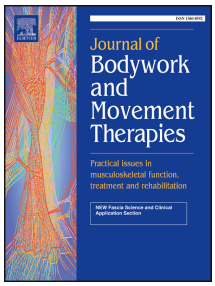

The MyotonPRO: a reliable and valid tool for quantifying the viscoelastic properties of a trigger point on the infraspinatus in non-traumatic chronic shoulder pain

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Title: The MyotonPRO: a reliable and valid tool for quantifying the viscoelastic properties of a trigger point on the infraspinatus in non-traumatic chronic shoulder pain

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ABSTRACT

Introduction: Clinicians rely on palpation for locating and diagnosing trigger points in muscles. Measuring a trigger point with clinical palpation remains a challenge. There are currently no validated tools available in clinical practice to objectively measure a trigger point.

Method: The presence of a trigger point within the infraspinatus muscle was identified on thirty-five individuals with non-traumatic chronic shoulder pain via palpation according to Travell and Simons criteria. Trigger and non-trigger points were marked within the same muscle and the viscoelastic properties of both points were independently measured twice with the MyotonPRO by two evaluators on two days.

Results: Significant differences were observed when the trigger and non-trigger point (discriminant validity) were compared. The trigger points showed greater tone and stiffness compared to the non-trigger points (tone: 15.30±1.99 Hz vs 13.57±1.76 Hz; stiffness: 270.20±46.96 N/m vs 227.86±43.44 N/m; $p<0.05$) and less elasticity (decrement of 1.13±0.21 vs 1.06±0.27; $p<0.05$). The reliability of the three viscoelastic properties was found to be excellent for intra- and inter-evaluator reliability (ICC: 0.925-0.984 and 0.918-0.972, respectively) and good to excellent for test-retest reliability (between days) (ICC: 0.770-0.875).

Conclusion: The MyotonPRO can differentiate the viscoelastic properties of a trigger point from a non-trigger point. Our findings support the reliability of this myotonometer. This

affordable and portable tool can be used to objectively measure viscoelastic properties of trigger points in the infraspinatus

1. INTRODUCTION

Physiotherapists are often confronted with clinical signs that are difficult to measure. This is particularly true when evaluating people with myofascial pain syndrome, a major cause of morbidity in society today (Tough, White et al. 2007). Studies show that a myofascial trigger point (TP) could be the primary source of this pain (Bron, De Gast et al. 2011, Rathbone, Grosman-Rimon et al. 2017). Simons and Travell (1999) define a TP as a 'hyperirritable spot in a taut band of skeletal muscle, whose stimulation by palpation, pressure, stretching or movement may cause local pain, referred pain, and motor dysfunction'. The prevalence of TPs in patients with musculoskeletal pain ranges from 30% to 85% (Fricton, Kroening et al. 1985, Trough, White et al. 2009, Mense 2010), with prevalence rates reaching as high as 93% in specialized pain clinics. TPs have been shown to be involved in various musculoskeletal conditions (Gerwin 2014). More specifically, TPs appear to play a key role in chronic non-traumatic shoulder pain (Ge, Fernandez-de-las-Penas et al. 2006, Ge, Fernandez-de-Las-Penas et al. 2008, Bron, de Gast et al. 2011, Albuquerque-Sendin, Camargo et al. 2013), given that nearly 77% of these patients present with active TPs in their infraspinatus, a muscle involved in the clinical presentation of rotator cuff tendinopathy.

Physiotherapists primarily rely on palpation for locating and diagnosing TPs in skeletal muscles. As recommended by Travell and Simons (1999), clinicians typically identify a painful area in a tight muscle band that reproduces the patient's symptomatology.

A recent systematic review on the reliability of palpation in locating TPs reported that palpation is only moderately reliable (in terms of intra- and inter-evaluator reliability) (Rathbone, Grosman-Rimon et al. 2017). On the other hand, Mayoral & al. (2018) and Mora-Relucio & al. (2016) report acceptable evidence of reproducibility and localization of TPs among experts and trained practitioners. The dichotomous nature (presence or absence) of the pain and muscle band tightness criteria, along with the subjective assessment from both the clinician's and patient's perspective, may explain this moderate reliability. Fortunately, some effort has been made over the last few years to standardize the assessment of perceived pain, due in part to experts recommending rigorous and multidimensional approaches for measuring pain (Dworkin, Turk et al. 2005). However, measuring muscle band (or hyperirritable spot) tightness with clinical palpation remains a challenge. Some technologies, such as ultrasound (Sikdar, Shah et al. 2008) or magnetic resonance elastography (Chen, Basford et al. 2008), can be used to localize and investigate the mechanical properties (e.g., stiffness) of myofascial taut bands based on shear wave transmission. However, accessibility to these tools and the high acquisition and/or operating costs involved are significant barriers to their use by physiotherapists. There are currently no validated tools available in clinical practice to objectively measure TP viscoelastic properties.

The MyotonPRO (Myoton SA, Tallinn, Estonia) is a portable hand-held myotonometer. This device is non-invasive and provides a quantitative assessment of a muscle's viscoelastic properties. These properties are characterized by different parameters

such as tone, elasticity and stiffness (Magnusson 1998, Gajdosik 2001). The MyotonPRO applies a short (15 ms), low- intensity (0.58 N) mechanical impulse on the skin overlaying the muscle. The tissue's response then generates a signal that is recorded, and an internal software program produces an acceleration graph (Figure 1). Measurements of various viscoelastic muscle properties, such as tone, elasticity and stiffness, are then extracted from this graph (Bizzini and Mannion 2003). Some studies have investigated the reliability and validity of the Myoton myotonometer to measure the viscoelastic properties of skeletal muscles in various populations (athletes, healthy participants and patients with neurological conditions). These studies focused on measuring the viscoelastic properties of the whole muscle, with measurements taken on the muscle belly. These studies demonstrated moderate to excellent intra- and inter-evaluator reliability with intra-class correlation coefficients (ICC) ranging from 0.67-0.99 for intra-evaluator reliability (Leonard, Deshner et al. 2003, Kerins, Moore et al. 2013, Pamukoff, Bell et al. 2016) and 0.62-0.96 for inter-evaluator reliability (Leonard, Deshner et al. 2003, Pamukoff, Bell et al. 2016, Davidson, Bryant et al. 2017), as well as poor to excellent test-retest reliability with ICCs ranging from 0.34-0.93 (Bizzini and Mannion 2003, Kerins, Moore et al. 2013, Pamukoff, Bell et al. 2016). The metrological properties of the MyotonPRO device for measuring the viscoelasticity of a localized area corresponding to a TP have so far never been studied.

The objectives of this research were: 1) to examine whether the MyotonPRO can discriminate the viscoelastic properties of a TP from that of a control non-TP (NTP) located in the infraspinatus of individuals with non-traumatic chronic shoulder pain (discriminant

validity); 2) to evaluate the intra-evaluator, inter-evaluator (intra-session) and test-retest (inter-session) reliability of the MyotonPRO in measuring the viscoelastic properties of a TP in the same population. We hypothesized that 1) the MyotonPRO device could discriminate the viscoelastic properties of a TP from those of an NTP, with the TP showing greater tone and stiffness and less elasticity compared to the NTP, and that 2) the intra-evaluator, inter-evaluator and test-retest reliability would be good, with intra-class correlation coefficients being >0.75.

2. METHODS

2.1 Design

This study was designed as a validation study, which took place at the research center of the XXX and in two physical therapy clinics of the area.

2.2 Participants

Thirty-five adults with unilateral chronic (> 3 months) shoulder pain were recruited (Figure 2) from February to March 2018 through social media (the research project's Facebook page) and posters displayed at the medical school, hospital and research center of the XXX. To be included, participants had to: 1) present with chronic shoulder pain of non-traumatic origin (rated at least 2/10 on a numeric rating scale (NRS) for more than 3 months. The pain had to be located in the shoulder area or referred in the area of the infraspinatus as described by Travell and Simons (1999); 2) have a hyperirritable spot within a palpable

tight band that reproduced the pain when compressed by palpation, and 3) have a body mass index (BMI) lower than 28 to account for some authors' findings that a high BMI could have an impact on the measurements (Gapeyeva and Vain 2008). Those with the following conditions were excluded: 1) diagnosis of capsulitis, cancer, or metastasis; 2) shoulder or thorax surgery or a mastectomy; 3) shoulder girdle bone fracture; 4) C4-C5 or C6 radiculopathy; 5) known osteoporotic profile (positive bone densitometry), or 6) apparent atrophy of the infraspinatus fossa (visual interpretation).

2.3 Data collection procedure

The study protocol was approved by the human research ethics committee of the XXX and all participants provided informed consent prior to enrollment. An evaluator conducted a structured interview to gather participant's baseline informations such as age, sex, dominance, height, weight, side of the painful arm, number of years since onset of symptoms, and pain intensity (NRS). The participant was then asked to complete the Disability of Arm, Shoulder and Hand (DASH) questionnaire. This combined data was used to describe the participants' sample (Table 1).

The presence of a TP in the infraspinatus was confirmed by a physiotherapist (Evaluator 1) with 20 years of experience in TP assessment. Evaluator 1 confirmed the presence of a TP with a standardized and recommended procedure in line with current practice (Simons and Travell 1999, Rathbone, Grosman-Rimon et al. 2017): the participant

had the painful arm undressed and was asked to lie on the contralateral shoulder on a treatment table. The upper arm rested on a wood block placed in front of the participant (Figure 3). Palpation with flat fingers perpendicular to the fibers was used to identify the taut band. Evaluator1 then searched for a TP, within this band and marked this TP using a red permanent ink Sharpie marker pen. She validated that compression of this TP reproduced 1) the patient's localized or referred pain; 2) the infraspinatus pain patterns described by Simons and Travell, and 3) a pain intensity of at least 2/10 on the Numeric Rating Scale (NRS). Ineligible participants received advice, a prescription for exercises related to their condition and a list with names of physiotherapists they could consult. After identifying the TP, a NTP was then localized in the same muscle, but outside and away from the taut band initially identified. This NTP was marked with an X using a black permanent ink Sharpie marker pen (Figure 3). For each participant, a scheme of the scapula and points (TP and NTP) were drawned in the research file to ensure the TP and NTP where far enough apart and to document where they were taken.

2.4 Intra-, inter-evaluator and test-retest reliability

Evaluator1 took the first set (T1) of viscoelasticity measurements on both points with the MyotonPRO device (Myoton SA, Tallinn, Estonia). Once these measurements were taken, Evaluator1 left the room so that a second evaluator (Evaluator2) could independently take the viscoelasticity measurements of the same points, using the MyotonPRO. This procedure provided the data to assess **inter-evaluator reliability**. Evaluator2 then left the room and Evaluator1 took the viscoelasticity measurements of the

same TP and NTP (T2) in order to document **intra-evaluator reliability**. Evaluator2 then repeated the measurements exactly the same way. On Day 2, these measurement procedures were repeated (T3 and T4), providing the data to assess test-retest reliability.

2.5 Outcome and instruments

The dependent variables (i.e., the viscoelasticity properties measured on the TP and the NTP of the infraspinatus muscle) were characterized by the following parameters: resting tone (Hz), elasticity (damping of oscillation frequency), and stiffness (N/m). These properties were measured using the MyotonPRO device as follows: The MyotonPRO device was placed and held stable on the skin over the marked TP or NTP, with the end of the small mechanical lever located at the bottom of the device positioned perpendicular to the plane of the TP. When the device was correctly positioned, a green light appeared and the device was set to give 5 mechanical impulses through the end of the small lever. The tissue's response to each impulse was recorded using an acceleration graph (Figure 1), providing oscillation frequency, decrement and stiffness parameters. The oscillation frequency (Hz) determined the tone at rest: the higher the oscillation frequency, the greater the tone. The logarithmic decrement damping of the oscillations quantified the elasticity, the elasticity being inversely proportional to the decrement of the oscillations. Stiffness (N/m) was defined as the resistance of the tissue to the force that attempted to deform it and was estimated as follows:

stiffness = $m\,{}^{\Delta amax}/_{\ell}$ where m was the mass of the lever that produced the mechanical impulse, $amax$ was the maximum amplitude of the oscillation and ℓ was the deformation,

i.e., the measurement of the deepest displacement of the tissue deformed by the mechanical impulse. The MyotonPRO device is programmed in such a way that in order for data to be recorded, the coefficient of variation (CV) estimated from the mean data of the 5 impulses must be <3%. If the CV of one of the parameters was >3%, a red light indicated that the measurements had to be taken again.

2.6 Sample size calculation

Sample size was calculated for a mean standardized effect of 0.5, a statistical power of 80%, and an alpha error of 5%. A mean standardized effect was chosen since no similar study had been done in the past (i.e., variance could not be estimated). A total sample size of at least 32 subjects had to be recruited based on a method suggested by Walter (1998) with 2 evaluators to statistically demonstrate that all intraclass correlation coefficients (ICC) would be >0.70 and different than a poor ICC <0.40. Thirty-five subjects considering a possible loss of 10% on the second day of measurements.

2.7 Statistical analysis

Data were analyzed using SPSS Statistics for Windows, Version 22.0 (IBM, Armonk, NY, USA). Standard error measurements (SEM) were calculated in Excel (Microsoft Inc., Redwood, WA). Univariate descriptive statistics were calculated and assumptions of normality and equal variances were checked for all viscoelasticity parameters. To investigate discriminant validity (Obj. 1), the mean value of the two measures taken during the first session (Day 1) by Evaluator1 where used. Paired t-tests

were conducted to determine the presence of a significant difference between the viscoelasticity of the TP and NTP and the level of significance was set at $p < 0.05$. To investigate the intra-evaluator, inter-evaluator and test-retest reliability (Obj. 2), ICCs were estimated and their 95% confidence intervals were calculated based on a mean rating (k=2), absolute agreement, 2-way mixed-effects model. Based on the 95% confidence interval for the ICC estimate, values less than 0.40 were indicative of poor reliability, values between 0.40 and 0.59 indicated fair reliability, values between 0.60 and 0.79 represented good reliability, and values greater than 0.80 suggested excellent reliability (Cicetti 1994). Standard errors of measurement (SEM) were also calculated for test-retest reliability in order to express the reliability in actual units to facilitate data interpretation. We calculated the SEM according to the formula SEM= $SD * \sqrt{1 - ICC}$. SD was derived from the ANOVA $\sqrt{MSw}$ (within-subjects mean square) (Bruton, Conway et al. 2000).

3. RESULTS

3.1 Participant characteristics

Thirty-five individuals aged 22-62 years (mean age 42 ± 12) were included in the study. Participant characteristics are summarized in Table 1.

3.2 Discriminant validity

The results of all viscoelastic parameters for the TP and NTP are shown in Table 2. Paired t-tests revealed a statistically significant difference for all parameters. As expected,

the MyotonPRO device could discriminate the viscoelastic properties of a TP from those of a NTP, with the TP showing greater tone (15.30 ± 1.99 vs 13.57 ± 1.76) and stiffness (270.20 ± 46.96 vs 227.86 ± 43.44) and less elasticity (1.13 ± 0.21 ± 1.06 ± 0.27) compared to the NTP.

3.3 Reliability

3.3.1 intra-evaluator reliability

Intraclass correlations of intra-evaluator measurements are shown in Table 3. Intra-evaluator reliability was excellent for a) tone (ICC ranging from 0.966-0.968 with a measurement difference of 15.21-15.57Hz (1.97-2.36)); b) elasticity (ICC ranging from 0.939-0.970 with a measurement difference in logarithmic decrement damping of 1.13-1.21 (0.21-0.24)), and c) stiffness (ICC ranging from 0.925-0.984 with a measurement difference of 270.20-289.17 N/m (46.96-54.44)).

3.3.2 inter-evaluator reliability

Intraclass correlations of inter-evaluator measurements of the TP are shown in Table 4. Measurements showed excellent inter-evaluator reliability for a) tone (ICC: 0.967-0.972); b) elasticity (ICC: 0.918-0.944), and c) stiffness (ICC: 0.942-0.957).

3.3.3 test-retest reliability

Intraclass correlations of test-retest measurements of the TP with 2 evaluators on two different days are shown in Table 5. Test-retest reliability of the MyotonPRO was good to excellent resulting in ICCs ranging from 0.770 to 0.875: a) tone (ICC: 0.821-0.866), b) elasticity (ICC: 0.866-0.875) and c) stiffness (ICC: 0.770-0.855).

4. DISCUSSION

The MyotonPRO (Myoton SA, Tallinn, Estonia) is a portable hand-held myotonometer. This device is non-invasive and provides a quantitative assessment of a muscle's viscoelastic properties. The measurements also showed excellent intra- and inter-evaluator reliability for the viscoelastic properties of a TP and good to excellent test-retest reliability.

The MyotonPRO device was able to measure a statistically significative difference ($p<0.05$) between a TP and an NTP for all viscoelastic parameters and confirmed our hypothesis that TPs have greater tone and stiffness and less elasticity. Only one study thus far had examined the discriminant validity of the Myoton myotonometer by investigating different muscle states. Chuang et al. 2012 compared the values of viscoelastic properties measured by the Myoton-2 over three different muscles of an affected and unaffected limb in a relaxed state in stroke patients, revealing a statistically significant difference only in some parameters for certain muscles. The present study was the second study to examine the discriminant validity of the Myoton device and demonstrate that this device is a valid

clinical tool to objectively measure not only the viscoelastic parameters of a muscle, but also of a TP.

MyotonPRO measurements have shown excellent intra- and inter-evaluator reliability of the viscoelasticity properties of a TP and good to excellent test-retest reliability. To our knowledge, this is the first study to report that the MyotonPRO can be used as a reliable and valid tool for assessing the tone, elasticity and stiffness of a TP. Many studies have reported on the reliability and validity of the MyotonPRO for systematically measuring the viscoelastic properties over a skeletal muscle in different pathologies, but never over a specific area or a TP. Even if we studied MyotonPRO measurements over a precise spot (TP), our ICC values would be similar or even better than in previous studies (Bizzini and Mannion 2003, Leonard, Deshner et al. 2003, Chuang, Wu et al. 2012, Kerins, Moore et al. 2013, Pamukoff, Bell et al. 2016, Pruyn, Watsford et al. 2016, Davidson, Bryant et al. 2017) that have examined the reliability of the MyotonPRO in measuring various muscle bellies in different populations (healthy patients, patients with neurologic conditions, athletes, etc.). Kerins & al. (2013), was the only study that have measured the infraspinatus muscle and showed similar values for inter-evaluator reliability (ICC: 0.93-0.95).

Good to excellent test-retest reliability was observed for all viscoelastic properties. The coefficients obtained were found to be higher than those observed by Kerins & al. in healthy subjects (ICC: 0.33-0.77), which may be explained by the fact that they did not standardize the placement of the probe on the muscle, that they did not position the muscle fibers into a slightly stretched position and also that they were using another myotonometer

called the Myotonometer® (Neurogenic Technologies Inc, Missoula, Montana, USA). With this particular device, the rate of probe pressure is not controlled and standardized by the device and is manually applied by the operator. This probably has an impact on the compliance of the tissue measured. In our study, it should also be highlighted that the test-retest reliability coefficients were found to be lower than the intra- and inter-rater reliability coefficients, which could be attributable to some sources of variance. We could not control all environmental and/or contextual factors between the sessions. For example, some participants had to deal with bad weather on the second day of evaluation. The poor driving conditions might have increased the participants' stress levels and their capacity to completely relax. Also, as reported by many authors (Bizzini and Mannion 2003, Leonard, Deshner et al. 2003, Kerins, Moore et al. 2013), even if the participants were positioned in a comfortable position and were told to relax their arm as much as possible, some participants could probably not relax because of the pain induced with the slight stretch in the muscle fibers. Future studies on MyotonPRO reliability should include a surface EMG to monitor muscle activity while taking measurements to ensure that the muscles are in a relaxed state.

Our study presents some limitations. Even though there is an intrinsic mechanism in the device to ensure that the mechanical lever arm is perpendicular to the plane of the skin above the muscle, we noticed that the impulse was activated even when the probe was not absolutely perpendicular to the surface. With a few participants (4/35), it was challenging to put the mechanical arm perfectly perpendicular depending on the shape of their shoulder

and/or the position of their scapula. In theses cases, the probe tended to glide slightly on the skin and it is possible that this might have influenced the acceleration graph output and estimation of the parameters. Other authors have reported the same issue (Chuang, Wu et al. 2012, Kerins, Moore et al. 2013). However, this should not have jeopardized our results since this phenomenon was only observed in a few participants and as mentioned, the CV was <3% for these people.

Another limitation to consider is the localization of the NTPs. When analyzing our data, we realized that the NTPs that were very close to the spine of the scapula were showing greater stiffness than those located in the other areas of the muscle. This is potentially explained by the close proximity of a bony surface. Although a significant difference was observed between the viscoelastic properties of the TP vs the NTP, this could have had an effect on the mean values of the NTP, with tone and stiffness possibly being overestimated, and elasticity underestimated. It would have been interesting to compare the TP with a NTP in the contralateral infraspinatus to ensure that the NTP was outside of the taut band, but at the same time we wanted to verify if the MyotonPro was able to discriminate two points in the same muscle.

However, we cannot generalized our results for TPs in other muscles and other populations. Future studies are required to validate the discriminant validity of the MyotonPro on TP in other muscle (deeper muscles, thicker muscles) and other population samples.

5. CONCLUSION

The MyotonPRO can discriminate the viscoelastic properties of a TP from an NTP located in the infraspinatus of individuals presenting with chronic, non-traumatic shoulder pain. The MyotonPRO is a reliable, affordable and portable tool that can objectively measure these properties in a clinical setting or for research purposes. This is an important breakthrough in the evaluation and treatment of musculoskeletal conditions associated with the presence of TPs, because as evidenced by Shah (2015), theories surrounding the pathogenesis, pathophysiology, and contribution of TPs in the diagnosis of myofascial pain syndrome have so far been mainly speculative.

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TABLES

Table 1. Participant characteristics

Variables	Mean (SD or N(%)) (n=35)
Age, years	42 years (12)
Gender: female/male	23 (66)/12 (34)
Dominance: right handed	27 (77)
Symptomatic side: right; left	19(54); 16(46)
BMI kg/m^2	27 kg/m^2 (4)
DASH score	31.66±18.50
Duration of pain	
3-6 mo	3 (8)
6-12 mo	9 (26)
1-2 yrs	10 (29)
>2 yrs	13 (37)
Pain intensity at rest, NRS	2 (2)
Pain intensity during activity, NRS	6 (2)
Participants using medication for pain	14(40)

Abbreviations: SD: standard deviation; BMI: Body Mass Index; DASH: Disabilities of the Arm, Shoulder and Hand

Table 2. Discriminant validity – Comparing TP and NTP viscoelasticity parameters

	TP $\overline{\boldsymbol{x}}$ (SD)	**NTP** $\overline{\boldsymbol{x}}$ (SD)	***P*-value**
Tone (Hz)	15.30 (1.99)	13.57 (1.76)	<0.001
Elasticity*	1.13 (0.21)	1.06 (0.27)	0.037
Stiffness (N/m)	270.20 (46.96)	227.86 (43.44)	<0.001

Comparisons were made for data collected by evaluator1 on Day 1. Scores are expressed as a mean score ± standard deviation.

Abbreviations: NTP: non-trigger point; TP: trigger point; ($\overline{\boldsymbol{x}}$ (SD)): Mean score (standard deviation); Hz: hertz; N/m: Newton/meters. A decrement is a coefficient of the logarithmic damping of oscillations; *logarithmic decrement of natural oscillation.

Table 3. Same day intra-evaluator reliability for evaluator1 and evaluator2 for TP parameters

		Day 1		
		Trial 1 $\bar{x}$ (SD)	Trial 2 $\bar{x}$(SD)	ICC [95% CI]
E1	Tone (Hz)	15.21(1.97)	15.38 (2.08)	0.966 [0.932-0.983]
	Elasticity*	1.13 (0.22)	1.13 (0.21)	0.970 [0.940-0.985]
	Stiffness (N/m)	270.20 (46.96)	278.63 (49.80)	0.925 [0.848-0.963]
E2	Frequency	15.38 (2.18)	15.57 (2.36)	0.968 [0.936-0.984]
	Elasticity*	1.21 (0.22)	1.19 (0.24)	0.939 [0.880-0.969]
	Stiffness	28.49 (50.12)	289.17 (54.44)	0.984 [0.962-0.993]

Abbreviations: ICC: intraclass coefficient of correlation; CI: confidence interval; E1: evaluator1; E2: evaluator2; Hz: hertz; N/m: Newton/meters). A decrement is a coefficient of the logarithmic damping of oscillations; *logarithmic decrement of natural oscillation.

Table 4. Inter-evaluator reliability for TP parameters on Day 1 and Day 2

	Day 1 Evaluator1 trial 1 - Evaluator2 trial 1	Day 2 Evaluator1 trial 1 - Evaluator2 trial 1
	ICC [95% CI]	ICC [95% CI]
Tone (Hz)	0.972 [0.944-0.986]	0.967[0.935-0.983]
Elasticity*	0.918[0.612-0.971]	0.944[0.882-0.972]
Stiffness(N/m)	0.942[0.828-0.975]	0.957[0.916-0.979]

ICCs were computed between evaluators based on data at trial 1.
Abbreviations: TP: trigger point; ICC: intraclass coefficient of correlation; CI: confidence interval; E1: evaluator 1; E2: evaluator 2; *logarithmic decrement of natural oscillation; LDNO: logarithmic decrement of natural oscillation.

Table 5. Test-retest reliability for TP parameters for evaluator1 and evaluator2

		ICC [95% CI]	SEM
E1	Tone (Hz)	0.821 [0.636-0.911]	0.58
	Elasticity*	0.866 [0.713-0.935]	0.04
	Stiffness (N/m)	0.770 [0.495-0.889]	17.88
E2	Tone (Hz)	0.866 [0.729-0.933]	0.45
	Elasticity*	0.875 [0.754-0.937]	0.04
	Stiffness (N/m)	0.855 [0.674-0.931]	11.17

ICCs were calculated as between-day reliability based on the data at day 1 trial 1 and day 2 trial 1; *logarithmic decrement of natural oscillation. SEM is expressed in the units of the corresponding variable.

Highlights

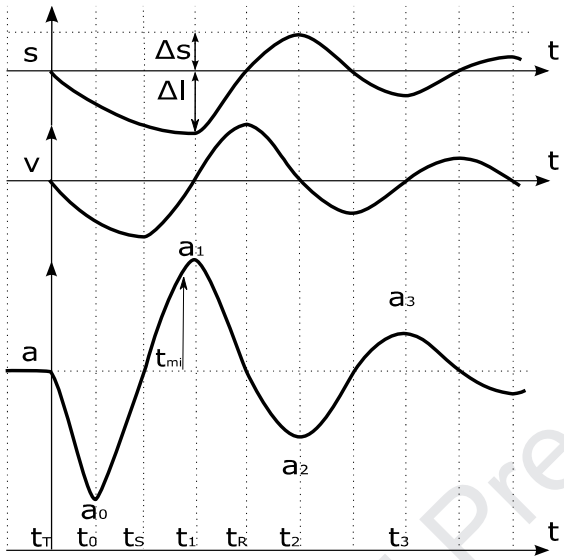
- There are currently no validated tools available in clinical practice to objectively measure a trigger point.
- The MyotonPRO (Myoton SA, Tallinn, Estonia) is a portable hand-held myotonometer, it is non-invasive and provides a quantitative assessment of a muscle's viscoelastic properties (stiffness, elasticity and tone).
- The metrological properties of the MyotonPRO device for measuring the viscoelasticity of a localized area corresponding to a trigger point have so far never been studied.
- The MyotonPRO device was able to measure a statistically significative difference ($p<0.05$) between a trigger point and an non-trigger point for all viscoelastic parameters (stiffness, elasticity and tone).
- The measurements also showed excellent intra- and inter-evaluator reliability for the viscoelastic properties of a TP and good to excellent test-retest reliability.

Declaration of interest

We declare that none of the authors had any personal or financial relationship with anyone or any organization that could inappropriately influence or work in this research project. We received from the Physiotherapy Foundation of Canada the annual grant of the Acupuncture division of the Canadian Physiotherapy Association while the project was already going on and that grant was obtained over a submission process. The grant was 10 000$ and was used to cover fees related to a research assistant; for participant expenses (parking) and travel fees for the student researcher,

FIGURES

Figure 1: Acceleration graph of the different variables produced by MyotonPRO



With permission from Myoton(AS 2010)

Frequency (Hz)

$F = f_{max}$

Stiffness (N/m)

$S = a_{max} \bullet m_{probe}/\Delta l$

$a_{max} = a^1$ max displacement

m_{probe} = probe mass

Logarithmic decrement

$D = \ln (a_1/a_3)$

Figure 2. Participant recruitment flow diagram

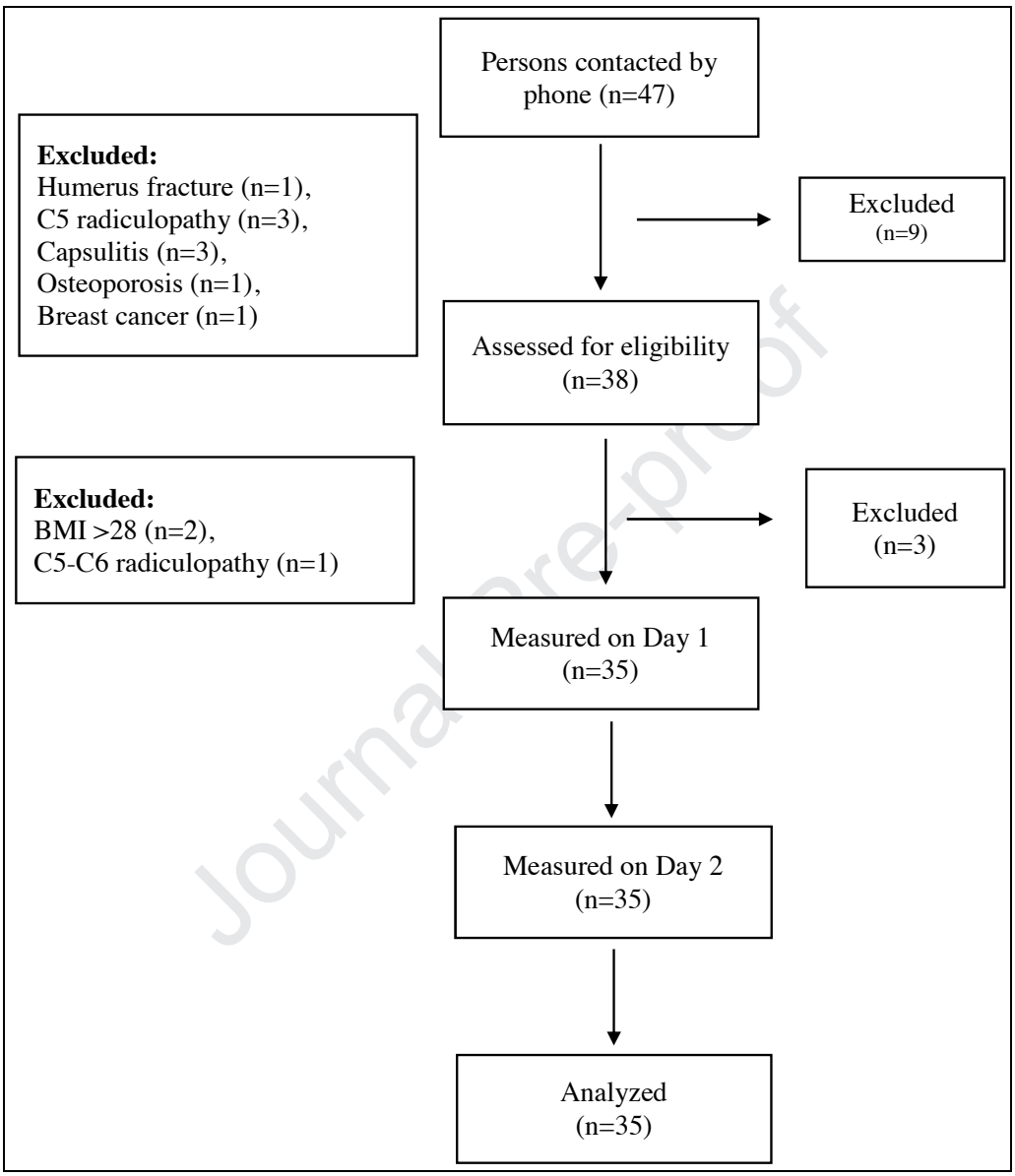
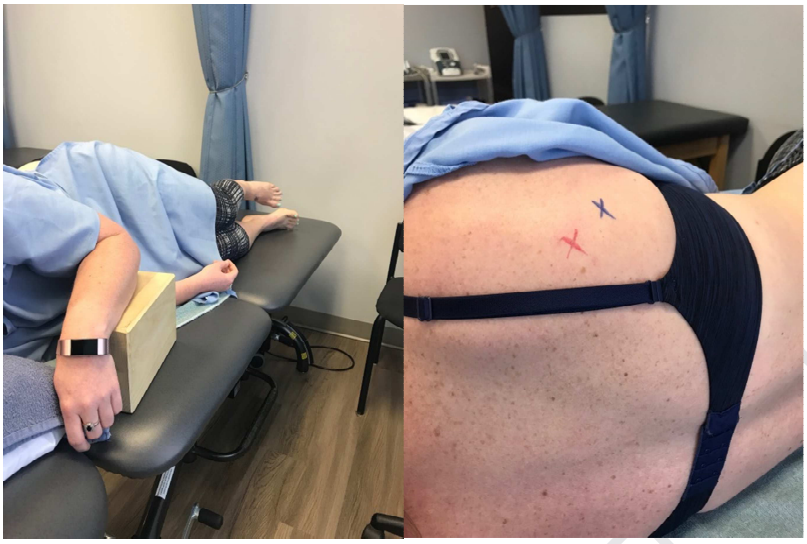


Figure 3. Participant's position during the measurements



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