Daniela Cortesão Fernandes

Consenso para a utilização da ecografia torácica pelo fisioterapeuta: Como? Onde? Para quê?

Consensus on the use of thoracic ultrasound by respiratory physiotherapists: how, where and for what?

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Fisioterapia ramo Respiratória, realizada sob a orientação científica da Doutora Ana Oliveira, Professora Adjunta da Escola Superior de Saúde da Universidade de Aveiro e coorientação científica da Doutora Alda Marques, Professora Coordenadora Principal da Escola Superior de Saúde da Universidade de Aveiro

Dedico este trabalho às pessoas que me apoiam e torcem por mim, à minha família e à família que fui escolhendo para pertencer à minha vida. Dedico este trabalho à Daniela de 22 anos, que quando terminou a sua licenciatura quis seguir um sonho e hoje está aqui.

O júri

Presidente	Professor Doutor Rui Jorge Dias Costa Professor Coordenador da Escola Superior de Saúde da Universidade de Aveiro
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Palavras-chave

Avaliação; Delphi; fisioterapia respiratória; ultrassonografia no leito; experiência do fisioterapeuta com ultrassonografia.

Resumo

A ultrassonografia (US) é uma ferramenta de avaliação torácica não invasiva e segura, que permite avaliação imediata sem exposição à radiação ionizante. O *Point-of-Care Ultrasonography* (POCUS) é uma forma de avaliação e monitorização da pleura, parênquima e diafragma, que facilita a tomada de decisão em fisioterapia. Contudo, a variabilidade de protocolos e procedimentos utilizados entre os estudos constituem desafios à padronização e utilização tranversal na prática clínica dos fisioterapeutas. Este estudo qualitativo teve como objetivo contribuir para estabelecer orientações para a aquisição e interpretação do POCUS nas avaliações torácicas por fisioterapeutas respiratórios. Utilizou-se o método Delphi modificado. Foram realizadas entrevistas semiestruturadas com fisioterapeutas respiratórios que realizam avaliações torácicas com US. As entrevistas foram gravadas, transcritas e analisadas com análise temática.

Participaram seis fisioterapeutas respiratórios (cinco homens e uma mulher; 41 ±5,88 anos) de seis países diferentes, com experiência de utilização de US entre 3 a 10 anos. Quatro temas principais emergiram: aquisição de imagem (protocolos e procedimentos), tomada de decisão (indicações e proficiência), barreiras e facilitadores (desafios e fatores facilitadores) e desenvolvimento futuro (estruturas educacionais atuais e necessidades futuras para fins educacionais e de pesquisa). Os participantes sublinharam a mais-valia da utilização da US em fisioterapia respiratória, identificaram protocolos-chave e procedimentos, e destacaram a importância da formação estruturada e da mentoria. Foram reconhecidas barreiras, como disponibilidade de equipamentos e perceções profissionais, enquanto os facilitadores incluíram bom suporte profissional na aprendizagem de competências e programas de educação estruturados. Este estudo enfatiza a necessidade de protocolos específicos, formação adaptada ao nível de utilizador e literatura que facilite a integração da US na prática do fisioterapeuta respiratório.

Keywords

Assessment; Delphi method; physiotherapists experiences on ultrasound; Point-of-care Ultrasonography; respiratory physiotherapy.

Abstract

Ultrasonography (US) is a non-invasive and safe form of thoracic assessment, offering real-time imaging without ionizing radiation exposure. Point-of-care ultrasound (POCUS) is a form of immediate assessment and monitoring of the pleurae, lung parenchyma and diaphragm that facilitates decision-making in physiotherapy. Nevertheless, the variability in US protocols and procedures among studies presents challenges for standardization and widespread adoption in clinical practice for physiotherapists. This qualitative study aimed to contribute to establish a consensus on the procedures and interpretation of the US for thoracic assessments by respiratory physiotherapists. A modified Delphi methodology was used. Semi-structured online interviews were conducted with respiratory physiotherapists with experience in using US. Interviews were audio-recorded, transcribed and analysed thematically.

Six respiratory physiotherapists (five male and one woman; 41±5,88 years old) from six different countries with a range of experience with US of 3 to 10 years, participated. Four main themes emerged: acquisition (protocols and technical procedures), decision-making (indications and proficiency), barriers and facilitators (difficulties and facilitating factors), and development process (current education structures and future needs for education and research purposes). Participants emphasized the value of using the US in respiratory physiotherapy, identified key protocols and technical procedures, and highlighted the importance of structured training and mentoring. Barriers such as equipment availability and professional perceptions were acknowledged, while facilitators included supportive workplace environments and structured training programs. The study underscores the need for standardized protocols, comprehensive training, and further research to advance the integration of the US into respiratory physiotherapy practice.

Abbreviations and/or acronyms

BMI – Body mass index

CLUE - Cardiopulmonary Limited Ultrasound Examination

COREQ - Consolidated criteria for reporting qualitative research

CT – Computed tomography

ER - Emergency room

F – Female

FAST - Focused Assessment with Sonography in Trauma

GUCCI - Global ultrasound check for the critical ill

ICU – Intensive care units

ID – Participant number

LUS – Lung Ultrasound Score

M – Male

POCUS – Point-of-care Ultrasonography

PT – Physiotherapist

PT – Physiotherapy

RP – Respiratory physiotherapy

SESAME – Sequencial Echographic Scanning Assessing Mechanism or Origin of Severe Shock of Indistinct Cause

TLC – Total lung capacity

TV – Tidal volume

UK – United Kingdom

US – Ultrasonography

Table of contents

1. Introduction

Ultrasonography (US) is a non-invasive evaluation technique that utilizes sound waves (Dietrich et al., 2022). During the application of this technique, a device called transducer converts electrical current into sound waves, which are sent into the body's tissues and then reflected to the transducer, allowing for the generation of an image based on the echo (Dietrich et al., 2022; Shriki, 2014). This technique is not only used to establish diagnoses but also to monitor the effects of healthcare interventions on body structures and functions, such as those respiratory-related, e.g., ventilation optimization, lung aeration assessment or respiratory dysfunction evaluation (Bouhemad et al., 2015; Brekka et al., 2022; Leech et al., 2015).

Point-of-care ultrasound/ultrasonography (POCUS) is a valuable skill that enables real-time imaging at the bedside, without the need for ionizing radiation exposure, such as X-ray radiation (Brekka et al., 2022; Leech et al., 2015). It is commonly used for thoracic assessments involving the pleurae, lung parenchyma, diaphragm, and intercostal muscles (Andersen et al., 2019; Hayward et al., 2020). Thoracic US exhibits high sensitivity and specificity for diagnosing respiratory conditions such as pleural effusion, interstitial syndrome, lung consolidation, lung contusion, and pneumothorax. The reported sensitivity and specificity values for these conditions range from 86% to 99% in patients with respiratory symptoms (Leech et al., 2015), comparable to computed tomography (Hansell et al., 2021).

The high reliability and clinical value of US have driven technological advances to enhance the equipment's affordability and portability. These advancements have facilitated the expansion of US use to various healthcare settings, including emergency rooms, intensive care units, wards, outpatient, and clinics, allowing its use by different healthcare professionals, such as physiotherapists (Andersen et al., 2021; Hansell et al., 2023; Hayward & Janssen, 2018; Le Neindre et al., 2016; Leech et al., 2015; Myszkowski, 2019; Truong et al., 2023).

There is a growing interest in POCUS by physiotherapists, with systematic reviews reporting over 80% of publications occurring in the last decade (Strike et al., 2022; Truong et al., 2023). However, the procedures for using POCUS vary considerably among studies. This heterogeneity is seen in the utilization of different modes, e.g., a linear probe in B or M mode for the same evaluation, like diaphragm thickness; with body positions ranging from supine to semi-recumbent to evaluate, e.g., diaphragm thickness, diaphragm thickening fraction and diaphragm excursion; lung volume measurements ranging from total lung capacity (TLC) to tidal volume (TV), and the probe frequency used ranging from 4-9MHz to 10-15MHz (Truong et al., 2023). Additionally, some studies describe bilateral assessment of the diaphragm, while others focus on unilateral evaluation

(Le Neindre et al., 2021; Truong et al., 2023). Also, several studies do not describe the image analysis software used (Truong et al., 2023). Taken together, this variability hinders replication, the development of specific recommendations for thoracic US use in clinical practice of respiratory physiotherapists (Truong et al., 2023), limits training of new users (Andersen et al., 2019) and, ultimately, impairs knowledge advance in the field. Therefore, it is crucial to develop guidelines for the use of POCUS in thoracic assessment by respiratory physiotherapists. Such guideline could improve assessment and management of respiratory dysfunction by these healthcare professionals (Leech et al., 2015), minimizing the need for potentially unnecessary assessments, and reducing patient's anxiety (Andersen et al., 2019; Brekka et al., 2022).

This study, therefore, aimed to contribute to establish an expert consensus on the procedures and interpretation of POCUS for thoracic assessments and monitoring by respiratory physiotherapists. Specifically, it aimed to obtain experts insights on:

i) the most relevant US assessments in different settings, such as hospital, outpatient, inpatient, intensive care, emergency department, clinic, and community;

ii) the most appropriate protocols in acute and chronic conditions;

iii) the procedures for image acquisition (e.g., preparation, probe type, image and/or video recording protocol, probe manipulation, and image optimization);

iv) the level of experience required (e.g., number of acquisitions in people with and without pathology) for autonomous practice;

v) the barriers, limitations and difficulties in the use of this assessment tool by respiratory physiotherapists.

2. Methods

2.1. Study design and ethical considerations

This was a cross-sectional qualitative study conducted using a modified Delphi methodology (Battle et al., 2023; Ogbeifun & Agwa-Ejon, 2016; Okoli & Pawlowski, 2004; Vogel et al., 2019), including three phases: semi-structured interviews, modified Delphi survey with two rounds, and a group interview in case of non-consensus being obtained (Battle et al., 2023; Niederberger & Spranger, 2020). For the purpose of this dissertation, only phase one was conducted and presented. The study was conducted and reported following the guidelines and recommendations of Consolidated criteria for reporting qualitative research (COREQ) and Research guidelines for the Delphi survey technique (Hasson et al., 2000; Tong et al., 2007).

The ethics committee of the University of Aveiro (statement 38-CED/2023) approved the study. Data protection followed the European regulation (EU 2016/679). Informed consent was obtained from each participant prior to any data collection.

2.2. Recruitment and Participants

The sampling method employed in this study was a combination of intentional and snowball sampling (Tong et al., 2007). These methods allowed the study to target specific people of interest while also identifying other individuals referred by each participant from their network to expand our sample size.

Participants were considered eligible if they were respiratory physiotherapists with skills in thoracic ultrasound with at least one form of training on thoracic ultrasound, certified by national or international credited regulators, such as professional associations and international organizations; and had experience in using the US in research or clinical practice demonstrated by 50 or more POCUS image acquisitions (Pietersen et al., 2023). These criteria were verified after the questionnaire, to ensure that the respiratory physiotherapists fitted the profile needed. Exclusion criteria were rejecting the informed consent or request to withdraw before the end of the study.

Recruitment was performed through institutions of physiotherapists (e.g., universities, associations, formations-certified centers, and research centers). The dissemination of the study was done by the institutional email, including a link to the informed consent and a brief sociodemographic questionnaire. Those interested in participating provided their informed consent online, filled out the sociodemographic questionnaire and were then contacted by the researcher, by email, to schedule an interview.

The recommended sample size found for a Delphi interview was 10 participants (Ogbeifun & Agwa-Ejon, 2016; Paliwoda, 1983; Santaguida et al., 2018).

2.3. Data collection

Data collection was carried out online. The brief questionnaire included sociodemographic (age, sex), work region/country, the context of POCUS utilization, e.g., intensive care units (ICU), emergency room (ER), ward, clinic, etc., years of experience in physiotherapy, years of experience using POCUS for thoracic assessments, as well as the population most seen in clinical practice (elderly, pediatric, acute, chronic, etc.) to characterize the sample. This questionnaire was developed using *LymeSurvey* (software used by FormsUA, University of Aveiro). Then, an individual semi-structured interview was scheduled individually with participants. Interviews were conducted online,

by Zoom, in English or Portuguese, according to the participant's preferences. The interview was recorded with the computer system recorder and had a maximum of two hours of duration. If more time was perceived as needed, a new interview could be scheduled with the participant. The main researcher first received training from the senior researchers (supervisors) in how to conduct semi-structured interviews and pilot tested together the interview. One interview was then conducted independently and shared with the supervisors who commented and made adjustments for improvement. Only then, remaining interviews were conducted. All interviews, followed a semi-structured guide with open-ended questions about:

i. the US assessments more relevant in thoracic assessment, in different settings;
ii. the most appropriate protocols in acute and chronic conditions;
iii. the procedures for image acquisition;
iv. structures of education in thoracic ultrasound for physiotherapists and the level of experience necessary for POCUS autonomous practice and proficiency (advanced knowledge on perform and integrate thoracic US assessments in respiratory physiotherapy);
v. barriers perception, limitations, and difficulties in this form of evaluation.

This semi-structured guide was informed by the literature (Cholley, 2011; Tong et al., 2007; Turner, 2010) and experience of the senior researchers.

Interviews were then transcribed verbatim by one researcher into a Word (Microsoft) file. In the transcription, participants' names were changed to pseudonyms to ensure data protection. Some notes were taken during and after interviews (e.g., non-verbal expressions), to complete data collection and enhance analysis.

Sociodemographic data and transcriptions were saved in the ARCA server (University of Aveiro), with access restricted only to the researchers. Audio files of the interviews were also kept on the server but destroyed when transcribed.

2.4. Data analysis

Descriptive statistics were used to analyze sample characteristics using the Statistical Package for the Social Sciences of International Business Machines Corporation®, United States - version 29. Absolute and relative frequencies, mean and standard deviation were used according to the nature of the data (i.e., categorical, ordinal, or continuous) to characterize the sample for age, sex, working region/country, POCUS context, years of experience in respiratory physiotherapy, years of experience with thoracic POCUS assessment, and the description of the population most assessed.

Qualitative data were thematically analyzed (Braun & Clarke, 2022), allowing new perspectives and experiences to emerge. Two researchers worked in parallel to analyze the individual interviews, using a semantic approach to identify the explicit meaning of the data (Braun & Clarke, 2022). To obtain an encoding code, the description of the main topics of discussion was analyzed, given a code label and refined. After that, the researcher gathered a cluster of codes that seemed to share a core idea or concept to develop the subthemes and then the themes, to be as reliable as possible according to the transcript data, as well as diminish the interpretation bias. In case of disagreement between the two researchers, a third researcher was consulted (Hsieh & Shannon, 2005; Turner, 2010). The analyses were written in an Excel file and the number of pages and lines of the transcription were added to each quote, used to code data, to facilitate their later identification in case of need.

3. Results

Fifteen invitations were sent, of which one was declined due to the individual's unavailability, one was excluded for not meeting the inclusion criteria and four had not responded up to the time of this dissertation. Nine participants have accepted to take part, but only six have been included in the analyses for the purpose of this dissertation.

3.1. Characterisation of participants

Participants included physiotherapists from England, Belgium, New Zealand, Portugal, Brazil, and Canada, comprising five men and one woman aged 30 to 46 years old, with 3 to 21 years of working experience. All conduct US acquisitions on inpatients, three on outpatients, and two in the emergency room in adults, and addressing acute, chronic, and exacerbations of chronic conditions. Two participants also worked with pediatrics. Four participants had completed a short course (with one to two days duration) (one exclusively for physiotherapists, three for health professionals), while the others learnt thoracic US during their educational path: one participant acquired US skills through mentoring (with a pulmonologist) during his PhD, and another during the undergraduate physiotherapy program. Five participants were clinical supervisors who provided training in this area to other physiotherapists. Further details of the sample characterization can be found in Table 1.

Table 1. Characterization of respiratory physiotherapists with experience in ultrasonography who participated in the interviews (n=6).

ID	Age	Sex	Country	Setting	Years as a PT	Years working in RP	Years using US	Patient population	Number of acquisitions	US training	Criteria to do the short course
1	30	M	Belgium	Inpatient, research	3	3	2	Adults, acute patients	>50	short course and mentoring during PhD	PT
2	46	M	England	Inpatient, outpatient, ER	17	15	10	Adults, pediatrics, acute patients, chronic patients, elderly, chronic exacerbation	>50	short course	Health professionals
3	44	M	New Zealand	Inpatient	21	17	5	Adults, acute patients	>50	short course and mentoring	PT
4	40	M	Portugal	Inpatient, outpatient, community, domiciliary, research	18	18	5	Adults, acute patients, chronic patients, elderly, chronic exacerbation	>50	lifelong course	Health professionals and PT
5	45	M	Brazil	Inpatient, outpatient, ER, community, domiciliary, research	20	18	8	Adults, pediatrics, acute patients, chronic patients, elderly, chronic exacerbation	>50	Under-graduate	-
6	40	F	Canada	Inpatient	16	16	5	Adults, acute patients, elderly, chronic exacerbation	>50	short course and master's degree	Health professionals and PT

Note: ER – emergency room; F – female; ID – participant number; M – male; PT – physiotherapist; RP – respiratory physiotherapy; US – ultrasound.

Interviews lasted an average of 81 minutes with a standard deviation of ±18 minutes. Four main themes with nine subthemes were identified:

- Decision-making: indications and proficiency;
- Acquisition: protocols and technical procedures used;
- Barriers and facilitators: barriers/difficulties and facilitators to US use;
- Development process: current education structures, future needs for education and research purposes.

3.2. **Decision making in respiratory physiotherapy**

Most participants emphasized the utility and contribution of US in their practice as it enabled them to have a better understanding of patient dysfunction and deviations from normal patterns, provided more effective measurements for treatment, and served as a rapid and accessible tool for determining the suitability and indication of physiotherapy interventions.

3.2.1. Indications

This emergent topic was widely discussed by all participants while explaining how they performed US assessments. Indications included: whenever there was a hypothesis of diaphragm paralysis, discovering the reason for a patient's high work of breathing, assessing a weak diaphragm, performing a physiotherapy diagnosis or guiding its treatment, using it as an outcome measure for intervention, evaluating lung aeration during hospitalization, rapidly assessing critical situations (e.g. in ICU), and for education and research purposes.

"I think it's ultrasound, thoracic ultrasound, including diaphragm, it's becoming a really valuable instrument for intensive care physiotherapists, but also, I think for respiratory physiotherapists, in general." [Participant 1, researcher, Belgium]

"(...) for me, as a physiotherapist, rather than using six points for diagnosis, I want to use 12 points with the lung ultrasound score to be able to use it as an outcome measure for intervention." [Participant 2, researcher, England]

Additionally, all participants highlighted that US should not be used independently in the clinical decision-making process but rather integrated with the information obtained from other useful outcome measures in respiratory physiotherapy, such as lung auscultation and complementary imaging studies.

"(...) to try to clarify the etiology of the dysfunction or ventilation compromise the patient has, the oxygenation the patient has, I end up interpreting various complementary means, not only the use of ultrasound, but also lung auscultation and identification of images, such as chest X-rays or when a thoracic CT scan is available (...)" [Participant 4, physiotherapist in ICU, Portugal]

3.2.2. Proficiency

Participants discussed various aspects related to proficiency in using thoracic US. These included the number of acquisitions needed, the level of training required, and the importance of mentoring. Opinions varied on the optimal number of acquisitions, with two participants suggesting over 50 acquisitions, while other advocated for 100 assessments. However, the majority agreed on the importance of initiating the learning process through accredited training endorsed by the country's association, followed by mentoring, with one participant referring to a mentoring period of 3-7 months.

Standardizing measurements was highlighted as crucial for reproducibility and consistency in assessments, particularly in diaphragm evaluations. This involved identifying structures accurately and selecting the appropriate probe for each assessment. It was considered crucial to extrapolate relevant information to improve patient treatment and distinguish between physiotherapy-related issues and those needing other professional attention, such as pleural edema. Additionally, almost all participants perceived practice to be the key ingredient to better perform thoracic US, advocating for daily practice until they reached a minimum of 30 acquisitions.

"The interpretation of what these images mean, then extrapolating them to what am I going to do for the patient. I think they're probably the key thing. People can have a reliable way of getting reproducible loops, reproducible views. They can work out what they see both in terms of accurately naming things in such a way that I can say to a consultant, to an ICU doctor and they know what I mean, but also then that I know what to do about that." [Participant 3, ICU physiotherapist, New Zealand]

"Between 25 to 30 sessions, I started to feel more confident (...), I started to stop asking for opinions, the image was already coming easier (...), in the 50 to 60 exams we can do diaphragmatic and thoracic assessments" [Participant 5, professor, Brazil]

3.3. **Acquisition**

Participants reported using protocols or specific parts of protocols and assessments in the context of US evaluations in respiratory physiotherapy. Some US protocols were perceived as better suited for specific contexts, such as acute inpatients; while others seemed more versatile and applicable across settings. The use of several technical procedures was also reported according to the anatomic structures being assessed; therefore, this theme was divided in two subthemes.

3.3.1. Protocols

A total of seven protocols were mentioned, namely the BLUE-protocol, the Lung Ultrasound Score (LUS), the Pink protocol, the Focused Assessment with Sonography in Trauma (FAST), the

Sequencial Echographic Scanning Assessing Mechanism or Origin of Severe Shock of Indistinct Cause (SESAME) protocol, the Cardiopulmonary Limited Ultrasound Examination (CLUE) protocol and the global ultrasound check for the critical ill (GUCCI) protocol. Additionally, participants referred two modifications of the LUS.

All participants reported regularly using the BLUE-protocol with 6-point assessment and the LUS with a 12 or 14-point evaluation, for a better understanding of lung aeration and treatment feedback. There was consensus regarding the utilization of a 0-3 score by assessed region, however, the number of landmarks were not consistent. Physiotherapists reported conducting assessments in various positions, determined by the assessment purpose (initial evaluation, ongoing evaluation, treatment feedback) or the patient's position (e.g. prone).

Other POCUS assessments were also highlighted as important such as diaphragm excursion, thickness and thickening fraction, respiratory muscles (both inspiratory and expiratory), upper airways and appendicular muscles. In the diaphragm excursion, diaphragm thickening fraction and thickness, the assessment primarily occurred on the right side, unless there was evidence of unilateral paralysis.

"It's the BLUE-protocol. There are also some protocols that are derived from the BLUE protocol, like the FAST or SESAME-protocol (...). The BLUE-protocol is a fundamental and central protocol for everyone performing thoracic ultrasound or point-of-care ultrasound (POCUS) at this level. (...) The emerging of the Lung Ultrasound Score and its use to monitor the progression of respiratory conditions, including those with infection, which can be assessed with an ultrasound machine. (...) I regularly use the 14-point assessment proposed (...) in 2020 in the Journal of Ultrasound in Medicine, (...)." [Participant 4, physiotherapist in ICU, Portugal]

3.3.2. Technical procedures

Participants reported using specific technical procedures to assess the diaphragm, the pleura and parenchyma. Other structures, such as respiratory muscles (intercostal, sternocleidomastoid, and abdominal), appendicular muscles like quadriceps or brachial and the upper airways were also reported.

The technical procedures for US use encompassed the selection of probe types and modes for various assessments, patient position, depth, gain, frequency, hardware used, and standardized measurements. The technical procedures presented next will be divided by the assessment of the anatomical structure and function.

Diaphragm thickness and thickening fraction

Participants mentioned the use of the linear probe. They also expressed that there was no consensus on whether to use a perpendicular or transverse probe position.

"Linear probe on the side for the thickness and thickening fraction evaluation" [Participant 1, researcher, Belgium]

" If it's to assess thickening, I choose the superficial probe" [Participant 6, physiotherapist in a ward, Canada]

The modes used in diaphragm assessments were inconsistent with some reporting the use of B-mode and others the M-mode for thickness and thickening fraction.

"So, in B mode to evaluate the thickness, and in M mode to evaluate thickening fraction." [Participant 1, researcher, Belgium]

"And I usually do an assessment in M mode, although there's not as much consensus on that either." [Participant 4, ICU physiotherapist, Portugal]

All participants performing diaphragm acquisitions preferred the patient in semi-Fowler position.

"(...) in the supine position, with the head elevated (...)" [Participant 6, ward physiotherapist, Canada]

In diaphragm assessments the depth described was 2.5cm to 4cm, varying by the fat mass of the patient, or a very low depth without specifying values.

"(...) we keep the depth for measuring the thickness as small as possible, so that we have the diaphragm really good in the image and we are not disturbed by lung, liver and what's happening apart from the diaphragm, and on average I think it's 2.5 to 4cm in depth (...)" [Participant 1, researcher, Belgium]

"In a diaphragmatic assessment of thickness or thickening fraction, I use a very, very superficial, very superficial assessment. Because I'm very interested in the ability to see with very good resolution and identify with very good resolution what we're assessing (...)" [Participant 4, ICU physiotherapist, Portugal]

The reported frequency used in the linear probe in the diaphragm thickness and thickening fraction was 6-12MHz or described as high frequency.

"(...) six to twelve or seven to twelve MHz for the linear one" [Participant 1, researcher, Belgium]

For standardized measurements, participants described performing three times and taking the average. It was also mentioned that diaphragm assessments should be performed on the right side except when there was suspicion or clear knowledge of unilateral dysfunction.

"I want to have at least 3 respiratory cycles in my image so that I can interpret it and take measurements. Normally it's around ten millimeters per second, but I'm interested in having three cycles. I'd prefer to have more cycles, but what's described will be 3 cycles in M-mode" [Participant 4, physiotherapist in ICU, Portugal]

Diaphragm excursion or diaphragm displacement

Participants described using a curvilinear/abdominal probe but phased array and linear probes were also mentioned. It was mentioned that during diaphragm displacement, an inferior difference of 0.5 cm or superior to 1.6 cm was considered abnormal and would lead to bilateral evaluation.

The depth in diaphragm displacement was described between 13-16 cm, but subjectivity regarding the image acquisition was acknowledged.

The frequency depended on the probe used, with lower frequencies of 2-5 or 3-5 MHz being mentioned for the curvilinear probe to visualize the image with greater depth.

"(...) two to five or three to five MHz for the curvilinear probe" [Participant 1, researcher, Belgium]

Respiratory muscles

Assessments of the intercostals, sternocleidomastoid, and abdominals (transverse and oblique) were described. The linear probe was identified as the preferred probe. No other specific procedures were provided, however, lack sufficient protocols or guidance for these assessments were mentioned.

Pleura and parenchyma

Almost all physiotherapists mentioned the use of the linear and curvilinear/abdominal (to achieve a wide range of images and depth) probe. In these assessments, individual preferences regarding the modes were clear. Participants referred using B-mode mostly and used M-mode to observe seashore sign and stratosphere barcode sign, explore the pleura and presence of pneumothorax. The use of colors mode was also mentioned to observe pleural sliding and investigate changes in flow in case of atelectasis or pneumothorax.

Various positions were described for patient position in these assessments, including supine, prone, sitting, upright and side-lying.

"With regards to position (...), other than them being perhaps critically unwell or if they're on the ward, they can't sit up or get out of bed, I would do the scan in the bed. But if I had the choice as a physiotherapist, if I was to do a scan, I'd probably get them out of bed, get them up, get them sat in a chair, and then scan in the chair. In my general intensive care, I would do a lot of scanning in the bed. But on a surgical intensive care, or cardiothoracic intensive care, I would like to scan them in the chair, get them up." [Participant 2, researcher, England]

The depth was described as low depth in the upper regions, increasing as it descended towards the base. The depth values varied from 3 cm to 8-10 cm or 9-12 cm, reaching 14-16 cm or more, depending on the amount of fat mass in the patient or if the patient's spine was visible in the image.

"Quite often maybe 8-10 centimeters, 10-12, 14-16, or even more if the patient is very big." [Participant 2, researcher, England]

"So apically, I'll try and get maybe one or two A lines. If I see A lines, I probably don't need more than one or two A lines. I'll generally change my depth to get that, then when I go down to the basis, I'll push the depth out to maybe 20 centimeters, depending again on the size of the patient. Then adjusted depending on where the spine is in the picture. If the spine is right up here, I've gone too deep, and if I can't see the spine, I probably need to adjust it because I want to see as much diaphragm as I can, but I don't want the whole diaphragm to be in the top centimeters of the picture" [Participant 3, ICU physiotherapist, New Zealand]

The gain was described by all participants as a subjective setting, dependent on the image quality during the acquisitions.

Participants mentioned using the Philips Lumify with an app called Lumify, or the General Electric venue Go.

3.4. **Barriers and facilitators**

The barriers and difficulties described by participants included difficulties performing assessments on specific clinic conditions, such as obesity; technical barriers like not having access on US material or the material not working properly and professional barriers. Among the facilitators, affordable equipment, easy access, a supportive team, well-established training programs, workplace support for professional development, and comparative support in exams were highlighted. Barriers and facilitators were further detailed below.

3.4.1. Barriers and difficulties

Difficulties performing assessments on specific clinic conditions were attributed to patients' amount of fat mass (which could restrain the diaphragm, pleura and parenchyma assessments), the presence of drains, the pos-operative patches, the presence of lung fibrosis or pleural effusion on assessment thickness and thickening fraction and the existence of abdominal constipation and restraint measures on trauma patient (e.g. spine fractures).

Technical barriers included unavailability of US machines for physiotherapists, length of the procedures taking 10 to 15 minutes, and becoming overwhelmed during high workload periods. Other difficulties included the lack of experience as a physiotherapist and the absence of colleagues in similar learning or developing stages for conducting thoracic assessments with ultrasonography. Additionally, challenges arose from the lack of education on thoracic US within one's country, geographical constraints preventing attendance at in-person training, limited resources, unavailability of mentors within one's region, and a scarcity of experienced physiotherapist proficient in ultrasonography.

Professional barriers were related with US being considered exclusively a medical tool in some contexts (e.g. hospital), and this perception could be reinforced by the hospital administration, medical staff, supervisors, or other colleagues.

Inconsistency in the terminology used was also observed in Portuguese, with some individuals using "*ecografia*" and others "*ultrassonografia*". However, all Portuguese-speaking participants unanimously agreed on the direct translation of ultrasonography to "*ultrassonografia"*.

"…limits the assessment of excursion, thickness and thickening fraction is the obesity, the BMI is a big limiting factor (…)" [Participant 1, researcher, Belgium]

"And for me, for my research, the biggest barrier that I identified was our own physiotherapy management would be very worried about what you were doing. They would be more worried than the doctors, it was more physiotherapy management, being scared" [Participant 2, researcher, England]

3.4.2. Facilitators

Facilitators for using thoracic US included affordable equipment, a supportive and multidisciplinary team and mentorship as well as experienced individuals who made the learning and growing process easier and more confident. Easy access to an US machine (common in hospital settings) and well-established training programs in some countries (e.g., England) were also mentioned. It was referred that the process was further facilitated when complementary imaging studies and the US acquisition comparisons mutually supported each other. A supportive workplace of professional development was also reported as essential for acquiring new skills and enhancing treatment quality.

"What facilitated is my very supportive management, they really helped me, to get the funding and get permissions and to sort out a lot of problems within the hospital to allow me to do it." [Participant 2, researcher, England]

"We have time to dedicate to the development of practical skills in this institute." [Participant 6, ward physiotherapist, Canada]

3.5. **Development process**

This theme encompassed current education structures and future needs for education and research purposes.

3.5.1. Current Education Structures

The predominant current education structures to acquire US skills involved short courses lasting one to two days, combining theoretical components, and practice with healthy subjects. In some countries such as in the United Kingdom or Canada, final exams with a logbook of 20 to 30

acquisitions, along with evaluations (e.g., comprehensive assessments or checklist passes), were reported as required. In countries like Canada or New Zealand, mentoring was common, but challenges arose due to the unavailability of mentors or professionals with expertise nearby. It was also reported that in Brazil, mentoring lack standardization and could be conducted online or in person, depending on the proximity of the experienced physiotherapists.

"(...) when we ask people to take training courses, they do often short courses, which basically involve just using theoretical knowledge and practice with colleagues, however, people usually do not feel competent afterwards, to carry out clinical practice or for using their images, they do not feel safe to make decisions." [Participant 4, physiotherapist in ICU, Portugal]

3.5.2. Future needs for educational purposes

All participants mentioned the need for training programs to incorporate structured basic components, such as fundamentals physics of US, the typical image in a healthy individual, and artifacts. Concerning the mode of delivery of training programs, it was suggested that the introduction could be online, covering theoretical components, followed by face-to-face practical sessions. Recommendations for the duration of the theoretical segment ranged from 8 to 10 hours or according to the time required for online delivery. It was also suggested to introduce US education in the undergraduate curriculum. The need for different levels of education as physiotherapists gained experience, with varying courses accessible based on experience levels was emphasized. There was a unanimous agreement that a logbook following the formal education or access to a mentor it was essential for ensuring better quality assessment results. Certification regulated by national entities, like in the UK or Canada was suggested to be reproduced in other countries.

"a theoretical part that must include: anatomy; how ultrasound works; what devices are available; which probes, the rational while you're using one or the other probe; protocol of assessments for different structure: could be lung, respiratory muscles; where to place the markers; how to standardize a measurement or as much as standardized. I would put something coming from the literature, for example, why you pick the performance or those assessments one from another; the improvements in secretion clearance, what's the performance when we perform diaphragm ultrasound and then predicting weaning." [Participant 1, researcher, Belgium]

3.5.3. Future needs for research purposes

Development of physiotherapy (specifically respiratory physiotherapy) protocols for thoracic assessments was suggested.

The non-consensus on the use of probe for each assessment, modes and manipulation during assessments (e.g. perpendicular or transverse) was reinforced.

All participants advocated for a structured training, and based their responses on personal experiences, lacking literature or guidelines on the subject.

"... in my vision of the future, all respiratory physiotherapists that consistently work in respiratory, I think will and should learn lung ultrasound as part of their assessment techniques and as an outcome measure for their interventions" [Participant 2, researcher, England]

"Do we need to have a physio-lung-ultrasound protocol? Rather than following the BLUE Protocol or other protocol, whether we have a physio one that's got specific constraints around what we're trying to identify, for what we're trying to achieve" [Participant 3, ICU physiotherapist, New Zealand]

A thematic map summarizing our findings is presented in Figure 1.

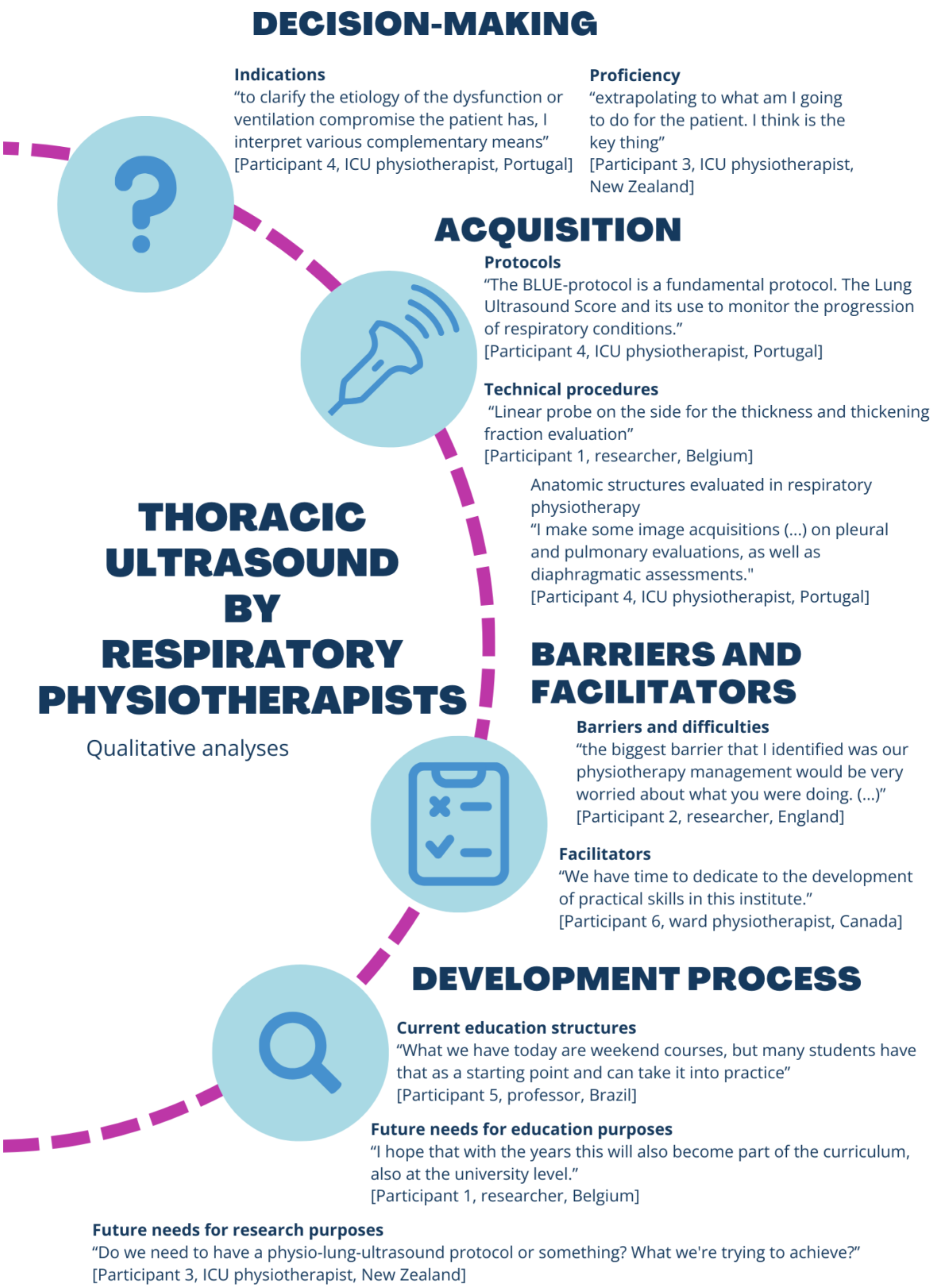

Figure 1 - Thematic map obtained from the interviews (n=6) conducted to contribute to establish the consensus on the use of thoracic ultrasound by respiratory physiotherapists. ICU - intensive care unit.

4. Discussion

This study aimed to gather the perspectives of respiratory physiotherapists experienced in thoracic US to contribute to establish an expert consensus on the procedures and interpretation of POCUS for thoracic assessments and monitoring within this professional group. Four themes emerged related with the impact on the respiratory physiotherapy process decision-making; the image acquisition; barriers and facilitators to US use; and development processes. Experiences of physiotherapists varied across the six different countries, nevertheless, convergence regarding the future needs and applicability of POCUS for respiratory physiotherapists was observed.

Similarly to previous studies (Hansell et al., 2021; Hansell et al., 2022; S. Hayward et al., 2020; Le Neindre et al., 2021) the BLUE-protocol and the LUS are the main protocols used in POCUS. While valuable for thoracic assessments, these protocols lack specific characteristics for physiotherapy evaluation. Therefore, protocols designed by physiotherapists can improve intra-professional communication, and enable benchmarking for quality assurance in respiratory physiotherapy (Truong et al., 2023).

Participants acknowledged the importance of taking advantage of the US assessment by not only evaluating the conventional thoracic structures, such as the diaphragm, pleura, and parenchyma, but also the accessory respiratory muscles, appendicular muscles, and upper airways, improving patient care with the enhance diagnostic capabilities of the physiotherapists (Andersen et al., 2021; Brekka et al., 2022; Pałac et al., 2022 Hayward & Janssen, 2018). Despite increasing use of thoracic US in respiratory physiotherapy, lack of standardization in protocols and assessments on thoracic acquisitions persists. Addressing rationale behind these choices, along with potential standardization, and demonstrating clear evidence improvements in decision-making and/or treatment outcomes for patients is needed (Hayward et al., 2022; Pałac et al., 2022). This could lead to optimizing thoracic US use in respiratory physiotherapy, as suggested in the literature (Hayward et al., 2020, 2022; Truong et al., 2023). It was also observed that responses regarding respiratory muscles were limited, with the diaphragm as the exception. This could be attributable to the insufficient robustness in existing literature, therefore, further research in these assessments should be considered, to better understand the benefits and the impact on patient care (Truong et al., 2023).

Shared perspectives on the various US training programs for respiratory physiotherapists, emphasized the importance of theoretical components, practical sessions, and hands-on experiences. Current guidance for training intensive care medical professionals had served as a starting point (Cholley et al., 2011), but specific educational guidance for physiotherapists considering the profession's distinct characteristics is necessary (Hansell et al., 2022). While, most training programs were characterized as introductory, featuring short courses, with hands-on healthy subjects, determining the best model to implement this training remains unclear. Probably a range from an

initiation level for beginners, progressing to an optimization level for intermediate practitioners, and an advanced level for those seeking further proficiency, will be needed (Hayward et al., 2022; Smith et al., 2022). Tailoring educational programs to the varying experience levels can enhance the effectiveness of training (Hayward et al., 2022). In addition, the role of mentors has the possibility not only to provide practical guidance, but also to foster a supportive learning environment (Smith et al., 2022). Mentoring should be an integral part of the US education process, has participants repletely have mentioned. The necessity for structured mentoring programs that offers continuous support remain a reality and should be considered in the future (Hansell et al., 2022; Hayward et al., 2020, 2022). Thoracic US showed to be an emergent field and further clinical and research developments are needed (Myszkowski, 2019; Truong et al., 2023).

Standardizing the use of Portuguese terminology is imperative, as it poses risks to patients and professionals, potentially resulting in intraprofessional (as well as interprofessional) miscommunication. This issue has been observed in other specialized areas of respiratory physiotherapists, such as lung auscultation, where efforts to standardize nomenclature have been conducted to improve diagnoses and facilitate communication between professionals and patients (Pasterkamp et al., 2016).

4.1. Strengths

This study conducted interviews with physiotherapists from various countries to explore their utilization of thoracic US in respiratory physiotherapy. Participants had diverse backgrounds, experiences, and educational paths. The interviews revealed valuable insights into the acquisition of thoracic ultrasound skills, decision-making processes, barriers and facilitators faced by physiotherapists, and their perspectives on the development of education in this field.

4.2. Limitations

Study limitations included a small sample size, although data is still being collected. At the time of this dissertation conclusion, some participants had not yet responded. Therefore, the interviews will be conducted until the predetermined sample size is reached.

5. Conclusions

The findings of the study shed light on current practices, challenges, and opportunities associated with integrating thoracic ultrasound in respiratory physiotherapy evaluations. Within the theme of acquisitions, the results exhibit consistency with certain procedures while highlighting

inconsistencies with others. The identified barriers and facilitators provided useful insights for developing strategies to enhance the effective utilization of ultrasound in clinical settings. The study also emphasized the importance of continuous education and standardized training programs to ensure that respiratory physiotherapists are proficient in using ultrasound. Further research is required to establish guidelines and protocols specific to the physiotherapy applications of thoracic US, as well as to determine the appropriate structure and level of training required for this area of physiotherapy in the future. Overall, the study contributed to the growing body of knowledge of POCUS utilization within the field of respiratory physiotherapy. The next phases of the study will focus on developing consensus on protocols, procedures, training structures and guidance for future research for thoracic assessments.

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