Lymphology 48 (2015) 175-183

THE PITTING TEST: AN INVESTIGATION OF AN UNSTANDARDIZED ASSESSMENT OF LYMPHEDEMA

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ABSTRACT

Soft tissue pitting is the occurrence of a temporary indentation on the body surface after the release of sustained thumb or finger pressure. In the management of lymphedema, presence or absence of pitting can contribute to clinical reasoning and guide healthcare management. However, the pitting test and its application has not been described consistently nor is it a standardized part of assessment. Therefore investigations are needed to assess the outcome measures of pitting identification and characterization of lymphedematous tissue. To determine valid testing parameters for a future study, we evaluated six therapists of varying lymphedema experience who assessed a range of locations on six patients with lymphedema representing the breadth of pitting assessment techniques used clinically. The consequence of an unstandardized assessment is demonstrated by the large variation in techniques observed for test duration (1.1 to 76.0 seconds), pressure (1.3 to 14.4 N/cm^2) and contact area (0.2 to 6.8 cm^2). Experienced therapists performed the pitting test with a significantly different technique from their inexperienced counterparts, involving a longer duration ($p<0.001$), higher pressure ($p<0.001$) and a larger contact area ($p<0.001$). The results of this pilot study support the need for evaluation of the underlying tissue response to sustained pressure and release, in order to inform the development of a standardized procedure.

Keywords: palpation, pitting, pitting edema, pitting test, lymphedema, assessment

There are a variety of methods used by health practitioners to assess lymphedematous tissue including quantitative and qualitative indicators. Quantitative indicators include bioimpedance and measurement of dimensions or volume (1). Qualitative indicators include visual inspection and palpation of tissue texture and pitting (1). Factors that can affect the reliability of qualitative indicators include variations in assessment method, consistency of outcomes and the skill of the therapist (2). This study aimed to investigate variation in the pitting test assessment method.

The pitting test is widely used to identify and characterize edema of lymphatic and venous origin and is frequently referenced in publications addressing the physical examination of edema (1,3-6). In spite of being extensively utilized in clinical practice, the performance (1,3-5) and interpretation (1,5-8) of the pitting test varies in both clinical and research fields. The inconsistency is evident in even the most fundamental components of the pitting test such as the amount and duration of pressure. Descriptions of amount of pressure such as "as hard as possible" (9)

or "firmly but without hurting the patient" (1) are open to reader interpretation and likely to result in technique variation. The inconsistency is perhaps more evident in duration with recommendations ranging from 5 to 60 seconds (3-5,9). The reason for such diversity in time of application is unclear, although it may relate to various stages of lymphedema, volume severity, tissue composition, or the individuals' objective for applying the test. For example, the test can be terminated once a pitting effect has been sensed when identifying the presence of edema, whereas the test time can be extended in order to characterize pitting quality. The lack of standardization of pitting assessment introduces ambiguity to the accuracy and comparability of the assessments performed (2).

The pitting test is considered to be an indicator of the presence of excess free-fluid that has accumulated in the superficial interstitial tissue space (1). The test involves application of sustained thumb or finger pressure to the skin and superficial tissues. On release of the applied pressure, an indentation of the tissue at the test site is defined as "pitting," and the absence of tissue changes is regarded as "non-pitting" (1). In the presence of pitting, the tissue qualities can be further evaluated in terms of tissue response to the applied pressure and release. Other components of lymphedema examination are combined with the pitting test to more fully characterize the edema.

Pitting occurs when there is a change in tissue composition involving increased fluid volume. In International Society of Lymphology (ISL) Stage 1 lymphedema (10), pitting may not be a prominent feature due to the edema composition allowing immediate refill of any indentation left by the test. As lymphedema progresses into ISL Stage 2, the tissue composition evolves through fibrotic and fatty changes (10) which may relate to the reduced mobility of the edema and more evident pitting. In ISL Stage 3, the absence of pitting can be associated with progression into fatty tissue change (11-12), and thus may be less responsive to conservative treatment (13). Although the pitting test does not specifically assess fatty or fibrotic changes, evaluative outcome measures for the qualities of pitting tissue (e.g., pitting indentation depth (1,5-6), speed of pitting production, and tissue rebound (6,8)) may be used to differentiate between various clinical presentations and to guide lymphedema management.

To understand the pitting test, it would be necessary to know what changes occur in the underlying tissues during the test. This understanding could then clarify the interpretation of the test and enable greater standardization in how the test is performed and interpreted. Prior to conducting a study to measure changes in the tissues underlying the pitting test, it was necessary to determine how the test is performed in clinical practice. The primary purpose of this study is therefore to investigate how therapists, with varying experience in treating lymphedema, perform the pitting test on individuals with a range of lymphedema presentations. The study design also enabled the researchers to gain some indication of differences between therapists with varying levels of experience. Variables examined include the contact area of the therapist's thumb, and the amount and duration of applied pressure.

METHODS

The study was conducted on a single day at the Queensland Lymphoedema and Breast Oncology Physiotherapy (QLBOP) practice in Brisbane, Australia.

Participants

Six individuals with unilateral lymphedema (known as the patients) were each assessed by six physiotherapists (referred to as the therapists) with a range of lymphedema experience. Patient eligibility criteria included individuals over 18 years of age with a

TABLE 1
Lymphedema Patient Participant Characteristics (n=6)

Patient number	Affected limb	Estimated Volume (ml)		Circumference differences (cm)	Bioimpedance L-Dex*
		Affected	Difference**		
1	L arm	3739	+307	-0.9 to +4.0	+18.7
2	R arm	3650	+756	-0.2 to +4.7	+22.1
3	L arm	2295	+224	+0.1 to +7.4	+43.3
4	R arm	4616	+1229	+1.6 to +7.4	+53.5
5	R leg	11651	+2034	+0.2 to +4.6	+45.1
6	L leg	13825	+2301	-0.6 to +12.8	+76.6

* Reference normal L-Dex range -10 to +10 (16)
** Absolute difference between estimated volume of the unaffected limb and the affected limb.

diagnosis of unilateral limb lymphedema (secondary to cancer treatment), with a pitting quality to the soft tissues. Recruitment was a convenience sample of patients from the QLBOP clinic who met the inclusion criteria and agreed to participate in the study. The participants were selected to be representative of a range of lymphedema presentations within the ISL Stage 2 lymphedema criteria, that is, with evident pitting edema (10). Collectively, the lymphedema-affected limbs of the patients included two lower limbs and four upper limbs (*Table 1*).

All participants gave informed written consent, and the Griffith University Human Research Ethics Committee approved the study.

Assessments

The circumferential tape measurement method developed by the Australasian Lymphology Association (14) was used to estimate limb volume. The calculations were based on a circular frustum model of a limb segment (15) with hand and foot excluded from calculation (16). Each 10cm segment was summed to estimate the total limb volume.

The Bioimpedance L-Dex® measure using the ImpediMed XCA device was recorded (*Table 1*). As fibrotic and fatty change is known to influence the L-Dex® value (17), the recorded measurements provided a general comparison of tissue impedance rather than a specific measure of lymphedema severity. The range of L-Dex® values was +18.7 to +76.6, all outside the reference normal range of -10 and +10 where values further away from 0 indicate increased extracellular free fluid volume but no indication of other tissue changes.

The six therapists were recruited using the investigators' clinical networks in a sample based on experience of treating lymphedema. Three therapists were experienced in lymphedema assessment and management, each with more than six years in specialized clinical practice, with a total of 48 years of lymphedema experience. The remaining three therapists had no lymphedema-specific training but were familiar with the presentation of edema and the pitting test. The intended sample was to also include therapists with moderate lymphedema experience; however, recruitment of this group was unsuccessful. Throughout this report the therapists are grouped as either 'experienced' or 'inexperienced.'

Assessment Protocol

The six therapists used their thumb to perform four pitting assessments on each of the six patients with lymphedema.

TABLE 2
Palpation Data Results For Independent Analyses Between Experienced And Inexperienced Therapist Groups

Limb	Distal M (SD)	Sig*	Proximal M (SD)	Sig*	Affected M (SD)	Sig*	Unaffected M (SD)	Sig*	Overall M (SD)	Sig*
Duration (s)										
Experienced	42.4 (14.7)		43.2 (16.7)		44.7 (15.6)		40.8 (15.3)		42.8 (15.5)	
Inexperienced	10.6 (11.2)	***	14.1 (16.5)	***	12.6 (13.1)	***	12.2 (15.3)	***	12.2 (14.1)	***
Overall	26.5 (20.6)		28.7 (22.0)		28.9 (21.6)		26.7 (21.0)		27.6 (21.3)	
Pressure (N/cm^2)										
Experienced	9.7 (2.6)		7.9 (2.2)		9.2 (2.5)		8.5 (2.6)		8.8 (2.5)	
Inexperienced	4.0 (0.7)	***	4.6 (1.2)	***	4.3 (1.1)	***	4.3 (1.0)	***	4.3 (1.1)	***
Overall	6.8 (3.4)		6.3 (2.4)		6.8 (3.1)		6.4 (2.9)		6.6 (3.0)	
Contact Area (cm^2)										
Experienced	4.7 (0.9)		5.0 (1.0)		5.0 (1.0)		4.8 (1.0)		4.9 (1.0)	
Inexperienced	1.3 (0.8)	***	1.3 (0.6)	***	1.4 (0.8)	***	1.2 (0.5)	***	1.3 (0.7)	***
Overall	3.1 (2.0)		3.2 (2.1)		3.2 (2.0)		3.0 (2.0)		3.1 (2.0)	

M= mean SD= Standard Deviation
* Mann-Whitney U test results for comparisons between the experienced and inexperienced therapist groups for the various test sites
*** $p<0.001$ level of significance

The body locations assessed included two areas (proximal and distal) on the lymphede-matous (affected) limb and two similar areas on the non-edematous (unaffected) limb. Three test sites were marked in each of the areas. The test sites within each area were 2cm in diameter and spaced 2cm apart, larger than the average thumb size, and with the aim to reduce a potential residual effect from preceding pitting tests. The first three therapists performed the pitting assessments consecutively, randomized to test site within each of the body locations and the order for each patient. Randomization was carried out using two envelopes, the first contained the letters A to F (patients), the second contained all possible combinations for 3 therapists to each test once two of the total six sites. An independent person drew a patient letter and a testing combination from the envelopes, recorded the allocation and returned the testing combination to the envelope. Two testing combinations were drawn for each patient for allocation of test sites to two groups of 3 therapists. To permit tissue to return to the pre-palpation state, a minimum of 30 minutes was allowed before the second group of three therapists repeated the procedure on the same three test sites in each area for each patient.

Data Collection

The data collected were recorded by the Tekscan™ Grip® system (Tekscan Inc., USA) and included the duration, pressure and contact area applied during the pitting tests. Pitting tests were performed with one thin (0.102 mm thickness) 32mm x 16mm pad of the Grip® system

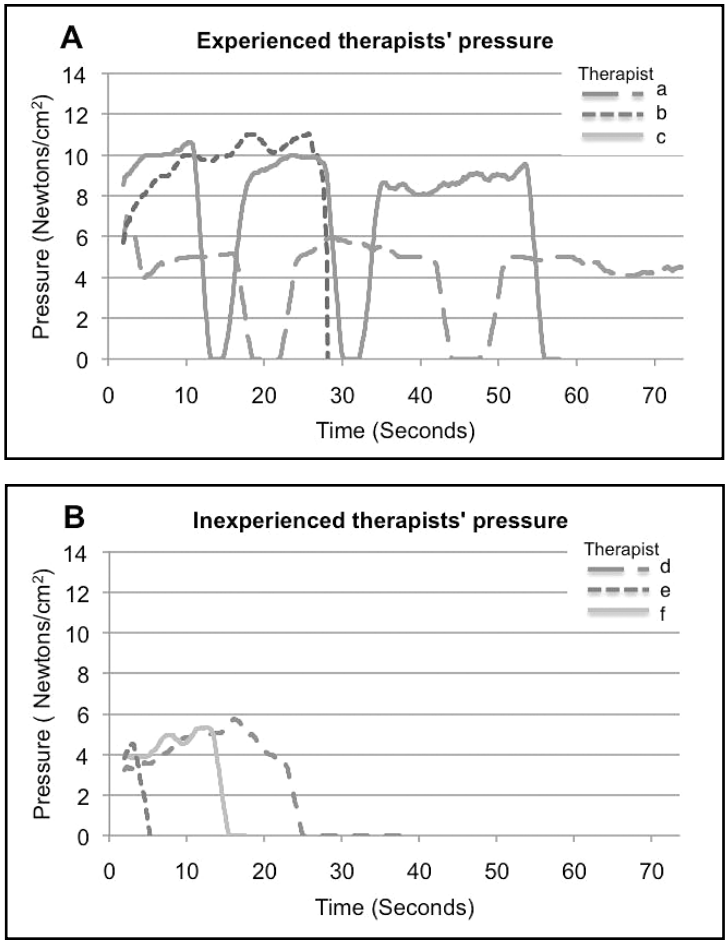

Fig. 1. Examples of pitting test pressure trend line data obtained from patient 5 on the affected distal leg by experienced (A) and inexperienced (B) therapists.

placed between the therapist's thumb pad and the patient's skin. The pad contained 32 individual pressure sensing sensels resulting in a sensel density of 6.2 per cm^2. The system records the pressure applied to each sensel at a frequency of 20Hz. Contact area (area of therapists' thumb in contact with the sensor), average pressure (the force per unit area over the test period) and a visual representation of the raw data were extracted using the Tekscan™ research software (version 6.70). To maximize accuracy, the system was calibrated using the materials that were being tested i.e., thumb pressure on a sensor onto a kitchen scale.

Data Analysis

The data were assessed using the IBM statistics software package SPSS version 22, with a significance level set at 0.05. Descriptive statistics were calculated and Mann-Whitney U tests were used to compare results for the experienced and inexperienced therapists' (*Table 2*).

RESULTS

A representative example of pitting test pressure and duration data obtained from each therapist is presented in *Fig. 1.*

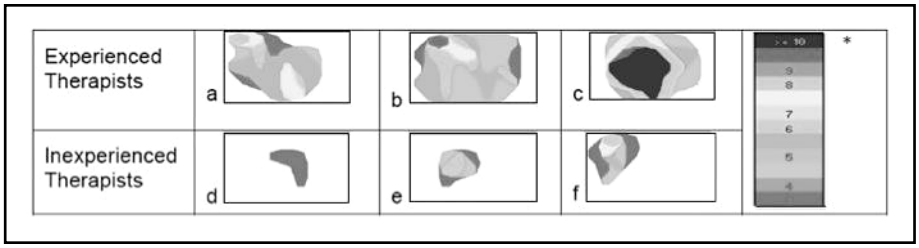

Fig. 2. Examples of Tekscan™ thumbprint image of average contact area (cm²) applied by experienced (top) and inexperienced (bottom) therapists. (: Key for pressure applied within thumbprint, ascending pressure on scale)*

Duration

The duration of the pitting assessment for each therapist was calculated as the time from the moment the thumb contacted the tissue to the moment the thumb contact was removed, indicated by 0.00cm^2 contact area readings. Extraneous data recorded while the therapist was positioning the sensors was excluded.

If therapists used a "staged" technique (whereby pressure was applied for a period of time, the thumb lifted for assessment of tissue qualities, and then re-applied), the total duration was calculated as the sum of assessment periods with the time between thumb contact periods removed.

The duration of the pitting test across all therapists and locations ranged from 1.1 to 76.0 seconds. Two of the experienced therapists used a "staged" technique, and the other four therapists performed the test continuously (*Fig. 1*). The experienced therapists applied pressure for a longer duration than the inexperienced therapists (*Table 2*).

Pressure

Pressure applied by each therapist was measured as the force applied on palpation per unit contact area (N/cm^2) using the Tekscan™ sensors. Pressure values were averaged over the total duration of the pitting test as these values best represent the pressure applied. Contact area was not constant between tests so that pressure (force per unit area) was the most suitable measure to allow direct comparison between assessments.

The average pressure applied throughout the assessment period ranged from 1.3 to 14.4 N/cm^2. Experienced therapists applied a higher pressure than the inexperienced therapists (*Table 2*).

Contact Area

The contact area represents the area of the therapist's thumb in contact with the sensor pad during the pitting test and is calculated as the number of sensels that register a value greater than zero multiplied by the area of each sensel (0.16cm^2).

The average contact area applied by the therapists' thumb on the sensor pad throughout the pitting assessment period ranged from 0.16cm^2 to 6.84cm^2. The experienced therapists applied a larger contact area than the inexperienced therapists (*Table 2*).

Fig. 2 illustrates an example of the contact area and pressure distribution for each therapist as a still image from the data recording. The experienced therapists performed the test with the broad thumb pad, whereas the inexperienced therapists have used the tip of the thumb.

DISCUSSION

This study investigated how therapists perform the pitting test with the aim to

determine test parameters for future research into lymphedema tissue behavior. To determine the extent of variation of technique, a variety of tissue presentations were assessed including distal and proximal limb locations, upper and lower limbs, and presence and absence of lymphedema. The range of pitting test techniques observed would likely contribute to inconsistent identification of pitting and characterization of lymphedematous tissue, which further emphasizes the need to standardize the test.

The experienced and inexperienced therapists demonstrated statistically significant differences in the three technique components of duration, pressure, and contact area. The experienced therapists consistently used a longer duration, firmer pressure, and larger contact area than the inexperienced therapists. Previous research involving experienced lymphedema therapists (18) and nurses trained to perform the pitting test (19) demonstrated an inconsistency in interpretation with low to moderate agreement between assessors. In this study, the test method of the experienced group was more consistent within the group than the inexperienced group, but the extent of agreement in their interpretation was not assessed.

The test durations measured across all therapists and pitting assessments are consistent with the broad range of durations described in the literature (3-5). Experienced therapists used consistently longer durations than inexperienced therapists, which may be associated with the therapist's purpose for performing the test. For example, a therapist who aims to only determine the presence of pitting may release the pressure as soon as pitting is noted while a therapist aiming to characterize the pitting or other unnamed tissue characteristics of lymphedema presentation may use longer durations.

A higher pressure would be expected to produce pitting although our results found the experienced therapists who applied higher pressures also sustained the pressure longer. It is not clear if the higher pressure was considered necessary to elicit a pitting effect or to further characterize the tissue once pitting had occurred.

The lowest pressure was unexpectedly low and the highest over twice the value reported in other research. A previous study using a smaller single pressure sensor reported that therapists applied a maximum pressure of $7N/cm^2$ while performing the pitting test (18), whereas the maximum pressure recorded in this study was $15.23N/cm^2$. The difference may be associated with the technology, setup or methodology as the previous study investigated palpation technique that in part included the pitting test, whereas the pitting test alone was the focus of this study.

Although the therapists were all physiotherapists by profession, their training and experience with lymphedema, and subdiscipline area of professional expertise differed, which could account for the differences in technique. The unique palpation experience of each therapist contributes to variation in the way palpation is performed in everyday clinical practice, and the location on the thumb that is most sensitive during palpation (2). The experienced therapists may be more sensitive with the larger surface area of the thumb pad and with a firm pressure, whereas the inexperienced therapists may have perceived that they gained more information from light touch to a small area of the thumb pad or the tip of the thumb (often used for other techniques in physiotherapy such as manual therapy). The position of the therapist and patient also may have contributed to the contact area difference, where experienced therapists were prepared to modify their position for personal comfort as they would in clinical practice.

As described in the introduction, values for pressure rather than force were reported in the current study. As an indicative measure, the forces measured for the inexperienced therapists averaged just over 5N (about the force necessary to click a retractable pen), while for experienced therapists, the average

was nearly ten times higher approaching 50N (about twice the force to push the lever on a soap dispenser).

Limitations

The participants did not include therapists with moderate lymphedema experience but it is not expected that their addition would have altered the range of data collected for pitting test duration, contact area or pressure.

A potential drawback in the study design was that the therapists were not asked to record the result of the pitting test that they had performed. In preliminary work by the same investigators, there was only fair agreement between therapists of high experience when characterizing outcome measures, so the information was not expected to be meaningful when therapists had a wider range of experience. However, the inclusion of a judgment may have influenced a change in technique with therapists being under the impression that their results would be compared.

Lastly, the Tekscan™ Grip® sensor may have influenced the data collected at the extreme limits of thumb contact area. It was noted that the full area of the thumb being used for the palpation exceeded the boundaries of the sensor tile for the highest contact area readings. For this reason, the data analysis investigated pressure (Force/unit area) rather than force. The recordings of lowest contact area suggest that the pressure applied may not have been sufficient to keep the sensor in contact with the skin. The expected error is small and given that this only occurred at the extreme low end of contact area recording range, the data were still included.

CONCLUSION

The large variation in methods used to perform a pitting test challenges the clinical validity and comparability of the lymphedema assessment outcome. Experience in lymphedema assessment is a predictor for technique with experienced therapists performing the pitting test for a longer duration, with higher pressure, and a larger contact area than their inexperienced counterparts.

The range of pressures (1.3 to 14.4 N/cm^2), contact areas ($0.16cm^2$ to $6.84cm^2$) and durations (1.1 to 76.0 seconds) identified in this study provide a range of testing parameters for use in future studies of the pitting test. In particular our subsequent research aims to investigate this range of parameters to assess the effect of the pitting test on underlying tissue. By investigating the relationship between tissue composition and tissue response to sustained pressure and release, research can guide standardization of the pitting test technique, and improve the validity of the outcomes that identify pitting and characterize lymphedematous tissue. Advancements in lymphedematous tissue assessment will enhance the evaluation of intervention effectiveness in clinical and research settings, and thereby contribute to improved patient outcomes.

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