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Original article

Exploring the use of ultrasound imaging by physiotherapists: An international survey

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ARTICLE INFO

In Memoriam: Professor Archie Young: This paper is dedicated to the memory of Professor Archie Young, a pioneering physician, who introduced ultrasound imaging to physiotherapy in the early 1980s while at the University of Oxford. A textbook on ultrasound imaging use in physiotherapy opens with *"If I have seen a little further, it is by standing upon the shoulders of giants" (Whittaker, 2007)*. A great ally of the physiotherapy profession, Archie was the giant who took that first step.

Keywords:
Physical therapy
Physiotherapy
Ultrasound imaging
Survey
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ABSTRACT

Background: National surveys in New Zealand, Australia and the United Kingdom suggest ultrasound imaging (USI) use by physiotherapists is increasing. However, concerns exist regarding clarity for scopes of practice, and availability and standardisation of training.
Objectives: To investigate physiotherapists' understanding of scopes of practice for the use of USI; clarify the professional contexts, clinical uses and levels of training; and identify barriers preventing physiotherapists' USI use.
Design: A cross-sectional, observational survey.
Methods: An Internet-based survey, offered in 20 different languages, was used including items covering five domains: (1) demographic and professional characteristics; (2) knowledge of scope of practice; (3) USI use; (4) USI training content and duration; and (5) perceived barriers to physiotherapists' use of USI.
Results: 1307 registered physiotherapists from 49 countries responded; 30% were unsure of the scope of practice for physiotherapists' USI use. 38% of participants were *users* of USI, reporting varied contexts and clinical uses, reflected in the broader categories of: (i) biofeedback; (ii) diagnosis; (iii) assessment; (iv) injection guidance; (v) research; (vi) and teaching. The training *users* received varied, with formal training more comprehensive. 62% were *non-users*, the most common barrier was lack of training (76%).
Conclusion: These findings suggest physiotherapists' USI use is increasing in various contexts; however, there is uncertainty regarding scopes of practice. There are discrepancies in training offered, with a lack of training the most common barrier to physiotherapists' use of USI. International guidelines, including a USI training framework, are needed to support the consistent and sustainable use of USI in physiotherapy.

1. Introduction

Once only common within musculoskeletal and sports physiotherapy, evidence indicates wider use of ultrasound imaging (USI) across the physiotherapy profession (Ellis et al., 2018). As equipment costs reduce, technologies improve, and more training is offered,

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opportunities for physiotherapists to incorporate USI into their practice increase. International physiotherapy USI meetings since 2006, have increased understanding of the variety of methods that physiotherapists utilise USI (Whittaker et al., 2019). Rehabilitative USI (e.g. evaluation of soft tissue morphology and function, biofeedback, etc.) (Teyhen, 2006; Whittaker et al., 2007; Whittaker and Stokes, 2011), diagnostic USI (e.g. evaluation of injury, disease, etc.) (Teyhen, 2006; Whittaker et al., 2007), interventional USI (e.g. guidance of needles, etc.) (Whittaker et al., 2019), and research USI (Whittaker et al., 2019) are recognised physiotherapy applications of USI (Whittaker et al., 2019). In addition to the well recognised use of USI in musculoskeletal and sports physiotherapy (Carnero et al., 2019; Hodges, 2005), uses are emerging in areas such as women's (Chan et al., 2015) and men's (Doorbar-Baptist et al., 2017) pelvic floor health, cardiorespiratory (Hayward and Janssen, 2018), paediatric (Noh et al., 2016), and neurological (Akazawa et al., 2018; Calvo-Lobo et al., 2018) physiotherapy.

This increased use of USI requires better understanding of the scope of practice (SoP) related to using USI within physiotherapy. To date, four small national surveys have explored the use of USI by physiotherapists and scopes of practice in Australia (Jedrzejczak and Chipchase, 2008; McKiernan et al., 2011), New Zealand (Ellis et al., 2018), and the United Kingdom (UK) (Potter et al., 2012). Respondents of these surveys were primarily musculoskeletal physiotherapists working in private practice.

A recent consensus statement by Whittaker et al. (2019) raised concern about confusion of physiotherapists regarding their SoP, which guide and legislate their use of USI in various countries within their own legislative rules. This was highlighted in a survey of New Zealand physiotherapists where 47% of respondents were unsure if USI was within their SoP (Ellis et al., 2018). No international standards outlining the SoP and regulation of use of USI by physiotherapists exist, and only a small number of physiotherapy regulatory bodies have established USI guidelines (Whittaker et al., 2019). Further, there is disparity and inconsistency of professional guidance across countries and licencing jurisdictions.

A better understanding of the international landscape of USI use by physiotherapists would contribute valuable knowledge and perspectives to the development of training guidelines and curricula standards, as well as inform physiotherapy SoP for USI use. An international survey would provide more encompassing and diverse knowledge than achieved by national-based surveys. The aim of this current survey was to explore the context in which USI is being used by physiotherapists internationally (including SoP), and the type and content of training received. More specifically regarding training, a secondary aim was to ascertain differences in content and comprehensiveness of formal versus non-formal training in USI for physiotherapists. The survey also aimed to understand the role of USI within the physiotherapy profession, along with highlighting the barriers preventing physiotherapists from utilising USI.

2. Materials and methods

This cross-sectional, observational survey used an Internet-based platform (SurveyMonkey (SurveyMonkey. 2018)). Participants included consenting, registered physiotherapists/physical therapists who had not responded to the previous New Zealand survey (Ellis et al., 2018). The current study had five phases: 1) survey development; 2) face validity testing; 3) survey translation; 4) survey distribution and data collection; and 5) data analysis. The study was approved by the [anonymised for peer-review] Ethics Committee (reference number 16/352).

2.1. Survey development

The survey was an adaptation of previous New Zealand (Ellis et al., 2018) and UK (Potter et al., 2012) surveys, and included items grouped in five domains: 1) demographic and professional characteristics; 2) scope of practice; 3) uses of USI; 4) training content and duration; and 5) barriers preventing the use of USI. The survey was structured such that those who identified themselves as USI *users* answered items relevant to domains 1–4 and *non-users* domains 1, 2 and 5.

2.2. Confirmation of the face validity

Both the New Zealand (Ellis et al., 2018) and UK (Potter et al., 2012) surveys had undergone peer-review from expert panels consisting of physiotherapists, radiologists and academics. As the current survey was essentially unchanged, a third face validity test was not deemed necessary. Instead, the finalised survey was distributed amongst the co-authors, all of whom have expertise in physiotherapy USI (evidenced by extensive publications), for their peer-review and input. Further survey refinement, following this feedback, included survey flow and shaping items to portray an international context.

2.3. Survey translation and piloting

To facilitate its international reach, the survey was translated from English into 19 different languages including: Afrikaans, Arabic, Cantonese, Danish, Dutch, French, German, Greek, Hindi, Hungarian, Italian, Japanese, Korean, Norwegian, Polish, Portuguese, Spanish, Turkish and Vietnamese. The full survey (including participant instructions and consent, questions and answer options) was provided to the translators in an English-language document independent from SurveyMonkey. After inputting the translated survey items into SurveyMonkey and prior to the survey's distribution, a pilot version was returned to each of the translators to ensure accuracy of translation, and confirmation of survey logic and flow. Aside from this internal review of translation accuracy, an independent review of was not sought.

2.4. Distribution and data collection

Similar to the New Zealand (Ellis et al., 2018) and UK (Potter et al., 2012) surveys, this survey employed snowballing recruitment. Specifically, the URL to the Internet-based platform (SurveyMonkey) was distributed to national and international physiotherapy organisations (i.e. World Confederation of Physical Therapists, International Federation of Orthopaedic and Manipulative Physical Therapists, national physiotherapy professional organisations, etc.) and through social media platforms (i.e. Twitter, Facebook, LinkedIn, etc.). The survey URL was active for six months (July 1 -December 31, 2018).

2.5. Data analysis

Data were exported from SurveyMonkey and analysed using Statistical Package for the Social Sciences software (SPSS version 23.0, IBM Corp., Armonk, NY, USA). Frequencies and percentages were calculated for responses to closed-ended questions. Responses to open-ended questions were translated into English then grouped into similar categories (under common themes). The frequency and percentages of these themes were then calculated. Non-parametric chi-square tests (alpha = 0.05) compared responses between *users* or *non-users* (to examine differences in professional and/or demographic characteristics), and between *users* who received formal and non-formal USI training (to assess differences in content and comprehensiveness of the two types of training, and differences in the competency of physiotherapists who received either type of training).

3. Results

3.1. Survey response

Of the 1437 individual responses to the survey, 1376 participants were deemed eligible, with 1307 participants (56% male) completing the survey to the point where they identified themselves as an USI *user* or

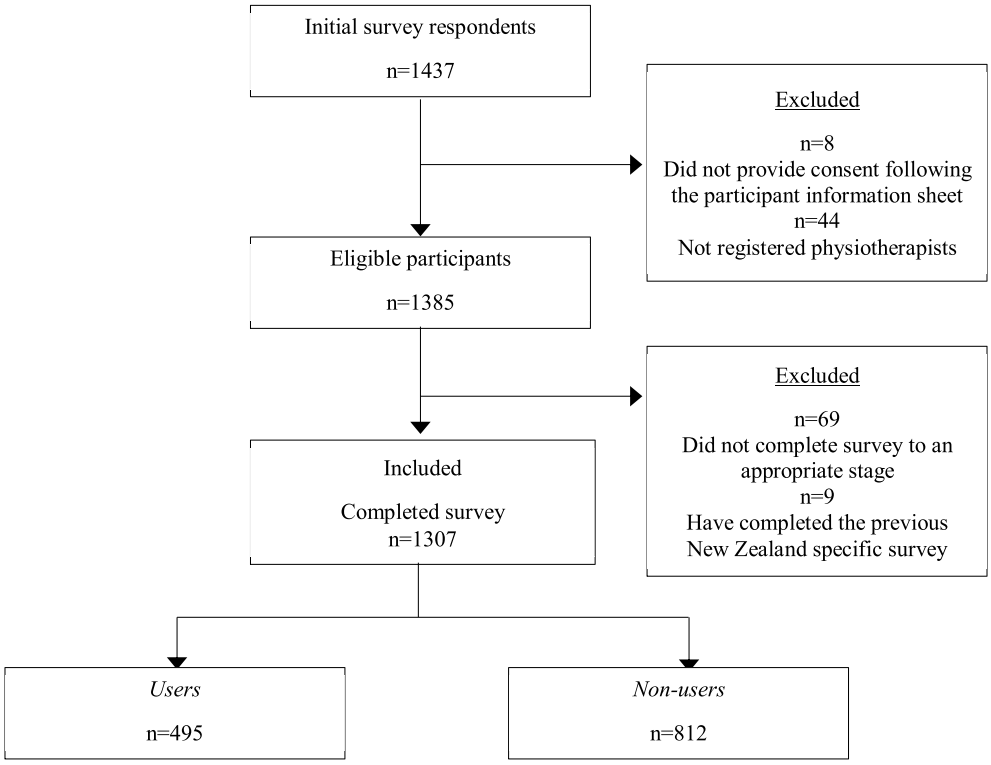


Fig. 1. Prototypical STARD diagram of the flow of participants through the study.

Table 1
Demographic characteristics and physiotherapy training.

	Total sample (%) n = 1307	Users (%) n = 495	Non-users (%) n = 812	Statistic	Significance (*p* value)
Gender				$\chi2(1) = 2.78$	0.095
Male	734 (56.2%)	293 (59.2%)	441 (54.3%)		
Female	573 (43.8%)	202 (40.8%)	371 (45.7%)		
Age (years)				$\chi2(8) = 60.63$	**0.0005**
20–24	67 (5.1%)	12 (2.4%)	55 (6.8%)		
25–29	246 (18.8%)	63 (12.7%)	183 (22.5%)		
30–34	259 (19.8%)	79 (16.0%)	180 (22.5%)		
35–39	243 (18.6%)	111 (22.4%)	132 (16.3%)		
40–44	173 (13.2%)	77 (15.6%)	96 (11.8%)		
45–49	127 (9.7%)	67 (13.5%)	60 (7.4%)		
50–54	105 (8.0%)	44 (8.9%)	61 (7.4%)		
55–59	55 (4.2%)	24 (4.8%)	31 (3.8%)		
60+ years	32 (2.45%)	18 (3.64%)	14 (1.72%)		
Postgraduate Qualification				$\chi2(6) = 82.28$	**0.0005**
None	274 (21.0%)	58 (11.7%)	216 (26.6%)		
Postgraduate certificate	193 (14.8%)	80 (16.2%)	113 (13.9%)		
Postgraduate diploma	158 (12.9%)	86 (17.4%)	82 (10.1%)		
Masters degree	448 (34.3%)	165 (33.3%)	283 (34.9%)		
Graduate entry doctoral degree	66 (5.0%)	17 (3.4%)	49 (6.0%)		
Doctoral degree	134 (10.3%)	82 (16.6%)	52 (6.4%)		
Other	24 (1.8%)	7 (1.4%)	17 (2.1%)		
Geographical location				$\chi2 = 67.46$	**0.0005**
Australasia	189 (14.5%)	98 (19.8%)	91 (11.2%)		
Asia	117 (9.0%)	26 (5.3%)	91 (11.2%)		
Africa	43 (3.3%)	9 (1.8%)	34 (4.2%)		
Europe	678 (51.9%)	296 (59.8%)	382 (47.0%)		
North America	203 (15.5%)	50 (10.1%)	153 (18.8%)		
South America	77 (5.9%)	16 (3.2%)	61 (7.5%)		

n = participant numbers; $\chi2$ = chi-square statistic.

non-user, and included in the analyses (Fig. 1).

3.2. Professional and demographic characteristics

Respondent demographic and professional characteristics are summarised in Tables 1 and 2. Respondents represented 49 different countries (Fig. 2). The proportion of participants, as a ratio of the number of members of each countries professional body (as registered with the World Confederation of Physical Therapists (World Confederation for P, 2019)), varied significantly. The top five countries for overall respondents included Spain (April 33, 1000 members), Australia (September 6, 1000 members), Poland (February 52, 1000 members),

Table 2
Professional characteristics of participants.

	Total Sample (n = 1307)	Users (n = 495)	Non-users (n = 812)	Statistic	Significance (p value)
Type of work				$\chi 2(4) = 18.07$	**0.0005**
Clinical	1107 (84.7%)	404 (81.6%)	703 (86.6%)		
Teaching/Education	105 (8.0%)	44 (8.9%)	61 (7.5%)		
Research	51 (3.9%)	33 (6.7%)	18 (2.2%)		
Management	20 (1.5%)	7 (1.4%)	13 (1.6%)		
Other (e.g. sales, data science)	24 (1.8%)	7 (1.4%)	17 (2.1%)		
Years of work experience				$\chi 2(3) = 61.31$	**0.0005**
0–5 years	302 (23.1%)	70 (14.1%)	232 (28.6%)		
6–10 years	301 (23.0%)	95 (19.2%)	206 (25.4%)		
11–15 years	227 (17.4%)	94 (19.0%)	133 (16.4%)		
16 years or more	477 (36.5%)	236 (47.7%)	241 (29.7%)		
Area of work[a]					
Private Practice	865 (66.2%)	350 (70.7%)	515 (63.4%)		
Public hospital/clinic	326 (24.9%)	118 (23.8%)	208 (25.6%)		
University	208 (15.9%)	106 (21.4%)	102 (12.6%)		
Sports team or sports institute	148 (11.3%)	60 (12.1%)	88 (10.8%)		
Private organisation	98 (7.5%)	25 (5.1%)	73 (9.0%)		
Private hospital	89 (6.8%)	29 (5.9%)	60 (7.4%)		
Research facility	46 (3.5%)	29 (5.9%)	17 (2.1%)		
Community	35 (2.7%)	9 (1.8%)	26 (3.2%)		
In a field unrelated to physiotherapy/physiotherapy (e.g. *sales/ marketing etc.)*	5 (0.4%)	0 (0.0%)	5 (0.6%)		
Other	28 (2.1%)	7 (1.4%)	21 (2.6%)		
Area of physiotherapy[a]					
Musculoskeletal	1138 (87.1%)	423 (85.5%)	715 (88.1%)		
Sports medicine	570 (43.6%)	240 (48.5%)	330 (40.6%)		
Neurology	264 (20.2%)	73 (14.7%)	191 (23.5%)		
Hand therapy	218 (16.7%)	112 (22.6%)	106 (13.1%)		
Aged care	167 (12.8%)	29 (5.9%)	138 (17.0%)		
Women's health	163 (12.5%)	94 (19.0%)	69 (8.5%)		
Paediatrics	128 (9.8%)	40 (8.1%)	88 (10.8%)		
Cardiorespiratory and/or cardiovascular	120 (9.2%)	36 (7.3%)	84 (10.3%)		
Occupational health	95 (7.3%)	32 (6.5%)	63 (7.8%)		
Mental health	22 (1.7%)	6 (1.2%)	16 (2.0%)		
Other (e.g. men's health, oncology, pain management, etc.)	66 (5.0%)	24 (4.8%)	42 (5.2%)		

Note. n = participant numbers.
[a] Responses to question not mutually exclusive (statistical comparison not possible due to multiple responses).

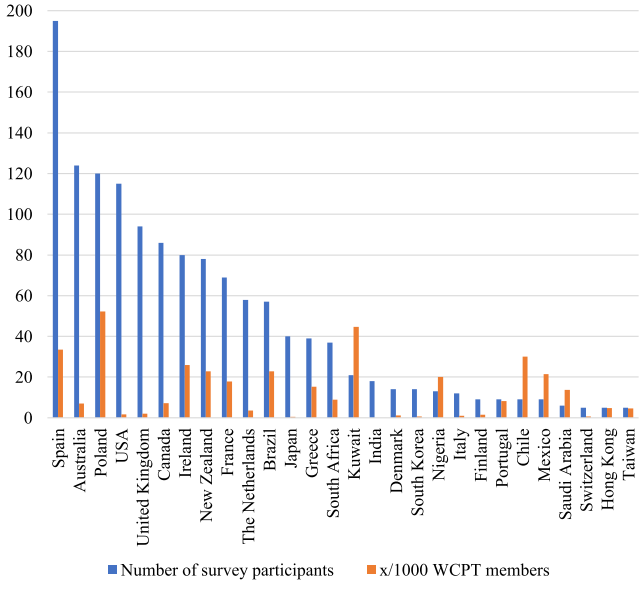
USA (July 1, 1000 members) and UK (2.0/1000 members; Fig. 2). The majority were identified as clinicians, with 87% working in musculoskeletal physiotherapy and 66% in private practice settings (Table 2).

3.3. Scope of practice

When asked about their awareness of the different USI applications within physiotherapy, 85% of participants were aware of diagnostic USI, 78% rehabilitative USI, 64% interventional USI, and 41% research USI. When asked whether physiotherapists in their home country, state or licensing jurisdiction, have a SoP to use USI, 44% answered "yes", 30% answered "no", and 27% were "unsure". For those participants who believed there was a SoP for USI in physiotherapy, 89% believed this SoP included rehabilitative USI, 56% research USI, 53% diagnostic USI, and 53% interventional USI.

3.4. Uses of USI

Of the 1307 participants, 495 (38%) were *users* of USI. *Users* and *non-users* differed statistically ($p < 0.05$) with respect to age, years of experience, likelihood of being research active, and holding a post-graduate qualification (Tables 1 and 2). The majority of *users* (61.%) had used USI for 1–5 years. The number of hours USI was utilised each month varied, with most (37%) using it between 1 and 5 h per month and more than 11% utilised USI for 30 h or more per month. On average, participants rated the overall importance of USI as a clinical tool as 7/10 (0 = not important at all; 10 = very important). The context in which



Other countries with less than 5 respondents included: Algeria, Argentina, Austria, Bangladesh, Belgium, China, Colombia, Cyprus, El Salvador, Germany, Indonesia, Malta, Norway, Pakistan, Philippines, Qatar, Singapore, Sweden, Turkey, Uganda, United Arabic Emirates

Fig. 2. Country of residence for survey participants, including the number of respondents and the number of respondents per 1000 members of WCPT for that particular country.

Table 3
Uses of ultrasound imaging within physiotherapy.

Context of using USI (n = 476)[a]	Total n (%)	Formal and Informal (n = 278)	Formal only (n = 143)	Informal only (n = 37)
Biofeedback tool	275 (57.8%)	164 (59.0%)	86 (60.1%)	21 (56.8%)
Monitoring outcome of treatment	267 (56.1%)	166 (59.7%)	90 (62.9%)	6 (16.2%)
Measuring linear soft tissue thickness and/or width	248 (52.1%)	157 (56.5%)	74 (51.7%)	7 (18.9%)
To assist in making a diagnosis of injury and/or pathology	238 (50.0%)	145 (52.2%)	80 (55.9%)	6 (16.2%)
Assessment of soft tissue trauma and monitor healing	236 (49.6%)	146 (52.5%)	76 (53.1%)	9 (24.3%)
Evaluating muscle structure (e.g. shape, pennation angle, muscle fascicle length, fatty infiltration etc.)	236 (49.6%)	138 (49.6%)	84 (58.7%)	7 (18.9%)
Measuring cross-sectional area (CSA) and/or volume of soft tissues	231 (48.5%)	143 (51.4%)	73 (51.0%)	9 (24.3%)
For guiding percutaneous injections (e.g.) acupuncture, needle guidance)	196 (41.2%)	119 (42.8%)	68 (47.6%)	3 (8.1%)
As a research tool	149 (31.3%)	94 (33.8%)	38 (26.6%)	10 (27.0%)
Training other physiotherapists how to use USI	114 (23.9%)	85 (30.6%)	22 (15.4%)	4 (10.8%)
To conduct research to examine new USI techniques	55 (11.5%)	35 (12.6%)	15 (10.5%)	3 (8.1%)
Training other clinicians (e.g. podiatrists, GP's etc.) how to use USI	33 (6.9%)	27 (9.7%)	6 (4.2%)	0 (0.0%)
Other (e.g. measuring bladder volume, therapeutic ultrasound)	43 (9.0%)	12 (4.3%)	4 (2.8%)	3 (8.1%)
What regions of the body do you routinely image? (n = 476)[a]				
Lower Limb	323 (67.9%)	189 (68.0%)	106 (74.1%)	15 (40.5%)
Upper Limb	314 (66.0%)	182 (65.5%)	105 (73.4%)	16 (43.2%)
Anterolateral abdominal wall (e.g. abdominal muscles)	183 (38.4%)	121 (43.5%)	44 (30.8%)	13 (35.1%)
Multifidus and/or other spinal extensors	167 (35.1%)	105 (37.8%)	47 (32.9%)	8 (21.6%)
Pelvic floor and/or bladder	132 (27.7%)	88 (31.7%)	30 (21.0%)	12 (32.4%)
Lumbosacral region	95 (20.0%)	67 (24.1%)	24 (16.8%)	1 (2.7%)
Cervical spine region	66 (13.9%)	44 (15.8%)	15 (10.5%)	4 (10.8%)
Diaphragm/respiratory muscles	52 (10.9%)	35 (12.6%)	12 (8.4%)	2 (5.4%)
Thoracic spine region	49 (10.3%)	32 (11.5%)	12 (8.4%)	2 (5.4%)
Other (e.g. face, bowel, lung)	17 (3.6%)	9 (3.2%)	2 (1.4%)	4 (10.8%)
Hours per month using USI (n = 476)				
1–5 h	178 (37.4%)	81 (29.1%)	58 (40.6%)	28 (75.7%)
6–10 h	91 (19.1%)	58 (20.9%)	27 (18.9%)	3 (8.1%)
11–15 h	62 (13.0%)	39 (14.0%)	18 (12.6%)	3 (8.1%)
16–20 h	52 (10.9%)	35 (12.6%)	16 (11.2%)	1 (2.7%)
21–25 h	15 (3.2%)	11 (4.0%)	4 (2.8%)	0 (0.0%)
26–30 h	24 (5.0%)	13 (4.7%)	8 (5.6%)	2 (5.4%)
More than 30 h	54 (11.3%)	41 (14.7%)	12 (8.4%)	0 (0.0%)
Percentage of patients that USI is used (n = 476)				
Not applicable, I do not use USI on patients (e.g. research)	33 (6.9%)	18 (6.5%)	5 (3.5%)	6 (16.2%)
1–10%	122 (25.6%)	51 (18.3%)	49 (34.3%)	17 (45.9%)
11–20%	78 (16.4%)	51 (18.3%)	18 (12.6%)	4 (10.8%)
21–30%	67 (14.1%)	42 (15.1%)	21 (14.7%)	2 (5.4%)
31–40%	42 (8.8%)	26 (9.4%)	13 (9.1%)	1 (2.7%)
41–50%	24 (5.0%)	15 (5.4%)	7 (4.9%)	2 (5.4%)
51–60%	39 (8.2%)	30 (10.8%)	8 (5.6%)	1 (2.7%)
61–70%	16 (3.4%)	11 (4.0%)	5 (3.5%)	0 (0.0%)
71–80%	22 (4.6%)	11 (4.0%)	9 (6.3%)	2 (5.4%)
81–90%	14 (2.9%)	9 (3.2%)	4 (2.8%)	1 (2.7%)
91–100%	19 (4.0%)	14 (5.0%)	4 (2.8%)	1 (2.7%)

[a] Participants were able to select multiple items. n = participant numbers.

physiotherapists were using USI (Table 3) was diverse, and responses were grouped into six broad categories: (i) biofeedback; (ii) diagnosis; (iii) assessment; (iv) injection guidance; (v) research; and (vi) teaching.

3.5. Training

Of the 495 USI *users,* 30% had received formal training only, 8% had attended informal training only, 58% had received both formal and informal training, and 4% had received no training. A wide and varied range of topics were covered for both formal and informal training (Table 4). For a majority of topics, formal training covered more content consistently compared to informal training. The greater content covered by formal training indicated it was more comprehensive than informal training. Furthermore, the level of competence described by the *users* in the key training topics was greater for those trained formally than for those trained informally (Fig. 3).

Table 4
Content of USI training and percentage of each topic covered in formal and informal training.

Content of training[a]	Formal (n = 421) n (%)	Informal (n = 315) n (%)
Practical use of USI (scanning) on other course members	365 (86.7%)	170 (54.0%)
Background physics of USI	358 (85.0%)	99 (31.4%)
How to enhance the quality of the image	357 (84.8%)	150 (47.6%)
Understanding and identifying artefacts	357 (84.8%)	113 (35.9%)
How to operate the ultrasound machine ("knobology")	353 (83.8%)	161 (51.1%)
Safety issues around the use of the ultrasound machine	323 (76.7%)	80 (25.4%)
Shown more than one type of transducer	295 (70.1%)	97 (30.8%)
How to take structural measurements (e.g. CSA, thickness, width etc.) of soft tissues (eg. muscle, tendon, nerve etc.)	285 (67.7%)	109 (34.6%)
Understanding variations in soft tissue structure	263 (62.5%)	114 (36.2%)
Ergonomics of ultrasound machine use and scanning	234 (55.6%)	67 (21.3%)
Research that shows the reliability and validity of USI	233 (55.3%)	61 (19.4%)
Using USI as a biofeedback tool	216 (51.3%)	120 (38.1%)
How to standardise measurements of soft tissue (see item above)	215 (51.1%)	87 (27.6%)
Use of Doppler imaging	207 (49.2%)	79 (25.1%)
Ethical and/or professional considerations (e.g. scope and codes of practice, consent, storage of data, etc.)	200 (47.5%)	55 (17.5%)
Identifying research showing the effectiveness of USI in clinical practice	161 (38.2%)	43 (13.7%)
Practical use of USI (scanning) on patients	152 (36.1%)	133 (42.2%)
Interpretations of types of muscle activity (e.g. isometric or dynamic contractions)	134 (31.8%)	66 (21.0%)
Which muscle groups have you been trained to image?[a]		
Anterolateral abdominal wall (e.g. abdominal muscles)	236 (56.1%)	139 (44.1%)
Multifidus and/or other spinal extensors	215 (51.1%)	106 (33.7%)
Pelvic floor (transabdominal and/or transperineal)	152 (36.1%)	110 (34.9%)
Cervical spine musculature	104 (24.7%)	54 (17.1%)
Upper limb muscles	306 (72.7%)	164 (52.1%)
Lower limb muscles	311 (73.9%)	164 (52.1%)
Diaphragm/respiratory muscles	70 (16.6%)	40 (12.7%)
Other	24 (5.7%)	15 (4.8%)
Have you been informally trained to image structures other than muscle?[a]		
No, I have not been trained to image other tissues	79 (18.8%)	108 (34.3%)
Bone	203 (48.2%)	99 (31.4%)
Ligament	274 (65.1%)	127 (40.3%)
Nerve	255 (60.6%)	130 (41.3%)
Tendon	297 (70.5%)	148 (47.0%)
Vascular system (e.g. blood vessels)	148 (35.2%)	75 (23.8%)
Other (e.g. bladder, bowel, cartilage, lung)	39 (9.3%)	21 (6.7%)

[a] Participants were able to select multiple items. n = participant numbers. Formal training = "study/learning from a provider of education; involvement in research as part of a tertiary qualification; attendance at conferences, paid seminars, etc.". Informal training = "work-based continuing professional development (i.e. inservice training, staff/student supervision); professional activities, etc.".

3.6. Barriers to using USI

Of the 1307 respondents, 62% (812) indicated that they were *non-users* of USI. The most common barriers cited for non-use included lack of available training (76%), no access to USI equipment (56%), and cost of USI equipment (42%; Table 5). Only 3% reported that USI was not legislated for or not in their SoP.

4. Discussion

This international survey aimed to better understand how physiotherapists use USI and what barriers prevent its use. To maximise survey reach and diversity of participants, the survey was available in 20 different languages, with recruitment via a snow-balling method using social media. This resulted in participation from 49 different countries, representing the widest reaching survey of its kind for USI in physiotherapy.

The 1307 eligible participants were similar to those in previous USI surveys (Ellis et al., 2018; Jedrzejczak and Chipchase, 2008; McKiernan et al., 2011; Potter et al., 2012), the majority working clinically in musculoskeletal physiotherapy within private practice. A notable difference observed in this study was the educational level of participants, with 79% holding a postgraduate qualification, compared to 54% from the New Zealand study (Ellis et al., 2018).

Of interest were responses concerning knowledge of the SoP for USI use within their own profession, location and context. There was substantial uncertainty, with 44% of participants believing there is a SoP for physiotherapists to use USI, and the remainder either unsure (27%) or believing there was no SoP (30%). These results mirror those from the only other survey to examine understanding of physiotherapists' SoP (Ellis et al., 2018), which also demonstrated that less than half believed they had a SoP to use USI. Replicating these results on an international scale highlights physiotherapists' uncertainty about their own professional SoP regarding USI use. This lack of certainty could affect USI uptake, therefore restricting further evolution of the tool and supports the need for consensus around physiotherapy SoP.

There was a notably higher percentage of *users* in the international survey (38%) than the New Zealand survey (24%) (Ellis et al., 2018). The international sample of *users* and *non-users* differed statistically in that *users* were older, had more years of clinical experience, were more likely to be research active, and more likely to hold a postgraduate qualification.

Although *users* worked predominantly in musculoskeletal physiotherapy (86%) and sports medicine (49%), a surprising and exciting finding was the growing use of USI in other areas of practice, notably hand therapy (23%), women's pelvic floor health (19%), and neurology (15%), among others. This finding confirms reports of USI being more widely used across the profession (Ellis et al., 2018; Whittaker et al., 2019). Furthermore, the study demonstrated a variety of ways in which USI was being utilised, rather than primarily as a biofeedback tool, as reported previously (Ellis et al., 2018; Jedrzejczak and Chipchase, 2008). Furthermore, areas of the body most frequently imaged also contrasted with previous USI studies, with the most commonly imaged areas now being the upper (66%) and lower limbs (68%). Previous studies consistently reported the abdominal region as the most commonly area imaged (Ellis et al., 2018; Jedrzejczak and Chipchase, 2008; McKiernan et al., 2011; Potter et al., 2012). It was not possible to discern whether imaging of limbs was more diagnostic compared to abdominal imaging being more rehabilitative, but this is a possibility and may reflect the increased diagnostic USI training available to physiotherapists.

With respect to USI training, 88% of *users* reported attending formal training, which is greater than previously reported, where only 42% (Ellis et al., 2018) and 52% (Potter et al., 2012) of participants had attended formal training. Sixty-six percent of users attended informal training. Notably, the number of *users* that had not received any training in USI (5%) was also significantly lower than reported in previous studies (10–32% of participants) (Ellis et al., 2018; Jedrzejczak and Chipchase, 2008; McKiernan et al., 2011).

As seen previously (Ellis et al., 2018; Potter et al., 2012), disparities between formal and informal training content were evident, with formal training covering many more content areas. Informally trained *users* reported lower usage and competence in key areas compared to formally trained *users*. For example, formal training consistently taught topics/skills of understanding and identifying artefacts (84%), background physics of USI (85%), and enhancing image quality (85%), compared with informal training which reported frequencies of only 36%, 31%

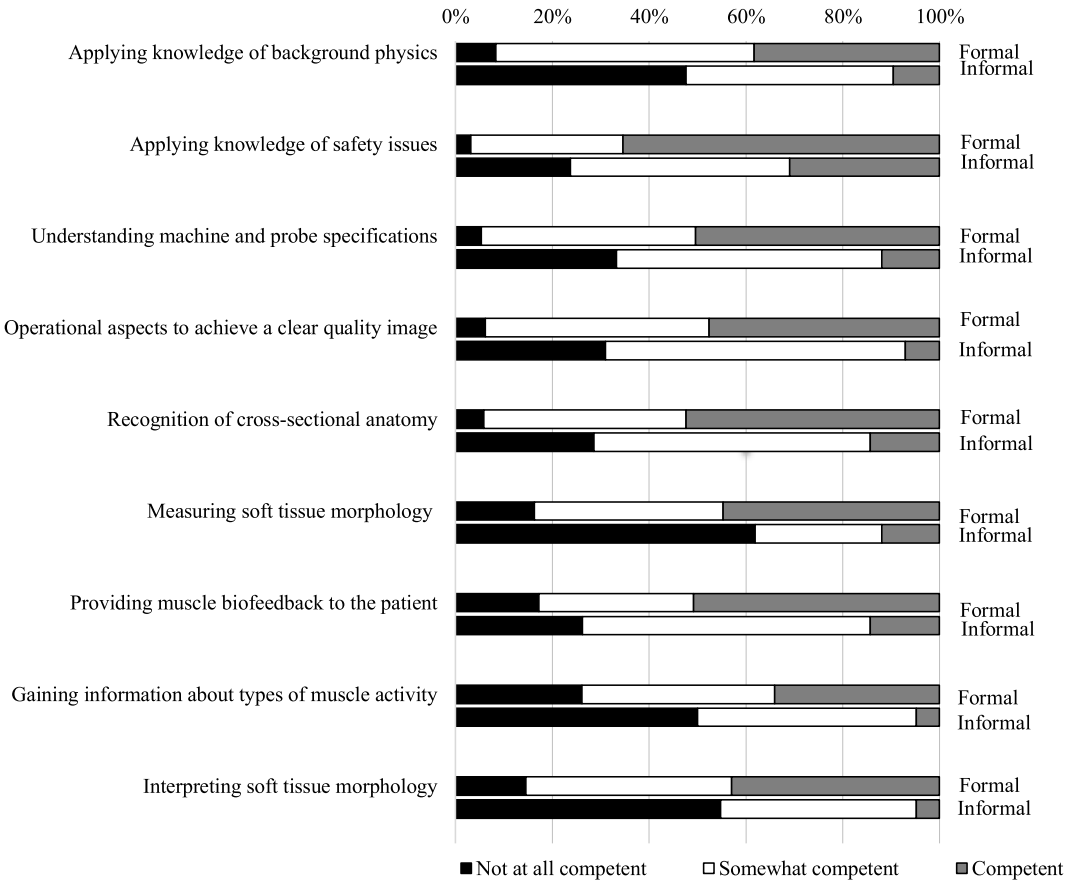


Fig. 3. Perceived competency of USI skills in participants who received formal training compared to those who received informal training.

Table 5
Barriers to using USI.

Barriers to using USI (n = 812)*	n (%)
I have not been trained to use USI	616 (75.9%)
There is no ultrasound equipment on site	451 (55.5%)
The equipment is expensive	344 (42.4%)
I am not confident in using USI	168 (20.7%)
There is no specific remuneration available for providing an USI service	123 (15.1%)
There is a lack of support for providing an USI service from management	108 (13.3%)
The ultrasound equipment on site is not available for use	85 (10.5%)
I don't understand the potential uses for USI in my clinical practice	83 (10.2%)
There are time constraints to use USI	74 (9.1%)
There is not enough evidence for the effectiveness of USI in clinical practice to convince management to purchase ultrasound equipment	70 (8.6%)
I have no interest in using USI in my clinical practice	58 (7.1%)
There is a lack of supervision for my use of USI	51 (6.3%)
My patients are not willing to pay for USI/scan	38 (4.7%)
USI use is not legislated for/not in my scope of practice	27 (3.3%)
Use of USI is not suitable for the patients that I see	15 (1.8%)
My patients are unable to comply with instructions	10 (1.2%)
There are not enough correct probes/transducers available to allow scanning in my area of interest	7 (0.9%)
Other (e.g. Patients are not wanting to be scanned, USI is not in my scope of practice, easier to refer to someone else)	22 (2.7%)

Note. n = participant numbers. *Participants were able to select multiple items.

and 48% respectively. Imaging of structures other than muscles (e.g. ligaments, tendons, bone) was taught more often in formal than informal training, indicating more comprehensive formal training, as was concluded in previous studies (Ellis et al., 2018; Potter et al., 2012).

Of *non-users* (812/1307; 62%), the largest barrier to USI use was a lack of training (76%), followed by lack of equipment (56%), and the perceived high cost of USI equipment (42%). These findings matched those previously reported (Ellis et al., 2018). Notably, only 7% of *non-users* indicated that they were not interested in using USI in their clinical practice. This highlights the need to remove barriers to facilitate future development of the use of USI within the physiotherapy profession.

4.1. Strengths and limitations

The study was robust in that the survey was based on two previous surveys (Ellis et al., 2018; Potter et al., 2012), both of which have demonstrated face validity and been reviewed by expert panels. A further strength was providing the survey in 20 different languages and using snow-balling recruitment via social media, which enabled a greater recruitment of a diverse sample, thereby enhancing external validity.

This study is the largest physiotherapy USI survey to date. However, it is acknowledged that a convenience sample was used, it may be biased to those physiotherapists that use technology and social media, and is not likely representative of the entire population of physiotherapists globally. There was variability in response rate seen across the 49 countries. For example, in regard to the proportion of physiotherapists that belong to their national professional body (World Confederation for P, 2019) (represented as x/1000 members), the survey received responses from 52/1000 society members in Poland and 45/1000 in

Kuwait, compared to <1/1000 in Japan and USA.

Furthermore, as described in the literature (Wright, 2005), a limitation of using an Internet-based survey is that it is not possible to know how many people the survey reached, therefore non-response rates cannot be determined. It is possible that the advertisement of the survey may have appealed more to USI *users*, and therefore the results may be skewed to represent a higher proportion of USI users than *non-users*, however there is no possible way of knowing whether this bias exists without knowing how many potential participants did not respond to the survey.

5. Conclusions

The results of this international survey revealed that over a third of physiotherapists who completed the survey were using USI in their clinical practice, although the proportion of using USI in the physiotherapy profession is still relatively low. The variety of clinical applications of USI observed was notable, demonstrating the versatility of the tool to suit the individual's needs and its widening use throughout the physiotherapy profession.

There is a clear lack of consensus surrounding the field and scope for use of USI within the physiotherapy profession. In order to further promote the growth of the tool within the profession, international guidelines from collaborating regulatory bodies, including a USI training framework for physiotherapists, are needed to enable consistency and sustainability of use of USI in physiotherapy. Furthermore, the opportunity for physiotherapists to undertake training in USI must be increased to help facilitate *non-users* to consider utilising USI in their clinical practice. Greater accessibility to formal training would be particularly warranted due to the superiority of the content covered, as demonstrated in the survey.

Ethics approval

This study was approved by the Auckland University of Technology Ethics Committee (reference number 16/352).

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Declaration of competing interest

The authors have no conflicts of interest to declare.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.msksp.2020.102213.

Other countries with less than 5 respondents included: Algeria, Argentina, Austria, Bangladesh, Belgium, China, Colombia, Cyprus, El Salvador, Germany, Indonesia, Malta, Norway, Pakistan, Philippines, Qatar, Singapore, Sweden, Turkey, Uganda, United Arabic Emirates.

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