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ORIGINAL CLINICAL ARTICLE

Is it time to rethink using digital palpation for assessment of muscle stiffness?

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Abstract

Aim: Physiotherapists typically use digital palpation to determine residual tension in a muscle, referred to as muscle stiffness or tone. These assessments are subjective, and little is known about their accuracy or repeatability. Despite this, it is standard practice to base clinical treatment on these findings. The aim of this study was to assess physiotherapists' ability to assign a seven-point palpation scale to quantitative stiffness values generated by a novel device.

Methods: Prospective observational study involving 125 musculoskeletal and pelvic floor physiotherapists. A novel device was developed that replicates the haptic feedback that clinicians assess as muscle stiffness. Measurements of displacement, force, and stiffness were recorded.

Results: There was wide overlap between each scale category assigned to the stiffness values, from low stiffness at −3 (119 [106, 132] N/m) to moderate stiffness at 0 (462 [435,489] N/m); to high stiffness at +3 (897 [881,913] N/m). Consistency in applying the scale was poor, and the probability of a similar value of stiffness being assigned to the same scale category by different participants was low.

Conclusions: While palpation is used globally by physiotherapists as a readily available and low-cost method of assessing muscle stiffness, these results indicate that it should be used with caution in diagnosing and defining patient care. Clinical assessment of muscle stiffness requires a validated and reliable palpation scale if this metric is to be used to diagnose pathology and develop treatment protocols. Training in this scale should then be recommended to improve reliability in patient assessment.

KEYWORDS
assessment, digital palpation, muscle stiffness, scale, tone

1 | INTRODUCTION

Digital palpation is used globally by physiotherapists to assess muscle strength and stiffness, with subsequent clinical management of the patient based on these subjective assessments.[1,2] Muscle strength is typically defined as the voluntary active contractile force of the muscle, while muscle stiffness is typically defined as a measure of the extent to which the muscle resists deformation in response to an applied force.[3] This resistance to deformation is often alternatively described as tightness, tension, or tone.[4] Methods for subjective muscle strength assessment have been the subject of multiple studies to validate and assess their reliability.[5-7] However, methods for assessing muscle stiffness have not received as much attention. While recommendations have been made to assess muscle stiffness as part of a functional assessment of the skeletal system, there is little information on how this might be accurately achieved.[8] There are no validated quantitative palpation scales for either the pelvic floor, or other skeletal muscles with assessment of stiffness relying solely on the opinion and skill levels of the clinicians.[2,9-12] Various scales for assessing stiffness have been proposed for the pelvic floor muscles.[13,14] However, all have issues with ambiguous scale descriptions, and poor reliability and validity, and thus are not widely used.[15,16] For areas outside of the pelvic floor, the Modified Ashworth Scale (a six-point scale for assessing the resistance of the limb during passive soft-tissue stretching of muscles over joints) is used, typically to assess spasticity of the extremities in patients affected by neurological conditions.[17]

The primary aim of this study was to assess physiotherapists' ability to assign to a seven-point palpation scale the stiffness values presented by a novel "Palpation Instrument." The secondary aims were to see how consistently the scale was used, the probabilities of each category of the scale being applied to similar stiffness values, and if duration of clinical experience or area of clinical focus influenced the use of the scale.

2 | METHODS

This was a prospective observational study. Qualified physiotherapists who palpated for a minimum of 30 minutes per week were invited to participate in the study. Participants were excluded if they did not have a conversational level of English. Their gender, years of clinical experience, and area of clinical focus (whether they identified themselves as a "musculoskeletal physiotherapist" or a "pelvic floor physiotherapist") were collected.

A novel device, the "Palpation Instrument," was developed at the Auckland Bioengineering Institute (Figure 1) for use in this study. The instrument controllably replicates the muscle stiffness that clinicians might be presented with during digital palpation of the small muscles of the body, such as the pelvic floor, hand, or spinal muscles. The instrument comprises a feedback-controlled voice coil motor supported by a low-friction linear bearing and attached to a metal plunger. A silicone foam pad (2-mm thickness) is fixed to the plunger end. The voice coil position is feedback-controlled by an adjustable analog control system, while motor force is inferred from motor current. In this way, the stiffness presented by the instrument can be varied. Calibration of the instrument's force recordings was achieved by use of a force meter (Vernier, WDSS), and displacement measures were confirmed with a digital micrometer (Mitutoyo). Using a rotary dial control, the spring constant (stiffness) can be continuously varied between 1 and 1050 N/m, enabling the participant to feel a range of stiffness values while palpating the plunger end. Values of force (N), displacement (mm), and stiffness (N/m), calculated using the force and displacement measures, can be manually read off the display panels.

During pilot trials with volunteer clinicians, the electromechanical instrument was adjusted to match the range of stiffness values the volunteers agreed they typically experienced during clinical assessment. The range available on the instrument was expanded slightly beyond the volunteers' recommendations, to ensure that the instrument's range was not a limitation in the study.

A seven-point qualitative palpation scale for stiffness was created by modifying descriptors of a scale published by Reissing et al[15] This scale was chosen as it offered seven categories of scale (the commonly used Modified Oxford Scale for muscle strength offers six categories). The scale descriptors were modified by adding specific force and displacement wording to ensure that participants understood the stiffness measurement boundaries at each category of the scale. The scale ranged from +3 ("very firm resistance and minimal movement of the muscle to palpation") down to −3 ("no resistance and muscle not palpable"), with 0 being "normal". Assessments were performed while participants were seated with the instrument positioned on a flat surface. Participants were instructed to palpate the instrument as they would a small muscle in the body using their normal palpation technique.

The study was conducted in two stages, with a different method for data collection used for each stage. In stage one, participants were given a number on the scale between −3 and +3 and requested the author to increase or decrease the

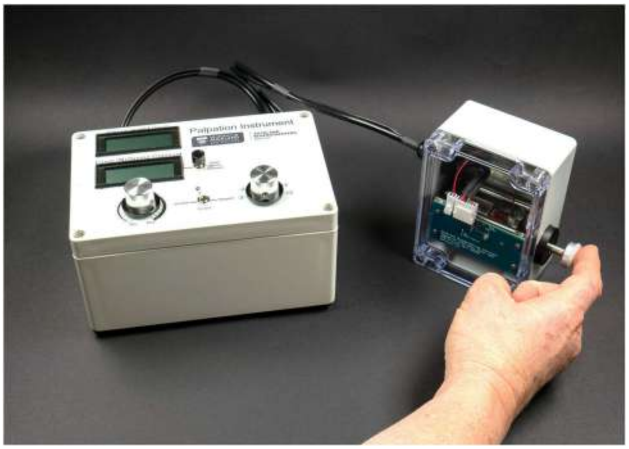

FIGURE 1 Palpation Instrument

stiffness provided by the instrument until the participant determined that the perceived stiffness matched the scale category that they were identifying (stiffness allocation to palpation scale). In stage two, the instrument stiffness was set (to a randomly selected value between 1 and 1050 N/m) and the participant was asked to identify the category of the seven-point scale to which the stiffness ought to be assigned (scale category assigned to stiffness value). In both stages of the study, participants completed three randomized trials of seven measures resulting in 21 measures per person. Measurements of displacement, force, and stiffness were recorded with each estimate, with participants blinded to the device controls and all measurement values.

Mean ± 95% confidence interval are presented for each stage of the study. Due to the different data collection methods of the two stages (reverse response variables requested in each stage), direct statistical comparison between the results of the two methods was not possible. As stage two (scale category assigned to stiffness values) replicated clinicians' usual practice, further analysis was conducted on these data. The participants' ability to consistently apply a stiffness value to a scale category was analyzed using a coefficient of variation for each scale category. The probability of assigning a stiffness value to each of the scale categories was analyzed by determining the cumulative frequency distribution of the stiffness values.

3 | RESULTS

A total of 125 participants, predominantly female (83%), took part in the study over a period of 9 months. Forty-three participants took part in both stages. Duration of clinical experience for participants ranged from 3 months to 56 years. The demographics of the participants are presented in Table 1. Participants reported receiving their physiotherapy undergraduate training from 11 different countries. Each stage of the study had 1764 data points for stiffness, force, and displacement recorded.

Participant palpation technique varied according to their preferred method of palpation for small muscles. All pelvic floor physiotherapists used the pad of their index finger of their dominant hand for palpation, while musculoskeletal physiotherapists' palpation techniques included using the pad of the index finger, the pads of index and middle fingers together, or both thumbs.

While direct statistical comparison between stage one and stage two results was not possible, similar values of stiffness for each category of the scale were reported from −3 to +3 in both stages (see Figure 2 for stage two results).

None of the participants were consistently able to categorise a stiffness value to a scale category when using the whole scale (ie, within a 10% margin of the stiffness values presented). Most participants (72%) were able to consistently use the scale within a 11% to 30% margin of the stiffness values presented. However, 28% of participants were over the 31% margin of the stiffness values, indicating poor consistently in use of the whole scale. When individual scale categories were analyzed, the individual participants' ability to consistently assign a stiffness to the single categories ranged from 1% to 92%, indicating large variations in the ability to apply the scale, with category −3 being most difficult. There was no apparent pattern for years of experience, nor type of physiotherapist.

The probabilities of the mean stiffness values for each scale category being assigned to that category (mean values as determined by participants in stage two) are presented in Table 2 and Figure 3. Only scale −3 had a probability over 50% of the same stiffness value being assigned to the same category on the scale.

Participants' application of force while estimating stiffness increased approximately linearly from category

TABLE 1 Demographics of participants

		Stage of study			
		Stage one: stiffness allocation to palpation scale (n = 84)		Stage two: scale category assigned to stiffness value (n = 84)	
		Pelvic floor (n = 42)	Musculoskeletal (n = 42)	Pelvic floor (n = 42)	Musculoskeletal (n = 42)
Years of clinical experience	0 to 10 y	8	21	6	13
	11 to 20 y	11	9	14	9
	21 to 30 y	11	7	12	11
	31 to 40 y	7	2	8	6
	41 to 50+ y	5	3	2	3

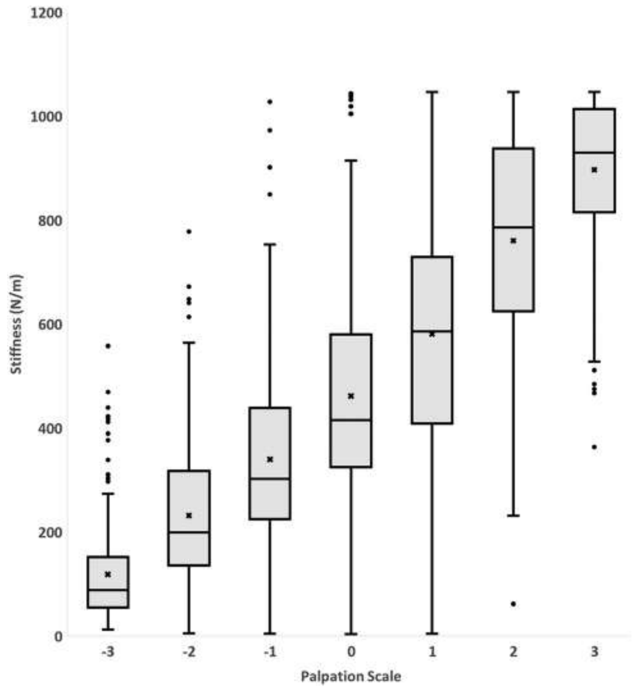

FIGURE 2 Scale category assigned to range of stiffness values (stage two)

−3 to category +3 (0.6 N ± 0.7 N at −3; to 3.4 N ± 1.8 N at +3). During measurement of stiffness, the plunger was moved between 4 and 6 mm on average, with increased movement of the plunger at lower ends of the scale compared to the higher end (6.3 mm ± 1.7 mm at −3 to 3.8 mm ± 1.7 mm at 3). From −3 to +3 on the palpation scale, there was an overall seven-fold increase in mean stiffness, a four-fold increase in force, and a two-fold decrease in displacement.

4 | DISCUSSION

To the authors' knowledge, this is the first study that has attempted to quantify physiotherapists' ability to assign stiffness values to a digital palpation scale for stiffness.

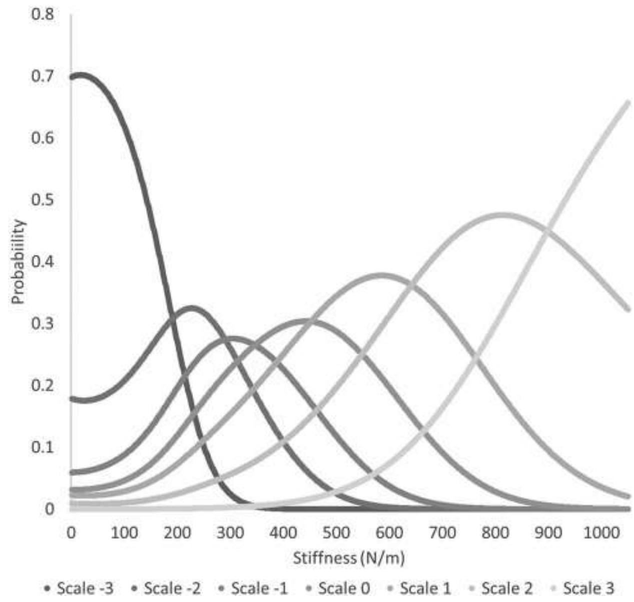

FIGURE 3 Probability of assigning stiffness values to each palpation scale category

Stiffness values associated with the palpation scale have a large variability between and within participants. For example, if the stiffness value was set at 462 N/m (mean of scale category 0: representing a "normal" muscle stiffness), participants assigned the stiffness value to anywhere between category −2 to +3 on the scale. Previous studies looking at repeatability of palpation scales in vivo have shown poor to moderate agreements, indicating the subjective nature of palpation.[16,18]

The force applied at each category varied widely with some participants applying very little force (0.1 N), compared with others applying a large force (8.5 N) within the same category. Displacement of the probe reflected a similar pattern, ranging from 0.7 mm to 8.6 mm. Similar variability in palpation skills was found by Anders et al[19] They developed a "Palpation Trainer" to teach clinicians how to standardize pressure application (speed and peak force application) using a three-fingered pincer grip for palpation. They found a slight

TABLE 2 Probability of the mean stiffness values (generated in stage two) being assigned to a particular scale category

Stiffness (N/m)	Scale −3 Probability %	Scale −2 Probability %	Scale −1 Probability %	Scale 0 Probability %	Scale 1 Probability %	Scale 2 Probability %	Scale 3 Probability %
119	57	23	10	5	3	1	0
232	15	32	24	16	10	3	0
340	1	20	27	26	19	7	0
462	0	5	16	30	31	16	2
581	0	0	5	22	38	29	6
761	0	0	0	5	25	46	24
897	0	0	0	1	10	45	45

improvement in the participants' repeatability of applying pressure at the same rate and speed as the training standards. However, it had only a temporary training effect (less than 48 hours) and it is unknown if this skill improvement transferred to clinical situations. Neither Anders et al nor this study relied on subjective clinical measures, or symptom changes in clinical patients, instead used objective devices to measure different aspects of participants' palpation skills. Using quantitative measurements to assess the participants ability to apply stiffness levels to the scale minimized any bias that may have been associated with clinical in vivo conditions.

Other qualitative scales using digital palpation have evaluated in vivo repeatability and construct validity in assessing muscle strength against instruments such as dynamometers and manometers.[20,21] These studies indicated poor to fair repeatability of palpation when compared with quantitative instruments. A systematic review and meta-analysis for the Modified Ashworth Scale reported inter- and intra-repeatability of the scale being fair to good.[17] However, the repeatability levels reduced when there were more assessors involved, primarily due to lack of standardized protocols and training in how to use the scale.

Participants' years of clinical experience appeared to have no influence on the ability of the participants to use the scale consistently in this study. Their level of experience ranged from new graduates to expert physiotherapy specialists; they had received undergraduate and post-graduate training from a wide variety of training institutes located in many different countries and had exposure to an extensive variety of clinical conditions. While it is a common belief that palpation skills increase with clinical practice and experience,[1,22] the results from this study and Anders et al do not support this assumption.

There appeared to be no difference between musculoskeletal and pelvic floor physiotherapists in their ability to assign a stiffness value to a scale category. While pelvic floor physiotherapists assess smaller internal muscles of the body, musculoskeletal physiotherapists tend toward palpation of larger muscles of the extremities and trunk. However, both groups undergo the same undergraduate training before branching into their chosen areas of interest, and while a "lighter" touch maybe recommended when assessing internal areas, pelvic floor physiotherapists still palpate and treat larger muscles associated with the pelvic region.

No participants had received formal training in using a scale for quantifying muscle stiffness. However, all reported "measuring" muscle stiffness, and using it to assist in defining patient treatment. During undergraduate training, physiotherapists have exposure to muscle strength scales using palpation as the assessment tool.[2,7,23] However, the authors are not aware of any undergraduate physiotherapist training using palpation scales for stiffness, even though physiotherapists are taught how to "identify and release tight" muscles using palpation as part of their core training. This lack of standardized training appears to be a glaring gap in undergraduate physiotherapy training globally.

Participants reported that the plunger end of the palpation instrument did replicate the stiffness they felt during clinical assessments, and that the wording associated with each scale category was agreeable and understandable. However, they reported difficulty with adjusting their concept of stiffness, with patient responses usually influencing how they graded the muscle stiffness clinically (eg, verbal and nonverbal communication of pain). Pelvic floor physiotherapists who predominately worked with "persistent pain" patients had difficulty identifying lower ends of the scale, even when presented with low stiffness values. This tendency has been identified previously,[24] with inter-rater repeatability higher when known pain cohorts are used in palpation studies for stiffness.[25,26] This linking of muscle stiffness and pain appears to be a common belief among physiotherapists, with some stiffness palpation scales actually measuring pain responses, not stiffness,[27] or including a possible pain response as part of their stiffness scale.[16]

Our results may have been influenced by the "newness" of using a formal scale to quantify what participants had previously measured ad hoc. As the basic skill of palpating muscle is entrenched in the physiotherapy profession, all participants regularly used palpation in their practice, and they all felt they were "quantifying" muscle stiffness clinically, this effect should have been minimal. Since the participants were representative of the physiotherapy population world-wide, the results of this study are applicable to the profession globally and have high external validity.

As this was an observational study to determine what levels of stiffness physiotherapists assign to a seven-point palpation scale, any refinement of the scale will require further research to test the inter- and intra-repeatability of its use. Approximately one-third of participants wanted to add "+" values to the seven-point scale as they believed it did not have enough category choices for them. Adding "+" to scales is a common clinical occurrence, with Dietz and Shek[16] adjusting his palpation scale after participant feedback from five-point to 21-points, although Frawley et al[28] found that adding "+" did not improve their results. In contrast to this, approximately one-third of participants wanted a simpler three- to five-point scale, similar to the International Continence Society four-point strength scale.[2]

Palpation is used globally as a low-cost and readily available method of subjectively assessing components of muscle properties, even though there are questions regarding the validity and reliability of these methods. Quantitative measurement of muscle stiffness using devices, such as the elastometer[29] or the dynamometer[30] would provide more reliable measurements of these muscle properties. However, currently these devices are limited to the research community, hence the reliance on subjective palpation measurements globally. If we are to continue to use palpation for patient assessment and management then there is a need for a reliable and validated palpation scale for stiffness to be developed against an objective reference standard. Standardized training in the use of the palpation scale could then be applied globally, promoting improved reliability and consistency in assessment of muscle stiffness and patient management.

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CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

ETHICS STATEMENT

This study has been approved by the University of Auckland Human Participants Ethics Committee on 23 November 2017 for 3 years. Reference Number 020490.

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