; Naredo et al. 2010b). Costantino et al. (2021) reported that the type of USI device may influence both power Doppler and grey-scale USI results. Advanced technology, such as 3-D imaging, may illustrate more in-depth information on joint pathology.

In keeping with the updated EULAR recommended procedures (Möller et al. 2017), grey-scale USI should be performed with high-resolution linear transducers with frequencies $\geq$15 MHz for superficial areas. Higher frequencies produce better resolution of superficial structures such as the first MTPJ (Taljanovic et al. 2015). However, 21 of the included studies used a transducer with an operating frequency $<$15 MHz. The machine setting for grey-scale and Doppler mode (*e.g.,* focal zone, frequency, gain, dynamic range, depth for B-mode; focal zone, colour box, frequency, gain, pulse repetition frequency and wall filter) were rarely reported by the included studies. Additionally, whether these settings were adjusted prior to and during the examination to optimise the USI acquisition procedure was uncertain. Optimal settings will depend on the individual machines; however, it is difficult to compare settings between studies because of the limited data reported. For the reporting of equipment items (15 and 16) of the EULAR checklist, future studies should detail the brand and model of USI device, type and model of transducer and whether the USI device was changed during the study (item 15). To comply with item 16, the USI modalities and settings should be reported.

In reference to patient and joint position, the orientation and positioning of the transducer are open to interpretation without images to ensure clarification of location. The position of the transducer has previously been reported to influence the reliability and accuracy of USI results in knee inflammation (Hong et al. 2010; Mandl et al. 2012; Terslev et al. 2012). Included studies that have used such phrases as “multiplanar examination” and “examined circumferentially” leave open to interpretation whether all surfaces of the joint were examined and in what plane they were imaged. It is unclear if the number of procedure variations reported was the result of missing information from the procedure description, or if studies intended to view only a certain aspect of the first MTPJ. Subsequently, it is possible that the reported descriptions were not a true reflection of what was conducted, and acquisition procedures might be more alike between studies than they appear.

Numerous studies referred to adherence to the 2001 EULAR guidelines, despite their description of transducer orientation and surfaces scanned not adhering to the standardised procedure (Backhaus et al. 2001). Discrepancies from the guidelines included the absence of an imaging plane (*e.g.,* transverse) or alteration in surfaces scanned such as including the medial aspect of the first MTPJ. Individual study interpretation of the lateral and medial aspects of the first MTPJ relative to the midline of the foot may explain the deviation from cited guidelines. This component of the original EULAR imaging procedure has since been amended to the medial aspect of the first MTPJ by the 2017 EULAR guidelines (Möller et al. 2017). For that reason, it is unclear if medial and lateral can be used interchangeably when comparing acquisition procedures between studies.

The updated EULAR guidelines for performing USI of the first MTPJ address transducer orientation and position (starting point), surfaces scanned and scanning technique (Möller et al. 2017). The probe placement starting point includes a longitudinal and transverse examination of the dorsal and plantar aspects of the forefoot, parallel to the metatarsal bones. Despite this addition, the current guidelines lack sufficient detail to ensure a standardised USI acquisition procedure. Given the general opinion that USI is heavily operator dependent for image acquisition, further refinement and details of anatomical reference points used to guide probe positioning are required. The scanning technique involves longitudinal and transverse sweeping. A sweeping scanning technique, involves slight movements of the probe from side to side or back to front or rotation to allow the best visualisation of the first MTPJ (Möller et al. 2017). In addition, the medial aspect of the first MTPJ is also scanned (Möller et al. 2017). However, it is difficult to make strong consensus-based recommendations, as the implementation of the revised technique lacks clear repeatable evidence to support this. It is problematic that one study reported applying the 2010 ESSR guidelines even though these guidelines did not include a procedure to scan the first MTPJ (Martinoli 2010). To fulfil the EULAR checklist items for acquisition procedures (Costantino et al. 2021), studies should detail the surfaces scanned (item 9c), the transducer orientation/location (item 9d) and whether the examination was dynamic (item 9e).

This scoping review is not without limitations. All relevant articles were included in this scoping review, regardless of methodological quality. We restricted the search to articles published in English. Inclusion of data from non-English language articles may alter the outcomes. Assessing the reliability between USI acquisition procedures and between sonographers was not an objective of this review. However, extraction of reliability data may have provided more insight into the reliability of different USI acquisition procedures given the inconsistencies reported, particularly between sonographers who possess different academic backgrounds and levels of USI experience.

Future studies should aim to accurately implement the updated EULAR guidelines. However, further refinement of anatomical reference points used to guide probe positioning is required to ensure a standardised USI acquisition procedure is used for evaluating the first MTPJ. Given the ambiguity in procedure descriptions, future research should adopt the EULAR recommendation checklist for reporting USI research of rheumatic and musculoskeletal diseases. A standardised procedure supplemented with a checklist for reporting the USI procedure for the first MTPJ will improve interpretability, reproducibility and generalisability of study results. Current guidelines have overlooked how the USI acquisition procedure may need to be adapted to accommodate severe structural changes. The degree of joint deformity often associated with rheumatic diseases poses a challenge when acquiring an optimal image. Consequently, future research should aim to provide guidance on how to image the first MTPJ that has significant deformity. Finally, there is also great value in developing guidelines that investigate volumetric probes to enable 3-D reconstruction of the anatomical area and automatic image acquisition, as this will reduce operator dependence in examining the first MTPJ.

CONCLUSIONS

The review found inconsistency in the application of the EULAR guidelines and limited implementation of consensus-based recommendations to guide image acquisition of the first MTPJ. There was wide variation in what items were reported as part of the USI acquisition procedure to evaluate the first MTPJ. Additionally, there were discrepancies between the levels of detail reported for each item the imaging procedure encompasses. The key inconsistencies identified were between patient position, USI mode and settings, transducer orientation and surfaces scanned. The review emphasises the need for further refinement to ensure a standardised USI acquisition procedure is used to evaluate the first MTPJ. A standardised procedure supplemented with a checklist for reporting the components the USI acquisition procedure encompasses will improve interpretability and reproducibility between studies.

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SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.ultrasmedbio.2021.11.009.

REFERENCES

Arksey H, O'Malley L. Scoping studies: Towards a methodological framework. Int J Social Res Methodol 2005;8:19–32.
Backhaus M, Burmester G, Gerber T, Grassi W, Machold K, Swen W, Wakefield R, Manger B. Guidelines for musculoskeletal ultrasound in rheumatology. Ann Rheum Dis 2001;60:641–649.
Benvenuti F, Ferrucci L, Guralnik JM, Gangemi S, Baroni A. Foot pain and disability in older persons: An epidemiologic survey. J Am Geriatr Soc 1995;43:479–484.
Bergin SM, Munteanu SE, Zammit GV, Nikolopoulos N, Menz HB. Impact of first metatarsophalangeal joint osteoarthritis on health-related quality of life. Arthritis Care Res 2012;64:1691–1698.
Costantino F, Carmona L, Boers M, Backhaus M, Balint PV, Bruyn GA, Christensen R, Conaghan PG, Ferreira RJ, Garrido-Castro JL,

Guillemin F, Berner Hammer H, van der Heijde D, Iagnocco A, Kortekaas MC, Landewé RBM, Mandl P, Naredo E, Schmidt WA, Terslev L, Terwee CB, Thiele R, D'Agostino MA. EULAR recommendations for the reporting of ultrasound studies in rheumatic and musculoskeletal diseases (RMDs). Ann Rheum Dis 2021;21:840–847.

Das S, Ghosh A, Ghosh P, Lahiri D, Sinhamahapatra P, Basu K. Sensitivity and specificity of ultrasonographic features of gout in intercritical and chronic phase. Int J Rheum Dis 2017;20:887–893.

Dawson J, Thorogood M, Marks SA, Juszczak E, Dodd C, Lavis G, Fitzpatrick R. The prevalence of foot problems in older women: A cause for concern. J Pub Health 2002;24:77–84.

Delle Sedie A, Riente L, Filippucci E, Scire C, Iagnocco A, Meenagh G, Gutierrez M, Guido V, Montecucco C, Grassi W. Ultrasound imaging for the rheumatologist: XXXII. Sonographic assessment of the foot in patients with psoriatic arthritis. Clin Exp Rheumatol 2011;29:217–222.

Dufour AB, Broe KE, Nguyen USD, Gagnon DR, Hillstrom HJ, Walker AH, Kivell E, Hannan MT. Foot pain: Is current or past shoewear a factor?. Arthritis Care Res 2009;61:1352–1358.

Elsaman AM, Muhammad EMS, Pessler F. Sonographic findings in gouty arthritis: Diagnostic value and association with disease duration. Ultrasound Med Biol 2016;42:1330–1336.

Filippucci E, Meenagh G, Delle Sedie A, Salaffi F, Riente L, Iagnocco A, Scirè C, Montecucco C, Bombardieri S, Guido V. Ultrasound imaging for the rheumatologist: XX. Sonographic assessment of hand and wrist joint involvement in rheumatoid arthritis: Comparison between two-and three-dimensional ultrasonography. Clin Exp Rheumatol 2009;27:197–200.

Filippucci E, Meenagh G, Delle Sedie A, Sakellariou G, Iagnocco A, Riente L, Gutierrez M, Bombardieri S, Valesini G, Montecucco C, Grassi W. Ultrasound imaging for the rheumatologist: XXXVI. Sonographic assessment of the foot in gout patients. Clin Exp Rheumatol 2011;29:901–905.

Filippucci E, Cipolletta E, Mirza RM, Carotti M, Giovagnoni A, Salaffi F, Tardella M, Di Matteo A, Di Carlo M. Ultrasound imaging in rheumatoid arthritis. Radiol Med 2019;124:1087–1100.

Gates LS, Arden NK, Hannan MT, Roddy E, Gill TK, Hill CL, Dufour AB, Rathod-Mistry T, Thomas MJ, Menz HB. Prevalence of foot pain across an international consortium of population-based cohorts. Arthritis Care Res 2019;71:661–670.

Grant JF, Taylor AW, Ruffin RE, Wilson DH, Phillips PJ, Adams RJ, Price K, Team NWAHS. Cohort profile: The North West Adelaide Health Study (NWAHS). Int J Epidemiol 2009;38:1479–1486.

Grassi W, Cervini C. Ultrasonography in rheumatology: An evolving technique. Ann Rheum Dis 1998;57:268–271.

Grassi W, Lamanna G, Farina A, Cervini C. Sonographic imaging of normal and osteoarthritic cartilage. Semin Arthritis Rheum 1999;28:398–403.

Grassi W, Filippucci E, Farina A, Cervini C. Sonographic imaging of the distal phalanx. Semin Arthritis Rheum 2000;29:379–384.

Hart DJ, Spector TD. The relationship of obesity, fat distribution and osteoarthritis in women in the general population: The Chingford Study. J Rheumatol 1993;20:331–335.

Hiraga M, Ikeda K, Shigeta K, Sato A, Yoshitama T, Hara R, Tanaka Y. Sonographic measurements of low-echoic synovial area in the dorsal aspect of metatarsophalangeal joints in healthy subjects. Mod Rheumatol 2015;25:386–392.

Hong BY, Lim SH, Cho YR, Kim HW, Ko YJ, Han SH, Lee J. Detection of knee effusion by ultrasonography. Am J Phys Med Rehabil 2010;89:715–721.

Howard RG, Pillinger MH, Gyftopoulos S, Thiele RG, Swearingen CJ, Samuels J. Reproducibility of musculoskeletal ultrasound for determining monosodium urate deposition: Concordance between readers. Arthritis Care Res 2011;63:1456–1462.

Huppertz A, Hermann KGA, Diekhoff T, Wagner M, Hamm B, Schmidt WA. Systemic staging for urate crystal deposits with dual-energy CT and ultrasound in patients with suspected gout. Rheumatol Int 2014;34:763–771.

Iagnocco A, Filippucci E, Ossandon A, Ciapetti A, Salaffi F, Basili S, Grassi W, Valesini G. High resolution ultrasonography in detection of bone erosions in patients with hand osteoarthritis. J Rheumatol 2005;32:2381–2383.

Iagnocco A, Filippucci E, Riente L, Meenagh G, Delle Sedie A, Sakellariou G, Ceccarelli F, Montecucco C, Bombardieri S, Grassi W, Valesini G. Ultrasound imaging for the rheumatologist: XXXV. Sonographic assessment of the foot in patients with osteoarthritis. Clin Exp Rheumatol 2011;29:757–762.

Jordan JM. An ongoing assessment of osteoarthritis in African Americans and Caucasians in North Carolina: The Johnston County osteoarthritis project. Trans Am Clin Climatol Assoc 2015;126:77.

Karim Z, Wakefield R, Conaghan P, Lawson C, Goh E, Quinn M, Astin P, O'connor P, Gibbon W, Emery P. The impact of ultrasonography on diagnosis and management of patients with musculoskeletal conditions. Arthritis Rheum 2001;44:2932–2933.

Keen HI, Redmond A, Wakefield RJ, Freeston J, Grainger AJ, Hensor EM, Emery P, Conaghan PG, Keen HI, Redmond A, Wakefield RJ, Freeston J, Grainger AJ, Hensor EMA, Emery P, Conaghan PG. An ultrasonographic study of metatarsophalangeal joint pain: Synovitis, structural pathology and their relationship to symptoms and function. Ann Rheum Dis 2011;70:2140–2143.

Klauser AS, Tagliafico A, Allen GM, Boutry N, Campbell R, Grainger A, Guerini H, McNally E, O'Connor PJ, Ostlere S. Clinical indications for musculoskeletal ultrasound: A Delphi-based consensus paper of the European Society of Musculoskeletal Radiology. Eur Radiol 2012;22:1140–1148.

Koenig M, Torp-Pedersen S, Christensen R, Boesen M, Terslev L, Hartkopp A, Bliddal H. Effect of knee position on ultrasound Doppler findings in patients with patellar tendon hyperaemia (jumper's knee). Ultraschall Med 2007;28:479–483.

Koski JM, Saarakkala S, Helle M, Hakulinen U, Heikkinen JO, Hermunen H, Balint P, Bruyn GA, Filippucci E, Grassi W. Assessing the intra-and inter-reader reliability of dynamic ultrasound images in power Doppler ultrasonography. Ann Rheum Dis 2006;65:1658–1660.

Koski JM, Alasaarela E, Soini I, Kemppainen K, Hakulinen U, Heikkinen JO, Laasanen MS, Saarakkala S. Ability of ultrasound imaging to detect erosions in a bone phantom model. Ann Rheum Dis 2010;69:1618–1622.

Le Boedec M, Jousse-Joulin S, Ferlet J-F, Marhadour T, Chales G, Grange L, Hacquard-Bouder C, Loeuille D, Sellam J, Albert JD. Factors influencing concordance between clinical and ultrasound findings in rheumatoid arthritis. J Rheumatol 2013;40:244–252.

Liu R, Han C, Wu D, Xia X, Gu J, Guan H, Shan Z, Teng W. Prevalence of hyperuricemia and gout in mainland China from 2000 to 2014: A systematic review and meta-analysis. BioMed Res Int 2015;2015 762820.

Machado FS, Natour J, Takahashi RD, Furtado RNV. Articular ultrasound in asymptomatic volunteers: Identification of the worst measures of synovial hypertrophy, synovial blood flow and joint damage among small-, medium- and large-sized joints. Ultrasound Med Biol 2017;43:1141–1152.

Mandl P, Brossard M, Aegerter P, Backhaus M, Bruyn G, Chary-Valckenaere I, Iagnocco A, Filippucci E, Freeston J, Gandjbakhch F. Ultrasound evaluation of fluid in knee recesses at varying degrees of flexion. Arthritis Res 2012;64:773–779.

Martinoli C. Musculoskeletal ultrasound: Technical guidelines. Insights Imaging 2010;1:99–141.

McQueen FM, Reeves Q, Dalbeth N. New insights into an old disease: Advanced imaging in the diagnosis and management of gout. Postgrad Med J 2013;89:87–93.

Messina C, Bignotti B, Tagliafico A, Orlandi D, Corazza A, Sardanelli F, Sconfienza LM. A critical appraisal of the quality of adult musculoskeletal ultrasound guidelines using the AGREE II tool: An EuroAIM initiative. Insights Imaging 2017;8:491–497.

Mickle KJ, Munro BJ, Lord SR, Menz HB, Steele JR. Cross-sectional analysis of foot function, functional ability, and health-related quality of life in older people with disabling foot pain. Arthritis Care Res 2011;63:1592–1598.

Möller I, Janta I, Backhaus M, Ohrndorf S, Bong DA, Martinoli C, Filippucci E, Sconfienza LM, Terslev L, Damjanov N. The 2017

EULAR standardised procedures for ultrasound imaging in rheumatology. Ann Rheum Dis 2017;76:1974–1979.
Naredo E, D'Agostino MA, Conaghan PG, Backhaus M, Balint P, Bruyn GA, Filippucci E, Grassi W, Hammer HB, Iagnocco A. Current state of musculoskeletal ultrasound training and implementation in Europe: Results of a survey of experts and scientific societies. Rheumatology 2010a;49:2438–2443.
Naredo E, Möller I, Acebes C, Batlle-Gualda E, Brito E, De Agustin J, De Miguel E, Martínez A, Mayordomo L, Moragues C. Three-dimensional volumetric ultrasonography: Does it improve reliabililty of musculoskeletal ultrasound. Clin Exp Rheumatol 2010b;28:79–82.
Naredo E, Acebes C, Brito E, de Agustín JJ, de Miguel E, Mayordomo L, Möller I, Moragues C, Rejón E, Rodriguez A. Three-dimensional volumetric ultrasound: A valid method for blinded assessment of response to therapy in rheumatoid arthritis. J Rheumatol 2013;40:253–260.
Norkuviene E, Petraitis M, Apanaviciene I, Virviciute D, Baranauskaite A. An optimal ultrasonographic diagnostic test for early gout: A prospective controlled study. J Int Med Res 2017;45:1417–1429.
Peat G, Thomas E, Wilkie R, Croft P. Multiple joint pain and lower extremity disability in middle and old age. Disability Rehabil 2006;28:1543–1549.
Peiteado D, De Miguel E, Villalba A, Ordóñez MC, Castillo C, Martín-Mola E. Value of a short four-joint ultrasound test for gout diagnosis: A pilot study. Clin Exp Rheumatol 2012;30:830–837.
Pineda C, Amezcua-Guerra LM, Solano C, Rodriguez-Henríquez P, Hernández-Díaz C, Vargas A, Hofmann F, Gutiérrez M. Joint and tendon subclinical involvement suggestive of gouty arthritis in asymptomatic hyperuricemia: An ultrasound controlled study. Arthritis Res Ther 2011;13:R4.
Rathod T, Marshall M, Thomas MJ, Menz HB, Myers HL, Thomas E, Downes T, Peat G, Roddy E. Investigations of potential phenotypes of foot osteoarthritis: Cross-sectional analysis from the clinical assessment study of the foot. Arthritis Care Res 2016;68:217–227.
Reuss-Borst MA, Pape CA, Tausche AK. Hidden gout—Ultrasound findings in patients with musculo-skeletal problems and hyperuricemia. SpringerPlus 2014;3:592.
Roddy E, Myers H, Thomas MJ, Marshall M, D'Cruz D, Menz HB, Belcher J, Muller S, Peat G. The clinical assessment study of the foot (CASF): Study protocol for a prospective observational study of foot pain and foot osteoarthritis in the general population. J Foot Ankle Res 2011;4:22.
Roddy E, Menon A, Hall A, Datta P, Packham J. Polyarticular sonographic assessment of gout: A hospital-based cross-sectional study. Joint Bone Spine 2013;80:295–300.
Roddy E, Thomas MJ, Marshall M, Rathod T, Myers H, Menz HB, Thomas E, Peat G. The population prevalence of symptomatic radiographic foot osteoarthritis in community-dwelling older adults: Cross-sectional findings from the clinical assessment study of the foot. Ann Rheum Dis 2015;74:156–163.
Rome K, Frecklington M, McNair P, Gow P, Dalbeth N. Foot pain, impairment, and disability in patients with acute gout flares: a prospective observational study. Arthritis Care Res 2012;64:384–388.
Sakellariou G, Conaghan PG, Zhang W, Bijlsma JW, Boyesen P, D'agostino MA, Doherty M, Fodor D, Kloppenburg M, Miese F. EULAR recommendations for the use of imaging in the clinical management of peripheral joint osteoarthritis. Ann Rheum Dis 2017;76:1484–1494.
Scire CA, Montecucco C, Codullo V, Epis O, Todoerti M, Caporali R. Ultrasonographic evaluation of joint involvement in early rheumatoid arthritis in clinical remission: Power Doppler signal predicts short-term relapse. Rheumatology 2009;48:1092–1097.
Scirè CA, Iagnocco A, Meenagh G, Riente L, Filippucci E, Delle Sedie A, Sakellariou G, Bombardieri S, Grassi W, Valesini G, Montecucco C. Ultrasound imaging for the rheumatologist: XXXIII. Sonographic assessment of the foot in early arthritis patients. Clin Exp Rheumatol 2011;29:465–469.
Smith J, Finnoff JT. Diagnostic and interventional musculoskeletal ultrasound: Part 1. Fundamentals. Am J Phys Med Rehabil 2009;1:64–75.
Stewart S, Dalbeth N, Vandal AC, Rome K. The first metatarsophalangeal joint in gout: a systematic review and meta-analysis. BMC Musculoskeletal Disord 2016;17:1–15.
Stewart S, Dalbeth N, Vandal AC, Allen B, Miranda R, Rome K. Are ultrasound features at the first metatarsophalangeal joint associated with clinically-assessed pain and function? A study of people with gout, asymptomatic hyperuricaemia and normouricaemia. J Foot Ankle Res 2017a;10:22.
Stewart S, Dalbeth N, Vandal AC, Allen B, Miranda R, Rome K. Ultrasound features of the first metatarsophalangeal joint in gout and asymptomatic hyperuricemia: comparison with normouricemic individuals. Arthritis Care Res 2017b;69:875–883.
Taljanovic MS, Melville DM, Gimber LH, Scalcione LR, Miller MD, Kwoh CK, Klauser AS. High-resolution US of rheumatologic diseases. Radiographics 2015;35:2026–2048.
Tan YK, Li H, Allen JC, Jr., Thumboo J. Extended 36-joint sonographic examination: What it reveals about bone erosions in patients with rheumatoid arthritis. J Clin Ultrasound 2020;48:14–18.
Ten Cate DF, Luime JJ, Swen N, Gerards AH, De Jager MH, Basoski NM, Hazes JM, Haagsma CJ, Jacobs JW. Role of ultrasonography in diagnosing early rheumatoid arthritis and remission of rheumatoid arthritis—A systematic review of the literature. Arthritis Res Ther 2013;15:1–9.
Terslev L, D'Agostino M, Brossard M, Aegerter P, Balint P, Backhaus M, Bruyn G, Chary-Valckenare I, Filippucci E, Freeston J. Which knee and probe position determines the final diagnosis of knee inflammation by ultrasound? Results from a European multicenter study. Ultraschall Med 2012;33:E173–E178.
Terslev L, Gutierrez M, Christensen R, Balint PV, Bruyn GA, Sedie AD, Filippucci E, Garrido J, Hammer HB, Iagnocco A, Kane D, Kaeley GS, Keen H, Mandl P, Naredo E, Pineda C, Schicke B, Thiele R, D'Agostino MA, Schmidt WA. Assessing elementary lesions in gout by ultrasound: Results of an OMERACT patient-based agreement and reliability exercise. J Rheumatol 2015;42:2149–2154.
Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, Moher D, Peters MD, Horsley T, Weeks L. PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation. Ann Intern Med 2018;169:467–473.
Van der Merwe L, Duke C, Ung Y, Williams K. The economic cost of arthritis in New Zealand in 2018. : Deloittes Touches Tohmatsu Ltd New Zealand; 2018.
Wakefield R, Green M, Marzo-Ortega H, Conaghan P, Gibbon W, McGonagle D, Proudman S, Emery P. Should oligoarthritis be reclassified? Ultrasound reveals a high prevalence of subclinical disease. Ann Rheum Dis 2004;63:382–385.
Wiell C, Szkudlarek M, Hasselquist M, Møller JM, Vestergaard A, Nørregaard J, Terslev L, Østergaard M. Ultrasonography, magnetic resonance imaging, radiography, and clinical assessment of inflammatory and destructive changes in fingers and toes of patients with psoriatic arthritis. Arthritis Res Ther 2007;9:1–13.
Wright SA, Filippucci E, McVeigh C, Grey A, McCarron M, Grassi W, Wright GD, Taggart AJ. High-resolution ultrasonography of the first metatarsal phalangeal joint in gout: A controlled study. Ann Rheum Dis 2007;66:859–864.
Yin L, Zhu J, Xue Q, Wang N, Hu Z, Huang Y, Liu F, Hu B. MicroPure imaging for the evaluation of microcalcifications in gouty arthritis involving the first metatarsophalangeal joint: A preliminary study. PloS One 2014;9:e95743.
Zappia M, Cuomo G, Martino MT, Reginelli A, Brunese L. The effect of foot position on power Doppler ultrasound grading of Achilles enthesitis. Rheumatol Int 2016;36:871–874.
Zayat AS, Freeston JE, Conaghan PG, Hensor EM, Emery P, Wakefield RJ. Does joint position affect US findings in inflammatory arthritis?. Rheumatology 2012;51:921–925.
Zhang W, Jin Z, Xiang W, Wu M, Wang S, Zhang H, Zhang P. Ultrasonographic features of lower-limb joints in gout: Which joints and clinical characteristics would provide more information for diagnosis?. J Clin Rheumatol 2020;26:14–18.