Is elastography type technology useful for quantifying the characteristics of fascia tissues, who uses diagnostic ultrasound in a musculoskeletal setting, and what are the beliefs of users and non-users?

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ABSTRACT

Detection of stiffness in muscle and fascia tissues through the application of subjective palpation helps guide the musculoskeletal practitioner to a working diagnosis. Elastography represents a new technology that measures the stiffness of these tissues quantitatively. Interest in fascia tissues has grown over the last two decades and its role in body movement and other physiological functions has seen a rapid growth in research during this time. This paper aims to investigate the potential of utilising elastography to quantitatively measure fascia tissue stiffness in a musculoskeletal setting. A mixed method approach was followed using a systematic narrative review and survey. The target population of the survey involved rheumatologists, musculoskeletal/sports doctors, chiropractors, physiotherapists, and osteopaths. Most musculoskeletal practitioners are not aware of elastography, hence diagnostic ultrasound was considered an appropriate substitution to gain the beliefs and attitudes of both users and non-users. No studies were found in the literature that utilised elastography to measure stiffness in fascia tissues other than in tendons. However, studies of tendons identified in the review illustrated very good to excellent sensitivity and specificity to detect pathological from non-pathological tissues. Additionally, preferred protocols to enhance elastography scanning were identified. The most likely users of diagnostic ultrasound are currently rheumatologists and musculoskeletal/sports doctors with the most common reason given by non-users being a lack of training/education. All professions mostly agree (>70%) that diagnostic ultrasound is able to produce reliable images of pathologic and non-pathologic tissues, should only be taken by trained professionals, can aid a clinician with good palpation skills, and may be useful to quantify diagnostic findings. This paper concludes that elastography may be useful to quantify tissue stiffness, however more research is required for elastography to be reliably utilised in a musculoskeletal setting.

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LIST OF ABBREVIATIONS

SWE	Shear Wave Elastography
SE	Strain Elastography
ROI	Region of Interest
kPa	Kilopascals
m/s	Meters per second
MSK	Musculoskeletal
RCT	Randomized Controlled Trial
dxUS	Diagnostic Ultrasound
MSK-DUS	Musculoskeletal Diagnostic Ultrasound
MRI	Magnetic Resonance Imaging
MRA	Magnetic Resonance Angiogram

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CHAPTER 1

INTRODUCTION

Is elastography type technology useful for quantifying the characteristics of fascia tissues, who uses diagnostic ultrasound technology in a musculoskeletal setting, and what are the beliefs of users and non-users?

Elastography represents a new technology that quantitatively measures tissue stiffness through the assessment of the target tissues viscoelastic properties and may be useful to quantify the characteristics of fascia tissues. The structure and function of fascia tissues is attracting more attention from scientists and body therapists over the last two decades (Fig 1.1) particularly since the first 'Fascia Research Congress' held at Harvard, Boston, in 2007 (Avila Gonzalez et al., 2018).

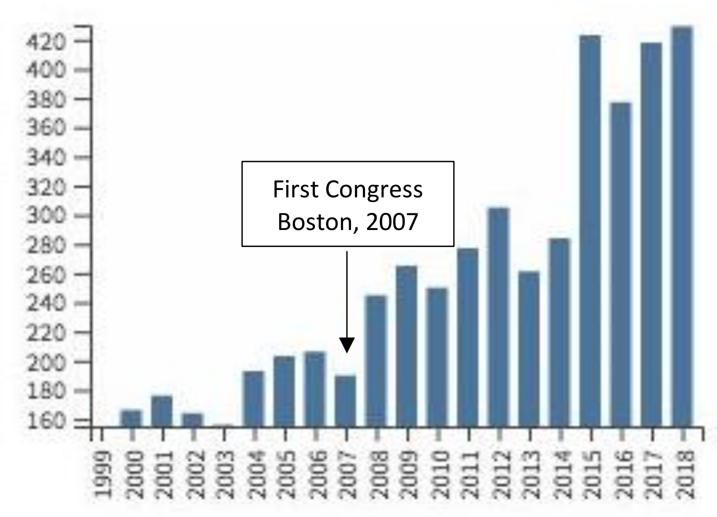


Fig. 1.1. **Results of publications with search of "Web of Science" using terms 'fascia OR fasciitis' from 2000 – 2018.**

The goal of this Masters thesis was to investigate the potential usefulness of elastography to quantitatively measure fascia tissues in a musculoskeletal setting. However, it is unlikely that musculoskeletal practitioners would be aware of elastography and its potential use to determine tissue stiffness due to the newness of this technology. As described in detail below, diagnostic ultrasound is very similar in appearance and application to elastography, hence it was used as a substitute in the survey tool. The goal of the survey was to collect data of the use and beliefs of a broad group of musculoskeletal practitioners that may provide insight into the usefulness of using elastography to measure fascia tissues in a clinical setting.

A mixed methodology was implemented consisting of a narrative review and a survey of musculoskeletal practitioners in New Zealand of the use and beliefs of a substitute (diagnostic ultrasound) to elastography usefulness in a clinical setting. An important and unique component of this study was to collect data from a broad group of musculoskeletal practitioners using the survey tool, and hence, required the use of an appropriate substitute to achieve this goal due to the reasons mentioned above.

Diagnostic ultrasound is very similar to elastography and is a familiar technology to the majority of musculoskeletal practitioners. This study will describe both elastography and diagnostic ultrasound to illustrate how each technology functions to measure musculoskeletal tissues and how the two technologies are similar but not the same. For example, hepatologists have been increasing the use of elastography to aid detection of liver masses over the last 10 years (Sporea, 2018). Initial assessment would involve a diagnostic ultrasound exam, to determine the presence of liver disease, followed by an elastography exam that provides greater accuracy of the stiffness of liver masses depending on the amount of fibrosis. The elastography exam would follow directly after the ultrasound exam using the same equipment on different settings with the patient having no perceived difference from the ultrasound exam. This example illustrates the likeness in equipment, application, and experience of the patient in ultrasound and elastography procedures and is why it is considered an appropriate substitute for the survey tool in this study.

Finally, the results of the review and survey are synthesized to help achieve the goal of this thesis project, namely, could elastography be useful to collect quantitative data of fascia tissues in a musculoskeletal setting.

Elastography first appeared as a method to assess tissue stiffness in 1991 when Japanese investigators used ultrasound waves to determine differences in stiffness of breast tissue that may indicate tumours or cysts (Wells & Liang, 2011). On-going technological and research advances into elastography use has resulted in the implementation of elastography to investigate firm tissues within soft tissues and soft tissues within firm tissues, both of which may indicate pathological processes. Further, elastography use in research has grown exponentially over the past decade (Fig 1.2) and has recently gained approval from the Food and Drug Administration on most state-of-the-art ultrasound scanners (Taljanovic et al., 2017).

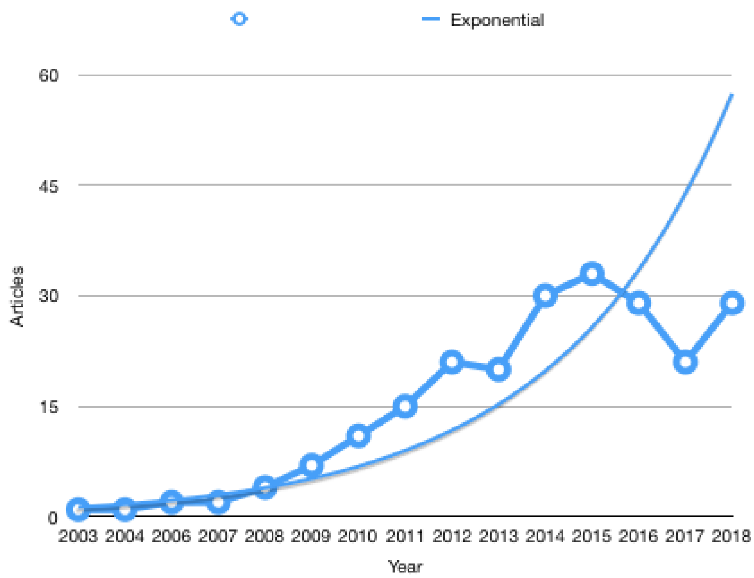


Fig. 1.2. **Results of PubMed search using terms 'elastograph*' AND 'sonoelastograph*'**

Specifically, elastography measures tissue stiffness through the assessment of the viscoelastic properties in a region of interest (ROI) (Ryu & Jeong, 2017; Taljanovic et al., 2017). Changes in tissue stiffness occur due to various pathological processes, such as fibrosis, cancerous masses, and calcifications which appear as hard nodules or stiffness, where vascularization, fatty infiltration, and other mechanisms of chronic or acute tissue repair appear as softness (Ooi, Malliaras, Schneider, and Connell (2014a). Hence, differences in tissue stiffness may provide the practitioner with useful information to determine a working diagnosis and possibly direct treatment to achieve better client outcomes.

There are multiple types of elastography, however all follow the same basic principle where a force is applied to the tissue (or ROI) and a measurement is made of tissue behaviour. An important assumption in this process is that a tissues tendency is to return to its original shape (Wells & Liang, 2011).

Differences between elastography types is determined by the mechanism of tissue displacement (i.e. force applied to tissue) and the mode of measuring the tissue's ability to rebound. Measures of stiffness can be either its resistance to deformation by the external force, or by the tissue behaviour to that force. Specialised elastography transducers produce the external force either manually or via acoustic radiation force impulses, and stiffness data is expressed as either a colour map (semi-quantitative), pressure (kPa), or velocity (m/s) which is then correlated with the presence or absence of a pathological cause (e.g. hard nodule or fatty infiltration) (Ooi et al., 2014a; Ryu & Jeong, 2017; Taljanovic et al., 2017).

Currently, two main types of elastography are used to investigate musculoskeletal tissues, these being strain elastography (SE) and shear wave elastography (SWE). Strain elastography provides tissue compression through an operator applied axial force perpendicular to the ROI. Tissue stiffness is then displayed on a B-mode ultrasound image through colour maps depicting cold colours as softness and warm colours as hardness (bookmarked as blue = soft, red = hard). Tissue stiffness is then interpreted by the operator and considered semi-quantitative (Ryu & Jeong, 2017). Shear wave elastography uses an acoustic radiation wave (force) applied by the transducer perpendicular to the ROI which distorts the tissues and propagates measurable shear waves. Shear wave velocities are detected using specialized ultra-fast transducers and produces a quantitative measure of tissue stiffness as either velocity of shear wave propagation (m/s), or pressure (kPa) depending on the algorithm software being used (Shiina et al., 2015).

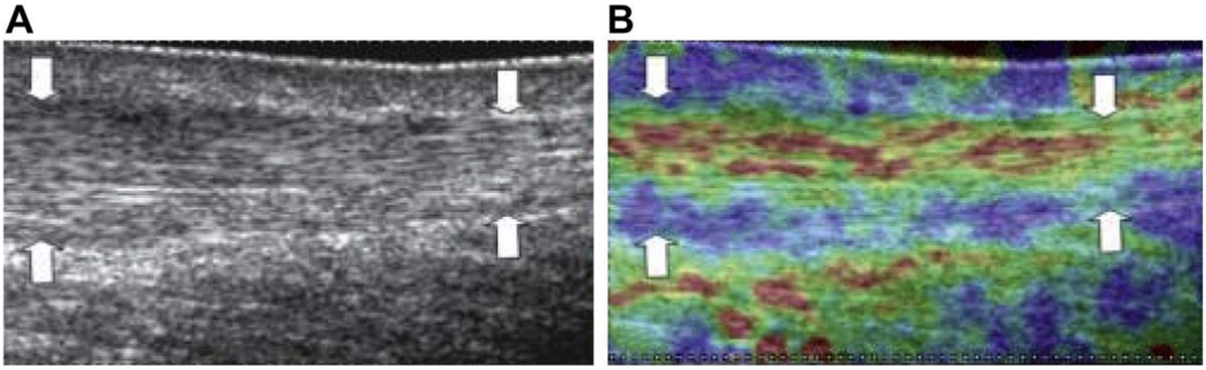


***Fig 1.3.* Comparative images of a symptomatic Achilles tendon of a 62 year old man. (A) A longitudinal B-mode ultrasound image (arrows showing thickened midportion). (B) A longitudinal strain elastogram showing red section in midportion of tendon (red equates to softness and associated viscoelastic changes indicating pathology). Image from De Zordo et al (De Zordo et al., 2009, p. W137)**

The first commercial elastography equipment was developed in 2003 (Shiina et al., 2015), however, to our knowledge, it has yet to be utilised in private practice in New Zealand. Elastography research has identified challenges which require addressing before sufficient reliability and utility allow the practitioner to confidently utilise this technology in their practice setting (Ooi et al., 2014a). These include: education of technical and operational protocols; standardisation of units and norms (Shiina et al., 2015); recognition of confounding variables such as age (Berko, Fitzgerald, Amaral, Payares, & Levin, 2014), gender (Kubo, Kanehisa, & Fukunaga, 2005), and special populations (Du et al., 2016); and, most notably, the highly operator-dependent nature of elastography scanning (Taş, Onur, Yılmaz, Soylu, & Korkusuz, 2017). These challenges will be considered in this thesis as we explore the usefulness of elastography in a musculoskeletal setting.

For over half a century ultrasound has been used to investigate musculoskeletal tissues (Primack, 2016). In 1972 the first B-mode image was used to differentiate a Bakers cyst from thrombophlebitis and, shortly afterwards, was followed by the first use of ultrasound to diagnose rotator cuff pathology (Crass, Craig, Thompson, & Feinberg, 1984). Technology improvements and increases in ultrasound 'scope of use' has increased ultrasound use amongst point of care practitioners where it may be utilised for diagnostic or intervention purposes (Dietrich et al., 2017).

Musculoskeletal ultrasound is now an accepted and often-used technology in the practice settings of musculoskeletal/sports doctors (Finnoff et al., 2015), rheumatologists (Naredo, 2015; Samuels, Abramson, & Kaeley, 2010), and physiotherapists, with several authors referring to it as 'the stethoscope of the musculoskeletal practitioner' (Ellis et al., 2018; Potter, Cairns, & Stokes, 2012). Further, musculoskeletal ultrasound use is rapidly increasing in other 'body-work' professions, such as chiropractic, osteopathic, and podiatrist (Sharpe, Nazarian, Parker, Rao, & Levin, 2012). Likely reasons for the rapid growth in ultrasound use may include: technology improvements continue to improve image quality; base units allow greater portability; allows real-time investigation; and, improved reliability (Filippo, Lars, Maria, & Sandra, 2019). Additionally, ultrasound is significantly less expensive in comparison to other imaging options, uses non-radiation sound waves, avoids potential risks from radiation from other forms of imaging, and provides the practitioner with an excellent adjunct to their diagnostic examination (D'Agostino & Terslev, 2014).

Differentiation of ultrasound and elastography may be described as: conventional ultrasound portrays differences in soft tissue acoustic properties (e.g. echogenicity) that is displayed on a B-mode image, where elastography portrays differences in elastic properties which is displayed as a value (e.g. kPa or m/s) (Kudo, 2015).

In all physical dimensions and appearance, elastography and ultrasound machines are identical and whilst protocols for elastography are in development (Drakonaki, Allen, & Wilson, 2009), foundations for its use are likely to mirror established ultrasound use in a point of care setting.

Differences between the two technologies mainly consist of specialised elastography software in the base unit and specialised elastography transducers (Ryu & Jeong, 2017). Specialised transducers represent the most significant difference between ultrasound and elastography technology with further differences between SE and SWE. Strain elastography requires the transducer to have a pressure gauge that is visible on the B-mode image to guide the operator (who provides the tissue disturbing force) as to how much pressure is being applied to the ROI. For shear wave elastography, the transducer produces the required push radiation force to the ROI and then measures the shear wave activity (i.e. tissue behaviour) through fast plane excitation and produces data using speckle tracking algorithms (Taljanovic et al., 2017). Most modern machines have both SE and SWE software in the base unit (Shiina et al., 2015). These differences between ultrasound and elastography are imperceptible to the client in both appearance and use.

The use of ultrasound has increased significantly over the last decade in both radiology centres and outside of specialist imaging settings (Mizrahi, Parker, Zoga, & Levin, 2018). A study of Medicare reimbursements in the United States, from 2003-2015, indicates ultrasound use increased across all fields by 316%, with the greatest increase occurring in private practice (717%) (Mizrahi et al., 2018). Additionally, of the non-radiologist groups who use ultrasound orthopaedic surgeons, chiropractors, and podiatrists had the most significant increases (10 – 14%) (Mizrahi et al., 2018). Increase in ultrasound imaging may be due to the greater portability of ultrasound base units resulting in point of care ultrasound not just being used at the bedside but on the sports fields and in private practice (Yim & Corrado, 2012).

Further, the increase in ultrasound use may not solely be due to its flexibility but also its increasing application of use. Depending on the scope of practice of the practitioner, ultrasound can be used for any of diagnostic, rehabilitation, and/or procedural purposes. For example, surveys that investigate ultrasound use indicate that: rheumatologists use ultrasound for therapeutic purposes (e.g. needle guidance) and diagnostic purposes (Samuels et al., 2010); physiotherapists mainly use ultrasound for rehabilitation and biofeedback (Ellis et al., 2018); and MSK/sports doctors have a broad application of ultrasound which provides more significant cost effective option than expensive MRI procedures (Finnoff et al., 2015).

In summary, applications of musculoskeletal ultrasound has extensive advantages such as cost effectiveness and real-time use compared to other imaging, however sensitivity and specificity of use by practitioners still requires validation through further research (Yim & Corrado, 2012).

In comparison to ultrasound, elastography has significantly less scope. Elastography may only be an effective tool to investigate tissue stiffness and assumed pathology causing these changes. Therefore, the scope of elastography use in a musculoskeletal setting may be predominately to provide quantitative data of tissue stiffness that helps support a working diagnosis.

Fascia and muscle tissue function synergistically throughout the whole body to provide all movement and structural support however each tissue has its own unique anatomy and function. Fascia tissue is: composed mostly of collagen fibres; has few elastic fibres; does not actively shorten or contract; and aids in many functions such as vascularity and specialised cell production (Antonio Stecco, Stern, Fantoni, De Caro, & Stecco, 2016). Muscle tissue, by comparison, has the capacity to contract through the anatomy and physiology of the sarcomere. The sarcomere is significantly more viscous than the tightly arranged collagen fibres of fascia which results in different pathological presentations. The most significant difference when viewing these tissues through elastography is that pathology in fascia tissues appears soft within firm tissues and muscle tissue pathology appears firm within soft tissues (Ooi et al., 2014a; Shiina et al., 2015).

Historically, detection of pathology in muscle and fascia tissues would be through palpation which is commonly used in a musculoskeletal practice (Rathbone, Grosman-Rimon, & Kumbhare, 2017). The practitioner is, in effect, testing tissue properties by applying a force to deform the tissue and feeling the response (as does elastography). However, palpation can assess qualities of the tissues that elastography doesn't, for example: position of structures, tenderness or non-tenderness response from client, and pulsations. These in turn indicate a possible pathologic or non-pathologic mechanism that is one component in the development of a working diagnosis. Hence, elastography is not a replacement for palpation but an additional tool which has the added value of providing quantitative data.

All palpation is influenced by the bias and skills of the practitioner and is completely subjective (Wells & Liang, 2011) with uncertain reliability. A recent review by Rathbone et al (2017) found moderate inter-rater reliability (Kappa 0.452) in location of myofascial trigger points through palpation, however studies were of low quality and results should be taken with caution (Rathbone et al., 2017). Another recent review by Jonsson et al. (2018), indicated inter and intra-rater reliability of palpation for the assessment of neck pain was, overall, acceptable to very good (Kappa >0.40). Additionally, Jonsson and Rasmussen-Barr (2018) reported higher reliability of palpation in studies where the practitioners were more experienced and held post-graduate qualifications (Jonsson & Rasmussen-Barr, 2018).

Technology may provide greater reliability versus palpation findings in the physical exam. For example; inter and intra-operator reliability of ultrasound was found to be moderate to excellent in a study by Del Bano-Aledo et al (2017) and only slight differences were found when comparing operators with less experience versus those with greater experience (Del Baño-Aledo et al., 2017). Therefore, technology may provide reliable results that enhance diagnostic impressions in a clinical setting even where the practitioners are not trained radiographers, though further research is needed.

Elastography may provide the following advantages: it provides a quantitative measure of tissue stiffness and that may indicate the presence of pathological processes in relation to stiffness. However, it does not replace palpation due to the many other pathological conditions that palpation may find. For example, as described above, these may include interaction with the client in regard to pain response, pulsations, and positioning of surrounding structures, and additionally may include detection of stiffness borders or nodules which require immediate medical assessment. Early diagnosis of pathological processes is an important factor in the physical examination as timely treatment may provide significant benefits to the client, and wider community, and is an expectation of the primary care provider in New Zealand.

This Masters project aims to investigate the usefulness of elastography to quantifiably measure fascia tissues in a musculoskeletal setting using a mixed method approach involving a narrative review and a survey. We selected a narrative review (versus a systematic review) to allow greater flexibility in searching the literature for possible plausible evidence of elastography use to quantitatively measure fascia tissues. According to Greenhalgh et al (2018), narrative reviews may provide the reviewer greater flexibility to be more interpretive of the existing literature without the stringent guidelines of a systematic review (Greenhalgh, Thorne, & Malterud, 2018). However, all reviews should maintain sufficient robustness to be of sufficient reliability (Greenhalgh et al., 2018). A survey of diagnostic ultrasound was implemented to gain an impression of the use and beliefs of elastography type technology in a musculoskeletal setting. Musculoskeletal practitioners in New Zealand that are licensed include: rheumatologists, musculoskeletal or sports doctors (MSK/sports doctors), chiropractors, osteopaths, and physiotherapists and therefore these professions provided the target population included for this study.

Finally, the two components of this study are combined and assessed to investigate the research questions, which are:

1. Is elastography a potentially useful tool to help the musculoskeletal practitioner quantify stiffness in fascia tissues in a practice setting.
2. What are the beliefs of musculoskeletal practitioners in New Zealand of diagnostic ultrasound use by both users and non-users with the assumption that this technology is an acceptable substitute of elastography use?
3. What are the strengths, weaknesses, challenges and potential protocols of implementing elastography into a musculoskeletal setting.

CHAPTER 2

REVIEW

Methods

The genesis of this review was to investigate how fascia tissues can be measured for research or diagnostic purposes in a clinical setting. Further, a scoping search identified elastography (an ultrasound type technology) as the most likely technology to provide quantitative data of fascia tissues and have the required potential utility in a musculoskeletal practice setting.

The protocol for this review has been designed following the PRISMA-P 2015 checklist for systematic reviews (Shamseer et al., 2015) even though the review is a narrative review. A search was conducted of titles and abstracts through SCOPUS, MEDLINE, CINAHL, and Google Scholar databases with filters applied to the advanced search function on each database and included: studies published between 2005 and 2019/current; clinical studies; participants over 18yrs old; human; and English.

The search strategy was designed following the Cochrane Handbook for systematic reviews of interventions (Higgins and Green, 2008) (Fig. 2.1) using keywords identified from the search table below (Table 2.1) that were used to develop search strings as presented below. The search was conducted by the principle investigator with search results checked by the primary supervisor and with discrepancies solved through discussion plus the inclusion of the secondary supervisor. If there was dispute for paper inclusion or exclusion through this process the primary supervisor would make the final decision. Hand searches were conducted of reference lists of studies that were presented at the Fifth Fascia Congress (attended by author in Berlin, November 2018). Finally, a recognised researcher of fascia tissues was emailed and invited to scan the selected article list and asked if there were other articles or authors that may be considered for inclusion – Box 2.1.

The goal of the review was to investigate elastography usefulness to acquire quantitative data of fascia tissues in a musculoskeletal setting. Results of the review are presented as a narrative review in this chapter and then discussed along with the results of the survey component of this project in the discussion chapter.

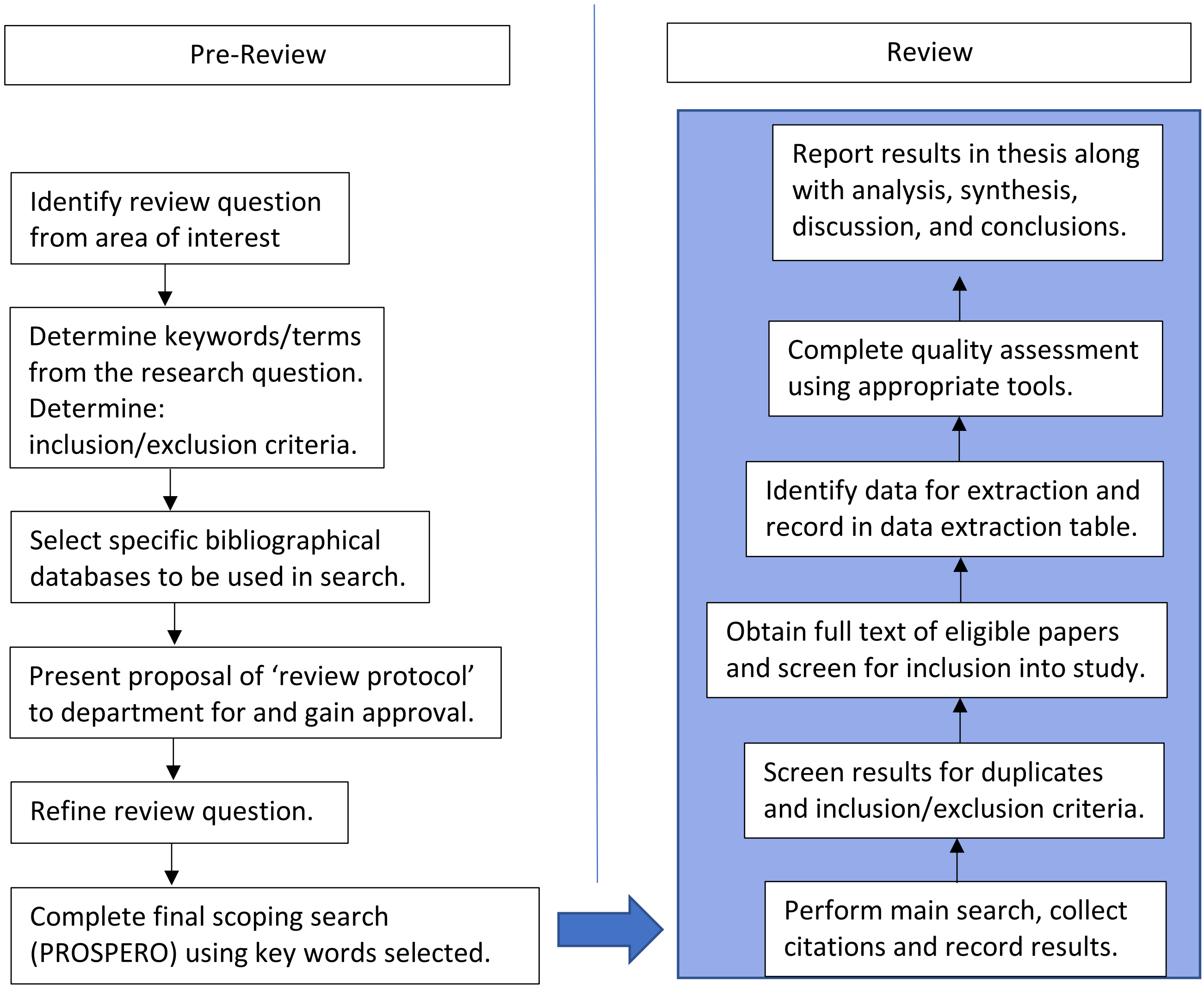


***Fig. 2.1.* Stages involved in review**

Defining the review question.

Fascia tissues are thought to play a key role in musculoskeletal function (Avila Gonzalez et al., 2018), including: support of muscles and viscera, force transduction, elastic recoil for movement dynamics, and an intricate role in 'loose connective tissue' transportation.

Fascia tissues differ from muscle tissue. Specifically, fascia is a non-contractile tissue that is derived almost exclusively of collagen fibres, however it functions in conjunction with all other musculoskeletal tissues and has its own physiologic role as described previously. Therefore, this review aims to investigate fascia tissues exclusively and, where reasonable to do so, will exclude all other musculoskeletal tissues.

As described previously, elastography is an ultrasound type technology that may potentially provide quantitative data as to the elastic modus of musculoskeletal tissues (Creze et al., 2018) and may potentially be used in a musculoskeletal setting. However, before introducing elastography into clinical practice, it is important to establish the validity and reliability of this technology, and hence, a review of the literature to assess elastography usefulness to provide quantitative data of fascia tissues was undertaken. Elastography type technologies include:

- Strain imaging.
- Shear wave elasticity imaging.
- Supersonic shear imaging.
- Acoustic radiation force impulse imaging.
- Magnetic resonance elastography.

Key words/terms.

Key terms from the above question were determined as:

"Is *elastography* type technology useful for *quantifying* the *characteristics* of *fascia tissues*?"

A table of all possible key words was developed (Table 2.1) for use in the scoping review before refining search terms applied to the review.

Table 2.1. Key Word Grid

Ultrasound	Musculoskeletal	Elasticity	Characteristics	Tendons
Elastography	Tissues	Density	Fascia	Ligaments
Sonoelastography	Skeletal	Deformability	Myofascia	Superficial
Imaging	Palpation	Hardness	Thickness	Deep
Subcutaneous Tissue	Manual Therapy	Fascial Manipulation	Connective tissue	Orthopaedic Assessment
Sonograph	Morphology	Displacement	Muscles	Architecture
Stiffness	Shear	Densification	Strain	Properties
Echogenicity	Real Time	In *vivo*	Aponeurosis	Collagen Fibres

From the above table, strings of search terms (with wildcards and truncation) to be used in the MEDLINE, SCOPUS, and CINHL databases were determined as:

String One: Sono* OR Elasto* OR Ultraso* OR 'shear wave' OR Acoustic

String Two: Quanti*

String Three: Characteristics OR Morpholog* OR Anatom* OR Architecture

String Four: Fascia* OR Myofascia* OR "connective tissue" OR "musculoskeletal tissue" OR Tendon OR Ligament

The search string for Google Scholar was determined as:

String: elastography sono quantitative fascia

Inclusion/exclusion criteria.

Studies were included if they: a) were published in English, after 2005, and from a peer reviewed journal; b) involved *in vivo* quantitative reporting of the morphological characteristics of fascia tissue that has been gained using elastography type technology; c) it was a clinical trial; d) involved participants who are over 18 years of age (Table 2.2). Studies included either pathological or non-pathological tissues and have comparisons with other imaging modalities.

Table 2.2. Inclusion and Exclusion Criteria

Inclusion Criteria	
Types of studies	Published after 2005 in peer review journals.
	English only.
	Papers that involve quantitative data reporting, including: papers that use qualitative reporting on quantitative data; and, qualitative reporting as part of a mixed methods study.
Types of participants	Adults (>18yrs old)
	Pathologic and non-pathologic musculoskeletal tissues.
Types of intervention	Use of elastography to gain quantitative data.
	In research or private setting.
	In *vivo.*
Types of comparisons	May include any type of comparison (e.g. MRI, Second Harmonic Microscopy, pain scale instruments).
Types of outcome measures	Any tissue morphological characteristics including: elasticity, density, densification, and thickness. Additionally, any comparative technology including: MRI, CT, Pain Instruments, Orthopaedic tests, other testing.
Exclusion Criteria	
Types of studies	Non-English language.
	Published before 2005.
	Grey literature and non-published peer review articles.
	Dissertations/theses.
	Non full-text articles.
Types of participants	Children (<18yrs old).
	Non-musculoskeletal tissues (including organs).
	Non-human or Cadavers
Types of outcome measures	Commentaries, opinions, non-quantitative data.

Publication and language bias may affect papers selected in any review. This review involves multiple databases and is of peer reviewed journals which, although it does not exclude bias, helps mitigate bias at an editor/journal level (Carroll, Toumpakari, Johnson, & Betts, 2017).

Databases.

Four databases were selected to provide wide search parameters and to account for different database platforms. MEDLINE is an international biomedical database that uses

MeSH headings when conducting systematic or scoping reviews. CINAHL is the Cumulative Index for Nursing and Allied Health which contains content for nursing and allied health professions. CINAHL uses MeSH subject headings similar to MEDLINE but may have content not found in MEDLINE. SCOPUS is a multidisciplinary database for: social sciences, life sciences, physical sciences, and arts and humanities. Additionally, SCOPUS may provide greater coverage of European journals versus the American based MEDLINE and CINAHL. Additionally, a Google Scholar search for articles was included at the amendment stage of the thesis using the search string: elastography sono quantitative fascia, with limits on year of publication being 2005-2020.

Table 2.3. Databases and Platforms

Database	Platform
CINAHL – used in main search	EBSCO host (wildcard = *)
Medline – used in main search	Ovid (wildcard = *)
Pubmed	www.ncbi.nlm.nih.gov/pubmedhealth/
Cochrane	www. onlinelibrary.wiley.com
SCOPUS – used in main search	www.service.elsevier.com (wildcard = *)
Google Scholar	www.scholar.google.com

Scoping search.

A preliminary literature search was conducted using the keywords and databases identified above. Additionally, a review of the PROSPERO (international prospective register of systematic reviews) and of articles presented at the Fifth International Fascia Congress in Berlin was conducted. This review was not registered with PROSPERO as it did not fit the criteria of being a systematic review.

A search of the PROSPERO database using broad keywords (fascia, elastography, imaging, ultrasound, musculoskeletal) found no similar reviews were being conducted (Table 2.4).

Table 2.4. Results of scoping search through the PROSPERO database for prospective registered systematic reviews in health and social care.

Keywords	Number of reviews	Similar reviews
Fascia	91	none
Elastography	5	none
Fascia Ultrasound	0	-
Musculoskeletal Imaging	3	none

Refine review question.

The final review question was established as:

"Is elastography type technology useful for quantifying the characteristics of fascia tissues?"

Main search.

The main search was conducted during June and July 2019 using the keywords and databases selected above. Initial citations were recorded using the software tool 'Endnote' (https://endnote.com/) and followed the 'PRISMA' reporting protocol (Moher et al., 2015). Additionally, results were matched against searches conducted by the primary supervisor of this Masters thesis.

The main reviewer screened all titles and abstracts and recorded the reason for each excluded article. Discrepancies and/or disputes were resolved through discussion between reviewer and supervisors with the final decision being made by the primary supervisor.

Obtain full text and screen for inclusion.

Full text papers were obtained and individually screened to ensure they meet the inclusion/exclusion criteria before inclusion in the review. A purpose designed "Data Collection Form" was designed for this review – Appendix A. The Data Collection Form recorded data to be included in the summary table, risk of bias assessment, and the strength of the clinical trial.

Data extraction and bias/strength assessment.

The purpose of this review is to investigate the usefulness of elastography to provide quantitative data when assessing fascia tissues. Therefore, each article was assessed for evidence that would help answer the review question. It was determined that important components of each article would include: the population characteristics, the tissues involved in each trial, comparisons within the trial, results, and the authors conclusion. For example, if the trial involved an assessment of interobserver reliability as a primary or secondary component to the trial, this data would be included in this narrative review.

In summary, the extraction table had the following titles:

- Author/Title
- Population
- Technology used
- Tissues involved
- Comparisons
- Results
- Authors conclusions
- Bias and strength assessment

Assessment of bias was based on the Cochrane method for assessing clinical trials (Higgins et al., 2011). Articles were assessed for internal validity through examination of the protocols used to assess selected tissues, the experience of the examiners, and the blinding of examiners when comparative studies were involved. External validity was determined to be acceptable if the protocols and results could be emulated outside the research setting (i.e. could the study protocol be used in a musculoskeletal setting) and the author's conclusions were consistent with the study results. For example, due to the *in vivo* nature of elastography, emphasis was placed on methods determining pathological or non-pathological tissues (if appropriate) rather than blinding of participants. A purpose designed form based on the Cochrane method was implemented – Appendix B.

Strength of articles was based on the GRADE system for assessing evidence (Schunemann et al., 2016). The GRADE approach rates randomized controlled trials (RCT's) as having greater strength than observational studies. This review selected only RCT's. However, if the trial had poor reporting of methods or incomplete presentation of results the strength of the study would be reported as a lesser strength. A purpose designed form based on the GRADE system was implemented – Appendix B.

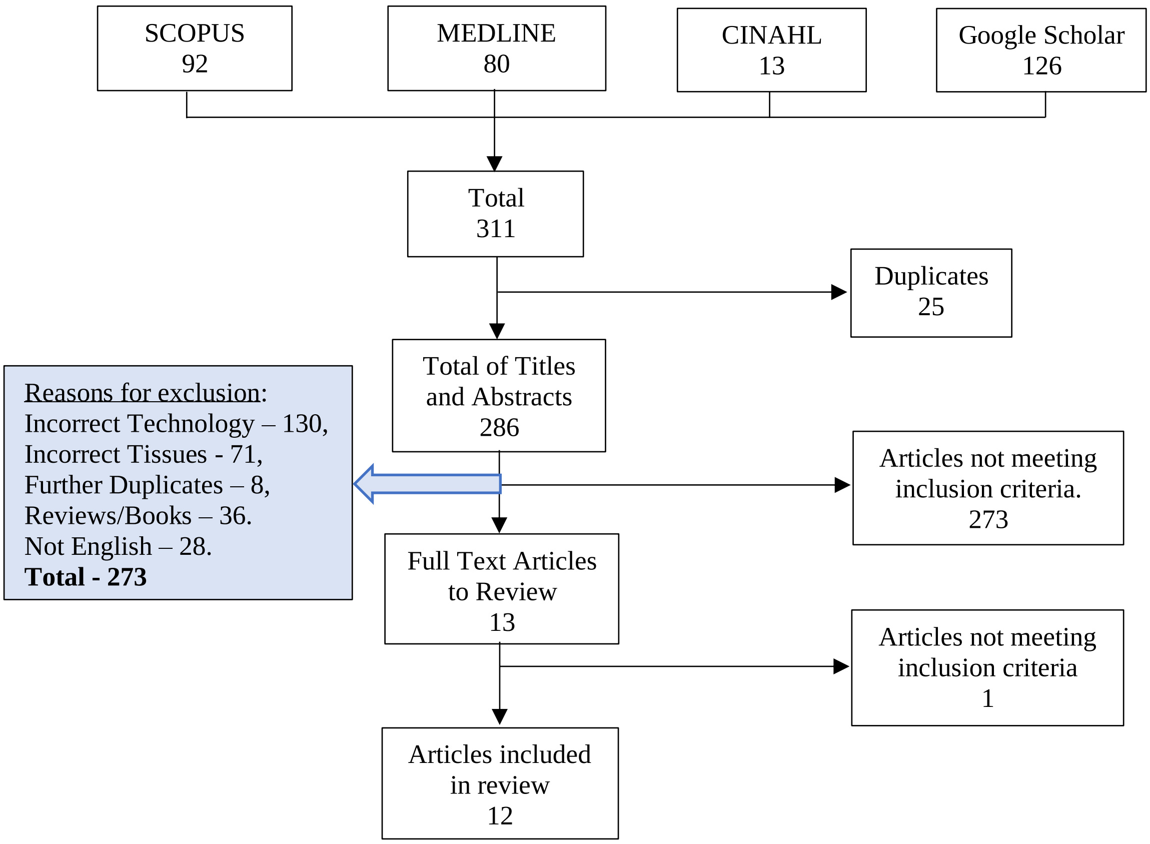
Reporting.

The review will be presented in the thesis of this project. Review results are presented separately within one chapter, along with the second component of this project (survey), however both components of this project are synthesized in the discussion and conclusions chapters.

Results

The literature search in the three selected databases identified 311 articles that may be relevant to this review (Figure 3.12). Following the removal of duplicates, the titles and abstracts of 286 articles were screened against the inclusion and exclusion criteria. The most common reason for exclusion was the use of incorrect technology with ultrasound being the most common incorrect technology used (130:273, 48%) (Table 3.8).

Fig 2.2. **Flow Chart of Review**



Thirteen full text articles were retrieved for further review and one article (Ooi, Malliaras, Schneider, & Connell, 2014b) failed inclusion due to the article being a review and not a clinical investigation. Twelve articles were selected for inclusion to the review (Alsiri, Al-Obaidi, Asbeutah, & Palmer, 2020; Sébastien Aubry et al., 2015; Gatz et al., 2020; Khodair, 2020; Li, Zhang, Cai, & Hua, 2018b; François Petitpierre et al., 2018; Sahan, Inal, Burulday, & Kultur, 2018b; Turo et al., 2013; Wu, Chang, Mio, Chen, & Wang, 2011; Yamamoto et al., 2016; Yoshida et al., 2017b; Zhang et al., 2018b). No further articles were included from grey searches of the Fifth International Fascia Congress proceedings, or from a direct email to a prominent fascia researcher, Dr Tom Findley (Box. 3.1).

Table 2.5. Reasons why articles removed from initial database search

Number of Articles Removed	Reason for Removal
130	Incorrect Technology - Ultrasound
15	Incorrect Technology other than Ultrasound - MRI, CT, Biopsy, Orthopaedic testing, Monometry, Myography, Callipers
71	Incorrect Tissues – Cadavers, Vocal cords, Muscle, Liver Fibrosis, Phantom Tissues
8	Non-Human Tissue – Rabbits, Pigs
8	Duplicates
36	Reviews or Book Chapters
28	Non-English language

Box 2.1. Email to Fascia Researcher

Email Sent: 12/07/2019

Dear Sir,

Re: Is Elastography useful for gaining quantitative data of fascia tissues in a musculoskeletal setting?

I am currently completing a Masters project (University of Otago, New Zealand) looking at the usefulness of Elastography to investigate fascia tissues in a musculoskeletal practice setting. I have identified seven articles that meet the inclusion and exclusion criteria (please see attached) through a systematic search for a narrative review. The review is limited to clinical trials using Elastography and fascia tissues, however all articles involve tendons and none involved other fascia tissues.

I would be grateful if, after a quick view of articles, you could recommend any other relevant studies and/or any other studies that involve fascia tissues outside of tendons.

Thank you for your help and the sessions you provide through the Fascia Society.

Sincerely

Matt Short

***Response:** 13/07/2019*

"Matt

Raul Martinez in Madrid has been working with elastography for ten years

I think your clinical trials criteria is too strict to get anything other than tendons, for which the science is more advanced"

The twelve articles included in this review were published between 2011 and 2020 with seven of the 12 being published in the last three years. Seven articles involved shear wave elastography and five involved axial strain elastography. The most common region of interest was the Achilles tendon and the most common comparisons were pathologic tissues versus healthy volunteers, however, multiple tools were used to determine the pathologic group (e.g. pain scales, MRI, Blood samples). Multiple studies used healthy tissues only to investigate: different zones of the region of interest in dorsal and planter flexion; use of an acoustic coupler (gel pad); and to examine intra and inter-rater reliability. The most common technology utilised was Aixplorer US system (SuperSonic Imagine S.A., Aix-en-Provence, France) and the metric used for reporting included: four shear wave velocity (m/s); three shear wave pressure (kPa); and seven colour maps (bookmarked with red = firm, blue = soft). Finally, in the nine articles that commented on effectiveness of elastography to determine pathological from non-pathological tissues, all authors concluded that elastography can quantitatively detect differences in tissue stiffness and hence pathologic from non-pathologic tissues.

Table 2.6. Summary of components of articles selected in review

Article publication range	Shear wave/axial elastography	Region of interest of study	Comparisons	Metrics used
2011 – 2020 (2011 x1, 2015 x2, 2016 x1, 2017 x1, 2018 x4, 2019 x1, 2020 x2)	Shear wave = 7 Axial strain = 5	Achilles tendon = 7 Shoulder tendons = 6 Knee = 1 Gastrocnemius = 1 Planter Fascia = 2 Muscles = 5	Healthy vs Pathologic = 9 Non-pathologic only = 3	m/s = 4 kPa = 3 Colour map = 7

Assessment of article strength and bias.

The assessment of article strength and risk of bias was determined by following the guidelines of the GRADE system (article strength) and Cochrane protocols (article bias). The criteria for this review put emphasis on: methodology describing how pathological subjects were determined from healthy subjects; experience of operators; clear description on how data was recorded and metrics used; protocol of scanning; and reporting of results – Appendix B.

Major findings.

Most articles included in this review investigated the use of elastography to quantitatively measure tendons with one article including elastography to measure muscle. There was a range of tendon morphology investigated which included tube-like structures, such as the biceps tendon, and the sheet like structures, such as the Achilles and rotator cuff tendons. All articles illustrated potential protocols for further investigation into quantitatively measuring fascia tissues as well as indicating limitations and future research suggestions (discussed further in next chapter). For example, one paper specifically investigated transducer (or probe) positioning and reported axial scans resulted in lower shear wave velocity (m/s) data than sagittal positioning. Further, two other papers concluded axial positioning would provide more accurate results due to limiting anisotropic effects (discussed further in next chapter).

Conclusions reported in all studies indicated positively that elastography can detect stiffness in tendons and is useful to differentiate between pathological and non-pathological tissues. Elastography sensitivity and specificity were reported in four studies with three studies indicating high sensitivity, specificity and accuracy, and one of these studies reporting "relatively low" sensitivity but high specificity and accuracy. However, most studies reported high sensitivity, specificity, and accuracy of elastography versus ultrasound with better results when combining the two technologies.

Table 2.7. Summary of Bias and Strength Assessment

Article (Author/year)	Strength Rating	Bias rating	Comments
Aubrey et al/2015	●●●○	Moderate	Methods were considered poorly described. No reported blinding of operators. Scans performed by operator with 10yrs experience and good sample size (80 subjects).
Dirrichs et al/2016	●●●●	Low	Methods included random allocation of subjects and blinding of operators. Operators with <5ys experience and good sample size (112 subjects).

Li et al/2018	●●○○	Moderate	No description of where study population came from and relatively small sample size (52 subjects). Operator with > 14yrs experience. No indication of blinding. Data collection unique and well described.
Petitpiere et al/2018	●●○○	Moderate	Small sample group (healthy subjects only: 15) and two operators with 3 and 6yrs experience. ROI determined by operator and no explanation as to how it was determined.
Sahan et al/2018	●●●○	Low	Sample and operators were allocated randomly. Two operators with >10yrs experience. Small sample size (10 subjects).
Yoshida et al/2017	●●○○	High	Methods inadequately described processes of selection and blinding. Impressive use of cadavers to set up study design. Sample size small (33 subjects).
Zhang et al/2018	●●●●	Unclear	Very good methodology with inclusion of study group confirmed through blood analysis. Operators with >5yrs experience and good size study group (66 subjects).
Khodair & Ghieda/2020	●●○○	Unclear - High	No description of; where population came from, what objectives were, tables to illustrate results, and how colour mapping/scores were arrived at. Involved two experienced orthopaedic surgeons for assessment of shoulder pain and follow up with MRI to confirm lesions.
Alsiri et al/2020	●●●○	High	Very poor sample population. Most participants were obese and inactive. Subjects were mostly female and potential subjects that did activity once/week were excluded making external validity very poor.
Gatz et al/2020	●●●●	Low	All components of study were well explained and results well presented. Examination was through experienced orthopaedic surgeon and well tested pain tools.
Wu et al/2011	●●○○	Unclear - Low	Recruitment of population unclear. Study involved two components and overall objective unclear with no hypothesis provided.
Yamamoto et al/2015	●●●●	Low	Very good distribution of population into five groups. Study well explained and results well presented.

Table 2.8. Data Extraction Table

Paper, Year, Authors	Population	Technology Type	Tissues Studied	Comparisons included in Study	Results	Authors Conclusions	Bias Rating/ Strength Rating
Viscoelasticity in Achilles Tendinopathy: Quantitative Assessment by Using Real-Time Shear-Wave Elastography. Aubry et al (2015)	80 Healthy volunteers (mean age 50yrs, M/F – 68/12), and 25 patients (mean age 56yrs, M/F) with uni or bilateral Achilles Tendon tendinopathies.	Shear Wave Study. Aixplorer Supersonic Imagine. 12MHz Transducer.	Achilles Tendon (AT)	Normal versus Symptomatic AT's in relaxed and stretched positions. Probe positioned in Axial (AX) or Sagittal (SG) plane of tendon.	Normal Achilles Tendon: Relaxed – AX; 4.98m/s, SG; 6.61m/s. Stretched – AX; 5.51m/s, SG; 15.75m/s. Symptomatic Achilles Tendon: Relaxed – AX; 4.04m/s, SG; 6.32m/s. Stretched -AX; 4.77m/s, SG; 14.53m/s.	SWE demonstrated quantitative findings of softening in symptomatic versus healthy Achilles tendons in both relaxed and stretched positions. There was no significant difference in sagittal or axial position. SWE was highly specific and moderately sensitive. Axial probe position provides lower stiffness data than sagittal positioning.	Bias score: Unclear Strength score: ●●●○
Shear Wave Elastography (SWE) for the Evaluation of Patients with Tendinopathies. Dirrichs et al (2016)	112 patients with uni or bilateral tendinopathies. Mean age 42yrs M/F – 74/38.	Shear Wave Study. Aixplorer, Supersonic Imagine. 15Mhz Transducer.	Achilles Tendon, Patellar Tendon, Humeral Epicondylar Tendon.	Pathologic versus Non-Pathologic of each of the three tendons. Comparisons with subjective pain instrument for each tendon.	All Three Tendons: Colour Mapping:(Red = Firm, Blue = Soft) Asymptomatic – 69% Red vs 14% Blue Symptomatic – 4% Red vs 57% Blue Quantitative Tendon Rigidity (m/s): Asymptomatic – 9.5m/s Symptomatic – 4.48m/s Observed difference was stronger in Achilles and patella group vs Humeral Epicondylar group.	Tissue rigidity, as assessed by SWE, corresponds strongly with clinical symptom scores. SWE helps to significantly aid diagnosis of tendinopathies.	Bias score: Low Strength score: ●●●●
Patients with Achilles Tendon Rupture Have a Degenerated Contralateral Achilles Tendon: An Elastography Study. Li et al (2018)	19 asymptomatic volunteers: Mean age 35yrs; 14 Male. 33 unilateral Achilles Tendon rupture patients: Mean age 35yrs; M/F – 14/5.	Axial Strain Elastography Study. Hi Vision Ascendus System. 18MHz Transducer.	Achilles Tendon (AT)	Contralateral side of patient with AT rupture and comparison with healthy controls. Three areas of interest: proximal, middle, and distal area of tendon.	Hmean scores for contralateral side vs controls. (Hmean = computer generated score from calculating hue values of colour map data, 0 = soft – 6 = hard) Controls: Prox. – 50, Mid. – 45, Dist. – 43 Versus Contralateral side to AT rupture: Prox. – 43, mid. – 42, Dist. - 43	In patients with AT ruptures, the contralateral AT are softer than healthy controls at the proximal third of the asymptomatic tendon.	Bias score: Unclear Strength score: ●●○○
Quantitative elastography of Achilles tendon using Shear Wave Elastography (SWE): correlation with zonal anatomy. Petitpiere et al (2018)	15 asymptomatic volunteers. M/F – 7/8. Mean age 30yrs.	Shear Wave Study. Aixplorer Supersonic Imagine. 15 MHz Transducer.	Achilles Tendon (AT)	Data collected from four points of the AT: musculo-tendinous junction (MTJ); body area; pre-insertional area (PIA); and enthesis. Measures taken in dorsal flexion and planter flexion. Interobserver reproducibility of two radiologists.	AT stiffness increases from MTJ to enthesis in all four AT points. Higher stiffness is recorded in dorsal flexion than planter flexion in all four points. Higher stiffness is recorded with the transducer in sagittal position verses axial plane position in all four AT points. There was no significant difference between the two radiologists.	When using SWE to assess AT stiffness it is important to have the tendon in planter flexion and the transducer in a sagittal plane. AT stiffness increases significantly, when using SWE, from the MTJ to the enthesis. This study showed perfect interobserver correlation in planter flexion and very good correlation in dorsal flexion.	Bias score: Unclear Strength score: ●●○○

Evaluation of tendinosis of the long head of the biceps tendon by strain and shear wave elastography. Sahan et al (2018)	20 asymptomatic volunteers. Mean age 48yrs. 20 symptomatic patients. Mean age 55yrs. Even split of male and female in both groups.	LOGIQ E9 Sonographic system with elastographic software. 15MHz Transducer	Long Head Biceps Tendon (LHBT)	Pathologic tendinous of the LHBT as confirmed by MRI versus non-pathologic LHBT as confirmed by MRI. SWE, SE, and MRI comparisons for sensitivity and specificity.	<u>Strain Elastography</u> (SE) Diagnosed LHBT tendinosis group indicated 75-90% of colour map in Blue/Blue-Green (indicating softness). Non-pathologic group indicated 90% of colour map in Green/Green-yellow-red (indicating stiffness). <u>Shear Wave Elastography</u> (SWE) Diagnosed LHBT tendinosis group = 39kpa (indicates softness). Non-pathologic group = 19kpa (firm). 100% sensitivity and specificity of SWE with transducer in transverse plane.	When diagnosing tendinosis of the LHBT, SE and SWE can be diagnosed with very high sensitivity and specificity, close to MRI diagnostic values.	Bias score: Low Strength score: ●●●○
Application of Shear Wave Elastography for the Gastrocnemius Medial Head to Tennis Leg. Yoshida et al (2017)	33 subjects with Tennis Leg. M/F - 22/11. Mean age 32yrs. 15 subjects aged below 30yrs. 18 subjects aged above 30yrs.	ACUSON S3000 Ultrasound System. 9MHz Transducer	Gastrocnemius medial head aponeurosis.	Data collected at three points: musculo-tendinous junction (MTJ) of the gastrocnemius medial head; 10mm proximal to MTJ; 10mm distal to MTJ. Comparisons made between below and above 30yrs, and between male and female.	<u>Overall group</u> Proximal to MTJ – 2.82m/s. Central to MTJ – 3.43m/s. Distal to MTJ – 4.83m/s. <u>Below 30yrs</u> Proximal to MTJ – 2.88m/s, Central MTJ – 3.44m/s, Distal to MTJ – 4.72m/s. <u>Above or equal 30yrs</u> Proximal to MTJ – 2.76m/s, Central MTJ – 3.42m/s, Distal to MTJ – 4.93m/s. <u>Male vs Female</u> Proximal to TMJ: M- 2.79m/s, F- 2.87m/s, Central TMJ: M- 3.51m/s, F- 3.28m/s, Distal to MTJ: M- 5.15m/s, F- 4.19m/s.	SWE can measure elasticity of the aponeurosis in the MTJ of the gastrocnemius medial head. Greater stiffness is reported at the distal point of the aponeurosis. There is no significant difference between age groups of <30yrs and > 30yrs, however there is a significant lower stiffness in female versus male gastrocnemius medial head aponeurosis.	Bias score: High Strength score: ●●○○
Grayscale ultrasonic and shear wave elastographic characteristics of the Achilles tendon in patients with familial hypercholesterolemia: A pilot study. Zhang et al (2018)	47 patients with familial hyper-cholesterolemia. M/F - 21/26. Mean age 32yrs. 19 normal participants. M/F – 9/10. Mean age 28yrs.	AixPlorer SuperSonic Imagine. 15MHz Transducer.	Achilles Tendon (AT).	Data collected at three points: proximal segment at the musculo-tendinous junction; middle segment; and distal segment at the insertion of the heal.	<u>Familial Hypercholesterolemia Group</u> Proximal – 295kpa, Middle – 281kpa, Distal – 282kpa. <u>Normal Participants</u> Proximal – 418kpa, Middle – 426kpa, Distal – 408kpa.	SWE can quantitatively measure the mean elasticity modulus of the proximal, middle, and distal segments of the AT. The mean elasticity modulus is significantly different in healthy AT's versus AT's in the familial hypercholesterolemia group.	Bias score: Unclear Strength score: ●●●○
Rotator Cuff Tendinopathy; Comparison Between Conventional Sonography, Sonoelastograhy, and MRI in Healthy Volunteers and patients with Shoulder Pain. Khodair and Ghieda (2020)	40 patients with shoulder pain (mean age 48yrs, M/F 22/18) and 40 healthy volunteers (mean age 40yrs, 22/18).	Axial Sonoelastography, B-Mode US, and MRI. Logic S7 expert – GE.	Rotator cuff tendons: Biceps T., Supraspinatus T., Infraspinatus T., Teres Minor T.	Symptomatic shoulder pain verses healthy controls. Additional comparison of; specificity, sensitivity, and accuracy, of sonoelastography and B-mode ultrasound. MRI used as gold standard to detect lesions.	Using subjective colour mapping and reporting using strain ratio and strain index this study indicated that: B-mode ultrasound; 85% sensitivity, 95% specificity, 90% accuracy, verses Sonoelastography; 95% sensitivity, 100% specificity, 97.5% accuracy.	Sonoelastography shows better sensitivity, specificity, and accuracy for rotator cuff tendinopathy however due to compounding artefacts in shoulder pathology sonoelastography together with ultrasound provides greater results.	Bias score: Unclear – high Strength score: ●●○○
Shear Wave Elastography (SWE) for the Evaluation of Patients with Planter Fasciitis.	31 subjects with Planter Fasciitis (mean age 50yrs, M/F 16/38 Planter	Shear Wave Elastography, Aixplorer, Supersonic	Planter Fascia	Comparisons of symptomatic and asymptomatic Planter Fascia using SWE and ultrasound.	B-Mode US: Sensitivity 61%, Specificity 95%, Accuracy 79%. SWE: Sensitivity 85%, Specificity 83%, Accuracy 84%.	SWE improves Planter Fascia accuracy of symptomatic and asymptomatic patients in comparison to B-Mode US.	Bias score: Low

Gatz et al (2020)	Fasciitis) and 10 healthy volunteers (mean age 30ys, M/F 5/5).	Imagine – 18Hz transducer.			B-Mode US & SWE combined: Sensitivity 100%, Specificity 81%, Accuracy 90%.	However, combined results are greater still.	Strength score: ●●●●
Sonoelastography of the Planter Fascia (PF). Wu et al (2011)	20 Younger Volunteers (mean age 31yrs, M/F 10/10). 20 Older Volunteers (mean age 55yrs, M/F 10/10). 13 symptomatic patients 9mean age 50yrs, M/F 6/7).	Ultrasound and Strain Elastography, Acuson S2000 US system – 12Hz transducer.	Planter Fascia	Three groups consisting of younger healthy subjects, older healthy subjects, and subjects with uni or bi-lateral Planter Fasciitis. Comparisons of thickness via ultrasound and softness via Strain Elastography. Interrater Reliability.	Younger and older asymptomatic groups shared similar thickness scores (2.4 – 2.7) versus symptomatic group being significantly thicker (3.7). Using a colour score (from colour mapping) young and old healthy subjects scored 149 and 148 versus the fasciitis group score of 134. Interrater reliability was excellent (ICC 0.765, 95%CI).	There is no difference between age related thickness of the PF however patients with Planter Fasciitis have significant thickening. There is softening of the PF in patients with Planter Fasciitis.	Bias score: Unclear – low Strength score: ●●○○
Quantitative Ultrasound Elastography With an Acoustic Coupler for Achilles Tendon Elasticity. Yamamoto et al (2015)	50 asymptomatic volunteers (mean age 45yrs, M/F 25/25) split into 5 decades (20's – 60's) with M/F 5/5.	Axial Sonoelastography, Hi Vision Preirus, Hitachi – 14Hz Linear probe with acoustic coupler (gel pad) with known Youngs modulus (22.6kPa).	Achilles Tendon	Inter and Intra observer reliability of strain ratios of 5 groups split into 5 decades (20's – 60's). Comparison between two experienced sonographers and findings of subjects in each decade.	High inter and intra-observer reliability. Strain ratio or stiffness of Achilles tendons similar to other studies including greater stiffness in 30's group.	Strain ratio measurement of the Achilles tendon using a gel pad/acoustic coupler is a reproducible method.	Bias score: Low Strength score: ●●●●
Intra-rater reliability and smallest detectable change of compression sonoelastography in quantifying the material properties of the musculoskeletal system. Alsiri et al (2019)	22 asymptomatic volunteers (mean age 35yrs, M/F 4/18).	Strain Elastography, Voluson E8, General Electric – 15MHz transducer. Additionally, an **I**mage**J** processor was used to quantifiably score image pixels by colour.	Deltoid, Biceps Brachii, Brachioradialis, Rectus Femoris, Gastrocnemius muscles, and the Achilles tendon.	Inter-rater reliability of a range of musculoskeletal issues – consisting of five muscles and one tendon (Achilles).	All intra-rater reliability showed moderate to excellent results depending on the morphology and location of the tissue being examined. In general, ICC scores were higher (all in the excellent range) for the Achilles tendon verses muscle tissue when using colour scores from strain elastography.	This study indicates moderate to excellent intra-rater reliability for examining a range of musculoskeletal tissues. Colour pixel analysis indicates more precise and reliable results when compared with strain ratio and strain index. Hence, colour pixel analysis could be used to provide a more precise clinically important data.	Bias score: High Strength score: ●●●○

CHAPTER 3

SURVEY

Methods

A survey was designed to collect data on who uses diagnostic ultrasound amongst a broad group of musculoskeletal practitioners in a musculoskeletal setting. Additionally, the survey investigated the beliefs of users and non-users of diagnostic ultrasound and the demographics of participants.

The survey involved three phases: 1) questionnaire development; 2) distribution and data collection; and 3) data analysis. All three phases were completed using ‘Qualtrics’, version X9 (Qualtrics, Provo, UT), an internet survey tool provided by the University of Otago. This tool allowed for essential components of: design templates, participant anonymity, data collection and analysis, and secure storage. Further, the use of an electronic questionnaire allowed ease of distribution via an email invitation or through a link on a web portal (electronic noticeboard or electronic newsletter).

Due to the involvement of human subjects departmental ethics approval was required and obtained before distribution of the questionnaire (Ref# D18/268) – Appendix E.

Survey development.

The purpose of the survey was to collect data from a broad population of musculoskeletal clinicians who use diagnostic ultrasound, and record their beliefs about its usefulness and application in a musculoskeletal setting. Further, the questionnaire was distributed to a wide target population of musculoskeletal practitioners, being; musculoskeletal/sports doctors, rheumatologists, physiotherapists, osteopaths, and chiropractors. To our knowledge this is the first survey where one instrument (questionnaire) was applied to clinicians from different disciplines as opposed to previous surveys which have been applied to a single profession only.

The aim of the survey was to collect data that identified: who uses diagnostic ultrasound; the beliefs of users and non-users in regard to diagnostic ultrasound use; and the participants demographics. The goal of the questionnaire was to, first and foremost, collect data that measures the goals of the survey (Song, Son, & Oh, 2015).

Good questionnaire design helps to ensure validity of survey results (Edwards et al., 2009). Questionnaires are more likely to be valid if questions are: in a language appropriate for participants; designed to maintain interest in the survey; are of an appropriate duration; and are pertinent to the survey goals. Other factors required in good questionnaire design include: gaining initial consent (including ensuring confidentiality); logically leading the participant through the questionnaire; asking more challenging questions nearer to the beginning of the questionnaire; provide text boxes for qualitative data collection and participant feedback; and be of acceptable duration (Edwards et al., 2009).

An original draft questionnaire was designed following a scoping review of diagnostic ultrasound surveys performed within the target professions. Due to multiple professions comprising the target population the scoping review attempted to find previous surveys in each profession. Unfortunately, the review found appropriate papers only within the Rheumatology (Brown et al., 2007; Larche et al., 2011; Samuels et al., 2010) and Physiotherapy (Ellis et al., 2018; Jedrzejczak & Chipchase, 2008; McKiernan, Chiarelli, & Warren-Forward, 2011; Potter et al., 2012) professions.

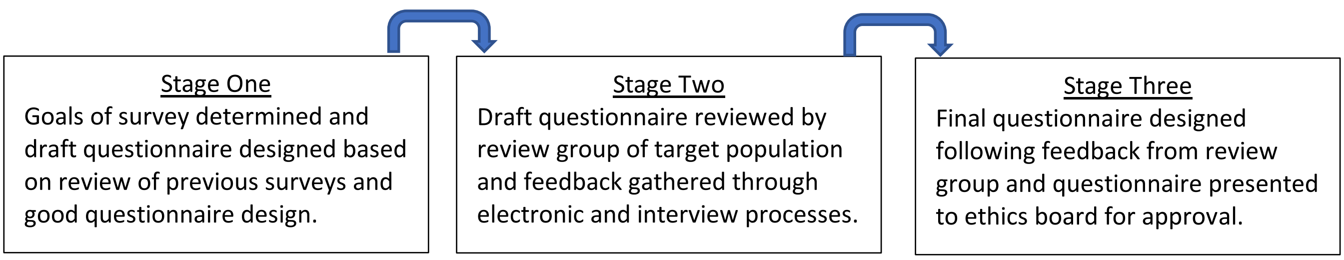


***Fig. 3.1.* Design stages of questionnaire**

An original draft of the questionnaire consisted of 28 items for users and 25 items for non-users. The questionnaire was composed of three parts: did the participant use or not use diagnostic ultrasound images in their practice; what were their beliefs concerning diagnostic ultrasound; and participant demographics. The questionnaire used a variety of responding methods ranging from Likert scales, yes/no tick boxes, sliding scales, and open text boxes to maintain participant interest through the questionnaire.

The draft questionnaire was tested on a review group consisting of two chiropractors, three osteopaths, one MSK/sports doctor, and two physiotherapists. All participants worked from different clinics and were independent from one another. Both physiotherapists used ultrasound in their clinics and one osteopath and one chiropractor infrequently referred out for ultrasound services. Both physiotherapists clinics had ultrasound units in their practice setting and used them frequently as an assessment and rehabilitation tool. Following completion of the questionnaire each reviewer filled out a feedback form (using Qualtrics software) to indicate predetermined themes of acceptable or non-acceptable duration of the questionnaire, relevance of the questions, and logic of questionnaire flow. Additionally, reviewers were invited to comment on the questionnaire in open text boxes. Finally, five practitioners (both physiotherapists, one osteopath, one chiropractor, and one musculoskeletal doctor) were interviewed for feedback and suggestions concerning the draft questionnaire.

Comments from the review group included:

1. There was a need for greater clarity to determine if the participant is deemed a ‘user’ or ‘non-user’. Specifically, some of the group would read reports of diagnostic ultrasound images but not view the images to determine their own impression.
2. Further clarity was required in regard to questions concerning pathological or non-pathological use.

3. Greater clarity concerning the term diagnostic needed. For example, does diagnostic involve: only detection of pathologic or non-pathologic tissues; only used for initial assessment; or may include use for rehabilitation treatment plans.

Feedback of the outside review group resulted in modifications to the draft questionnaire that included:

1. Greater clarity of who are 'users' and 'non-users'. Practitioners who view ultrasound images are 'users' whether they read a report or not. Practitioners who don't view the images are 'non-users' even if they read a report. Question one was modified to read *"Do you use ultrasound images for diagnostic purposes in your practice setting? This would involve viewing ultrasound images for assessment, rehabilitation, or for pathological conditions. It may also involve reading reports but must include viewing of ultrasound images."*
2. More specific wording in questions that investigated diagnostic ultrasound use for diagnosing pathologic or non-pathologic tissues was included in the question seven. For example, question seven/part three, was modified to read "Only useful to confirm suspected pathology *(e.g. Trauma, Growths, Inflammatory Conditions)* – modified text in italics. Additionally, further questions were included to provide data concerning use of diagnostic ultrasound for pathologic or non-pathologic tissues. These were: Q.7/3 *"Able to produce reliable images that indicate changes in non-pathologic and pathologic tissues"* and Q.7/5 *"May be useful to diagnose non-pathologic tissues."*
3. Any assessment where the practitioner was using diagnostic ultrasound to investigate musculoskeletal tissues was considered diagnostic. Procedures that involved diagnostic ultrasound to deliver treatment was defined as non-diagnostic. This mainly

involved needle guidance procedures performed by MSK/sports doctors and rheumatologists.

Feedback on other components of the questionnaire, such as: time to complete questionnaire, ease, flow, and degree of interest were considered as acceptable from the review group.

A final draft of the questionnaire was deemed to satisfy the feedback of the review group and the outcome goals of the survey. The final questionnaire consisted of 29 items for users and 27 items for non-users which is considered a good number of items to help reduce participant fatigue yet still provide sufficient data to achieve the survey goals (Edwards et al., 2009; Song et al., 2015). The survey was implemented over a period of eight weeks which corresponded with the mean duration of previous surveys identified in the scoping review.

Finally, participants interested in receiving a summary of survey results were invited to provide their email address. The invitation also carried the following text to ensure the email address would only be used to disseminate the survey summary: *"NB – your email will be separate from the survey details and only used to disseminate results from this survey."*

Distribution.

Distribution of the questionnaire was carried out over eight weeks and consisted of two primary methods:

1. Direct email of an invitation to participate in the survey through each profession's association (or like body). Access to the questionnaire was through a link contained in invitation.
2. Posting of survey invitation and questionnaire link to the survey on the profession's electronic notice board.
3. Advertisement of survey invitation and questionnaire link on electronic newsletter.

Each professional body of the target population were contacted by email and phone requesting permission to distribute an invitation to the survey through direct email. If direct email invitations were not acceptable to the professional body, placement of an invitation was requested to be placed within a newsletter (if appropriate) and/or an electronic notice board. Additionally, an announcement of the survey from the administrator of the professional body was included in all communications with their members.

After three weeks a reminder was distributed to each profession via direct email or on the electronic notice boards with a final reminder distributed at week six. The survey was closed after eight weeks (56 days). A summary of the distribution of the survey and examples of scripts used for the invitation and reminders are illustrated below (Box 3.1) and distribution to each profession is summarised in table 3.7.

Box 3.1 Rollout, Timeline, and Basic Script for Invitation and Reminders

Week One – 13th August 2018

Initial Invitation

Would you be interested in participating in our survey (click link below)?
The survey will take less than five minutes. The aim of the survey is to collect data from ***users*** and ***non-users*** of diagnostic ultrasound technology. We are looking for participants from a broad population of musculoskeletal (MSK) practitioners (Osteopaths, Chiropractors, Physiotherapists, Rheumatologists, and MSK doctors). Your participation is anonymous, confidential and would be greatly appreciated.

This survey is a Masters project and has gained approval from the University of Otago Ethics Committee (#D18/268). Results are intended for publication.

The survey is administered using 'Qualtrics' – a survey tool that ensures confidentiality. No identifying information is gathered, including: your name, email, or IP address.

Week Four – 3rd September 2018

First Reminder

How this survey may affect you?
This survey has three unique features from other similar studies:

1. The survey participants are from a broad range of musculoskeletal (MSK) practitioners (vs just one). The study proposes that this will provide a general landscape of the use and beliefs of diagnostic ultrasound by users and non-users in the New Zealand MSK practitioners setting and
2. This survey is one part (of two) of an investigation into the use of ultrasound type technology (Elastography) in clinical practice to detect changes in density and elasticity of non-pathologic tissues. This may be of benefit to MSK practitioners to aid diagnostic impressions, rehabilitation progress, and communication between and within MSK professionals.
3. This Masters project is likely to provide a basis for further study, at a Ph.D level, that is intended to investigate how to implement Elastography into a clinical setting – such as yours.

The questionnaire takes less than five minutes and you can access it by clicking the link below.

Again, thank you for your help.

Week Seven – 24th September 2018

Final Reminder

Thank you to the many practitioners who have participated in this survey. Please complete this short survey if you are yet to do so. The more practitioners from each profession that participate, the greater the validity of the between profession results we can find. Currently, it would be great to have just 10 more from each profession.

Thanks for your help.

Week Eight – 12th October 2018

Survey Ends

All professional associations were asked to distribute the invitation to the survey to their members. Three professions directly emailed their members an invitation (with an endorsed message), one profession displayed the invitation on their website notice board, and one profession included the invitation (with an endorsement) into their monthly newsletter as well as displaying it on their website notice board (Table 2.7).

Table 3.1. Distribution of Questionnaire by Profession

Profession	Invitation (13th August, 2018)	First Reminder	Final reminder
Musculoskeletal and Sports Doctors	Received email invitation with endorsed message from member of their association.	Email sent in or around week four.	Email sent in week seven.
Rheumatologists	Received email invitation from chairman of association.	Email sent through association in week four.	Email sent through association in week seven.
Physiotherapists	Invitation to participate in survey displayed on notice board of association web-site. Additionally, fourteen Physiotherapy clinics were directly invited to participate in survey.	Change of text on Physiotherapy web-site notice board acting as a reminder in week four.	No change to text on notice board.
Osteopaths	Invitation to participate in survey placed on Association web notice board.	Invitation included in Osteopaths Association monthly newsletter – 1st October (week six).	
Chiropractors	Invitation was directly emailed to members of the Chiropractic Association.	First reminder email was direct emailed to members.	Second/final reminder direct emailed to members.

Data collection and storage.

Data collection and storage was provided through Qualtrics software. Qualtrics is a password protected software that automatically stores its content on a cloud server. Finally, results are presented, along with all components of this project, in a thesis document that is stored in the Otago University Research Archive in accordance with Otago University procedures.

Analysis.

Data from completed questionnaires were analysed through descriptive statistics by each profession and as a combined study group. Descriptive statistics are effective in summarising characteristics, or central tendencies, of the groups which then allows for further analysis (Barkan, 2015). Further, descriptive statistics and percentage values offer easy yet appropriate measures of trends and themes of the professions individually and collectively to help answer the study question. Trends identified as pertinent to the research question were:

1. The number of users and non-users.
2. Who, by profession and demographics, are the users of diagnostic ultrasound.
3. The beliefs of users and non-users separately, and by profession.

Finally, power indication was calculated using Raosoft sample size calculator (www.raosoft.com/samplesize.html) and input of potential responders. Parameters were set at 10% error margin, 95% confidence interval, and 50% response distribution. Comparison of required sample size and actual responders were made to assess validity of trends, and hence, external validity of results.

Results are presented in this chapter (below) however these results are synthesised with results from the review and presented together in the discussion and conclusion chapters.

Results

The goal of the survey was to collect data from musculoskeletal practitioners concerning the use and beliefs of diagnostic ultrasound (dxUS) in both users and non-users. The questionnaire was formatted into three sections: number of users and non-users, and their use or reasons for not using dxUS; beliefs in usefulness or potential usefulness by users and non-users; and, demographics of all participants.

Response.

One hundred and seventy-two responders opened an email invitation to participate in the survey. One responder chose not to participate and 14 did not complete the questionnaire past question one. There was no comment from the respondent who elected not to participate even though there was an open text box available. There was no provision for comment by the 14 participants discontinuing at this stage.

Chiropractors provided the highest number of participants (n=87/386: 22.5%) which provides a good representation of their profession and validity of results. A possible reason for the very good response was the invitation was directly emailed to members of the Chiropractic Association with an endorsed message from the Association secretary.

Musculoskeletal and sports doctors (MSK/sports doctors) provided the highest response rate (49%) which suggests a good representation of their profession and validity of results. The high response rate is possibly due to the invitation being sent via a respected colleague who endorsed the study in a direct emailed invitation.

Rheumatologists provided a good response (n=11/100: 11%). Members of the Rheumatology Association were directly emailed an invitation to the survey, however unlike the chiropractic and MSK/sports doctors groups there was no endorsement of the study. The response rate of 11% may be an acceptable representation of rheumatologists use and beliefs and provide valid results provided the study design and questionnaire display good rigour

(Morton, Bandara, Robinson, & Carr, 2012). Further, it may provide data that can be compared with other like surveys where higher participant numbers were achieved through conferences and direct email invitations from members of their profession.

Osteopaths provided an adequate number of participants (n=30, response rate unknown). In this group there was no direct invitation to the members of their association. The invitation was displayed on the Osteopathic Association web notice board and included in an electronic newsletter. Approximately 20 participants came from the newsletter invitation. It is not possible to assess the number of osteopaths who may have viewed either the notice board or newsletter invitation therefore it is not possible to assess a response rate. According to Morton et al (2012) 30 participants may provide valid results if there is sufficient rigor in the survey design (Morton et al., 2012). Finally, there are no other studies of ultrasound use and beliefs in the literature for Osteopaths therefore these results are the first representation of this profession's views.

There was a poor response from physiotherapists (n=4, response rate unknown). The only invitation to the survey was placed on the Physiotherapy Association web notice board. The views of four physiotherapists does not represent the profession hence these results are deemed unreliable and cannot be used to compare physiotherapists views with other professions in the study. Fortunately, a recent study by Ellis et al (2018) (Ellis et al., 2018) collected data from 415 participants (response rate 9%) concerning many of the same themes of this study, including; number of users and non-users, demographic data on these two groups, and beliefs concerning costs and implementation (amongst other themes not included in this study – e.g. beliefs about training and barriers to use). Further, participants were New Zealand registered physiotherapists who were the same group invited to this survey. Data from the Ellis et al (2018) study will be referred to in the discussion of this paper as well as being included in the demographic data analysis.

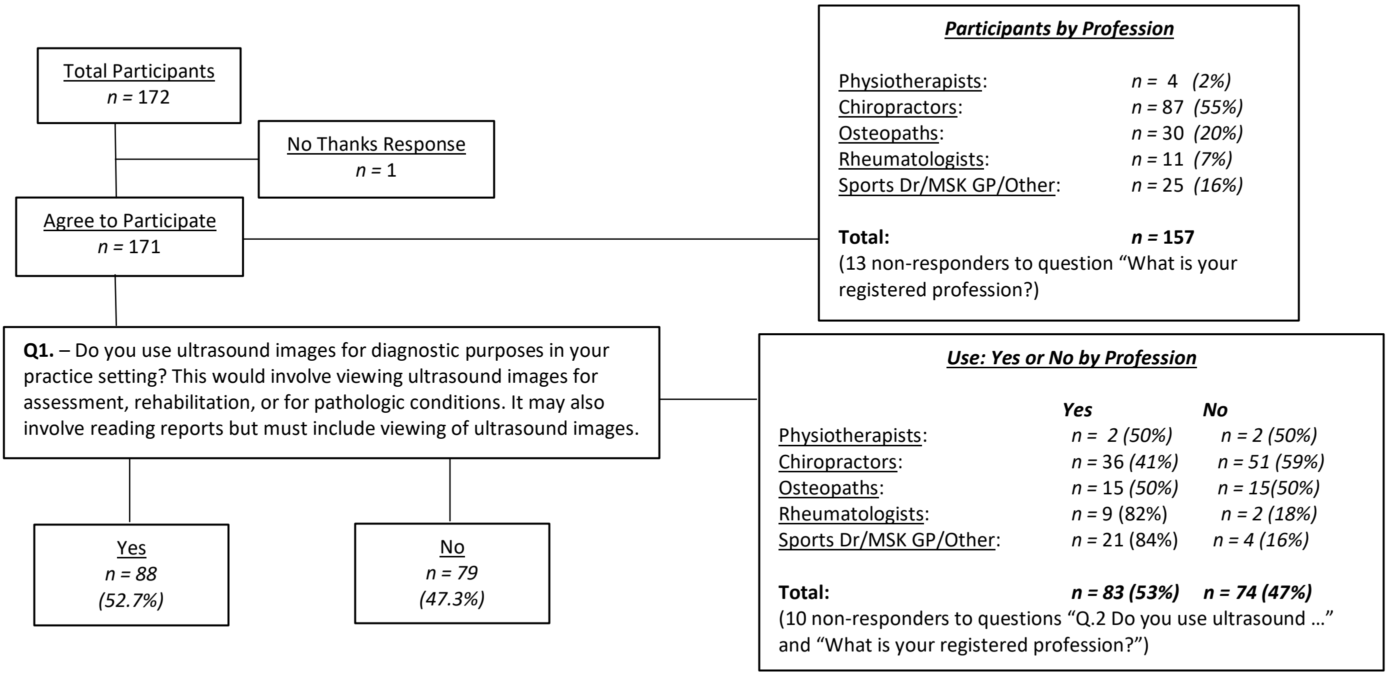


Fig. 3.2. **Summary of Participants, Use, Non-Use, and Professions**

Invitation and response.

As described previously, an invitation to participate was direct emailed to members by rheumatologists (n = 100), sports/MSK doctors (n = 51), and chiropractors associations (n = 386) which represent a known number of invitees. Invitations to osteopaths and physiotherapists association members were through electronic notice boards and an electronic newsletter which does not allow an accurate way of determining the number of potential invitees. Therefore, the response rate was calculated using the number of known potential invites (n=537) by the number of responses (n=123) and equates to 23% (Table 3.1).

Table 3.5. Invitation and Response Rate

Profession	Invitation Type	Possible Responders	Responders	Response Rate
Rheumatologists	Direct Email	100	11	11%
Sports/MSK Drs	Direct Email	51	25	49%
Chiropractors	Direct Email	386	87	22.5%
Osteopaths	Posted on Web Notice Board and electronic Newsletter	Unknown	30	Unknown
Physiotherapists	Posted on Web Notice Board	Unknown	4	Unknown

Users and non-users.

Over half of the participants used ultrasound images for diagnostic purposes (53%). By profession, over 80% of rheumatologists and MSK/sports doctors use ultrasound images, while half of the osteopath participants and over 40% of chiropractors use ultrasound images for diagnostic purposes (Table 3.2).

Table 3.6. Diagnostic ultrasound use by profession, users and non-users

Participants, Users, or Non-users by Profession

	Total *(% study)*	***Users*** *(% profession)*	***Non-users***
Physiotherapists:	4 (2%)	*2 (50%)*	*2 (50%)*
Chiropractors:	87 (55%)	*36 (41%)*	*51 (59%)*
Osteopaths:	30 (30%)	15 *(50%)*	*15 (50%)*
Rheumatologists:	11 (7%)	9 (82%)	*2 (18%)*
Sports Dr/MSK GP/Other:	25 (16%)	21 (84%)	*4 (16%)*
Total:	**157**	***83 (53%)***	***74 (47%)***

Q1. – Do you use ultrasound images for diagnostic purposes in your practice setting? This would involve viewing ultrasound images for assessment, rehabilitation, or for pathologic conditions. It may also involve reading reports but must include viewing of ultrasound images.

<u>Yes</u>
n = 88
(52.7%)

<u>No</u>
n = 79
(47.3%)

Q2. – In regard to <u>not</u> using diagnostic ultrasound, do you believe? (All Practitioners)

#	Question	Strongly disagree		Somewhat disagree		Neither agree nor disagree		Somewhat agree		Strongly agree		Total
1	You are not adequately trained to use or interpret ultrasound images.	6.41%	5	1.28%	1	7.69%	6	34.62%	27	50.00%	39	78
3	There is no access to ultrasound equipment or referral sources.	23.08%	18	25.64%	20	17.95%	14	14.10%	11	19.23%	15	78
4	Equipment or referral is not cost effective for the benefits the images may provide.	15.38%	12	25.64%	20	37.18%	29	12.82%	10	8.97%	7	78

Q3. – In regard to acquiring ultrasound images, do you? (All Practitioners)

#	Question	Always		Often		About half the time		Sometimes		Never		Total
1	Personally perform the ultrasound scan.	5.75%	5	3.45%	3	3.45%	3	6.90%	6	80.46%	70	87
2	Aquire images from within your place of work.	4.60%	4	3.45%	3	4.60%	4	4.60%	4	82.76%	72	87
3	Aquire images from a third party outside your place of work.	78.16%	68	6.90%	6	3.45%	3	8.05%	7	3.45%	3	87

Q4. – In a typical week, what percentage of clientele would you use ultrasound images for diagnostic purposes? (All Practitioners)

Percent	**0-4%**	**5-9%**	**10-14%**	**15-19%**	**20-24%**	**25-29%**	**30-34%**	**35-39%**	**40-44%**	**45-50%**	**Total**
Count	30	27	12	5	2	1	2	3	2	3	87
%	*35%*	*31%*	*14%*	*6%*	*2%*	*1%*	*2%*	*3.5%*	*2%*	*3.5%*	*100%*

Q5. – Do you or your place of work own/lease a diagnostic ultrasound machine? (All Practitioners)

#	Answer	%	Count
1	Yes	19.54%	17
2	No	80.46%	70

Q6. – In regards to the diagnostic ultrasound machine you own or lease, do you? (All Practitioners)

#	Question	Strongly disagree		Disagree		Somewhat disagree		Neither agree nor disagree		Somewhat agree		Agree		Strongly agree		Total
1	Think it's cost effective.	23.53%	4	0.00%	0	0.00%	0	11.76%	2	17.65%	3	23.53%	4	23.53%	4	17
2	Think it's easy to implement into a practice setting.	0.00%	0	23.53%	4	23.53%	4	0.00%	0	0.00%	0	29.41%	5	23.53%	4	17
3	Believe clients are favourable to the process and results.	0.00%	0	5.88%	1	5.88%	1	5.88%	1	0.00%	0	35.29%	6	47.06%	8	17

Fig. 3.3. Flow Diagram of Survey Questions 1 – 6: Users and Non-Users

Non-users of ultrasound images for diagnostic purposes (n=79) indicated they believe they are inadequately trained to use or interpret ultrasound images. By profession, 100% of rheumatologists (n=2) and MSK/sports doctors (n=4) also indicated inadequate training as did most osteopaths (14/15: 93%) and chiropractors (40/51: 78%). More non-users disagree that equipment or referral is not cost effective than agree that it may be too expensive, however approximately 40% neither disagreed or agreed, possibly indicating a large group of non-users are unaware of the ‘cost to benefit’ ratio of ultrasound equipment. Finally, there are slightly more non-users who believe there is access to ultrasound equipment or referral, however the differences between agreement, disagreement, and neither are small and not significant.

In summary, the non-users of diagnostic ultrasound images believe they are inadequately trained to interpret images; are unsure if it is financially viable; but believe access for referral or equipment is likely to be available. Users of ultrasound images for diagnostic purposes are most likely to never perform the scans themselves (80%) and acquire images from outside their place of work or from a third party (85%). Sixty-one percent of users use ultrasound for diagnostic purposes with less than 10% of their cliental, which may be due to only 20% of participants owning or leasing a diagnostic ultrasound machine. Of those who do own or lease a machine (n=17) most believe it is cost effective (75%) and that clients are favourable to the process and results (82%). However, agreement to the ease of implementing diagnostic imaging into a practice setting is split evenly with 46% believing it is not and 54% believing it is.

Compared with a non-user, a user of diagnostic ultrasound images would: acquire images from a source outside their place of work, not own a machine, apply images to less than 10% of their clientele during a typical working week, and, if they owned a machine, they would think it is cost effective, client friendly, but unsure if it easy to implement into their practice setting.

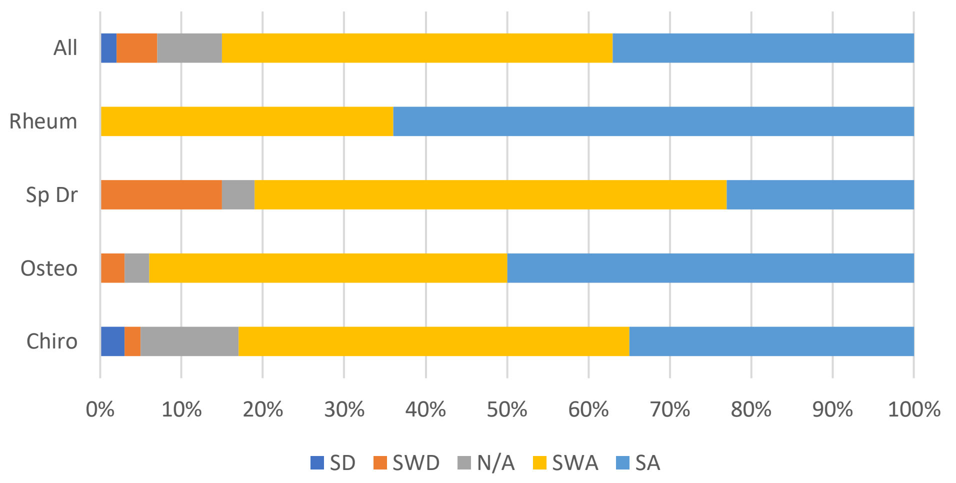
Beliefs of users and non-users.

Results from the 11 sub-questions of question seven gathered data concerning the beliefs of users and non-users of diagnostic ultrasound. These sub-questions were separated into two categories where the first six questions were designed to investigate ‘what’ diagnostic ultrasound may be useful for, and the remaining five questions investigating the 'usefulness' of diagnostic ultrasound in a clinical setting (data tables of question seven responses are presented in Appendices F – K).

What diagnostic ultrasound may be useful for.

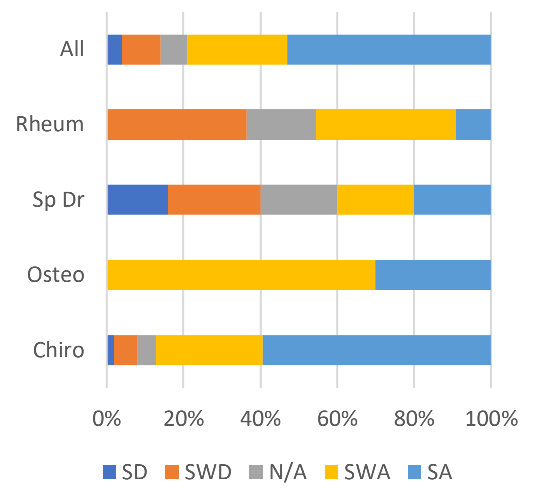
The majority of users (91%) and non-users (78%) agree or strongly agree that diagnostic ultrasound is able to produce reliable images that indicate changes in pathological and non-pathological tissues (indicated by dominance of light blue and yellow in Fig. 3.4). By profession, 100% of rheumatologists somewhat or strongly agree, however all professions mostly somewhat or strongly agree (>80%) diagnostic ultrasound is reliable to indicate changes in both non-pathologic and pathologic tissues.

Fig 3.4. Able to produce reliable images that indicate changes in non-pathologic and pathologic tissues.



All users and non-users in the osteopathic group and 88% of the chiropractic group agree or strongly agree that images should only be taken by trained radiologists or sonographers. There is no agreement amongst users in the rheumatologists and MSK/sports doctors group, however all non-users in the rheumatologists (n=2) group believe images should be taken by trained professionals whilst non-users in the MSK/sports doctors group remain neutral as illustrated in Fig. 3.5.

Fig. 3.5. Images should only be used if taken by trained radiographers/sonographers.



Ultrasound images for the sole purpose of confirming suspected pathology (e.g. trauma, growths, inflammatory conditions) was not dominated by one response with the exception of rheumatologists who mostly disagreed or strongly disagree. As illustrated in Table 3.7 below, percentage of ***users*** (presented in brackets) illustrate that there is no agreement within each profession as to whether diagnostic ultrasound is useful to confirm pathology with the exception of rheumatologists users (highlighted) who believe that diagnostic ultrasound is more useful than just confirming pathology. This may suggest diagnostic ultrasound is useful for more than diagnosing pathologic tissues and will be further discussed in the next chapter.

Fig 3.6. Only useful to confirm suspected pathology (EG. Trauma, Growths, Inflammatory Conditions).

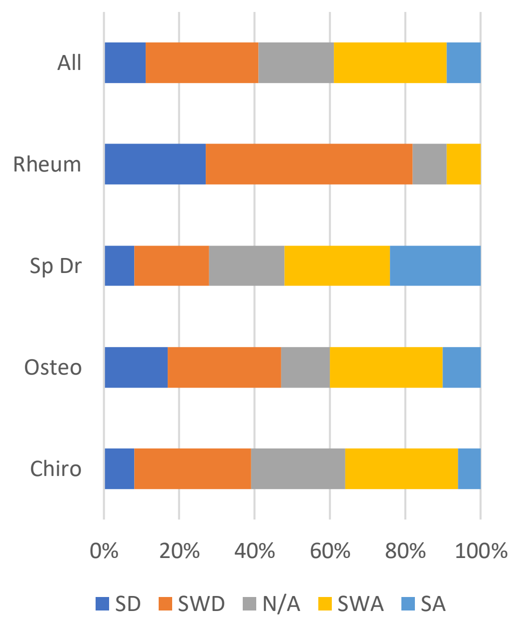
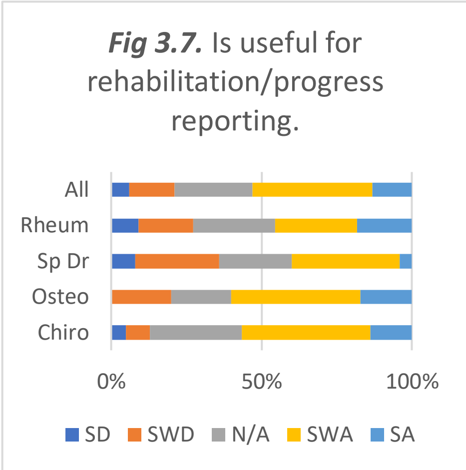


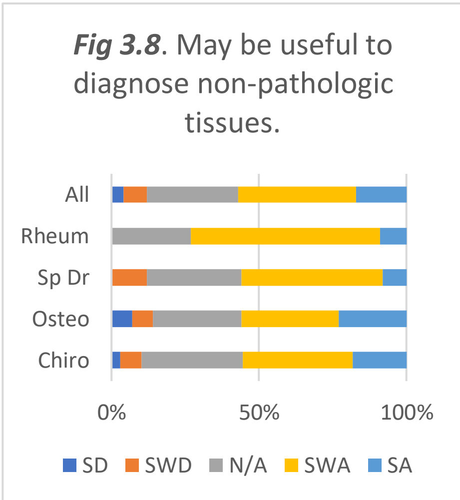
Table 3.7. Question Seven – Only Useful to Confirm Suspected Pathology

"Do you believe: only useful to confirm suspected pathology (e.g. Trauma, Growths, Inflammatory Conditions)."	Participants	Somewhat Disagree & Strongly Disagree (% of users)	Neither Agree nor Disagree (% of users)	Somewhat Agree & Strongly Agree (% of users)
Rheumatologists	11	82% (89%)	9% (11%)	9% (0%)
MSK/Sports Doctors	25	24% (35%)	20% (25%)	56% (40%)
Chiropractors	87	39% (33%)	25% (19%)	36% (48%)
Osteopaths	30	47% (53%)	13% (7%)	40% (40%)

There is more agreement that diagnostic ultrasound is useful for rehabilitation and/or progress reporting amongst the users and non-users in the chiropractic and osteopathic groups. Rheumatologists who use diagnostic ultrasound images mostly agree that it is useful for rehabilitation and/or progress reporting (55%), however there is no agreement within MSK/sports doctors (Fig 3.7).



All professions, and users and non-users, mostly agree that diagnostic ultrasound images may be useful to diagnose non-pathological tissues. However, in most of these groups approximately one-third responded 'neither agree nor disagree' which may indicate an 'unsure' or 'don't know' type response. This is indicated by the presence of grey bars within each profession in Figure 3.8 and further indicated by Table 3.4 with the highlighted figures consisting of one-third of responses.



Usefulness of Diagnostic Ultrasound in a Musculoskeletal Setting.

Most participants (>65%) responded they do not believe diagnostic ultrasound is surplus to requirements for a clinician with good palpation skills. When professions were divided into chiropractors, physiotherapists, and osteopaths, from rheumatologists and MSK/sports doctors there was very little difference between these groups, further users in each groups were close to identical. In summary, two-thirds disagree or strongly disagree that diagnostic ultrasound images are surplus to requirements (Fig 3.7).

Fig 3.9. Owning an ultrasound unit is not cost effective for private practice.

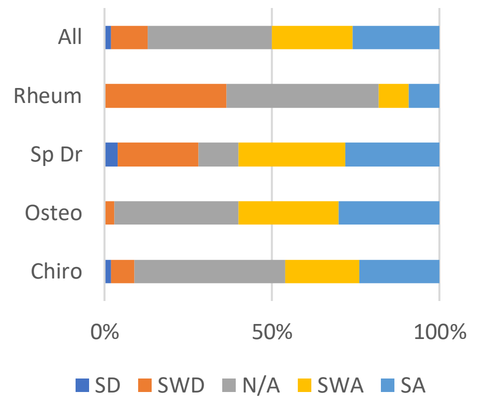


Table 3.8. Question Seven: Comparisons between Chiropractors, Physiotherapists, and Osteopaths versus Rheumatologists and MSK/Sports Doctors in response to "ultrasound images are surplus to requirements for a clinician with good palpation skills

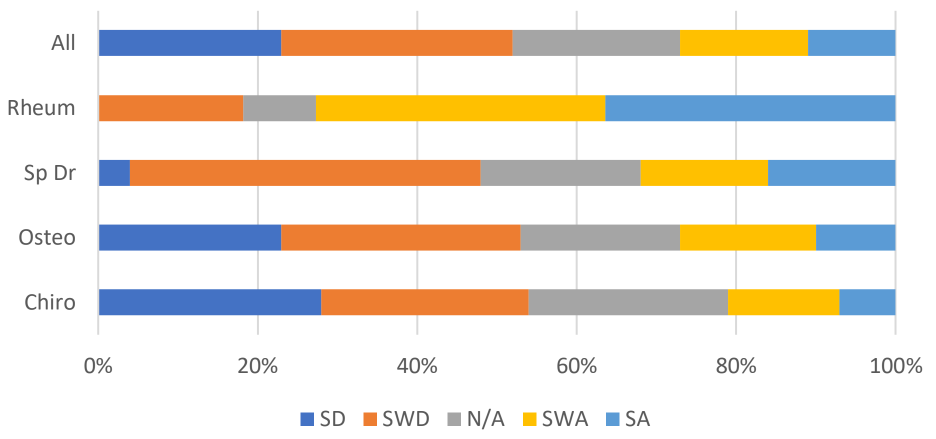
	Total			Users			Non-Users		
	n = 121			n = 54			n = 67		
Chiropractors, Physiotherapists, & Osteopaths	Somewhat and Strongly Disagree	Neither Agree or Disagree	Somewhat and Strongly Agree	Somewhat and Strongly Disagree	Neither Agree or Disagree	Somewhat and Strongly Agree	Somewhat and Strongly Disagree	Neither Agree or Disagree	Somewhat and Strongly Agree
	65%	20%	15%	69%	11%	20%	63%	27%	10%
	n = 36			n = 30			n = 6		
Rheumatologists & MSK/Sports Doctors	Somewhat and Strongly Disagree	Neither Agree or Disagree	Somewhat and Strongly Agree	Somewhat and Strongly Disagree	Neither Agree or Disagree	Somewhat and Strongly Agree	Somewhat and Strongly Disagree	Neither Agree or Disagree	Somewhat and Strongly Agree
	69%	11%	20%	67%	10%	23%	83%	17%	-

For chiropractors (46%) and osteopaths (60%), most participants agreed owning an ultrasound machine is not cost effective, however many neither agreed nor disagreed (chiro. 45%, osteo. 37%) which may indicate many participants in these professions not knowing if owning a machine is cost effective or not. Interestingly, there is a significant disparity between ***users*** in the rheumatology and MSK/sports doctors. Of users in the MSK/sports doctors group, 65% believe it would be cost effective versus only 11% of rheumatologists.

Further, 44% of rheumatologists compared with 15% of MSK/sports doctors neither agreed nor disagreed that owning a machine is not cost effective indicating further disparity between these professions that have the most users of diagnostic ultrasound (dxUS) in the target population.

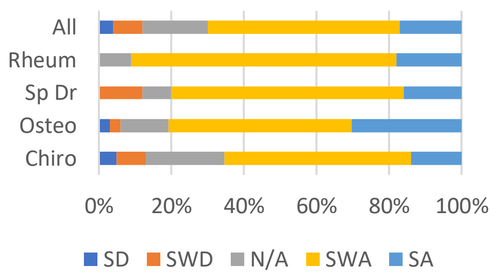
Over three-quarters of chiropractic, osteopathic, and MSK/sports doctors group don't believe dxUS may be easily incorporated into daily practice. However, the converse is true for rheumatologists where three-quarters do believe it may be easily incorporated into daily practice with 44% strongly agreeing amongst rheumatologists who are users of dxUS.

Fig 3.10. May be easily incorporated into your daily clinical practice.

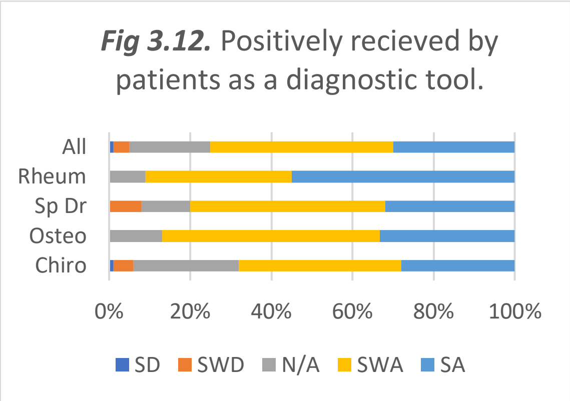


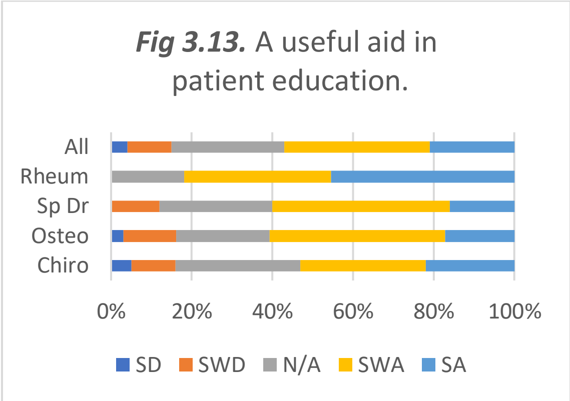
The majority of all professions, users and non-users, believe that diagnostic ultrasound images may be useful to quantify diagnostic findings (illustrated by dominance of yellow and light blue in Fig 3.11) .

Fig 3.11. May be a useful tool to quantify diagnostic findings.



The final two sub-questions in question seven addressed how diagnostic ultrasound would be received by the patient and if it would be a useful aid in patient education. The majority of all professions, users and non-users, agreed or strongly agreed that it would both be received well (average 75%, Fig 3.12) whilst most also believed it would be useful for patient education (average 57%, Fig 3.13).





Professional and demographic details.

All participants who completed the questionnaire (n = 158) are included in gender, age, and education data (Table 3.5). Further, all participants are included in profession, years in practice, and employment data (Table 3.6). Finally, all demographic data has been split into: total participants, users, and non-users of diagnostic ultrasound images as this is a central theme of this survey and is represented in Appendices F to K.

Gender and age.

The majority of respondents were male (58%) and equally likely to be a user (47) or non-user (45). Females were slightly more likely to use diagnostic ultrasound images (54%). Most participants were likely to be aged between 45 – 65yrs (53%) with users likely to be between 50 – 70yrs (57%) and non-users to be between 30 – 50yrs (68%). These results indicate that non-users are younger than users by a mean of 20yrs.

Level of education.

Most participants had completed post graduate study (72%), however if the postgraduate qualification was a Fellowship or Doctorate (72%), they are more likely to be users of diagnostic ultrasound images.

Table 3.9. Demographic Data: Gender, Age, and Education

	Total Sample (%) n = 158 (100%)	Users (%) n = 84 (53%)	Non-Users n = 74 (47%)
Gender			
Male	92 (58%)	47 (56%)	45 (61%)
Female	63 (40%)	34 (40%)	29 (39%)
Choose not to answer	3 (2%)	3 (4%)	-
Age			
20-24	5 (3%)	3 (4%)	2 (3%)
25-29	10 (6%)	5 (6%)	5 (7%)
30-34	19 (12%)	9 (11%)	10 (14%)
35-39	11 (7%)	4 (5%)	7 (9%)
40-44	15 (9%)	6 (7%)	9 (11%)
45-49	19 (12%)	6 (7%)	13 (18%)
50-54	23 (15%)	11 (13%)	12 (16%)
55-59	18 (11%)	12 (14%)	6 (8%)
60-64	24 (15%)	16 (19%)	8 (11%)
65-69	11 (7%)	9 (11%)	2 (3%)
70+	3 (2%)	3 (4%)	-
Education Level			
Undergraduate Degree	45 (28%)	20 (24%)	25 (34%)
Post Graduate Diploma	54 (34%)	27 (32%)	27 (36%)
Masters Degree	30 (19%)	16 (19%)	14 (19%)
Doctorate	20 (13%)	14 (17%)	6 (8%)
Fellowship	9 (6%)	7 (8%)	2 (3%)

Profession.

Chiropractors comprised of 55% of the survey participants of which 59% were non-users. Most users of diagnostic ultrasound images were either MSK/sports doctors (84%) or rheumatologists (81%). Osteopaths were divided 50/50 in users and non-users (Table 3.6).

Years in practice.

Two-thirds of the participants were likely to have been in practice between 0 -24yrs (100/157; 64%) with most of these participants likely to be non-users (51/74; 69%). Participants who had been in practice for over 30yrs (n = 38) were significantly more likely to be users (27/38; 71%) than non-users (11/38; 29%) (Table 3.6).

Table 3.10. Demographic data: Profession, Years in Practice, and Employment

	Total (%) n = 157 (100%)	Users (%) n = 83 (53%)	Non-Users(%) n = 74 (47%)
Registered Profession			
Chiropractor	87 (55%)	36 (45%)	51 (69%)
Osteopath	30 (19%)	15 (18%)	15 (20%)
Physiotherapist	4 (3%)	2 (2%)	2 (3%)
MSK/Sports Doctor	25 (16%)	21 (25%)	4 (5%)
Rheumatologists	11 (16%)	9 (11%)	2 (3%)
Years in Practice			
0-4	21 (13%)	11 (13%)	10 (13%)
5-9	23 (15%)	12 (14%)	11 (14%)
10-14	16 (10%)	8 (9%)	8 (10%)
15-19	25 (16%)	11 (13%)	14 (18%)
20-24	15 (10%)	7 (8%)	8 (10%)
25-29	8 (5%)	5 (6%)	3 (4%)
30-34	18 (11%)	13 (15%)	5 (6%)
35-39	12 (8%)	7 (8%)	5 (6%)
40-44	6 (4%)	5 (6%)	1 (1%)
45-49	1 (1%)	1 (1%)	-
50+	1 (1%)	1 (1%)	-
No-Response	21 (13%)	7 (8%)	14 (18%)
Employment Status			
Self Employed	131 (83%)	66 (80%)	65 (89%)
Employed Full Time	14 (9%)	10 (12%)	4 (5%)
Employed Part Time	12 (8%)	7 (8%)	5 (7%)
Employment Setting			
Private Practice	143 (91%)	72 (87%)	72 (97%)
Private Organisation	2 (1%)	2 (2%)	-
Public Hospital	8 (5%)	7 (8%)	1 (1%)
University/Education	3 (2%)	2 (2%)	1 (1%)
Main Area of Practice			
General Practice	112 (71%)	48 (58%)	63 (85%)
Sports	6 (4%)	5 (6%)	1 (1%)
Occupational	3 (2%)	2 (2%)	1 (1%)
Geriatric	3 (2%)	2 (2%)	1 (1%)
Paediatric	2 (1%)	1 (1%)	1 (1%)
Women's Health	1 (1%)	-	1 (1%)
Musculoskeletal	19 (12%)	17 (20%)	2 (3%)
Rheumatology	10 (6%)	8 (10%)	2 (3%)
Other*	1 (1%)	-	1 (1%)
Blanks			1 (1%)

*Rehabilitation

Employment status and setting.

The majority of participants (users, and non-users) are self-employed (131/157; 83%) and in private practice (143/157; 91%). Participants that are employed full time are more likely to be users of diagnostic ultrasound imaging (17/26; 65%). Participants who work in a private organisation, public hospital, or university/education facility are likely to be users (11/13; 85%), however non-users are very likely to be in private practice (97%).

Main area of practice.

Seventy-one percent of the participants are in general practice (112/157; 71%) with the majority of non-users being in general practice (63/74; 85%). Of the remaining eight areas of practice (n = 45; sports, occupational, geriatric, paediatric, women's health, musculoskeletal, rheumatology, rehabilitation) the majority use diagnostic ultrasound images (35/45; 78%).

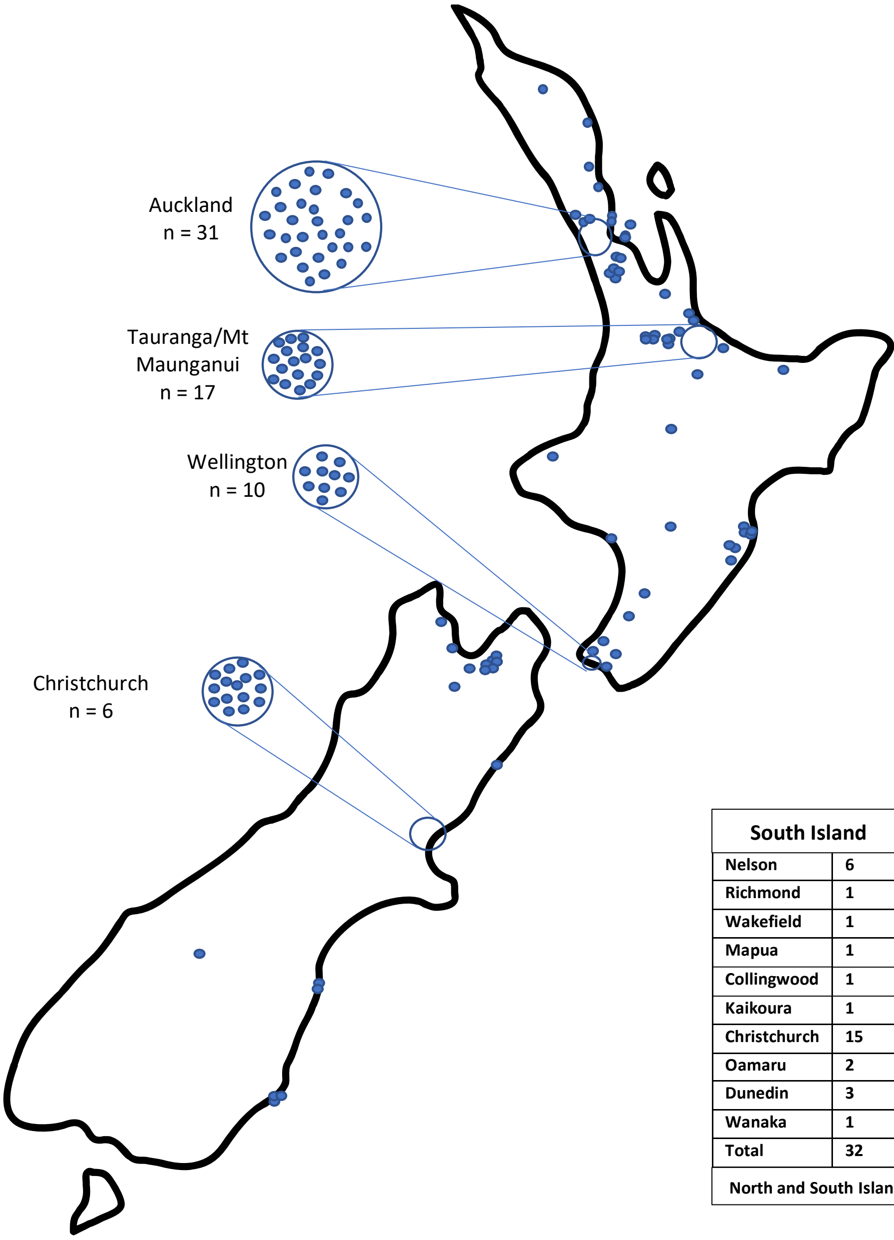
Geographical Demographics

Geographical location from postcodes are illustrated in diagram 1. Half the participants come from the top five cities in New Zealand (by population) and two thirds come from urban areas (Table 3.7). Further, two-thirds of users come from cities and two-thirds of non-users come from rural areas resulting in an inverse of one-third of non-users come from cities and one-third of users come from rural areas.

Table 3.11. Geographic distribution of users and non-users into cities, urban, and non-urban categories

	Users **n = 77 (53%)**	Non-Users **n = 68 (47%)**	Total **n = 145**
Top Five Cities **(Auckland, Christchurch, Wellington, Hamilton, Tauranga)**	41 (57%)	31 (43%)	72 (50%)
All 15 Cities - Urban **(Auckland, Christchurch, Wellington, Hamilton, Tauranga, Napier-Hastings, Dunedin, Palmerston North, Nelson, Rotorua, Whangarei, New Plymouth, Invercargill, Whanganui, Gisborne)**	57 (62%)	35 (38%)	92 (63%)
Non-Cities - Rural	20 (38%)	33 (62%)	53 (37%)

Diagram 1 Geographical demographics by postcode



North Island	
Kerikeri	1
Whangarei	1
Wellsford	1
Warkworth	1
Kawau Island	1
Orewa	1
Silverdale	1
Waiheke Island	2
Auckland	31
Riverhead	1
Kumeu	1
Waimaku	1
Takanini	2
Papakura	4
Thames	1
Hamilton	4
Cambridge	3
Matamata	1
Waihi	1
Omokoroa	1
Tauranga	12
Mt Maunganui	5
Papamoa	2
Rotorua	1
Whakatane	2
Taupo	1
Taihape	1
Napier	4
Hastings	2
Havelock North	1
New Plymouth	1
Whanganui	3
Palmerston Nth	2
Levin	1
Paraparaumu	1
Porirua	1
Upper Hutt	1
Lower Hutt	2
Wellington	10
Total	113

South Island	
Nelson	6
Richmond	1
Wakefield	1
Mapua	1
Collingwood	1
Kaikoura	1
Christchurch	15
Oamaru	2
Dunedin	3
Wanaka	1
Total	32
North and South Island Total	145

CHAPTER 4

DISCUSSION

The aim of this study was to investigate the usefulness of elastography to quantifiably measure fascia tissues in a musculoskeletal setting. The approach used a mixed method design that consisted of a narrative review and a survey implemented amongst a broad group of musculoskeletal practitioners. The role of the survey was to provide data on the use, beliefs, and demographics of users and non-users of diagnostic ultrasound and those findings were synthesised with the review findings to help present an insight into the potential usefulness of elastography in a musculoskeletal setting.

The goal of the review was to search the literature for the current use of elastography to provide quantitative measures of fascia tissues to present an authoritative argument on its current use. A narrative review was designed using systematic processes to ensure articles were not "cherry picked" to support the reviewers bias, which can be a criticism of these types of reviews (Greenhalgh et al., 2018).

The goal of the survey was to ascertain the current beliefs of users and non-users of dxUS with the assumption that dxUS use is an appropriate substitute to measure potential elastography use. Diagnostic ultrasound represents an established and more likely utilised technology versus elastography that is a new technology and, as yet, not widely known among musculoskeletal practitioners. Further, ultrasound is virtually identical to elastography in hardware, application, and real-time investigation of musculoskeletal tissues. For example, conclusions by Alsiri et al (2020) noted that it only required a further 2-3 minutes to perform an elastography scan following an ultrasound investigation (Alsiri et al., 2020). This may suggest a parallel process of elastography and ultrasound use in a musculoskeletal office and further suggest that a survey of diagnostic ultrasound use and beliefs may indicate the usefulness of elastography in a clinical setting.

The two components of this project are synthesised and discussed in this chapter, and the next, in relation to the study question:

Is elastography type technology useful for quantifying the characteristics of fascia tissues, who uses diagnostic ultrasound technology in a musculoskeletal setting, and what are the beliefs of users and non-users?

The review conclusively demonstrated that, other than for various tendons, there is currently no literature concerning elastography and the imaging of the web-like fascia tissues as defined by the "Fascia Research Society" (who refer to fascia tissues as the *fascia system*). Whilst the review included investigations using elastography to quantitatively measure Planter Fascia tissues, Wu et al (2011) acknowledge that "*In some but not all ways, planter fascia is similar to tendons"* (Wu et al., 2011). Tendons represent only a small component of the fascia system but may provide some insight into the use of elastography to quantifiably measure other collagen dominant tissues. The definition of the fascial system as described by the Fascia Research Society is:

"The fascial system consists of the three-dimensional continuum of soft, collagen containing, loose and dense fibrous connective tissues that permeate the body. It incorporates elements such as adipose tissue, adventitia and neurovascular sheaths, aponeuroses, deep and superficial fasciae, epineurium, joint capsules, ligaments, membranes, meninges, myofascial expansions, periostea, retinacula, septa, tendons, visceral fasciae, and all the intramuscular and intermuscular connective tissues including endo-/peri-/epimysium. The fascial system surrounds, interweaves between, and interpenetrates all organs, muscles, bones and nerve fibers, endowing the body with a functional structure, and providing an environment that enables all body systems to operate in an integrated manner." (Schleip, Hedley, & Yucesoy, 2019, p. 930)

Despite the lack of evidence in the literature for investigating elastography and the broadly defined fascial system as a whole, there is value in the findings of elastography use to quantifiably measure tendon tissues. Fascia tissues are mostly comprised of collagen fibres (with small amounts of elastic fibres) that are organised in varied shapes and thickness depending on its function. Tendon structure is similar to other fascia tissues where it is composed of mostly type I collagen fibres, has few elastic fibres (compared to muscle tissue), and are organised in a range of morphology (e.g. sheet-like or tube-like). However, further research is required on non-tendon fascia tissues to investigate more structures of the fascia system if elastography is to be useful in a musculoskeletal setting.

Is Elastography Potentially Useful to Quantitatively Measure Fascia Tissue?

In my view, elastography is potentially useful to provide quantitative data of the viscoelastic properties of tissues by measuring the relative stiffness of the tissue. Specifically, detection of tissue stiffness variations may indicate pathological processes that present symptomatically and commonly presents in a musculoskeletal office.

Pathology in tendons present as areas of softness due to the histological changes that occur during tissue repair. Stages of pathology were described by Klauser et al (2017) using elastography and ultrasound to establish grades of tendon pathology due to histological features (Klauser et al., 2017). Grade one was considered non-pathologic whilst grades two and three were pathologic. These were described as:

1. Grade One: non-pathologic histological alterations but no detection of changes to collagen configuration (i.e. they remain parallel), no fatty infiltration, and no capillary proliferation.
2. Grade Two: mild tendinopathy with the accumulation of peripheral blood mononuclear cells (lymphocytes, monocytes, granulocytes), capillary proliferation, and fatty degeneration.

3. Grade Three: moderate to severe tendinopathy with alterations of fibre orientation (i.e. loss of parallel configuration), fluid aggregation, and necrosis.

Interestingly, in an earlier study by Klauser et al (2013) and multiple studies in this review (Gatz et al., 2020; Khodair, 2020; Sahan, Inal, Burulday, & Kultur, 2018a) found that elastography had higher sensitivity than ultrasound and results of sensitivity and specificity are enhanced when both technologies are combined. This study of elastography of Achilles tendons reported:

"Sonoelastography depicted histologic degeneration in 14 of 14 (100%) tendon thirds of cadaver Achilles tendons, whereas B-mode US depicted it in 12 of 14 (86%) tendon thirds." (Klauser et al., 2013, p. 838)

The findings of our review supports this statement where SWE was reported to have high to very high sensitivity in diagnosing tendon softness in pathological tendons using elastography (Aubry et al., 2015; Dirrichs et al., 2016; Sahan, Inal, Burulday, & Kultur, 2018a). Further, in this review, SWE indicated detection of pathology in correlation with a range of assessment tools to determine pathology, such as: pain scales, MRI diagnosis, and morphologic findings on ultrasound. Gatz et al (2020) indicated a strong correlation of elastography findings of stiffness with clinical scores *($r = 0.6; p < 0.001$)* versus B-mode ultrasound correlation with clinical scores *($r = 0.35; p < 0.001$)* (Gatz et al., 2020). These findings may support the use of elastography in conjunction with ultrasound and other assessment tools to enhance sensitivity and specificity in the diagnosis of tendons (and possibly other fascia structures) in a musculoskeletal setting.

Currently, the majority of diagnosis of musculoskeletal tissues is through subjective measures such as palpation, orthopaedic testing, and pain scale questionnaires. Technological advances may enhance diagnostic processes through quantitative data gathering, such as elastography, that could aid the development of a working diagnosis. This is not to suggest that technology alone should be used in the process of forming a diagnostic impression, however it may be used to compliment the practitioners skill when determining a working diagnosis. Important components such as health history, visual impression, orthopaedic tests, consideration of biological, psychological, and social aspects of the clients presentation (i.e. the biopsychosocial model of pain), orthopaedic testing, and other forms of imaging and testing should all be considered in the development of a working diagnosis.

Dirrichs et al (2016), reported a correlation of SWE mean values (measured in kPa and m/s) and clinical symptoms measured using various pain/disabilities instruments (Dirrichs et al., 2016). Of potential clinical significance is the positive correlation where symptomatic scores (measured by pain scales) increased with lower SWE values at a specific range ≈ 70kPa or 4.8m/s (Figure 4.1). This range appears to represent a tipping point of non-symptomatic to symptomatic tendons and may represent the pathological cross-over from grade one to grade two as described by Klauser et al (2017) above. More studies are required to confirm or refute this finding, however it is encouraging that such a tipping point may be utilised for diagnosis and rehabilitation.

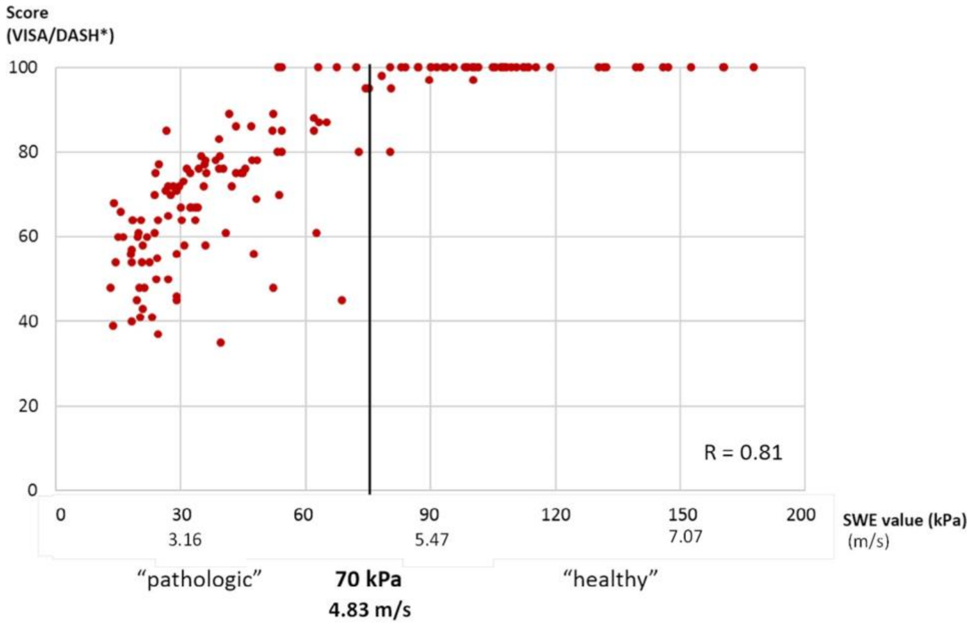


Fig 4.1 **Correlation of shear wave elastography (SWE) mean values and clinical symptoms (Dirrichs et al., 2016, p. 1210)**

Palpation is the most common method used to determine tissue characteristics (Jonsson & Rasmussen-Barr, 2018). However, fascia tissues vary greatly from muscle tissues in structure and function and it may be beneficial for the practitioner to identify each tissue on its own characteristics when determining a working diagnosis (Pavan, Stecco, Stern, & Stecco, 2014). Muscles are comprised principally of sarcomeres which physiologically shorten and return to their original shape via elastic fibres and release mechanisms (e.g. protein uncoupling) (Franchi et al., 2018). Additionally, the sarcomere unit is significantly more viscous which allows a dynamic flow of the physiological elements required for the production of movement and locomotion. By comparison, fascia tissues are comprised of significantly less elastic fibres and viscous elements and have no shortening mechanism for force production. Fascia tissues function to provide:

1. Structural support for muscles and viscera throughout the whole body.
2. Define spaces such as interstitium (Avila Gonzalez et al., 2018).
3. Participate in specialised cell production (e.g. telocytes and tenocytes) (Dawidowicz, Szotek, Matysiak, Mielanczyk, & Maksymowicz, 2015) and vascular mechanisms (e.g. pre-lymph) (Benias et al., 2018).

Fascia tissues are mostly organised in tight sheets or bundles of collagen fibres and are firm on palpation versus muscle which is soft (but not solid like bone). However, on palpation, pathology of fascia tissues presents as softness (due to histology described above) and pathology of muscle tissues appear firm due to the infiltration of tissue repair, or through processes that create mass like structures (Shiina et al., 2015).

Differences in structure and function between muscles and fascia combined with differences in pathological presentation may be beneficial to separate the diagnostic features of each tissue. Additionally, treatment and rehabilitation exercises may be modified or specifically designed to target these tissues differently (Sanjana, Chaudhry, & Findley, 2017), hence identifying these tissues separately may enhance the diagnosis and care from the practitioner in a musculoskeletal setting.

Elastography is likely to be beneficial for providing quantitative data for pathologic or non-pathologic fascia type tissues (as described above) however would it be useful in a musculoskeletal clinical setting? This paper utilised (and designed) a survey tool to investigate the current use and beliefs of an elastography like technology (diagnostic ultrasound) amongst a broad group of registered musculoskeletal practitioners in New Zealand to help answer this question.

Sample Size and Validity

A fundamental problem with on-line surveys is low response rates (Reinisch, Yu, & Li, 2016) and, other than Chiropractors, the response rate from our survey was low. Using an on-line instrument (www.raosoft.com/samplesize.html) to indicate statistical power (or degree of external validity), physiotherapists, osteopaths, rheumatologists, and sports/MSK doctors showed low response rates and hence low external validity. These statistical power indicators were calculated on the basis of a 50% response distribution, 95% confidence interval, and 10% margin of error. The greater than standard margin of error (most often set at 5%) was selected due to this study being interested in identifying themes of relationships and differences as a precursor to further studies which is considered an acceptable reason for relaxing the margin of error (Barlett, Kotrlik, & Higgins, 2001).

Web-based surveys have less response rate than mail-based surveys especially when surveys are sent with financial incentives (Reinisch et al., 2016). This may be due to factors such as guilt of accepting the cash incentive and not completing the survey resulting in greater response rates. Further, on-line surveys may allow the participant to read some of the survey and then opt out more easily than mail surveys. The ease and low expense of web-based surveys allow studies to be performed however at the cost of external validity. Our survey appears to have suffered the same fate with the exception of chiropractors and conclusions derived from data from all other professions should be considered with caution.

Table 4.1. Invitation Type, Response, and Power

Profession	Invitation Type	Possible Responders	Responders	Response Rate	Power Indicator - required number of responders for 50% response distribution*
Rheumatologists	Direct Email	100	11	11%	50
Sports/MSK Drs	Direct Email	51	25	49%	34
Chiropractors	Direct Email	386	87	22.5%	78
Osteopaths	Posted on Web Notice Board and electronic Newsletter	Unknown	30	Unknown	
Physiotherapists	Posted on Web Notice Board	Unknown	4	Unknown	

Who Are Users of Diagnostic Ultrasound

As described previously, ultrasound and elastography are virtually identical in appearance and application. Further, our survey was based on the assumption that dxUS is an acceptable substitute for elastography and results from the survey would correlate with the possible use of elastography in a clinical setting. Therefore, results from our survey may indicate how elastography could be utilised and who is most likely to adopt this technology into their clinics.

Table 4.2. Survey Results of Users and Non-Users by Profession

Participants, Users, or Non-users by Profession

	Total *(% study)*	**Users** *(% profession)*	**Non-users**
Physiotherapists:	4 (2%)	*2 (50%)*	*2 (50%)*
Chiropractors:	87 (55%)	*36 (41%)*	*51 (59%)*
Osteopaths:	30 (30%)	15 *(50%)*	*15 (50%)*
Rheumatologists:	11 (7%)	9 (82%)	*2 (18%)*
Sports Dr/MSK GP/Other:	25 (16%)	21 (84%)	*4 (16%)*
Total:	**157**	***83 (53%)***	***74 (47%)***

Results from our survey indicate that rheumatologists (84%) and MSK/sports doctors (82%) are high users of dxUS (Table 4.1) although caution must be applied as both samples are small (particularly rheumatologists n=11). Further, the sample of physiotherapists is too small (n=4) to provide reliable conclusions, however a recent survey of New Zealand physiotherapists and ultrasound use by Ellis et al (2018) provides a good comparable study to this survey (Ellis et al., 2018).

Previous surveys of rheumatologists have investigated use of ultrasound in a practice setting and reported that rheumatologists use ultrasound in equal amounts of diagnosis and treatment application. For example, Cannella et al (2014) reported that rheumatologist use of ultrasound is in equal parts diagnosis (82%) and procedures involving needle guidance (91%) (Cannella, Kissin, Torralba, Higgs, & Kaeley, 2014). Further, a survey conducted by Brown et al (2007) reported diagnosis of synovial fluid was considered the most important component of ultrasound (range 86-75% of multiple joints) where guided needle aspiration or injection was slightly less (range 84-65% of multiple joints) (Brown et al., 2007). Results from these studies are almost identical to our survey which indicated 82% of rheumatologists believe dxUS should only be used to confirm suspected pathology (Table 4.2). Our study did not investigate ultrasound use in treatment, however the studies described above appear to suggest that rheumatologists have a greater scope of use than other professions in our target population and may explain the high percentage of users in this study.

Table 4.3. Question Seven, Sub-Question 3: Responses by professions.

"Do you believe: only useful to confirm suspected pathology (e.g. Trauma, Growths, Inflammatory Conditions)."	Participants	Somewhat Disagree & Strongly Disagree	Neither Agree nor Disagree	Somewhat Agree & Strongly Agree
Rheumatologists	11	82%	9%	9%
MSK/Sports Doctors	25	24%	20%	56%
Chiropractors	87	39%	25%	36%
Osteopaths	30	47%	13%	40%

New Zealand physiotherapists in the Ellis et al (2018) study specifically asked participants if ultrasound is within the scope of practice. This study reported 9% of participants believe there is no scope of practice, 47% responded "I don't know" and 44% believe ultrasound is within the scope of practice. However, of the 47% who responded that ultrasound is within the scope of practice of physiotherapy most (54%) believe it should be for "rehabilitative purposes only and not for diagnostic purposes" (Ellis et al., 2018).

Unlike rheumatologists and physiotherapists, there are no surveys of the remaining three professions in our target population. From our survey, after rheumatologists, MSK/sports doctors are the most likely to be users of dxUS (Table 4.1).

There have been a number of reviews of ultrasound use in "sports medicine" which we shall assume is the same as our group of MSK/sports doctors (Coris et al., 2011; Finnoff et al., 2015; Yim & Corrado, 2012). For example, MSK/sports doctors use dxUS to diagnose soft tissue lesions, monitoring therapy outcomes, and to assess risk of injury in athletes (Yim & Corrado, 2012). A large systematic review by Coris et al (2011) reported ultrasound use, for diagnostic purposes, mostly involves: cardiac function; musculoskeletal pathology (tears, synovial accumulation, capsule thickening, and decreased joint space); and abdominal pathology (organ size, e.g. spleen) (Coris et al., 2011). Additionally, review papers of sports medicine ultrasound use report the favourable utility of ultrasound versus the expense of other imaging techniques (e.g. MRI, CT) indicating that ultrasound is less expensive, does not expose the client to radiation, and can provide acceptable specificity and sensitivity provided they are performed by an adequately trained operator (Finnoff et al., 2015). Moreover, ultrasound is a real-time imaging technology that is practical to use in a point-of-care setting (Dietrich et al., 2017). The varied scope of the use of dxUS to investigate cardiac function to spleen size may illustrate why MSK/sports doctors are high users of dxUS in our study (84%) but don't believe it is only useful to confirm suspected pathology (56%) unlike rheumatologists even though they both have similar exposure to ultrasound through their medical training (Davis et al., 2018).

To our knowledge there is no survey of the chiropractic profession in regard to ultrasound use, however Henderson et al (2017) surveyed teaching staff of chiropractic teaching institutions (worldwide) on the current and prospective use of musculoskeletal diagnostic ultrasound (MSK-DUS) (Henderson, Walker, & Young, 2017). Results from this survey indicate: 76% believe MSK-DUS is within the scope of chiropractic practice; 89% believe it is an important imaging modality in the future; and most respondents favoured post-graduate training in MSK-DUS. Additionally, of the 24 teaching institutions who took part in the survey, five (21%) currently used MSK-DUS in their curriculum, and nine (38%) planned to implement it, indicating that there is an increasing awareness of ultrasound among the chiropractic profession. This is supported by our study where 41% of participants indicated they use dxUS images in their practice, and further, may support the growing trend in chiropractic use of diagnostic imaging as indicated by Medicare statistics of imaging outside of specialist centres (Mizrahi et al., 2018).

Again, to our knowledge there are no studies investigating ultrasound use amongst the osteopathic community. Our survey indicates there is an awareness of dxUS with 50% of participants using dxUS images. Additionally, Kondrashova and Lockwood (2015) studied the use of ultrasound in an osteopathic teaching institution (Kirksville College of Osteopathic Medicine – Missouri) to aid students in identifying anatomical landmarks. Results from this study suggest ultrasound is useful as a teaching aid and may provide an impetus to use ultrasound in a musculoskeletal setting, however ultrasound for this purpose alone may be impractical as the study reported that palpation had acceptable accuracy and significantly better utility in terms of time and procedural application (Kondrashova & Lockwood, 2015).

Table 4.4. Comparison of MSK/Sports Doctors and Rheumatologists versus Chiropractors and Osteopaths in Users or Non-Users group

	Total	Users (%)	Non-Users (%)
MSK/Sports Doctors and Rheumatologists	36	30 (83%)	6 (17%)
Chiropractors and Osteopaths	117	51 (44%)	66 (56%)

In summary, our survey indicates that rheumatologists and MSK/sports doctors are almost twice as likely to be users of dxUS than chiropractors and osteopaths (Table 4.3). As described above this may be due to the wider scope of use of ultrasound for diagnosis and treatment procedures. However, elastography is not the same as ultrasound which is an important consideration for its potential use in a musculoskeletal setting.

Elastography, by comparison to ultrasound, has less scope in that it only measures stiffness in tissues, hence it may have greater specificity in its use. For example, radiographs primarily investigate hard tissue (bone) where MRI has a significantly greater scope of investigation. One is not superior to the other as each has its pros and cons (e.g. less radiation versus imaging soft tissues) and are utilised depending on the case. Therefore, it may be possible for elastography to be of greater benefit in a musculoskeletal setting due to its precise purpose being quantitative investigation of the stiffness of tissues in the region of interest (ROI).

All authors of the studies identified in the review concluded elastography was effective in providing quantitative data of tissue stiffness and that there were differences between comparative groups. Specifically, results from these studies suggest promising results to aid in diagnosis of pathological and non-pathological tissues. Additionally, all studies provided factors that would help achieve acceptable utility of using elastography outside the research setting. However, more research is required to confirm the utility of elastography to confidently use this technology to measure non-tendon fascia tissues in a musculoskeletal setting.

Current Diagnostic Ultrasound in the Musculoskeletal Setting

Our survey indicated that, of users of dxUS, 20% owned or leased a machine and two-thirds used it for less than 10% of their cliental. Half of the participants (50%) believe owning a machine is not cost effective for private practice with 37% neither agreeing nor disagreeing which may indicate that many participants of the study did not know the cost benefits.

These results support other studies' findings in physiotherapy (37% "Equipment is too expensive") (Ellis et al., 2018) and rheumatology (costs are the second reason for not using ultrasound) (Samuels et al., 2010). Further, the study by Ellis et al (2018) exploring the use of clinical ultrasound of physiotherapists in New Zealand reported 72% don't have a machine on site and two thirds of users (66%) use ultrasound on less than 20% of their cliental. A survey of rheumatologists use of musculoskeletal ultrasound in the United States by Samuels et al (2010) (Samuels et al., 2010) reported 36% of respondents scanned patients every day, however rheumatologists use ultrasound for diagnosis and treatment and the type of use was not identified in this study.

The majority of participants (80%) in our study acquire images from a third party. Professions most likely to perform their own scans were MSK/sports doctors and rheumatologists. Survey results reported that amongst users 40% of MSK/sports doctors and 33% of rheumatologists don't believe images should only be taken by trained radiographers or sonographers (Q.7b). A survey of rheumatologists in Canada (Larche et al., 2011) reported 93% refer to radiologists whilst Samuels et al (2010) reported significantly lower percentages with 26% referring to a third party and 21% performing their own scan. The variances in results may indicate differences in clinical environment factors, such as accessibility, training, and remuneration in different countries from our survey population.

Within the physiotherapy profession two surveys investigated ownership of ultrasound machines and usage. A survey by Jedrzejczak et al (2008) reported 12% of participants owned a machine and 88% used ultrasound 10 times or less per week (Jedrzejczak & Chipchase, 2008). Further, Ozcakar et al (2010) reported 58% ordered sonographic images on a daily basis with 18% performing the scan themselves (Ozcakar et al., 2010). Interestingly, 90% of the participants in this study believe physiatrists should perform sonography themselves and 75% reported they would if they had a machine.

Our survey results indicate 20% of practitioners own their own machine and at least 80% somewhat agree it is cost effective. The majority (80%) of users of dxUS acquire their images from a third party which appears to be the current trend among musculoskeletal practitioners. This may negate some of the benefits of using technology in a clinical setting. Referral is an extra expense of time and money to the client, and further, the advantages of acquiring real-time images to instantly aid in a working diagnosis is reduced. However, this current trend may be changing. Medicare in North America indicate a rapid increase of imaging in private practice (11%) with chiropractors and podiatrists being the most to increase outside a specialist imaging setting (including hospitals) increasing by 14.4% (Mizrahi et al., 2018). Caution is required when comparing our survey results with national trends in America, although further studies may provide a clearer impression concerning trends of imaging technology in New Zealand musculoskeletal clinical setting.

Finally, ultrasound and elastography are highly operator dependent. Time taken to acquire the skills, and the necessity to maintain skill levels, may be reasons why practitioners prefer to refer image taking to a third party. This finding is interesting due to the overall results indicating that participants in our survey indicated that dxUS is thought to have many favourable applications. For example, our survey indicated that two-thirds (67%) believe that dxUS is not surplus to requirements for a clinician with good palpation skills, and further results indicate that participants believe dxUS is useful for: rehabilitation and progress reporting; may be useful to diagnose non-pathological and pathological tissues; and would be positively received by patients. Therefore, it appears the main reason 80% of participants in this survey refer imaging to a third party is they don't believe they have adequate training to use elastography equipment.

In summary, elastography use in a clinical setting would require the practitioner to have a good understanding of the technical aspects of the equipment and its cost and cost effectiveness if they were to introduce elastography into their musculoskeletal setting. Trends indicate more "in-house" imaging procedures are being performed outside of hospitals and specialist imaging centres, hence more research is required to understand why the majority of practitioners are acquiring their images from a third party.

Limitations

This thesis project has a number of limitations. Firstly, the sample size for physiotherapists (n=4) and rheumatologists (n=11) is low. According to Morton et al, 2012 the minimum sample size for reliable results is 30, however reliability is not solely dependent on reaching this threshold (Morton et al., 2012). Studies have suggested good design and analysis can overcome small sample sizes. For example, MSK/sports doctors did not reach this threshold however the response rate was half of the available population (51:25, 49%) hence results are likely to represent this professions use and beliefs of dxUS.

Our survey used one questionnaire, concurrently, for all five professions in the target population. Whilst utilising one questionnaire may enhance reliability between professions' analysis, it is not necessary to deliver the survey concurrently. To improve the response rate from each profession it would be helpful to allow more time to develop a relationship with the people involved in delivering the survey invitation. For example, invitation advertisements at conferences, on newsletters, or longer collection times to allow social media “snowball” effects to occur. Moreover, the endorsement of a recognised leader in each profession is likely to be beneficial for increased responses. For example, the invitation to MSK/sports doctors was accompanied by an endorsed note/message from a leader in the profession and as such produced the strongest response rate.

Second, descriptive statistics were used in accordance with the goal of the study to investigate the possible utility of using elastography to collect quantitative data of fascia tissues in a musculoskeletal setting. Future studies may apply more robust statistical analysis such as ANOVA to measure variance between practitioner groups, however, to our knowledge no survey of its type appears in the literature and hence may provide a basis to which further research is designed. Specifically, future studies may follow the one questionnaire to multiple professions design to measure use and beliefs of both users and non-users in relation to technology use.

Third, there is a heavy reliance on beliefs about diagnostic ultrasound being an acceptable substitute for elastography use and beliefs to compare the results of our survey with results from our review, and with referenced studies. As at the time of writing, no study has investigated if this assumption is valid, however multiple reviews (Avila Gonzalez et al., 2018; Gatz et al., 2020; Khodair, 2020; Ryu & Jeong, 2017) investigating muscle and fascia tissues compared ultrasound and elastography which may suggest that these two technologies share similar investigative qualities.

Lastly, the nature of a narrative review is that it is not exhaustive (Greenhalgh et al., 2018). Specifically, grey searches of references from included studies were not included, and, as noted by Dr Tom Findley (refer personal communication noted in results chapter), the search parameters may have been too strict to provide studies of fascia tissues other than tendons. To mitigate this bias we adhered to a systematic approach following Cochrane

Review guidelines. Our reasoning for this is simply that time constraints and scope meant it was outside the resources of a Masters thesis.

Summary

This Masters project aimed to investigate the possible use of elastography to collect quantitative data of fascia tissues in a musculoskeletal clinic setting. We used a mixed method of a systematic narrative review and survey to collect data from a broad group of musculoskeletal professions and synthesised both sets of results to determine our findings.

In summary our findings illustrated that:

1. There are no studies that investigate elastography to quantifiably measure fascia tissues outside of tendons.
2. Studies that investigate elastography scanning of tendons illustrate that:
    a. There is very good to excellent sensitivity and specificity to detect pathological from non-pathological tendon tissues.
    b. There are preferred protocols that enhance reliability.
    c. There are cofounders that need to be considered when analysing data.
3. The most likely users of dxUS are rheumatologists and MSK/sports doctors.
4. The most common reason for not using dxUS is lack of training/education.
5. The use of dxUS varies between professions.
6. All professions mostly (>70%) agree dxUS is:
    a. Able to produce reliable images of pathologic and non-pathologic tissues.
    b. Should only be taken by trained professionals.
    c. Can aid a clinician with good palpation skills.
    d. May be useful to quantify diagnostic findings.
    e. Is positively received by patients.

7. Elastography may be useful to quantify tissue stiffness in a musculoskeletal setting.

CHAPTER 5

ELASTOGRAPHY IMPLEMENTATION INTO A MUSCULOSKELETAL SETTING

Investigating the potential of elastography's usefulness, for quantifying the characteristics of fascia tissues in a musculoskeletal setting, is the goal of this thesis project. This chapter will discuss findings from the review and survey that illustrates the challenges and benefits of implementing elastography into a musculoskeletal setting.

Assuming the practitioner will be performing the scan they will require an understanding of the technical aspects of the technology, appropriate scanning protocols, and awareness of other confounders that may influence the analysis of the images. Additionally, awareness of the limitations of elastography will aid the practitioner to assess the reliability of the images acquired. Finally, a proposed protocol for implementation of elastography in a musculoskeletal setting is presented.

Implementation of elastography would require the practitioner to have an appropriate understanding of: the principles of pathological changes in each musculoskeletal tissue (as described previously), the principles of elastography equipment parameters and its workings, the principles of scanning methodology, and special considerations. These would include:

1. Equipment parameters (technology and costs).
2. Physics of Elastography and Units of measure.
3. Scanning Protocols (scanning sites and positioning of transducer).
4. Confounding variables (gender, age, special populations).

Equipment Parameters

As described previously, elastography equipment is virtually identical to the ultrasound unit and transducer in appearance, however there are technical differences which the practitioner would need to be aware of. These include: elastography base units require elastography software; and the use of specialised transducers (Taljanovic et al., 2017).

For shear wave elastography (SWE) the transducer is specialised to provide acoustic pulses and detect tissue displacement through fast plane wave excitation technology (Box 4.1) where strain elastography (SE) requires the transducer to gauge the axial pressure being applied to the ROI. Application of SE requires the operator to maintain a consistent axial pressure perpendicularly to the tissue. Modern SE machines provide a pressure indicator on the side of the B-mode image for the operator to monitor the pressure placed on the target tissue. This aspect of SE scanning introduces more operator dependent variables and may explain why the preferred elastography type was SWE in our review.

In SWE, the transducer requires sufficient velocity detection width to account for the possibility of high stiffness recordings. For example, in our review, Petitpierre et al (2018) indicated that readings for an Achilles tendon in dorsal flexion (i.e. stretched) can reach as high as 106kPa which could potentially challenge the limitations of a 15MHz transducer. Studies in our review preferred scanning in a neutral (non-stretched) position which is likely to keep readings well within the scope of the transducer (Petitpierre et al., 2018). Further, studies in our review mostly used transducers with an upper limit of 18MHz which is likely to accommodate the majority of fascia tissues stiffness. Further studies of other fascia tissues may indicate denser tissues requiring a greater upper limit for stiffer recordings.

Finally, for SWE, gels or gel-pads allow better transducer docking. However, the detection of shear wave scatter is very sensitive and the use of gels may produce lower velocity values (hence indicating pathology) due to miniscule delays in shear wave detection. Recent guidelines from the European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB) suggest to avoid the inclusion of gels to prevent these detection effects of shear waves (Saftoiu et al., 2019).

Physics of Elastography and Units of Measure

Elastography may produce two types of data, quantitative, or semi-quantitative. Semi-quantitative data is produced using strain elastography where the disruption of the tissue is provided by a mechanical pressure being placed perpendicularly through the transducer (as described previously). Tissue displacement is then indicated by a colour map on a B-mode ultrasound image. Colours on the map indicate different stiffness states. Blue and red are the bookmarks of the colour scale with blue indicating softness and red indicating hardness. Dirrichs et al (2016) considered this data semi-quantitative due to the observers role in determining the tissue stiffness by subjectively recognising the colours (Dirrichs et al., 2016). For example, *"is that blue or turquoise?"* may be considered a subjective opinion by the observer (Figure 5.1).

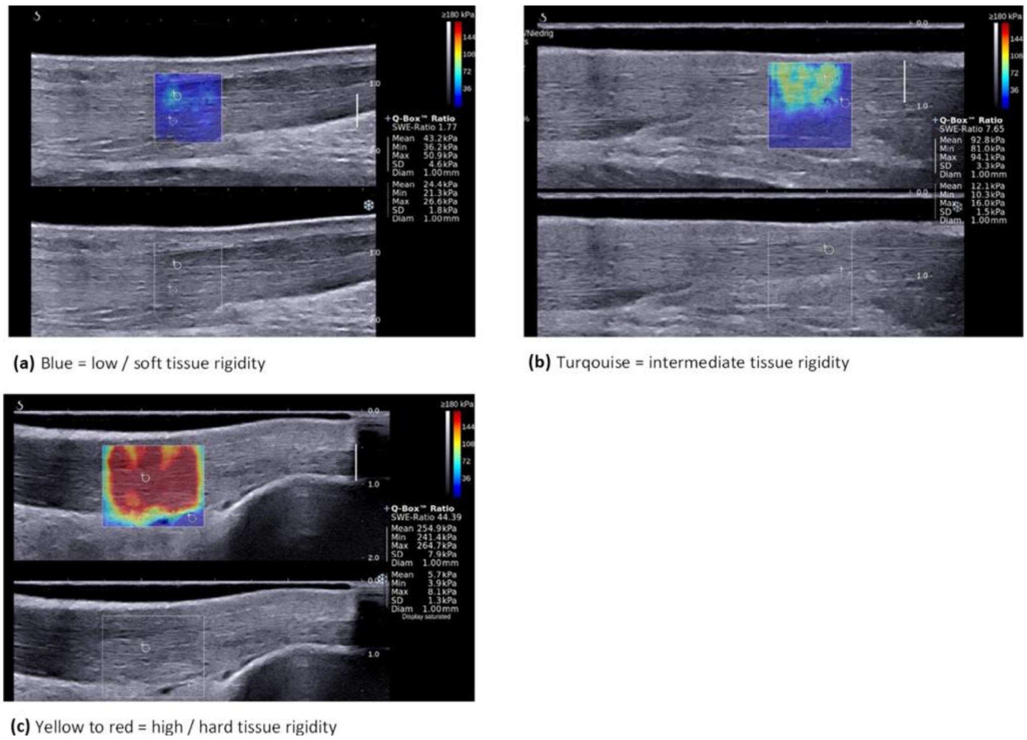


Figure 5.1. **Semiquantitative evaluation of tendon stiffness by shear wave elastography (SWE). Tissue rigidity of tendons was assessed semiquantitatively by color charts (a–c). (a) Blue: low/soft tissue rigidity, (b) turquoise: intermediate tissue rigidity, (c) yellow to red: high/hard tissue rigidity. (Color version of figure is available online.) (Dirrichs et al., 2016 p.1206)**

Yoshida et al (2017) attempted to quantify this data by giving each hue a value (i.e, blue = 0, red = 6) and created a specialised software program to calculate a mean hue score from the echo wave lengths created by the axial force disturbing the tissues (Yoshida et al., 2017a). Removing the subjective element of the observer and producing a quantitative score represents a unique way of representing tissue stiffness, however as discussed previously, SE requires axial pressure applied by the operator which may influence the inter-operator reliability – inter and intra-operator reliability is discussed later in this chapter.

Quantitative data may be acquired using Shear Wave Elastography (SWE) where an acoustic pulse is produced by the transducer and the shear wave effects on the tissue may be measured using pressure (kPa) or velocity (m/s). Box 4.1 describes the process of SWE, the differences in units of measure, and necessary assumptions.

Box 5.1 Summary of Shear Wave Elastography Physics and Units of Measure

Summary of Technical Aspects of Shear Wave Elastography

Basic Physics of Shear Wave Elastography

1. **Generation** of shear waves in tissues by an acoustic radiation force (via transducer).
2. **Detection** of induced shear waves through tissue displacement maps which are detected by "fast plane wave excitation" (up to 5000 frames/s) and shear wave velocities are estimated using a time of flight algorithm (Gennisson et al, 2010. pg. 791).
3. **Calculation** of shear wave velocity using equation $G=pc_s^2$, where G is the "Shear modulus", p is tissue density (assumed density equal to water p = 1g/cm^3), and c_s^2 is the shear speed (m/s) OR **calculation** of "Young modulus" (E), which is the resistance of a material to deformation using the equation $E=3$ μ=3 p cT^2, where μ is the resistance to shear force (kPa), p is assumed density 1g/cm^3, cT is the transverse propagation speed (m/s).

Differences in units of measure

Shear modulus records the velocity of shear wave propagation which is determined by the resistance of the material to the acoustic radiation force, hence provides a value of tissue stiffness in metres per second (m/s).

Young modulus records the pressure resistance to the shear force provided by the acoustic radiation and is recorded in kilo Pascals (kPa).

Assumptions

Both equations require the prerequisite assumption that the material is elastic, incompressible (IE, will return to its original shape), homogenous, and isotropic. However, most tissues in the human body are anisotropic, heterogenous, and vary from the assumed density of 1g/cm^3. Further, viscoelastic tissues (EG, muscles) have both solid and viscous elasticity properties.

However, for elasticity metrics, if solid and viscous properties are ignored and assuming linear tissue properties, tissue elasticity approximation is possible.

Two SE studies in our review used colour maps with the same bookends of blue for softness and red for hardness (multiple colours in between) and five SWE studies used either kPa or m/s as units of measure to report their results. Conversion from one value to another is possible using the formula: $E_{mean} \cong 3p.V_{mean2}$, where E is mean Young modulus, p is density, and V is the shear wave velocity (Aubry et al., 2018). It is unlikely the non-researcher is aware of the conversion formulae, hence a standard unit of measure would be beneficial to the investigating practitioner and additionally, aid cross practitioner communication. It appears that more recent studies use velocity (m/s) of shear waves as the unit of measure which may suggest this is the unit of choice.

Quantitative measures of tissue stiffness through elastography may provide the practitioner with an extra tool to aid in the working diagnosis, additional benefits would include a recognised reporting tool when communicating to other practitioners. Standardisation of the unit of measure would greatly enhance this benefit regardless of scanning being performed by a third party or within the musculoskeletal setting.

Scanning Protocols

In our review three studies (Aubry et al., 2015; Sahan et al., 2018b; Yoshida et al., 2017b) examined positioning of the probe in a sagittal or transverse plane and four (Li et al., 2018b; Petitpierre et al., 2018; Yoshida et al., 2017a; Zhang et al., 2018a) studies examined the optimal site on the tendon to provide reliable results.

Shear wave velocity is influenced by three factors; probe-fibre orientation, viscoelastic 'border effects', and the isotropic or anisotropic arrangement of the fibres in the ROI. All SWE studies in our review reported that data from sagittal plane scanning were significantly stiffer than data from transverse plane scans. According to Aubry et al (2015) this is due to shear waves dispersing quicker when impulse waves react to fibres arranged in a parallel orientation versus transverse fibre orientation (Aubry et al., 2015).

Anisotropy is an important consideration when using elastography. Tissue fibres organised in multiple planes (therefore are anisotropic) create greater shear wave scatter and are detected by the transducer at a slower rate than isotropic tissues, and as described previously slower readings of SWE scans indicate pathologic tissues. The body of the tendon is likely to be more isotropic with the fibres arranged in a tightly bunched parallel configuration compared to fibres attaching at the enthesis or at the myotendinous-junction (Petiterre et al., 2018) . For example, Aubrey et al (2015) calculated an anisotropic coefficient using the formula: $A = (sagV_{mean} – axV_{mean})/axV_{mean}$, where A = Anisotropy, $sagV_{mean}$ is the average velocity with the transducer in the sagittal plane, and axV_{mean} is the average velocity with the transducer in the axial plane (Aubry et al., 2015) . Hence, high *A* values indicate greater degrees of tissue anisotropy, slowing shear wave activity, and producing data indicating greater tissue softness values in the ROI. Anisotropic and viscoelastic properties of muscle are significantly higher than fascia tissues (Gennisson et al., 2010), hence elastography may be better suited for investigating fascia tissues where ultrasound may be better suited to investigate muscle tissues.

Border effects may influence elastogram readings. These effects are due to the detection field spilling over into surround tissue that has higher viscoelastic properties than the ROI. For example, tendons are arranged as tightly packed collagen type I fibres that have a small amount of viscoelastic properties, however neighbouring tissues (such as muscle) have higher viscoelastic properties and if the transducer includes the neighbouring tissues in its readings the elastogram will indicate a false positive for pathologic findings of the tendon. Therefore, positioning the transducer along the longitudinal plane (versus sagittal) is likely to reduce the possibility of border effects. Li et al (2018) designed software where the operator can interactively delineate the tendon border on ultrasound and SE which may represent a solution for reducing or mitigating border effects (Li, Zhang, Cai, & Hua, 2018a).

Two studies using SWE examined positioning of the probe in a sagittal or longitudinal plane (Aubry et al., 2015; Petitierre et al., 2018) and both studies reported data from sagittal plane scanning were significantly stiffer than data from longitudinal plane scans. Our review showed all studies (SE and SWE) used a longitudinal plane application of the transducer which is likely due to the need to limit border effects and reduce anisotropy.

Studies in this review scanned tendons where access was easy (five different tendons in total) and mostly involved the Achilles tendon. Usefulness of elastography in a musculoskeletal office will need to consider that the ROI may be a tendon with less access, either through anatomy or restricted patient positioning. Further, some tissues are anisotropic by nature. For example, the muscle and fascia tissues of the quadratus lumborum are highly anisotropic due to the multiple force production, support lines, and interweaving of muscle and fascia tissues (Wong et al., 2017) in comparison to the anatomy of the iliotibial band which is mostly comprised of tightly packed collagen fibres with mostly longitudinal forces applied between the knee and hip (Stecco, Gilliar, Hill, Fullerton, & Stecco, 2013).

Research into elastography for use in a musculoskeletal setting will need to broaden the scope of tissue investigation to include other structures and not just tendons. Determining the influence of anisotropic effects and utilising technology advances to control the detection field are likely to be important factors to allow sufficient reliability of elastography use in a musculoskeletal setting.

Confounding Variables - Gender, Age, and Special Populations

In this review, Yoshida et al (2018) was the only study of gender differences between male and female subjects (Yoshida et al., 2017a). They reported greater tendon stiffness norms in males than females which supports results from a previous study by Kubo et al (2003) who hypothesised the difference was due to higher muscle mass in males pulling with greater force on tendons making male tendons stiffer (or more tightly packed with collagen fibres and hence stiffer) (Kubo, Kanehisa, & Fukunaga, 2003). These differences are likely to influence tendon stiffness "norms" between genders when using elastography. Hence, for accurate use of elastography scanning in musculoskeletal tissues, gender is a consideration for the practitioner to include when assessing stiffness.

Again, in our review, Yoshida et al (2018) was the only study to consider age variables when scanning tendon stiffness and reported no significant difference between subjects under 30yrs and those equal or over 30yrs. However, these results should be taken cautiously due to the relatively young age of 30yrs being where the two groups were separated. A recent systematic review and meta-analysis by Delabastita et al (2018) indicated a difference between young adults (18-30yrs), middle age (30-64yrs), and older adults (65yrs plus) in stiffness of the Achilles tendon (Delabastita, Bogaerts, & Vanwanseele, 2018). Results from studies identified in the Delabastita et al (2018) review/analysis indicate a significant difference in young adults versus old adults in tendon stiffness (i.e. 24-99% less stiffness) which is hypothesised to be due to reduced exercise (Stenroth et al., 2015) and reduced collagen content in the old adult population (Couppé et al., 2009). There is less certainty in the middle age range (30-64yrs) as to when tendons begin their decline in stiffness however there is a definite decline in this age group versus young adults. Yoshida et al (2018) reported no change in Achilles stiffness up to age 40yrs, where other studies suggest changes occur sometime before 46yrs (Ackermans et al., 2016; Onambele, Narici, & Maganaris, 2006). These studies suggest there is a difference between young and old adult populations in regard to tendon stiffness, however when these changes occur is less certain although there is some evidence it is before 46yrs.

Activity levels of the client are likely to be routinely ascertained in the initial history examination and higher levels of activity is likely to result in firmer baseline values for tendon stiffness. These factors (age and activity levels) along with gender should be a consideration when determining normal or pathological findings from elastography scans.

Only one paper in this review used SWE to investigate a “special population”. Zhang et al (2018) (Zhang et al., 2018a), compared 19 healthy Achilles tendons to 47 healthy tendons of subjects with “familial hypercholesterolemia (FH)” and reported the healthy subjects had significantly stiffer tendons versus the FH group. Further, Turan et al (2013) investigated asymptomatic patients with Ankylosing Spondylitis and healthy subjects using SE (Turan et al., 2013). They found that the distal third (enthesis) was most commonly affected compared to healthy subjects and was most likely due to associated enthesopathy such as calcaneal bone erosions.

The studies of Zhang et al (2018), and Turan et al (2013), may illustrate two important benefits when using technology in a clinical setting. Firstly, that tendon stiffness presents softer in special populations and elastography is a useful tool to use when researching these populations. Secondly, there is evidence that special populations such as ankylosing spondylitis and familial hypercholesterolemia effect tendon stiffness, however other connective tissue disorders such as Lupus, Ehlers-Danlus syndrome, and Marfan syndrome may also affect tendon stiffness. Therefore, elastography in a clinical setting may detect these disorders before other signs of disease become apparent. A parallel example may be routine eye examinations by ophthalmologists that detect non-retinopathy diseases during a routine eye exam, such as: diabetes, hypertension, cancer, tumours, high cholesterol, thyroid disease, autoimmune diseases (e.g, Lupus), and neurological conditions (Prasad, 2018). Using quantitative data from an elastography scan may provide the practitioner with useful findings upon which to further investigate other health characteristics of the client and, if appropriate, refer the client for further testing in a timely manor.

Each client presents to a musculoskeletal office with a unique biopsychosocial profile that requires individual consideration when determining a working diagnosis. Technology may enhance the practitioners ability to arrive at a working diagnosis, however it does not replace other diagnostic tools and testing procedures. Elastography is a technology that specifically measures the viscoelastic properties of the tissues in the ROI and may be an effective tool to augment other examination tools for diagnostic purposes. Considerations of gender, age, and confounders (e.g. special populations) are important when the practitioner analyses the data from elastograms.

The potential benefits of elastography may encourage further research and technological development into its use, however more research is required to provide confidence of reliability and utility of elastography use in a musculoskeletal setting.

Limitations of Elastography Use in a Musculoskeletal Setting

The potential benefits of elastography may encourage further research and technological development into its use in private practice. Results from our review and survey suggest the main limitations to elastography use are; lack of education, uncertainty of cost-to-benefit ratio, and dependence on operator skill.

The majority of non-users (85%) in our survey indicated that they were inadequately trained to use or perform dxUS. This finding is similar to other surveys of physiotherapists and rheumatologist where either no training, or lack of time (for training), or costs of training, were the main reasons for the participants not using ultrasound (Cannella et al., 2014; Ellis et al., 2018). As described previously, chiropractic and osteopathic teaching institutions are investigating using ultrasound in their curriculum, however the main focus of these studies was to investigate the use of ultrasound to enhance skills concerning anatomical locations for the undergraduate.

At time of writing this paper, post-graduate courses (certificate or diploma) are available through the Universities of Otago and Auckland (New Zealand) and may be attended directly or remotely. It is unclear if chiropractors or osteopaths qualify to attend these courses as the inclusion criteria states: medical practitioners, nurses, and other professionals (https://www.auckland.ac.nz/en/study/study-options/find-a-study-option/ultrasound/postgraduate.html, https://www.otago.ac.nz/courses/qualifications/pgcertcpu.html).

Practitioners would need to consider the diagnostic benefits and patient acceptance of introducing this technology into their clinic. Our survey indicated that two-thirds of participants believe dxUS is a useful tool to quantify diagnostic findings and over 80% of participants believe dxUS is not surplus to requirements for a clinician with good palpation skills. Additionally, most participants (75%) agree dxUS would be received well by clients and that most (57%) agree it would aid patient education.

Patient education may help clients adhere to treatment plans. For example, a review by Joplin et al (2015), reported greater adherence to medication programs in patients with rheumatoid arthritis when coupled with visual information from musculoskeletal ultrasound (Joplin, van der Zwan, Joshua, & Wong, 2015). This may explain why over 80% of rheumatologists in our survey believe dxUS is a useful aid in patient education and is 20% more than other professions. Additionally, Louw et al (2016), reported that patient education was effective for chronic musculoskeletal disorders in: reducing pain and improving patient knowledge of pain; improving function and lowering disability; reducing psychological factors; and enhancing movement and minimising healthcare utilisation (Louw, Zimney, Puentedura, & Diener, 2016).

Rheumatologists who participated in the survey significantly agree (76%) that dxUS may be easily incorporated into daily clinical practice and mostly agree it would be cost effective. By comparison, MSK/sports doctors, chiropractors and osteopaths believe that dxUS would not be cost effective and is unlikely to be easily incorporated into daily practice. As described previously, the size of our rheumatologist sample may influence a sample error, however it appears that rheumatologists are more likely to introduce elastography into their clinical setting before the other professions. A possible reason for this may be that they have more training in dxUS whilst gaining their qualifications and that they have a wide scope of use. MSK/sports doctors have greater dxUS training than chiropractors and osteopaths, and may have a wider scope of use for this technology. However, their results mirrored responses from these two professions.

Cost-effectiveness of ultrasound use amongst MSK/sports doctors and rheumatologists may be due to a reduced need for more expensive imaging such as CT or

MRI imaging. Utilization of MRI increased by 353% between 1996 and 2005 and is projected to cost $2 billion of $3 billion spent on musculoskeletal imaging in 2020 amongst Medicare patients in the United States (Coris et al., 2011). These trends may not be shared outside of the United States as European rheumatologists utilise ultrasound more than their United States counterparts due to less access to MRI technology (Cannella et al., 2014).

Additionally, ultrasound imaging may reduce costs due to advances in imaging technics and technology. For example, a study by Nazarian (2008) of 3621 MRI reports, indicated that 45% of primary diagnoses could have been made with musculoskeletal ultrasound (Nazarian, 2008). Further, a systematic meta-analysis by Roy et al (2015) compared the sensitivity of ultrasound against MRI and MRA (Magnetic Resonance Angiogram) to detect full and partial tears of the rotator cuff. All three imaging modalities showed excellent diagnostic specificity and sensitivity for full thickness tears (>0.90) and partial tears. Further, dxUS was comparable whether the scan was taken by a trained sonographer or a non-radiologist suggesting that dxUS may not be as operator dependent as previously thought. This study concludes that when costs, availability, safety, and efficiency is considered, ultrasound is likely to be the best option for diagnostic imaging of full thickness tears of the rotator cuff (Roy et al., 2015).

When comparing elastography with alternative imaging it is important to ensure it is effective and safe. Comparatively, elastography is very safe due to the use of sound waves which are considered significantly less harmful than ionising waves as used in radiographic studies or magnetic impulses as used by MRI. However, elastography, as with ultrasound, does have thermal effects that increase heat in applied tissues. These “bio-effects” are minimal and there have been no undisputed reported harmful consequences (Dietrich et al., 2017).

When considering the practical use of elastography in a clinical setting (i.e. utility), our review has identified several factors to be considered. Firstly, the client should be in a relaxed, non-contracted position with easy access to the area of interest. Secondly, the transducer should be located on the body of the ROI and positioned longitudinally. Thirdly, confounding variables such as gender, age, and special conditions should be considered when analysing scanning data.

Ultrasound and elastography are highly operator dependent technologies. Two studies in our review indicated mixed interobserver correlation when performing SWE scans. Aubrey et al (2018), indicated that interobserver reliability is low due to the precision required to reduce anisotropic effects and the importance of transducer placement required to produce repeatable reliable results (Aubrey et al., 2018). These findings are partly supported by Peltz et al (2013), who compared *in vitro* studies of tendon stiffness with *in vivo* studies of tendons in multiple sites (Peltz et al., 2013). This study reported fair repeatability for Achilles tendon, moderate repeatability for patella tendon, and good repeatability for quadricep and flexor pollicis longus tendons. The authors suggested the loss of repeatability was mostly due to the difficulty to maintain a consistent imaging location of subject (or tendon/ROI) and of the probe.

The other study in our review to assess inter-observer reliability was by Petitpiere et al (2018), and reported no significant interobserver difference between two musculoskeletal radiologists (radiologists had three and six years post-residency experience). This study included inter-observer reliability at different “zones” of the Achilles tendon and reported greater reliability when the probe was placed in the body of the tendon versus the myotendinous junction and enthesis (Petitperre et al., 2018). This finding provides more support for the body of the tendon being the most reliable ROI which may be due to less anisotropic factors, as previously discussed.

Studies of inter and intra-observer reliability using ultrasound (Del Baño-Aledo et al., 2017; Henderson, Walker, & Young, 2015) to measure thickness of muscle and non-muscle soft tissues indicate encouraging results for muscle but mixed results for fascia type tissues. For example, a recent study by Filippo et al (2019), "demonstrated US imaging is highly reliable for measuring anterior thigh muscle thickness, though reliability was poor for measuring perimuscular fascia on its own" (Filippo et al., 2019). The authors stressed the importance of a standardised data collection protocol to reduce variables of data collection. Whilst the tissues of this study were not facial tissues, and it did not use elastography, the study contributes to a growing body of evidence that may improve the reliability of data collection in a clinical setting.

In summary, implementation of elastography into a musculoskeletal setting requires the practitioner to have a good knowledge of the technical aspects and of the different units that may be used depending on the technology used (i.e. SWE or SE). Additionally, due to anisotropic and border effects, scanning protocols require the probe to be orientated longitudinally and located in the body of the ROI. Finally, confounders such as age, sex, and special populations need to be considered when analysing scans. A proposed protocol for implementation of elastography in to a musculoskeletal setting is given in Figure 5.1 below.

Client Presents with Musculoskeletal Complaint

Client completes initial intake form that includes:
pain diagrams; pain scales; history of chief complaint; family health history; special conditions (e.g. diabetes), and consent for procedure/care.

Interview

Complete health history interview.

Elastography Scan Protocol

Perform scans (before physical exam) using following procedure:

1. Client appropriately dressed into gown/shorts (supplied) to allow access to ROI.
2. Client is in relaxed position on table (prone or supine depending on ROI).
3. Probe is placed longitudinally on the belly of the tendon of the ROI.
4. Scan is performed five times on each ROI (can scan multiple sites, e.g. Achilles and planter fascia).
5. Procedure includes scanning of contralateral pain side.
6. Save scan.

Physical Exam

Complete physical exam.

Analyse Data, Determine Working Diagnosis, and Begin Treatment

Analyse results of all presenting data to determine a working diagnosis. Include elastography co-founders (e.g. age, gender, special populations).
Begin treatment plan.

Follow-Up Appointments and Communication

Utilise elastography scans for:

1. Follow-up appointments or at scheduled stages of recovery.
2. Progress reporting and education.
3. Reports for third party payers (e.g. ACC).
4. Communication with other professionals.

Fig 5.2. **Proposed Protocol for Implementation of Elastography in a Musculoskeletal Setting**

CHAPTER 6

CONCLUSIONS

Further research is required for the reliable introduction of elastography into a musculoskeletal practice setting. Moreover, this review indicated that currently no clinical trials of non-tendon fascia tissues was found in the literature which represents a significant gap in the evidence for the potential use of elastography to measure tissue stiffness in a practice setting. Despite this, published studies involving tendons (only) indicated potential benefits for determining their pathological and non-pathological status as well as illustrating preferred scanning protocols. Additionally, studies illustrated confounders that will influence the analyses of elastograms and effect the reliability of elastography use when quantitatively measuring fascia or myofascial tissues in determining a working diagnosis.

Interest in the role fascia tissue plays in the physiology of the human body is attracting greater attention as indicated by the increased volume of research in this field. Additionally, fascia tissues are being differentiated from muscle tissue in treatment and rehabilitation exercises and current trends in North America suggest imaging in private practice is rapidly growing. Hence, elastography may potentially be an effective image technology to determine fascia tissue stiffness separate from muscle tissue stiffness which is potentially useful in a musculoskeletal setting.

This thesis project synthesised results of a review and survey to investigate the potential implementation of elastography into a musculoskeletal setting. As discussed previously there is a dearth of research that illustrates elastography can be introduced reliably into a clinical setting, however results from our survey indicates a favourable use of technology in a clinical setting from a broad range of musculoskeletal practitioners in New Zealand. Development of elastography technology and the growing trends of imaging in private practice may indicate that the barriers of education, costs, and reliance on skilled operators will be mitigated in the future to enable this technology to be utilised in private practice.

Finally, more research is required to determine if elastography can be used reliably to measure many other fascia or myofascial tissues, however our survey results appear to suggest that musculoskeletal practitioners would be favourable to its use. This study may help form a foundation upon which future research can implement elastography reliably into the musculoskeletal setting and ultimately improve the diagnosis, treatment, and outcomes for clients with musculoskeletal symptomology.

REFERENCES

Ackermans, T. M. A., Epro, G., McCrum, C., Oberländer, K. D., Suhr, F., Drost, M. R., . . . Karamanidis, K. (2016). Aging and the effects of a half marathon on Achilles tendon force–elongation relationship. *European Journal of Applied Physiology, 116*(11-12), 2281-2292. doi:10.1007/s00421-016-3482-z

Alsiri, N., Al-Obaidi, S., Asbeutah, A., & Palmer, S. (2020). Intra-rater reliability and smallest detectable change of compression sonoelastography in quantifying the material properties of the musculoskeletal system. *J Anat*. doi:10.1111/joa.13183

Aubry, S., Nueffer, J.-P., Tanter, M., Becce, F., Vidal, C., & Michel, F. (2015). Viscoelasticity in Achilles tendonopathy: quantitative assessment by using real-time shear-wave elastography. *Radiology, 274*(3), 821-829. doi:10.1148/radiol.14140434

Aubry, S., Nueffer, J. P., Tanter, M., Becce, F., Vidal, C., & Michel, F. (2015). Viscoelasticity in Achilles tendonopathy: quantitative assessment by using real-time shear-wave elastography. *Radiology, 274*(3), 821-829. doi:10.1148/radiol.14140434

Avila Gonzalez, C. A., Driscoll, M., Schleip, R., Wearing, S., Jacobson, E., Findley, T., & Klingler, W. (2018). Frontiers in fascia research. *J Bodyw Mov Ther, 22*(4), 873-880. doi:10.1016/j.jbmt.2018.09.077

Barkan, H. (2015). Statistics in clinical research: Important considerations. *Ann Card Anaesth, 18*(1), 74-82. doi:10.4103/0971-9784.148325

Benias, P. C., Wells, R. G., Sackey-Aboagye, B., Klavan, H., Reidy, J., Buonocore, D., . . . Theise, N. D. (2018). Structure and Distribution of an Unrecognized Interstitium in Human Tissues. *Sci Rep, 8*(1), 4947. doi:10.1038/s41598-018-23062-6

Berko, N. S., Fitzgerald, E. F., Amaral, T. D., Payares, M., & Levin, T. L. (2014). Ultrasound elastography in children: establishing the normal range of muscle elasticity. *Pediatr Radiol, 44*(2), 158-163. doi:10.1007/s00247-013-2793-z

Brown, A. K., Roberts, T. E., Wakefield, R. J., Karim, Z., Hensor, E., O'Connor, P. J., & Emery, P. (2007). The challenges of integrating ultrasonography into routine rheumatology practice: addressing the needs of clinical rheumatologists. *Rheumatology, 46*(5), 821-829. doi:10.1093/rheumatology/kel412

Cannella, A. C., Kissin, E. Y., Torralba, K. D., Higgs, J. B., & Kaeley, G. S. (2014). Evolution of musculoskeletal ultrasound in the United States: implementation and practice in rheumatology. *Arthritis Care Res (Hoboken), 66*(1), 7-13. doi:10.1002/acr.22183

Carroll, H. A., Toumpakari, Z., Johnson, L., & Betts, J. A. (2017). The perceived feasibility of methods to reduce publication bias. *PLOS ONE, 12*(10), e0186472. doi:10.1371/journal.pone.0186472

Coris, E. E., Pescasio, M., Zwygart, K., Gonzalez, E., Farrar, T., Bryan, S., . . . McElroy, T. (2011). Office-based ultrasound in sports medicine practice. *Clinical Journal of Sport Medicine, 21*(1), 57-61. doi:10.1097/JSM.0b013e31820758aa

Couppé, C., Hansen, P., Kongsgaard, M., Kovanen, V., Suetta, C., Aagaard, P., . . . Magnusson, S. P. (2009). Mechanical properties and collagen cross-linking of the patellar tendon in old and young men. *Journal of Applied Physiology, 107*(3), 880-886. doi:10.1152/japplphysiol.00291.2009

Crass, J. R., Craig, E. V., Thompson, R. C., & Feinberg, S. B. (1984). Ultrasonography of the rotator cuff: surgical correlation. *J Clin Ultrasound, 12*(8), 487-491.

Creze, M., Nordez, A., Soubeyrand, M., Rocher, L., Maitre, X., & Bellin, M. F. (2018). Shear wave sonoelastography of skeletal muscle: basic principles, biomechanical concepts, clinical applications, and future perspectives. *Skeletal Radiol, 47*(4), 457-471. doi:10.1007/s00256-017-2843-y

D'Agostino, M. A., & Terslev, L. (2014). A brief history of ultrasound in rheumatology: where are we going. *Clin Exp Rheumatol, 32*(1 Suppl 80), S106-110.
Davis, J. J., Wessner, C. E., Potts, J., Au, A. K., Pohl, C. A., & Fields, J. M. (2018). Ultrasonography in undergraduate medical education: A systematic review. *Journal of Ultrasound in Medicine, 37*(11), 2667-2679. doi:10.1002/jum.14628
Dawidowicz, J., Szotek, S., Matysiak, N., Mielanczyk, L., & Maksymowicz, K. (2015). Electron microscopy of human fascia lata: focus on telocytes. *J Cell Mol Med, 19*(10), 2500-2506. doi:10.1111/jcmm.12665
De Zordo, T., Fink, C., Feuchtner, G. M., Smekal, V., Reindl, M., & Klauser, A. S. (2009). Real-time sonoelastography findings in healthy Achilles tendons. *AJR Am J Roentgenol, 193*(2), W134-138. doi:10.2214/ajr.08.1843
Del Baño-Aledo, M. E., Martínez-Payá, J. J., Ríos-Díaz, J., Mejías-Suárez, S., Serrano-Carmona, S., & de Groot-Ferrando, A. (2017). Ultrasound measures of tendon thickness: Intra-rater, inter-rater and inter-machine reliability. *Muscles, Ligaments and Tendons Journal, 7*(1), 192-199. doi:10.11138/mltj/2017.7.1.192
Delabastita, T., Bogaerts, S., & Vanwanseele, B. (2018). Age-Related Changes in Achilles Tendon Stiffness and Impact on Functional Activities: A Systematic Review and Meta-Analysis. *J Aging Phys Act*, 1-12. doi:10.1123/japa.2017-0359
Dietrich, C. F., Goudie, A., Chiorean, L., Cui, X. W., Gilja, O. H., Dong, Y., . . . Blaivas, M. (2017). Point of Care Ultrasound: A WFUMB Position Paper. *Ultrasound Med Biol, 43*(1), 49-58. doi:10.1016/j.ultrasmedbio.2016.06.021
Dirrichs, T., Quack, V., Gatz, M., Tingart, M., Kuhl, C. K., & Schrading, S. (2016). Shear Wave Elastography (SWE) for the Evaluation of Patients with Tendinopathies. *Acad Radiol, 23*(10), 1204-1213. doi:10.1016/j.acra.2016.05.012
Drakonaki, E. E., Allen, G. M., & Wilson, D. J. (2009). Real-time ultrasound elastography of the normal Achilles tendon: reproducibility and pattern description. *Clin Radiol, 64*(12), 1196-1202. doi:10.1016/j.crad.2009.08.006
Du, L. J., He, W., Cheng, L. G., Li, S., Pan, Y. S., & Gao, J. (2016). Ultrasound shear wave elastography in assessment of muscle stiffness in patients with Parkinson's disease: a primary observation. *Clin Imaging, 40*(6), 1075-1080. doi:10.1016/j.clinimag.2016.05.008
Edwards, P. J., Roberts, I., Clarke, M. J., DiGuiseppi, C., Wentz, R., Kwan, I., . . . Pratap, S. (2009). Methods to increase response to postal and electronic questionnaires. *Cochrane Database of Systematic Reviews*(3). doi:10.1002/14651858.MR000008.pub4
Ellis, R., De Jong, R., Bassett, S., Helsby, J., Stokes, M., & Cairns, M. (2018). Exploring the clinical use of ultrasound imaging: A survey of physiotherapists in New Zealand. *Musculoskeletal Science and Practice, 34*, 27-37. doi:https://doi.org/10.1016/j.msksp.2017.12.002
Filippo, M., Lars, A. N., Maria, S., & Sandra, A. B. (2019). Inter-rater and intra-rater reliability of ultrasound imaging for measuring quadriceps muscle and non-contractile tissue thickness of the anterior thigh. *Biomedical Physics and Engineering Express, 5*(3). doi:10.1088/2057-1976/ab102f
Finnoff, J. T., Hall, M. M., Adams, E., Berkoff, D., Concoff, A. L., Dexter, W., & Smith, J. (2015). American Medical Society for Sports Medicine Position Statement: Interventional Musculoskeletal Ultrasound in Sports Medicine. *Clinical Journal of Sport Medicine, 25*(1), 6-22. doi:10.1097/JSM.0000000000000175
Franchi, M. V., Raiteri, B. J., Longo, S., Sinha, S., Narici, M. V., & Csapo, R. (2018). Muscle Architecture Assessment: Strengths, Shortcomings and New Frontiers of in

Vivo Imaging Techniques. *Ultrasound Med Biol, 44*(12), 2492-2504. doi:10.1016/j.ultrasmedbio.2018.07.010
Gatz, M., Bejder, L., Quack, V., Schrading, S., Dirrichs, T., Tingart, M., . . . Betsch, M. (2020). Shear Wave Elastography (SWE) for the Evaluation of Patients with Plantar Fasciitis. *Acad Radiol, 27*(3), 363-370. doi:10.1016/j.acra.2019.04.009
Gennisson, J.-L., Deffieux, T., Macé, E., Montaldo, G., Fink, M., & Tanter, M. (2010). Viscoelastic and Anisotropic Mechanical Properties of in vivo Muscle Tissue Assessed by Supersonic Shear Imaging. *Ultrasound Med Biol, 36*(5), 789-801. doi:https://doi.org/10.1016/j.ultrasmedbio.2010.02.013
Greenhalgh, T., Thorne, S., & Malterud, K. (2018). Time to challenge the spurious hierarchy of systematic over narrative reviews? *Eur J Clin Invest, 48*(6), e12931. doi:10.1111/eci.12931
Henderson, R. E., Walker, B. F., & Young, K. J. (2015). The accuracy of diagnostic ultrasound imaging for musculoskeletal soft tissue pathology of the extremities: a comprehensive review of the literature. *Chiropr Man Therap, 23*, 31. doi:10.1186/s12998-015-0076-5
Henderson, R. E., Walker, B. F., & Young, K. J. (2017). Current and Prospective Use of Musculoskeletal Diagnostic Ultrasound Imaging at Chiropractic Teaching Institutions: A Worldwide Survey of Diagnostic Imaging Staff. *J Chiropr Med, 16*(1), 54-63. doi:10.1016/j.jcm.2016.10.001
Higgins, J. P., Altman, D. G., Gotzsche, P. C., Juni, P., Moher, D., Oxman, A. D., . . . Sterne, J. A. (2011). The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ, 343*, d5928. doi:10.1136/bmj.d5928
Higgins, J. P. T., & Green, S. (2008). Cochrane Handbook for Systematic Reviews of Interventions Version 5.0.1. Retrieved from https://www.cochranelibrary.com/central/doi/10.1002/central/CN-00871375/full
Jedrzejczak, A., & Chipchase, L. S. (2008). The availability and usage frequency of real time ultrasound by physiotherapists in South Australia: an observational study. *Physiotherapy Research International, 13*(4), 231-240. doi:doi:10.1002/pri.409
Jonsson, A., & Rasmussen-Barr, E. (2018). Intra- and inter-rater reliability of movement and palpation tests in patients with neck pain: A systematic review. *Physiother Theory Pract, 34*(3), 165-180. doi:10.1080/09593985.2017.1390806
Joplin, S., van der Zwan, R., Joshua, F., & Wong, P. K. (2015). Medication adherence in patients with rheumatoid arthritis: the effect of patient education, health literacy, and musculoskeletal ultrasound. *Biomed Res Int, 2015*, 150658. doi:10.1155/2015/150658
Joy, J., McLeod, G., Lee, N., Munirama, S., Corner, G., Eisma, R., & Cochran, S. (2015). Quantitative assessment of Thiel soft-embalmed human cadavers using shear wave elastography. *Ann Anat, 202*, 52-56. doi:10.1016/j.aanat.2015.06.007
Khodair, S. G., U. (2020). Rotator Cuff Tendinopathy; Comparison Between Conventional Sonography, Sonoelastography, and MRI in Healthy Volunteers and Patients with Shoulder Pain. *International Journal of Medical Imaging, Vol.7*(No. 4), 91-97. doi:10.11648/j.ijmi.20190704.12
Klauser, A. S., Miyamoto, H., Tamegger, M., Faschingbauer, R., Moriggl, B., Klima, G., . . . Jaschke, W. R. (2013). Achilles tendon assessed with sonoelastography: histologic agreement. *Radiology, 267*(3), 837-842. doi:10.1148/radiol.13121936
Klauser, A. S., Pamminger, M. J., Halpern, E. J., Abd Ellah, M. M. H., Moriggl, B., Taljanovic, M. S., . . . Jaschke, W. R. (2017). Sonoelastography of the Common Flexor Tendon of the Elbow with Histologic Agreement: A Cadaveric Study. *Radiology, 283*(2), 486-491. doi:10.1148/radiol.2016160139

Kondrashova, T., & Lockwood, M. D. (2015). Innovative approach to teaching osteopathic manipulative medicine: the integration of ultrasonography. *J Am Osteopath Assoc, 115*(4), 212-220. doi:10.7556/jaoa.2015.043
Kubo, K., Kanehisa, H., & Fukunaga, T. (2003). Gender differences in the viscoelastic properties of tendon structures. *Eur J Appl Physiol, 88*(6), 520-526. doi:10.1007/s00421-002-0744-8
Kubo, K., Kanehisa, H., & Fukunaga, T. (2005). Effects of cold and hot water immersion on the mechanical properties of human muscle and tendon in vivo. *Clinical Biomechanics*, *20*(3), 291-300. Retrieved from
Kudo, M. (2015). Foreword to the WFUMB guidelines and recommendations on the clinical use of ultrasound elastography. *Ultrasound Med Biol, 41*(5), 1125. doi:10.1016/j.ultrasmedbio.2015.03.006
Larche, M. J., McDonald-Blumer, H., Bruns, A., Roth, J., Khy, V., de Brum-Fernandes, A. J., . . . Bykerk, V. (2011). Utility and feasibility of musculoskeletal ultrasonography (MSK US) in rheumatology practice in Canada: needs assessment. *Clin Rheumatol, 30*(10), 1277-1283. doi:10.1007/s10067-011-1743-0
Li, Q., Zhang, Q., Cai, Y., & Hua, Y. (2018a). Patients with Achilles Tendon Rupture Have a Degenerated Contralateral Achilles Tendon: An Elastography Study. *Biomed Res Int, 2018*, 2367615. doi:10.1155/2018/2367615
Li, Q., Zhang, Q., Cai, Y., & Hua, Y. (2018b). Patients with Achilles Tendon Rupture Have a Degenerated Contralateral Achilles Tendon: An Elastography Study. *BioMed Research International, 2018*. doi:10.1155/2018/2367615
Louw, A., Zimney, K., Puentedura, E. J., & Diener, I. (2016). The efficacy of pain neuroscience education on musculoskeletal pain: A systematic review of the literature. *Physiother Theory Pract, 32*(5), 332-355. doi:10.1080/09593985.2016.1194646
McKiernan, S., Chiarelli, P., & Warren-Forward, H. (2011). A survey of diagnostic ultrasound within the physiotherapy profession for the design of future training tools. *Radiography, 17*(2), 121-125. doi:https://doi.org/10.1016/j.radi.2010.08.003
Mizrahi, D. J., Parker, L., Zoga, A. M., & Levin, D. C. (2018). National Trends in the Utilization of Skeletal Radiography From 2003 to 2015. *J Am Coll Radiol, 15*(10), 1408-1414. doi:10.1016/j.jacr.2017.10.007
Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., . . . Stewart, L. A. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Syst Rev, 4*, 1. doi:10.1186/2046-4053-4-1
Morton, S. M., Bandara, D. K., Robinson, E. M., & Carr, P. E. (2012). In the 21st Century, what is an acceptable response rate? *Aust N Z J Public Health, 36*(2), 106-108. doi:10.1111/j.1753-6405.2012.00854.x
Naredo, E. (2015). Ultrasound in Rheumatology: two decades of rapid development and evolving implementation. *Med Ultrason, 17*(1), 3-4. doi:10.11152/mu.2013.2066.171.ezn
Nazarian, L. N. (2008). The top 10 reasons musculoskeletal sonography is an important complementary or alternative technique to MRI. *American Journal of Roentgenology, 190*(6), 1621-1626. doi:10.2214/AJR.07.3385
Onambele, G. L., Narici, M. V., & Maganaris, C. N. (2006). Calf muscle-tendon properties and postural balance in old age. *Journal of Applied Physiology, 100*(6), 2048-2056. doi:10.1152/japplphysiol.01442.2005
Ooi, C. C., Malliaras, P., Schneider, M. E., & Connell, D. A. (2014a). "Soft, hard, or just right?" Applications and limitations of axial-strain sonoelastography and shear-wave

elastography in the assessment of tendon injuries. *Skeletal Radiol, 43*(1), 1-12. doi:10.1007/s00256-013-1695-3
Ooi, C. C., Malliaras, P., Schneider, M. E., & Connell, D. A. (2014b). "Soft, hard, or just right?" Applications and limitations of axial-strain sonoelastography and shear-wave elastography in the assessment of tendon injuries. *Skeletal Radiology, 43*(1), 1-12. doi:10.1007/s00256-013-1695-3
Özçakar, L., Tok, F., Kesikburun, S., Palamar, D., Erden, G., Ulasli, A., . . . DeMurnck, M. (2010). Musculoskeletal sonography in physical and rehabilitation medicine: results of the first worldwide survey study. *Archives of Physical Medicine & Rehabilitation, 91*(2), 326-331. doi:10.1016/j.apmr.2009.10.022
Pavan, P. G., Stecco, A., Stern, R., & Stecco, C. (2014). Painful connections: densification versus fibrosis of fascia. *Curr Pain Headache Rep, 18*(8), 441. doi:10.1007/s11916-014-0441-4
Peltz, C. D., Haladik, J. A., Divine, G., Siegal, D., Van Holsbeeck, M., & Bey, M. J. (2013). ShearWave elastography: Repeatability for measurement of tendon stiffness. *Skeletal Radiology, 42*(8), 1151-1156. doi:10.1007/s00256-013-1629-0
Petitpierre, F., Perez, J.-T., Bise, S., Fournier, C., Hauger, O., & Dallaudiere, B. (2018). Quantitative elastography of Achilles tendon using Shear Wave Elastography (SWE): correlation with zonal anatomy. *Muscles, Ligaments & Tendons Journal (MLTJ), 8*(2), 229-237. Retrieved from
Petitpierre, F., Perez, J. T., Bise, S., Fournier, C., Hauger, O., & Dallaudière, B. (2018). Quantitative elastography of achilles tendon using shear wave elastography (SWE): Correlation with zonal anatomy. *Muscles, Ligaments and Tendons Journal, 8*(2), 229-237. doi:10.11138/mltj/2018.8.2.229
Potter, C. L., Cairns, M. C., & Stokes, M. (2012). Use of ultrasound imaging by physiotherapists: A pilot study to survey use, skills and training. *Manual Therapy, 17*(1), 39-46. doi:https://doi.org/10.1016/j.math.2011.08.005
Prasad, S. (2018). A Window to the Brain: Neuro-Ophthalmology for the Primary Care Practitioner. *The American Journal of Medicine, 131*(2), 120-128. doi:https://doi.org/10.1016/j.amjmed.2017.10.008
Primack, S. J. (2016). Past, Present, and Future Considerations for Musculoskeletal Ultrasound. *Phys Med Rehabil Clin N Am, 27*(3), 749-752. doi:10.1016/j.pmr.2016.04.009
Rathbone, A. T. L., Grosman-Rimon, L., & Kumbhare, D. A. (2017). Interrater Agreement of Manual Palpation for Identification of Myofascial Trigger Points: A Systematic Review and Meta-Analysis. *Clin J Pain, 33*(8), 715-729. doi:10.1097/ajp.0000000000000459
Reinisch, J. F., Yu, D. C., & Li, W. Y. (2016). Getting a Valid Survey Response From 662 Plastic Surgeons in the 21st Century. *Ann Plast Surg, 76*(1), 3-5. doi:10.1097/sap.0000000000000546
Roy, J. S., Braen, C., Leblond, J., Desmeules, F., Dionne, C. E., MacDermid, J. C., . . . Fremont, P. (2015). Diagnostic accuracy of ultrasonography, MRI and MR arthrography in the characterisation of rotator cuff disorders: a systematic review and meta-analysis. *Br J Sports Med, 49*(20), 1316-1328. doi:10.1136/bjsports-2014-094148
Ryu, J. A., & Jeong, W. K. (2017). Current status of musculoskeletal application of shear wave elastography. *Ultrasonography, 36*(3), 185-197. doi:10.14366/usg.16053
Saftoiu, A., Gilja, O. H., Sidhu, P. S., Dietrich, C. F., Cantisani, V., Amy, D., . . . Vilmann, P. (2019). The EFSUMB Guidelines and Recommendations for the Clinical Practice of

Elastography in Non-Hepatic Applications: Update 2018. *Ultraschall Med, 40*(4), 425-453. doi:10.1055/a-0838-9937
Sahan, M. H., Inal, M., Burulday, V., & Kultur, T. (2018a). Evaluation of tendinosis of the long head of the biceps tendon by strain and shear wave elastography. *Med Ultrason, 20*(2), 192-198. doi:10.11152/mu-1323
Sahan, M. H., Inal, M., Burulday, V., & Kultur, T. (2018b). Evaluation of tendinosis of the long head of the biceps tendon by strain and shear wave elastography. *Medical Ultrasonography, 20*(2), 192-198. Retrieved from
Samuels, J., Abramson, S. B., & Kaeley, G. S. (2010). The use of musculoskeletal ultrasound by rheumatologists in the United States. *Bull NYU Hosp Jt Dis, 68*(4), 292-298.
Sanjana, F., Chaudhry, H., & Findley, T. (2017). Effect of MELT method on thoracolumbar connective tissue: The full study. *J Bodyw Mov Ther, 21*(1), 179-185. doi:10.1016/j.jbmt.2016.05.010
Schleip, R., Hedley, G., & Yucesoy, C. A. (2019). Fascial nomenclature: Update on related consensus process. *Clinical Anatomy, 32*(7), 929-933. doi:10.1002/ca.23423
Schunemann, H. J., Mustafa, R., Brozek, J., Santesso, N., Alonso-Coello, P., Guyatt, G., . . . Oxman, A. D. (2016). GRADE Guidelines: 16. GRADE evidence to decision frameworks for tests in clinical practice and public health. *J Clin Epidemiol, 76*, 89-98. doi:10.1016/j.jclinepi.2016.01.032
Shamseer, L., Moher, D., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., . . . Stewart, L. A. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. *BMJ, 350*, g7647. doi:10.1136/bmj.g7647
Sharpe, R. E., Nazarian, L. N., Parker, L., Rao, V. M., & Levin, D. C. (2012). Dramatically increased musculoskeletal ultrasound utilization from 2000 to 2009, especially by podiatrists in private offices. *J Am Coll Radiol, 9*(2), 141-146. doi:10.1016/j.jacr.2011.09.008
Shiina, T., Nightingale, K. R., Palmeri, M. L., Hall, T. J., Bamber, J. C., Barr, R. G., . . . Kudo, M. (2015). WFUMB guidelines and recommendations for clinical use of ultrasound elastography: Part 1: basic principles and terminology. *Ultrasound Med Biol, 41*(5), 1126-1147. doi:10.1016/j.ultrasmedbio.2015.03.009
Song, Y., Son, Y. J., & Oh, D. (2015). Methodological Issues in Questionnaire Design. *J Korean Acad Nurs, 45*(3), 323-328. doi:10.4040/jkan.2015.45.3.323
Sporea, I. (2018). Clinical elastography. *Medical Ultrasonography, 20*(3), 263. doi:10.11152/mu-1693
Stecco, A., Gilliar, W., Hill, R., Fullerton, B., & Stecco, C. (2013). The anatomical and functional relation between gluteus maximus and fascia lata. *J Bodyw Mov Ther, 17*(4), 512-517. doi:10.1016/j.jbmt.2013.04.004
Stecco, A., Stern, R., Fantoni, I., De Caro, R., & Stecco, C. (2016). Fascial Disorders: Implications for Treatment. *PM&R, 8*(2), 161-168. doi:https://doi.org/10.1016/j.pmrj.2015.06.006
Stenroth, L., Sillanpãã, E., McPhee, J. S., Narici, M. V., Gapeyeva, H., Pããsuke, M., . . . Sipilã, S. (2015). Plantarflexor muscleâ€"tendon properties are associated with mobility in healthy older adults. *Journals of Gerontology - Series A Biological Sciences and Medical Sciences, 70*(8), 996-1002. doi:10.1093/gerona/glv011
Taljanovic, M. S., Gimber, L. H., Becker, G. W., Latt, L. D., Klauser, A. S., Melville, D. M., . . . Witte, R. S. (2017). Shear-Wave Elastography: Basic Physics and Musculoskeletal Applications. *RadioGraphics, 37*(3), 855-870. doi:10.1148/rg.2017160116

Taş, S., Onur, M. R., Yılmaz, S., Soylu, A. R., & Korkusuz, F. (2017). Shear Wave Elastography Is a Reliable and Repeatable Method for Measuring the Elastic Modulus of the Rectus Femoris Muscle and Patellar Tendon. *Journal of ultrasound in medicine : official journal of the American Institute of Ultrasound in Medicine, 36*(3), 565-570. doi:10.7863/ultra.16.03032

Turan, A., Tufan, A., Mercan, R., Teber, M. A., Tezcan, M. E., Bitik, B., . . . Haznedaroglu, S. (2013). Real-time sonoelastography of Achilles tendon in patients with ankylosing spondylitis. *Skeletal Radiol, 42*(8), 1113-1118. doi:10.1007/s00256-013-1637-0

Turo, D., Otto, P., Shah, J. P., Heimur, J., Gebreab, T., Zaazhoa, M., . . . Sikdar, S. (2013). Ultrasonic characterization of the upper trapezius muscle in patients with chronic neck pain. *Ultrasonic Imaging, 35*(2), 173-187. doi:10.1177/0161734612472408

Wells, & Liang. (2011). Medical ultrasound: imaging of soft tissue strain and elasticity. *J R Soc Interface, 8*(64), 1521-1549. doi:10.1098/rsif.2011.0054

Wong, K.-K., Chai, H.-M., Chen, Y.-J., Wang, C.-L., Shau, Y.-W., & Wang, S.-F. (2017). Mechanical deformation of posterior thoracolumbar fascia after myofascial release in healthy men: A study of dynamic ultrasound imaging. *Musculoskeletal Science and Practice, 27*, 124-130. doi:https://doi.org/10.1016/j.math.2016.10.011

Wu, C. H., Chang, K. V., Mio, S., Chen, W. S., & Wang, T. G. (2011). Sonoelastography of the plantar fascia. *Radiology, 259*(2), 502-507. doi:10.1148/radiol.11101665

Yamamoto, Y., Yamaguchi, S., Sasho, T., Fukawa, T., Akatsu, Y., Nagashima, K., & Takahashi, K. (2016). Quantitative Ultrasound Elastography With an Acoustic Coupler for Achilles Tendon Elasticity. *Journal of Ultrasound in Medicine, 35*(1), 159-166. doi:10.7863/ultra.14.11042

Yim, E. S., & Corrado, G. (2012). Ultrasound in sports medicine: relevance of emerging techniques to clinical care of athletes. *Sports Med, 42*(8), 665-680. doi:10.2165/11632680-000000000-00000

Yoshida, K., Itoigawa, Y., Maruyama, Y., Saita, Y., Takazawa, Y., Ikeda, H., . . . Okuwaki, T. (2017a). Application of shear wave elastography for the gastrocnemius medial head to tennis leg. *Clin Anat, 30*(1), 114-119. doi:10.1002/ca.22788

Yoshida, K., Itoigawa, Y., Maruyama, Y., Saita, Y., Takazawa, Y., Ikeda, H., . . . Okuwaki, T. (2017b). Application of shear wave elastography for the gastrocnemius medial head to tennis leg. *Clinical Anatomy, 30*(1), 114-119. Retrieved from

Zhang, L., Yong, Q., Pu, T., Zheng, C., Wang, M., Shi, S., & Li, L. (2018a). Grayscale ultrasonic and shear wave elastographic characteristics of the Achilles' tendon in patients with familial hypercholesterolemia: A pilot study. *Eur J Radiol, 109*, 1-7. doi:10.1016/j.ejrad.2018.10.003

Zhang, L., Yong, Q., Pu, T., Zheng, C., Wang, M., Shi, S., & Li, L. (2018b). Grayscale ultrasonic and shear wave elastographic characteristics of the Achilles’ tendon in patients with familial hypercholesterolemia: A pilot study. *European Journal of Radiology, 109*, 1-7. doi:10.1016/j.ejrad.2018.10.003

APPENDIX A

Ref:

Data Collection Form for Individual Papers

(Inclusion Criteria Meet)

Title of Paper:

Date form completed: ____/____/_______

Year of Publication	
Authors	
Notes	

Data Collection

Technology Type(s)			
Population			
Tissues Investigated			
Comparisons Technology Type Tissue Type Pathologic Tissues			
Results Overall Unit of Measure			
Notes			

APPENDIX B

Ref:

Risk of Bias and Article Strength Form – Individual Papers in Review

Domain	**Risk of Bias** *Low/Unclear/High*	**Reason for Judgement**	**Review Judgement**
Population Recruitment	☐ ☐ ☐		
Statement of goals/aims	☐ ☐ ☐		
Blinding of Investigators	☐ ☐ ☐		
Blinding of Outcome Assessment	☐ ☐ ☐		
Investigator suitably experienced >5yrs	☐ ☐ ☐		
Internal Validity Factors	☐ ☐ ☐		
Reporting of Outcome Data	☐ ☐ ☐		
Selective Outcome Reporting	☐ ☐ ☐		
External Validity Factors	☐ ☐ ☐		
Overall Bias Score:			
	Strength Review	**Notes**	**Rating**
Trial			
Author/Institution information supplied			
Introduction: – clear.			

- objectives given.			
Methods: - clear. - logical.			
Results: – clear. - full set of results. - supported by tables and graphs.			
Discussion: – clear. - supported by previous work.			
Conclusions: – clear. - answer objectives previously stated.			
Limitations and further suggestions stated.			
Notes			**Overall Rating:**

APPENDIX C

Flow Diagram of Survey Q1 – Q6: Participants by Profession, User and Non-User

Total Participants
n = 172

No Thanks Response
n = 1

Agree to Participate
n = 171

Participants by Profession

Physiotherapists:	*n* = 4 *(2%)*
Chiropractors:	*n* = 87 *(55%)*
Osteopaths:	*n* = 30 *(20%)*
Rheumatologists:	*n* = 11 *(7%)*
Sports Dr/MSK GP/Other:	*n* = 25 *(16%)*
Total:	***n* = 158**

(13 non-responders to question "What is your registered profession?)

Q1. – Do you use ultrasound images for diagnostic purposes in your practice setting? This would involve viewing ultrasound images for assessment, rehabilitation, or for pathologic conditions. It may also involve reading reports but must include viewing of ultrasound images.

Use: Yes or No by Profession

	Yes	***No***
Physiotherapists:	*n* = 2 *(50%)*	*n = 2 (50%)*
Chiropractors:	*n* = 36 *(41%)*	*n = 51 (59%)*
Osteopaths:	*n* = 15 *(50%)*	*n = 15(50%)*
Rheumatologists:	*n* = 9 (82%)	*n = 2 (18%)*
Sports Dr/MSK GP/Other:	*n* = 21 (84%)	*n = 4 (16%)*
Total:	***n = 83 (53%)***	***n = 74 (47%)***

(10 non-responders to questions "Q.2 Do you use ultrasound …" and "What is your registered profession?")

Yes
n = 88
(52.7%)

No
n = 79
(47.3%)

Q2. – In regard to not using diagnostic ultrasound, do you believe? (All Practitioners)

#	Question	Strongly disagree		Somewhat disagree		Neither agree nor disagree		Somewhat agree		Strongly agree		Total
1	You are not adequately trained to use or interpret ultrasound images.	6.41%	5	1.28%	1	7.69%	6	34.62%	27	50.00%	39	78
3	There is no access to ultrasound equipment or referral sources.	23.08%	18	25.64%	20	17.95%	14	14.10%	11	19.23%	15	78
4	Equipment or referral is not cost effective for the benefits the images may provide.	15.38%	12	25.64%	20	37.18%	29	12.82%	10	8.97%	7	78

Q3. – In regard to acquiring ultrasound images, do you? (All Practitioners)

#	Question	Always		Often		About half the time		Sometimes		Never		Total
1	Personally perform the ultrasound scan.	5.75%	5	3.45%	3	3.45%	3	6.90%	6	80.46%	70	87
2	Aquire images from within your place of work.	4.60%	4	3.45%	3	4.60%	4	4.60%	4	82.76%	72	87
3	Aquire images from a third party outside your place of work.	78.16%	68	6.90%	6	3.45%	3	8.05%	7	3.45%	3	87

Q4. – In a typical week, what percentage of clientele would you use ultrasound images for diagnostic purposes? (All Practitioners)

Percent	**0-4%**	**5-9%**	**10-14%**	**15-19%**	**20-24%**	**25-29%**	**30-34%**	**35-39%**	**40-44%**	**45-50%**	**Total**
Count	30	27	12	5	2	1	2	3	2	3	87
%	*35%*	*31%*	*14%*	*6%*	*2%*	*1%*	*2%*	*3.5%*	*2%*	*3.5%*	*100%*

Q5. – Do you or your place of work own/lease a diagnostic ultrasound machine? (All Practitioners)

#	Answer	%	Count
1	Yes	19.54%	17
2	No	80.46%	70

Q6. – In regards to the diagnostic ultrasound machine you own or lease, do you? (All Practitioners)

#	Question	Strongly disagree		Disagree		Somewhat disagree		Neither agree nor disagree		Somewhat agree		Agree		Strongly agree		Total
1	Think it's cost effective.	23.53%	4	0.00%	0	0.00%	0	11.76%	2	17.65%	3	23.53%	4	23.53%	4	17
2	Think it's easy to implement into a practice setting.	0.00%	0	23.53%	4	23.53%	4	0.00%	0	0.00%	0	29.41%	5	23.53%	4	17
3	Believe clients are favourable to the process and results.	0.00%	0	5.88%	1	5.88%	1	5.88%	1	0.00%	0	35.29%	6	47.06%	8	17

APPENDIX D
Survey Questionnaire – Use and Beliefs of Diagnostic Ultrasound

Introduction/Consent

Thank you for your time.

This survey investigates the use and beliefs of musculoskeletal practitioners use of ultrasound for diagnostic purposes. The following questionnaire is designed to collect data from users and non-users of a broad group of musculoskeletal professionals - physiotherapists, osteopaths, chiropractors, musculoskeletal doctors, and rheumatologists.

The questionnaire should take approximately five minutes to complete. The survey and responses will be administered and stored on a password protected program called Qualtrics (www.qualtrics.com) and will not collect identifying information such as: your name, email address, or IP address. Further, this survey: · *Has Approval by the University of Otago Human Ethics Committee (Ref #D18/268). · Is confidential. · Is anonymous. · Is voluntary. · Results are intended for publication in a peer reviewed journal.

This research project is part of a Masters thesis by an Otago University student (Orthopaedic Medicine and Musculoskeletal Management department). Any questions regarding any component of this study can be directed to the research supervisor Dr Bronwyn Thompson (bronwyn.thompson@otago.ac.nz).

*This study has been approved by the Department stated above. However, if you have any concerns about the ethical conduct of the research you may contact the University of Otago Human Ethics Committee through the Human Ethics Committee Administrator (ph +643 479 8256 or email gary.witte@otago.ac.nz). Any issues you raise will be investigated in confidence and you will be informed of the outcome.

CONSENT Clicking on the “Agree” button indicates that:

- You have read the above information.
- You voluntarily agree to participate.
- You are 18 years of age or older.

○ Agree (1)

○ No Thanks (2)

Skip To: No response message If Introduction/Consent = No Thanks

Skip To: Q1 If Introduction/Consent = Agree

No response message: We completely respect your decision.
If you would like to make any comment, please do so below.
Thank you for your time.

Skip To: End of Survey If No response message =

Q1 Do you use ultrasound images for diagnostic purposes in your practice setting?
This would involve viewing ultrasound images for assessment, rehabilitation, or for pathological conditions. It may also involve reading reports but must include viewing of ultrasound images.

- ○ Yes (1)
- ○ No (2)

Q2 In regard to you not using diagnostic ultrasound, do you believe?

	Strongly disagree (1)	Somewhat disagree (2)	Neither agree nor disagree (3)	Somewhat agree (4)	Strongly agree (5)
You are not adequately trained to use or interpret ultrasound images. (1)	○	○	○	○	○
There is no access to ultrasound equipment or referral sources. (3)	○	○	○	○	○
Equipment or referral is not cost effective for the benefits the images may provide. (4)	○	○	○	○	○

Q3 In regards to acquiring ultrasound images, do you?

	Always (1)	Often (2)	About half the time (3)	Sometimes (4)	Never (5)
Personally perform the ultrasound scan. (1)	○	○	○	○	○
Aquire images from within your place of work. (2)	○	○	○	○	○
Aquire images from a third party outside your place of work. (3)	○	○	○	○	○

Q4 In a typical week – what percentage of clientele would you use ultrasound images for diagnostic purposes?

	0 10 20 30 40 50 60 70 80 90 100
% of clientele whose diagnosis involves ultrasound images. ()	

Q5 Do you or your place of work own/lease a diagnostic ultrasound machine?

- Yes (1)
- No (2)

Q6 In regards to the diagnostic ultrasound machine you own/lease, do you?

	Strongly disagree (20)	Disagree (21)	Somewhat disagree (22)	Neither agree nor disagree (23)	Somewhat agree (24)	Agree (25)	Strongly agree (26)
Think it's cost effective. (1)	○	○	○	○	○	○	○
Think it's easy to implement into a practice setting. (2)	○	○	○	○	○	○	○
Believe clients are favourable to the process and results. (3)	○	○	○	○	○	○	○

Q7 In regard to ultrasound imaging for diagnostic processes, do you believe it is/might be?

	Strongly disagree (1)	Somewhat disagree (2)	Neither agree nor disagree (3)	Somewhat agree (4)	Strongly agree (5)
Able to produce reliable images that indicate changes in non-pathologic and pathologic tissues. (2)	○	○	○	○	○
Images should only be used if taken by trained radiographers/sonographer. (6)	○	○	○	○	○
Only useful to confirm suspected pathology (e.g. Trauma, Growths, Inflammatory conditions). (5)	○	○	○	○	○
Is useful for rehabilitation/progress reporting. (12)	○	○	○	○	○
May be useful to diagnose non-pathologic tissues. (13)	○	○	○	○	○
Surplus to requirements for a clinician with good palpation skills. (4)	○	○	○	○	○
Owning a ultrasound unit is not cost effective for private practice. (7)	○	○	○	○	○
May be easily incorporated into your daily clinical practice. (3)	○	○	○	○	○
May be a useful tool to quantify diagnostic findings. (8)	○	○	○	○	○
Positively received by patients as a diagnostic tool. (11)	○	○	○	○	○
A useful aid in patient education. (9)	○	○	○	○	○

Q22 The following questions relate to your demographics as a musculoskeletal practitioner and is of interest as to who does or does not use diagnostic ultrasound.

Please note: all responses are anonymous.

Q4 Main area of employment/study.

Private practice. (1)

Private organisation. (2)

Public hospital/clinic. (3)

University/education institution (includes sports or research institutions). (4)

Other. (5) ____

Q2 Employment status - are you currently?

◯ Self-employed (1)

◯ Employed Full Time (2)

◯ Employed Part Time (3)

◯ Not currently employed (4)

◯ Student (5)

Q5 What is your main area of practice?

◯ General practice. (1)

◯ Sports. (2)

◯ Occupational. (3)

◯ Geriatric. (4)

◯ Paediatric. (5)

◯ Cardiovascular or cardiorespiratory. (6)

◯ Womens health. (7)

◯ Other (8) ____

Q6 Level of education.

◯ Undergraduate degree. (1)

◯ Post graduate certificate or diploma. (2)

- ○ Masters. (3)
- ○ Doctorate. (4)
- ○ Other (5) ____

Q1 Please indicate your current age group.

- ○ 20-24 (1)
- ○ 25-29 (2)
- ○ 30-34 (3)
- ○ 35-39 (4)
- ○ 40-44 (5)
- ○ 45-49 (6)
- ○ 50-54 (7)
- ○ 55-59 (8)
- ○ 60-64 (9)
- ○ 65-69 (10)
- ○ 70 + (11)

Q3 Please indicate gender.

- ○ Male (1)
- ○ Female (2)
- ○ Choose not to answer (3)

Q16 What is your registered profession?

- ○ Physiotherapist (1)
- ○ Chiropractor (2)

- ◯ Osteopath (3)
- ◯ Sports Doctor (4)
- ◯ Rheumatologist (5)
- ◯ Other (6) ____

Q17 How long have you practiced in your profession?

	0 5 10 15 20 25 30 35 40 45 50
Years in practice. ()	

Q18 Please enter the postcode of your practice location.

____

Q20 Thank you for your participation in this survey.

If you would like to receive a summary of the survey results please provide your email address below.

NB - your email will be separate from the survey details and only used to disseminate results from this survey.

Thank you for your time.

____

____

APPENDIX E

Ethics Approval

Academic Services
Manager, Academic Committees, Mr Gary Witte

Dr B Lennox Thompson
Department of Orthopaedic Surgery & Musculoskeletal Medicine (ChCh) University of Otago, Christchurch
University of Otago Medical School

Dear Dr Lennox Thompson,

17 August 2018

D18/268

I am writing to confirm for you the status of your proposal entitled "**Is ultrasound technology useful for quantifying the characteristics of fascia tissues in musculoskeletal clinical setting, who uses it, and what are the beliefs of users and non-users?**", which was originally received on August 8, 2018. The Human Ethics Committee's reference number for this proposal is **D18/268**.

The above application was Category B and had therefore been considered within the Department or School. The outcome was subsequently reviewed by the University of Otago Human Ethics Committee. The outcome of that consideration was that the proposal was approved.

Approval is for up to three years from the date of HOD approval. If this project has not been completed within three years of this date, re-approval must be requested. If the nature, consent, location, procedures or personnel of your approved application change, please advise me in writing.

Yours sincerely,

Mr Gary Witte

Manager, Academic Committees

Tel: 479 8256
Email: gary.witte@otago.ac.nz

APPENDIX F

All Professions responses for "In regard to ultrasound imaging for diagnostic purposes, do you believe it is/might be?

Sub-Question	Total (%) n =159 (100%)					Users (%) n = 84 (53%)					Non-Users (%) n = 75 (47%)				
	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
1. Able to produce reliable images that indicate changes in non-pathologic and pathologic tissues.	3	8	12	77	59	1	5	1	43	34	2	3	11	34	25
	2%	5%	8%	48%	37%	1%	6%	1%	51%	40%	3%	4%	15%	45%	33%
2. Images should only be taken by trained radiographers or sonographers.	6	16	11	42	84	3	12	7	19	43	3	4	4	23	41
	4%	10%	7%	26%	53%	4%	4%	8%	23%	51%	4%	5%	5%	31%	55%
3. Only useful to confirm suspected pathology (EG. Trauma, Growths, Inflammatory Conditions).	17	48	32	47	15	12	21	12	27	12	5	27	20	20	3
	11%	30%	20%	30%	9%	14%	25%	14%	32%	14%	7%	36%	27%	27%	4%
4. Is useful for rehabilitation and/or progress reporting.	10	23	42	63	21	4	13	13	39	15	6	10	29	24	6
	6%	15%	26%	40%	13%	5%	15%	15%	46%	18%	8%	13%	39%	32%	8%
5. May be useful to diagnose non-pathologic tissues.	7	12	50	63	27	4	7	18	37	18	3	5	32	26	9
	4%	8%	31%	40%	17%	5%	8%	21%	44%	21%	4%	7%	43%	35%	12%
6. Surplus to requirements for a clinician with good palpation skills.	43	63	28	21	4	26	31	9	14	4	17	32	19	7	0
	27%	40%	18%	13%	2%	31%	37%	11%	17%	5%	23%	43%	25%	9%	
7. Owning an ultrasound unit is not cost effective for private practice.	3	17	59	39	41	3	11	30	22	18	0	6	29	17	23
	2%	11%	37%	24%	26%	4%	13%	36%	26%	21%		8%	39%	23%	31%
8. May be easily incorporated into your daily clinical practice.	36	47	34	25	17	13	25	21	12	13	23	22	13	13	4
	23%	29%	21%	16%	11%	15%	18%	25%	14%	15%	31%	29%	17%	17%	5%
9.May be a useful tool to quantify diagnostic findings.	6	12	29	85	27	2	8	5	50	19	4	4	24	35	8
	4%	8%	18%	53%	17%	2%	10%	6%	60%	23%	5%	5%	32%	47%	11%
10. Positively received by patients as a diagnostic tool.	1	6	32	72	48	1	3	6	40	34	0	3	26	32	14
	1%	4%	20%	45%	30%	1%	4%	7%	48%	40%		4%	35%	43%	19%
11. A useful aid in patient education.	6	18	44	58	33	3	7	19	30	25	3	11	25	28	8
	4%	11%	28%	36%	21%	4%	8%	23%	36%	30%	4%	15%	33%	37%	11%

Appendix G

Rheumatologists responses for "In regard to ultrasound imaging for diagnostic purposes, do you believe it is/might be?

Sub-Question	Total (%) n = 11 (100%)					Users (%) n = 9 (82%)					Non-Users (%) n = 2 (18%)				
	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
1. Able to produce reliable images that indicate changes in non-pathologic and pathologic tissues.	0	0	0	4	7	0	0	0	3	6	0	0	0	1	1
				36%	64%				33%	67%				50%	50%
2. Images should only be taken by trained radiographers or sonographers.	0	4	2	4	1	0	4	2	3	0	0	0	0	1	1
		36%	18%	36%	9%		44%	22%	33%					50%	50%
3. Only useful to confirm suspected pathology (EG. Trauma, Growths, Inflammatory Conditions).	3	6	1	1	0	3	5	1	0	0	0	1	0	1	0
	27%	55%	9%	9%		33%	56%	11%				50%		50%	
4. Is useful for rehabilitation and/or progress reporting.	1	2	3	3	2	1	1	2	3	2		0	0	2	0
	9%	18%	27%	27%	18%	11%	11%	22%	33%	22%				100%	
5. May be useful to diagnose non-pathologic tissues.	0	0	3	7	1	0	0	3	5	1	1	0	1	0	0
			27%	64%	9%			33%	56%	11%	50%		50%		
6. Surplus to requirements for a clinician with good palpation skills.	4	6	1	0	0	3	6	0	0	0	0	0	1	0	1
	36%	55%	9%			33%	67%						50%		50%
7. Owning an ultrasound unit is not cost effective for private practice.	0	4	5	1	1	0	4	4	0	1	0	0	0	2	0
		36%	45%	9%	9%		44%	44%		11%				100%	
8. May be easily incorporated into your daily clinical practice.	0	2	1	4	4	0	2	1	2	4	0	0	0	2	0
		18%	9%	36%	36%		22%	11%	22%	44%				100%	
9.May be a useful tool to quantify diagnostic findings.	0	0	1	8	2	0	0	1	6	2	0	0	1	1	0
			9%	73%	18%			11%	67%	22%			50%	50%	
10. Positively received by patients as a diagnostic tool.	0	0	1	4	6	0	0	0	3	6	0	0	1	1	0
			9%	36%	55%				33%	67%			50%	50%	
11. A useful aid in patient education.	0	0	2	4	5	0	0	1	3	5	0	0	1	1	0
			18%	36%	45%			11%	33%	56%			50%	50%	

APPENDIX H

MSK and Sports Doctors responses for "In regard to ultrasound imaging for diagnostic purposes, do you believe it is/might be?

Sub-Question	Total (%) n = 25 (100%)					Users (%) n = 20 (80%)					Non-Users (%) n = 5 (20%)				
	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
1. Able to produce reliable images that indicate changes in non-pathologic and pathologic tissues.	0	4	1	14	6	0	4	1	10	5	0	0	0	4	1
		16%	4%	56%	24%		20%	5%	50%	25%				80%	20%
2. Images should only be taken by trained radiographers or sonographers.	4	6	5	5	5	3	5	4	3	5	1	1	1	2	0
	16%	24%	20%	20%	20%	15%	25%	20%	15%	25%	20%	20%	20%	40%	
3. Only useful to confirm suspected pathology (EG. Trauma, Growths, Inflammatory Conditions).	2	5	5	7	6	2	3	3	6	6	1	1	2	1	0
	8%	20%	20%	28%	24%	10%	15%	15%	30%	30%	20%	20%	40%	20%	
4. Is useful for rehabilitation and/or progress reporting.	2	7	6	9	1	1	6	5	7	1	1	1	1	2	0
	8%	28%	24%	36%	4%	5%	30%	25%	35%	5%	20%	20%	20%	40%	
5. May be useful to diagnose non-pathologic tissues.	0	3	8	12	2	0	3	6	9	2	0	0	2	3	0
		12%	32%	48%	8%		15%	30%	45%	10%			40%	60%	
6. Surplus to requirements for a clinician with good palpation skills.	5	10	3	4	3	3	7	3	4	3	2	3	0	0	0
	20%	40%	12%	16%	12%	15%	35%	15%	20%	15%	40%	60%			
7. Owning an ultrasound unit is not cost effective for private practice.	1	6	3	8	7	1	3	3	8	5	0	3	0	0	2
	4%	24%	12%	32%	28%	5%	15%	15%	40%	25%		60%			40%
8. May be easily incorporated into your daily clinical practice.	1	11	5	4	4	1	9	5	2	3	0	2	0	2	1
	4%	44%	20%	16%	16%	5%	45%	25%	10%	15%		40%		40%	20%
9.May be a useful tool to quantify diagnostic findings.	0	3	2	16	4	0	3	1	13	3	0	0	1	3	1
		12%	8%	64%	16%		15%	5%	65%	15%			20%	60%	20%
10. Positively received by patients as a diagnostic tool.	0	2	3	12	8	0	2	2	10	6	0	0	1	2	2
		8%	12%	48%	32%		10%	10%	50%	30%			20%	40%	40%
11. A useful aid in patient education.	0	3	7	11	4	0	2	7	7	4	0	1	0	4	0
		12%	28%	44%	16%		10%	35%	35%	20%		20%		80%	

APPENDIX I

Chiropractors responses for "In regard to ultrasound imaging for diagnostic purposes, do you believe it is/might be?

Sub-Question	Total (%) n = 87 (100)					Users (%) n = 36 (41)					Non-Users (%) n = 51 (59)				
	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
1. Able to produce reliable images that indicate changes in non-pathologic and pathologic tissues.	3	2	10	42	30	1	0	0	19	16	2	2	10	23	14
	3%	2%	11%	48%	34%	3%			53%	44%	4%	4%	20%	45%	27%
2. Images should only be taken by trained radiographers or sonographers.	2	5	4	24	52	0	2	1	10	23	2	3	3	14	29
	2%	6%	5%	28%	60%		6%	3%	27%	64%	4%	6%	6%	27%	57%
3. Only useful to confirm suspected pathology (EG. Trauma, Growths, Inflammatory Conditions).	7	27	22	26	5	4	8	7	15	2	3	19	15	11	3
	8%	31%	25%	30%	6%	11%	22%	19%	42%	6%	6%	37%	29%	22%	6%
4. Is useful for rehabilitation and/or progress reporting.	4	7	27	37	12	0	3	5	19	9	4	4	22	18	3
	5%	8%	31%	43%	14%		8%	14%	52%	25%	8%	8%	43%	35%	6%
5. May be useful to diagnose non-pathologic tissues.	3	6	30	32	16	1	2	8	14	11	3	5	22	18	3
	3%	7%	34%	37%	18%	3%	6%	22%	39%	31%	6%	10%	63%	51%	18%
6. Surplus to requirements for a clinician with good palpation skills.	24	29	21	13	0	13	11	5	7	0	11	18	16	6	0
	28%	33%	24%	15%		36%	31%	14%	19%		22%	35%	31%	12%	
7. Owning an ultrasound unit is not cost effective for private practice.	2	6	39	19	21	2	3	15	7	9	0	3	24	12	12
	2%	7%	45%	22%	24%	6%	8%	42%	19%	25%		6%	47%	24%	24%
8. May be easily incorporated into your daily clinical practice.	24	23	22	12	6	9	9	9	6	3	15	14	13	6	3
	28%	26%	25%	14%	7%	25%	25%	25%	17%	8%	29%	27%	25%	12%	6%
9.May be a useful tool to quantify diagnostic findings.	4	7	19	45	12	1	4	1	22	8	3	3	18	23	4
	5%%	8%	22%	52%	14%	3%	11%	3%	61%	22%	6%	6%	35%	45%	8%
10. Positively received by patients as a diagnostic tool.	1	4	23	35	24	1	1	2	15	17	0	3	21	20	7
	1%	5%	26%	40%	28%	3%	3%	6%	42%	47%		6%	41%	39%	14%
11. A useful aid in patient education.	4	10	27	27	19	1	3	7	12	13	3	7	20	15	6
	5%	11%	31%	31%	22%	3%	8%	19%	33%	36%	6%	14%	39%	29%	12%

APPENDIX J

Osteopaths Question Seven "In regard to ultrasound imaging for diagnostic purposes, do you believe it is/might be?

Sub-Question	Total (%) n = 30 (100%)					Users (%) n = 15 (50%)					Non-Users (%) n = 15 (50%)				
	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
1. Able to produce reliable images that indicate changes in non-pathologic and pathologic tissues.	0	1	1	13	15	0	0	0	8	7	0	1	1	5	8
		3%	3%	43%	50%				53%	47%		7%	7%	33%	53%
2. Images should only be taken by trained radiographers or sonographers.	0	0	0	21	9	0	0	0	3	12	0	0	0	6	9
				70%	30%				20%	80%				40%	60%
3. Only useful to confirm suspected pathology (EG. Trauma, Growths, Inflammatory Conditions).	5	9	4	9	3	3	5	1	3	3	2	4	3	6	0
	17%	30%	13%	30%	10%	20%	33%	7%	20%	20%	13%	27%	20%	40%	
4. Is useful for rehabilitation and/or progress reporting.	0	6	6	13	5	0	2	1	9	3	0	4	5	4	2
		20%	20%	43%	17%		13%	7%	60%	20%		27%	33%	27%	13%
5. May be useful to diagnose non-pathologic tissues.	2	2	9	10	7	2	1	1	7	4	0	1	8	3	3
	7%	7%	30%	33%	23%	13%	7%	7%	47%	27%		7%	53%	20%	20%
6. Surplus to requirements for a clinician with good palpation skills.	8	14	3	4	1	5	5	1	3	1	3	9	2	1	0
	27%	47%	10%	13%	3%	33%	33%	7%	20%	7%	20%	60%	13%	7%	
7. Owning an ultrasound unit is not cost effective for private practice.	0	1	11	9	9	0	1	7	5	2	0	0	4	4	7
		3%	37%	30%	30%		7%	47%	33%	13%			27%	27%	47%
8. May be easily incorporated into your daily clinical practice.	7	9	6	5	3	1	3	6	2	3	6	6	0	3	0
	23%	30%	20%	17%	10%	7%	20%	40%	13%	20%	40%	40%		20%	
9.May be a useful tool to quantify diagnostic findings.	1	1	4	15	9	0	0	1	8	6	1	1	3	7	3
	3%%	3%	13%	50%	30%			7%	53%	40%	7%	7%	20%	47%	20%
10. Positively received by patients as a diagnostic tool.	0	0	4	16	10	0	0	1	9	5	0	0	3	7	5
			13%	53%	33%			7%	60%	33%			20%	47%	33%
11. A useful aid in patient education.	1	4	7	13	5	1	2	3	6	3	0	2	4	7	2
	3%	13%	23%	43%	17%	7%	13%	20%	40%	20%		13%	27%	47%	13%

APPENDIX

Physiotherapists responses for "In regard to ultrasound imaging for diagnostic purposes, do you believe it is/might be?

Sub-Question	Total (%) n = 4 (100)					Users (%) n = 3 (75%)					Non-Users (%) n = 1 (25%)				
	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
1. Able to produce reliable images that indicate changes in non-pathologic and pathologic tissues.	0	1	0	3	0	0	1	0	2	0	0	0	0	1	0
		25%		75%			33%		67%					100%	
2. Images should only be taken by trained radiographers or sonographers.	0	1	0	0	3	0	1	0	0	2	0	0	0	0	1
		25%			75%		33%			66%					100%
3. Only useful to confirm suspected pathology (EG. Trauma, Growths, Inflammatory Conditions).	0	0	0	3	1	0	0	0	2	1	0	0	0	1	0
				75%	25%				67%	33%				100%	
4. Is useful for rehabilitation and/or progress reporting.	2	1	0	1	0	1	1	1	0	0	1	0	0	0	0
	50%	25%		25%		33%	33%	33%			100%				
5. May be useful to diagnose non-pathologic tissues.	1	1	0	2	0	0	1	0	2	0	1	0	0	0	0
	25%	25%		50%			33%		67%		100%				
6. Surplus to requirements for a clinician with good palpation skills.	1	3	0	0	0	1	2	0	0	0	0	1	0	0	0
	25%	75%				33%	67%					100%			
7. Owning an ultrasound unit is not cost effective for private practice.	0	0	1	1	2	0	0	1	1	1	0	0	0	0	1
			25%	25%	50%			33%	33%	33%					100%
8. May be easily incorporated into your daily clinical practice.	3	1	0	0	0	2	1	0	0	0	1	0	0	0	0
	75%	25%				67%	33%				100%				
9.May be a useful tool to quantify diagnostic findings.	1	1	1	1	0	1	1	0	1	0	0	0	1	0	0
	25%	25%	25%	25%		33%	33%		33%				100%		
10. Positively received by patients as a diagnostic tool.	0	0	0	4		0	0	0	3	0	0	0	0	1	0
				100%					100%					100%	
11. A useful aid in patient education.	1	1	0	2	0	1	0	0	2	0	0	1	0	0	0
	25%	25%		50%		33%			67%			100%			