Interrater reliability of muscle tone, stiffness and elasticity measurements of rectus femoris and biceps brachii in healthy young and older males

Sandra Agyapong-Badu, Lucy Aird, Louise Bailey, Kate Mooney, James Mullix, Martin Warner, Dinesh Samuel, Maria Stokes

Abstract

Purpose: To examine interrater and within-session reliability of using the MyotonPRO device for measuring non-neural tone and mechanical properties of the rectus femoris and biceps brachii muscles in healthy young and older adults.

Methods: Forty-two healthy males were studied: n=21 aged 25.9 (SD 4.4) years and n=21 aged 72.1 (SD 4.9) years. The MyotonPRO device applied brief, low force mechanical impulses to the muscle belly to produce damped oscillations of the muscle at rest. Computing of the parameters was made automatically from the oscillation curve of non-neural mechanical tone (state of intrinsic tension) measured as frequency [Hz], dynamic stiffness [N/m] and elasticity (logarithmic decrement).
Analysis: The means and standard deviations of all three parameters for each rater were calculated. Reliability was assessed using intra-class correlation coefficients (ICCs) and Bland and Altman analysis.

Results: Excellent within-session intra-rater reliability was demonstrated by raters for both participant groups (intraclass correlation coefficients, ICC 3,2 = 0.94-0.99). Interrater reliability was excellent for all rectus femoris parameters in the young (ICC 3,1= 0.92-0.95) and older group (0.86-0.94). In biceps brachii, reliability was excellent in the young group (0.78-0.94) and for elasticity in the older group (0.89) but was only classed as good for tone (0.67) and stiffness (0.68).

Conclusions: Different raters obtained acceptably similar results for all three parameters of rectus femoris in both age groups and for biceps brachii in the young group, and for elasticity only in the older group. The findings indicate that the MyotonPRO has potential use for objective assessment of mechanical muscle properties in clinical and research settings and that the protocol for locating the site for testing biceps brachii in older participants could be modified to improve reliability.

Implications: The MyotonPRO device can be used reliably by different users to assess muscle parameters in healthy people of different ages. Further studies are needed to add to the existing literature to establish Myoton technology as a valid and reliable clinical and research tool for examining the effects of injury, disease and interventions in various muscles in clinical conditions.

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Keywords:
Quadriceps, Biceps Brachii, Mechanical properties, Muscle tone, Myoton technology, Reliability

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Acknowledgments

The authors thank staff and students of the University of Southampton and residents in the local community for taking part in the study, Dr Peter Nicholls for statistical advice, the Ghana Education Trust Fund for sponsoring SAB, Faculty of Health Sciences, University of Southampton for PhD studentship (SAB), Myoton AS (Estonia) and Myoton Ltd London for providing the MyotonPRO and Aleko Peipsi (CEO, Myoton AS Estonia) for training. There were no conflicts of interest within the present study, which was conducted independently of the company providing the equipment.

INTRODUCTION

Clinical assessments of skeletal muscle tone and stiffness are often subjective. This limits their value for comparisons between groups or to population norms, as well as for monitoring the effects of medical or therapeutic treatment. Research into tone and mechanical properties of skeletal muscles has utilised sophisticated techniques, such as magnetic resonance elastography, ultrasound imaging, torque, ramp and hold, and pendulum (electrogoniometric) tests (Dresner et al. 2001), as well as electrophysiological tests to examine the neural component of muscle tone, including H-reflex, H:M ratio, electromyographic ratio to length change, and F wave measurements (Leonard et al. 2003). Although these techniques provide robust, objective measures of various muscle characteristics, they are not suitable for routine clinical use or testing in community settings, as they are expensive, labour and time intensive, and require specialized staff training. Myoton technology (Myoton AS, Estonia and Myoton Ltd London) offers an in-vivo, clinical, non-invasive measurement of state of tension and some of the mechanical properties of skeletal muscle, with the added advantage of portability and is relatively inexpensive (Gavronski et al. 2007; Veldi et al. 2004).

The MyotonPRO device elicits oscillations of muscle after a probe applies a brief mechanical impulse with quick release under constant pre-load to the skin over the muscle belly. From these oscillations, the device computes various parameters simultaneously, including non-neural tone (recorded as frequency) and mechanical properties such as dynamic stiffness and elasticity (indicated by logarithmic decrement). A myotonometer was used by Leonard et al (2003) but their device used different method and technology to the Myoton devices and involved compression (≥1≤2 seconds) of the muscle tissue to record tissue displacement, rather than induce an oscillation (<150 milliseconds).

Test-retest reliability between days of using an earlier prototype, the Myoton-2, was found to be high for testing stiffness of the biceps femoris, rectus femoris and gastrocnemius muscles (Intraclass Correlation Coefficient ICC; 0.80-0.93) and poor reliability (ICC 0.40) was found for vastus lateralis (Bizzini and Mannion 2003). More recently, between-day reliability of all three mechanical parameters was reported (ICCs >0.70) using the MyotonPRO to test quadriceps (rectus femoris) in older males over 65 years (Aird et al. 2012). Similar reliability was found in young males (aged 20-35 years) for quadriceps (ICCs 0.81-0.87) and hamstrings (long head of biceps femoris; ICCs 0.72-0.86) (Mullix et al. 2012). Reliability of testing between different raters, interrater reliability, is important for clinical purposes, as patients may be seen by different clinicians on different visits. Interrater reliability has not yet been reported for the MyotonPRO but for the Myoton-2 device, high interrater reliability was found (ICCs 0.97-0.99) for testing the trapezius muscle in females (Viir et al. 2006). Myoton technology was shown to be a valid measure when compared with electromyography and a tensiomyography device (Ditroilo et al. 2011). Although earlier reliability studies have generally reported good results, these were conducted in young participants and it cannot be assumed that this will be the case for all populations and different muscles, so further reliability studies are needed. Thus the aim of the present study was to examine interrater and within session test-retest reliability of measurements obtained using the MyotonPRO device in young and older healthy males. It was hypothesized that measurements of tone, stiffness and elasticity of rectus femoris (RF) and biceps brachii (BB), using the MyotonPRO, in healthy young and older males would show acceptable reliability.

METHODS

Research design

This study was a descriptive, cross-sectional reliability study.

Participants

Sample size requirements for reliability testing vary with recommendations of 15-20 participants suggested in the literature (Atkinson and Nevill 2001) and previous studies on Myoton have reported findings on 20 or fewer participants (Bizzini and Mannion 2003; Janecki et al. 2011; Viir et al. 2006). Therefore a convenience sample of forty-two healthy males were recruited for this study; 21 young men aged between 20-35 years (mean 25.9 years, standard deviation SD 4.4), and 21 older men aged 65-82 years (mean 72 years, SD 4.9). Participants from the middle age group were excluded in order to assess differences between young and older muscles. Body mass index (BMI) was 23.9 (SD 2.5), range 19.2-29.4 kg/m^2 and, 25.2 (SD 3.4), range 18.6-30 kg/m^2 in young and older groups

respectively. Young participants included staff and students recruited through the University website and older participants were recruited from the local community following presentations at social events and using posters displayed in community areas. Interested participants were sent information on the study and completed a screening questionnaire to ensure eligibility. Inclusion and exclusion criteria were selected to ensure the normal healthy population was well represented, although screening excluded conditions that may potentially skew data (Aird et al. 2012).

Participants were included if they presented with controlled medical conditions and were independently mobile (ability to walk for ≥ 5 mins indoors or outdoors without requiring support). Participants were excluded if they had conditions known to affect muscle tone and movement; neurological conditions, such as stroke, Parkinson's disease, multiple sclerosis, muscular dystrophy etc; and musculoskeletal conditions, such as severe arthritis or injuries severe enough to require treatment or prevent activity for more than one week in the previous five years. Participants taking medications, such as skeletal muscle relaxants, neuromuscular blocking drugs, an inability to understand study requirements and a BMI >30 kg/m^2 were excluded (Gapeyeva and Vain 2008). Both groups were right-hand and right-foot dominant, as determined by the Edinburgh Handedness Inventory (Oldfield 1971) and the ball kick test respectively (Hoffman et al. 1998; Kong and Burns 2010).

Prior to testing sessions, participants were asked to refrain from alcohol consumption for at least 24 hours and to avoid strenuous physical activity for at least 48 hours. Young males were recruited if they did not participate in sports or did not exercise more than three times per week or competitively at university level or above. For older participants, activity was assessed using the Physical Activity Scale for the elderly (PASE)(Washburn et al. 1993) to ensure only those involved in moderate physical activities were included. Participants were tested in a laboratory with a room temperature of approximately 23^{o}C. All participants gave their written informed consent. The study was approved by the Faculty of Health Sciences Ethics Committee, University of Southampton, and followed recommendations of the World Medical Association Declaration of Helsinki (W.M.A. 2008).

Standardisation of limb position and locating testing site

Recording conditions were standardized as far as was clinically feasible. The recording sites were located on the skin visibly over the muscle belly of RF and BB. Positioning for RF muscle measurements was achieved with the participant supine, knee extended and hip in neutral. A sandbag was placed along the lateral and medial aspect of the ankle to maintain this position. Measurements were taken at two thirds of the distance between the anterior superior iliac spine (ASIS) and the superior pole of the patella, to locate a reproducible site over the muscle belly.

For BB, the participant lay supine with the shoulder externally rotated and elbows extended and wrist supinated. A sand bag was placed under the wrist to flex the elbow approximately 10-15^0, to take the stretch off the muscle and enable relaxation (Aarrestad et al. 2004). The MyotonPRO was applied at three-quarters of the distance between the lateral tip of the acromion and the mid cubital fossa.The muscle testing sites were marked on the skin as a small circle, approximately the diameter of the probe, using a non-toxic skin marker (Aarrestad et al. 2004).

Measurement of Muscle Tone and Mechanical Properties

The MyotonPRO device has a testing end (probe) that is applied under constant pre-load (0.18 Newtons) to pre-compress subcutaneous tissues. The probe then exerts a brief (15 milliseconds) mechanical impulse (tap) at a pre-determined force (0.4N) followed by quick release, inducing dampened natural oscillations of the muscle. The device records these oscillations in the form of an acceleration graph (Bailey et al. 2013) and performs subsequent simultaneous computation of tissue parameters. These include its state of tension or non-neural tone, characterized by frequency (Hz; $F=f_{max}$) computed from the signal spectrum by Fast Fourier Transform; the higher the frequency the higher the muscle tone. The mechanical properties include stiffness (N/m), indicating the muscle's ability to resist an external force that modifies its shape (the higher the value the greater the stiffness), and elasticity, characterized by logarithmic decrement, indicating ability of the tissue to recover its shape after being deformed, the higher the value, the lower the amount of mechanical energy lost during a single oscillation cycle (Masi et al. 2010; Özkaya et al. 1999). The initial sampling rate of the device is 3200Hz and average accuracy of the measurement series (coefficient of variation) for each parameter is; frequency (0.62%), decrement (1.8%) and stiffness (1.72%). The mechanical impulse from the device causes elastic deformation to the tissue being measured, and as the tissue returns to its initial shape it produces its natural damped oscillation, which is registered by the accelerometer of the device attached to the frictionless and sensitive measurement mechanism (Gapeyeva and Vain 2008) to provide values for the mechanical properties.

The earlier Myoton prototypes contained a single axis accelerometer which required that the device be held vertical (±15 degrees) to the gravity vector to obtain an accurate reading. The MyotonPRO has a triaxial accelerometer and a system which allows multidirectional measurements in relation to the gravity vector. The probe is held perpendicular to the skin surface to ensure that the energy from a mechanical impulse goes to the muscle maximally and constantly. However, due to the fact that muscle tissue is affected by gravity, it is recommended that recordings are made with the device held between 0-90 degrees to the gravity vector (keeping the end of the probe perpendicular to the skin). This ensures that the muscle is not hanging without support beneath it, such as bone, so that oscillations can be elicited effectively for testing.

The device was used in multiscan mode consisting of 10 single measurements, at one second intervals, and mean values for each parameter were produced for the set of 10 measurements (Gavronski et al. 2007). Each rater took two sets of 10 recordings for each muscle and the mean of the two sets was used for analysis. All measurements were taken from muscles on the right side, with the participant in supine lying and instructed to relax as much as possible and the device was held perpendicular to the skin over the muscle being tested (Figure 1).

Figure 1 The MyotonPRO device being held perpendicular to the skin over the rectus femoris muscle to obtain measurements of mechanical parameters of non-neural tone, elasticity and stiffness

Raters

Five raters who included a qualified physiotherapist and four final year physiotherapy students collected data for the study. Training involved a half day session on use of the device provided by Myoton (AS Estonia) and a half day session with research colleagues to develop and agree testing protocols. Rater 1 tested both muscles in all participants. Raters 2 and 3 collected data for RF in young and older participants respectively. Data for BB were collected by Raters 4 and 5 in the young and older participants respectively. The results of raters 2, 3, 4 and 5 were compared with those of Rater 1.Only the recording technique was compared between raters and not the relocation of the anatomical testing site.

Data analyses

Data were imported into Microsoft Excel and analysed using SPSS 18 (SPSS Inc, Chicago, IL). The data were examined for normality using the Shapiro-Wilks test and found to be normally distributed. Descriptive statistics were used to summarise the data as means and standard deviations (SD). Intraclass correlation coefficients (ICCs) were used to assess intrarater within session reliability and between rater reliability. Intrarater reliability (within session) was analysed using a two-way mixed model repeated measures ANOVA where the mean of each set of 10 measurements was used (ICC3,2). The intrarater reliability was assessed between the two sets. The mean measures ICC was used as clinically, the mean of the two sets would be used to reduce error. For interrater reliability, the association between the two raters was analysed using a two-way mixed single measure ANOVA (ICC3,1). Fleiss (2007) proposed that for excellent reliability, ICC values should be above 0.75.

In the present study the following scale was used to interpret reliability; excellent > 0.75, good to fair 0.4-0.74, poor <0.4 (Fleiss 2007). Standard errors of measurements (SEM) were also calculated using the following formula, where SD is the pooled standard deviation and ICC is the reliability coefficient (Portney and Watkins 2000).

$$SEM = SD(\sqrt{1-ICC})$$

Agreement between raters was assessed using Bland and Altman analysis, providing mean difference ($\bar{d}$) and 95% confidence intervals (CI), and plots to visually observe the level of agreement and allow easy identification of bias and outliers.

RESULTS

Absolute values for tone, stiffness and elasticity

The mean and standard deviations of the three measured parameters are presented for both sets of Raters for each muscle in Table 1

Intrarater Reliability

All five raters showed excellent within-session reliability (ICC3,2 >0.90) for two sets of repeated measurements from the RF and BB muscles in both young and older groups of participants (Table 2).

Reliability between raters was greater for RF (ICC3,1 0.86-0.95) than BB (0.67-0.94) and was also influenced by age (Table 3). In the younger group, all ICCs were excellent for RF (0.92-0.95) and BB (0.78-0.94). In the older group, ICC values for RF were also excellent, with those for stiffness and tone (0.93-0.94) greater than that for elasticity (0.86). Values for BB in the older group were excellent for elasticity (0.89) but produced the lowest reliability for the other two parameters, with ICCs classed

Table 1 Absolute values for tone, stiffness and elasticity for both raters

Muscle	P	Rater	Young Males n=21			Older Males n=21		
			M1(SD)	M2(SD)	TM(SD)	M1(SD)	M2(SD)	TM(SD)
BB	Tone (Hz)	1	14.7(0.7)	14.7(0.8)	14.7(0.8)	14.4(1.1)	14.3(1.1)	14.3(1.1)
		2	14.7(0.9)	14.8(0.9)	14.8(0.9)	14.4(1.4)	14.5(1.4)	14.4(1.4)
	Stiffness (N/m)	1	223(26)	224(26)	223(26)	237(29)	236(27)	236(28)
		2	227(28)	225(28)	226(28)	236(27)	239(26)	238(26)
	Elasticity (D Log)	1	1.08(0.1)	1.07(0.1)	1.08(0.1)	1.33(0.2)	1.32(0.2)	1.33(0.2)
		2	1.06(0.1)	1.01(0.1)	1.04(0.1)	1.31(0.2)	1.32(0.2)	1.32(0.2)
RF	Tone (Hz)	1	16.1(1.1)	16.1(1.2)	16.1(1.1)	16.2(1.8)	16.4(1.7)	16.3(1.7)
		2	15.5(0.9)	15.5(0.9)	15.5(0.9)	16.1(1.6)	16.2(1.6)	16.1(1.6)
	Stiffness (N/m)	1	288(23)	288(23)	288(23)	321(28)	323(29)	322(28)
		2	276(20)	276(20)	276(19)	317(26)	320(27)	318(26)
	Elasticity (Log)	1	1.38(0.2)	1.37(0.2)	1.38(0.2)	1.82(0.3)	1.79(0.3)	1.81(0.3)
		2	1.31(0.2)	1.29(0.2)	1.29(0.2)	1.72(0.4)	1.71(0.4)	1.69(0.4)

P = Parameter measured; M1 = Mean of first set of ten measurements; SD = Standard deviation; M2 = Mean of second set of ten measurements; TM = Total Mean; BB = Biceps Brachii; RF = Rectus Femoris; D Log = Logarithmic Decrement

Table 2 Intrarater reliability within the same session for both raters for each muscle in young and older males; intra-class correlation co-efficient ICC3,2 values for tone, stiffness and elasticity.

		Young Males (n=21)			Older Males (n=21)		
		Tone (F; Hz)	Stiff-ness (N/m)	Elastic-ity (D Log)	Tone (F; Hz)	Stiff-ness (N/m)	Elas-ticity (D Log)
BB	Rater 1	0.97	0.98	0.95	0.99	0.99	0.98
	Rater 2	0.99	0.99	0.94	0.99	0.99	0.99
RF	Rater 1	0.99	0.99	0.98	0.99	0.99	0.99
	Rater 2	0.99	0.99	0.99	0.99	0.98	0.99

F = Frequency (Hz); D Log = Logarithmic Decrement; BB = Biceps Brachii; RF = Rectus Femoris

as good for tone (0.67) and stiffness (0.68). Overall, across both muscles and groups, elasticity produced the most consistently robust results (ICC 0.78-0.95). The SEM values in Table 3 give an indication of the degree of variability in the units of measurement relevant to each measured parameter.

Mean differences and limits of agreement

The mean differences and limits of agreement for Bland and Altman plots (interrater reliability) are presented in Table 4. Notably, the mean differences in RF stiffness values between raters were high. Examples of Bland and Altman plots are given which showed good agreement between raters for elasticity (Figure 2) and variations between raters for tone measurement in older males showing three outliers (Figure 3).

DISCUSSION

The present study demonstrated excellent reliability by novice users of the MyotonPRO device for testing the tone, stiffness and elasticity of BB and RF, when measured by the same person within the same session. Interrater reliability was more variable, ranging from excellent to fair, and depended on the muscle studied, parameter measured and the age group of the participants. Rectus femoris in the young males showed excellent interrater reliability for all three parameters and results for BB in the older group were the least reliable. Greater absolute values for stiffness and lower elasticity (i.e. higher values of logarithmic decrement, as elasticity is inversely proportional to decrement) observed in RF and BB of the older participants indicated an influence of ageing. The higher elasticity (low decrement indicating lower dissipation of mechanical energy) seen in the muscles of the younger participants would indicate that their muscles were more economic in function. However, the small numbers involved in the present study cannot allow definitive conclusions to be drawn on the effects of ageing.

Reliability

In the current study within session measurement of tone, stiffness and elasticity using the MyotonPRO proved to be excellent according to criteria for ICC levels by Fleiss (2007) and clinically useful (ICCs

Table 3 Interrater reliability for each muscle in young and older males; intra-class correlation coefficients ICC3,1 between raters for tone, stiffness and elasticity.

		Tone (Frequency; Hz)			StiffnessN/m)			Elasticity (Decrement; Log)		
		ICC3,1	95% CI	SEM	ICC3,1	95%CI	SEM	ICC3,1	95%CI	SEM
Young males n=21	BB	0.84	0.64 - 0.93	0.05	0.94	0.86 - 0.98	6.59	0.78	0.53 - 0.90	0.05
	RF	0.93	0.84 - 0. 97	0.04	0.92	0.81 - 0.97	5.89	0.95	0.88 - 0.98	0.04
Older Males n=21	BB	0.67	0.34 – 0.85	0.07	0.68	0.36 - 0.85	15.3	0.89	0.74 - 0.95	0.07
	RF	0.94	0.86 - 0.98	0.13	0.93	0.84 - 0.97	7.16	0.86	0.69 - 0.94	0.13

CI = Confidence interval; SEM = Standard error of measurement; BB = Biceps Brachii; RF = Rectus Femoris

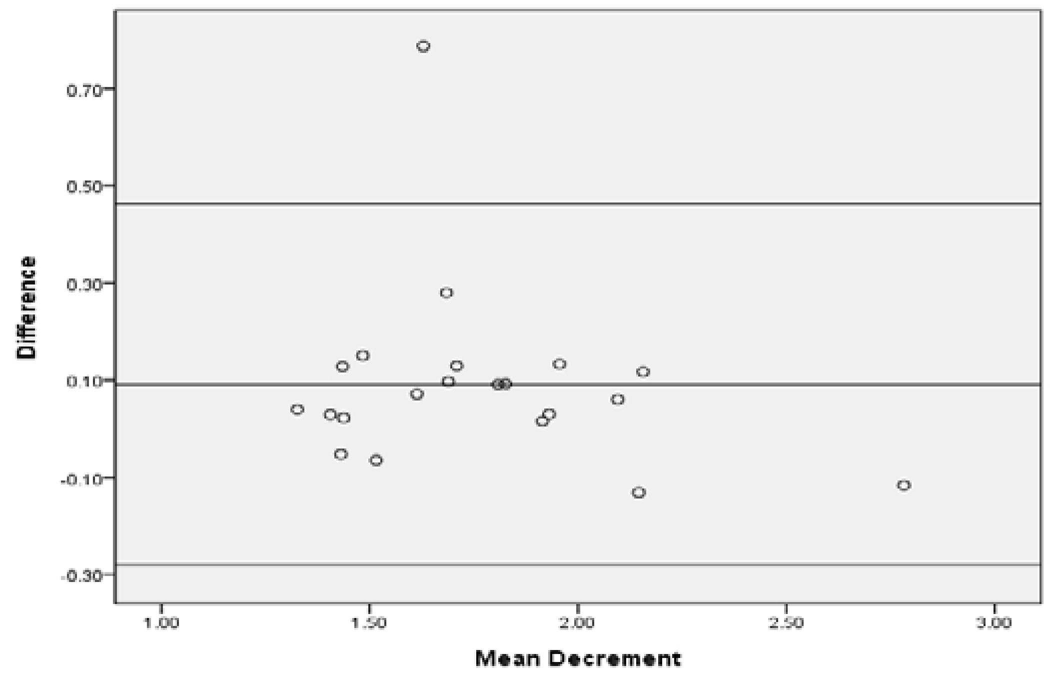

Figure 2 Bland and Altman plot showing agreement between raters for rectus femoris elasticity (logarithmic decrement) in older males with one outlier. The difference in values between raters is plotted against mean values for each participant. The middle line shows the mean difference (0.09). The 95% upper and lower limits of agreement represent 2 standard deviations above and below the mean difference.

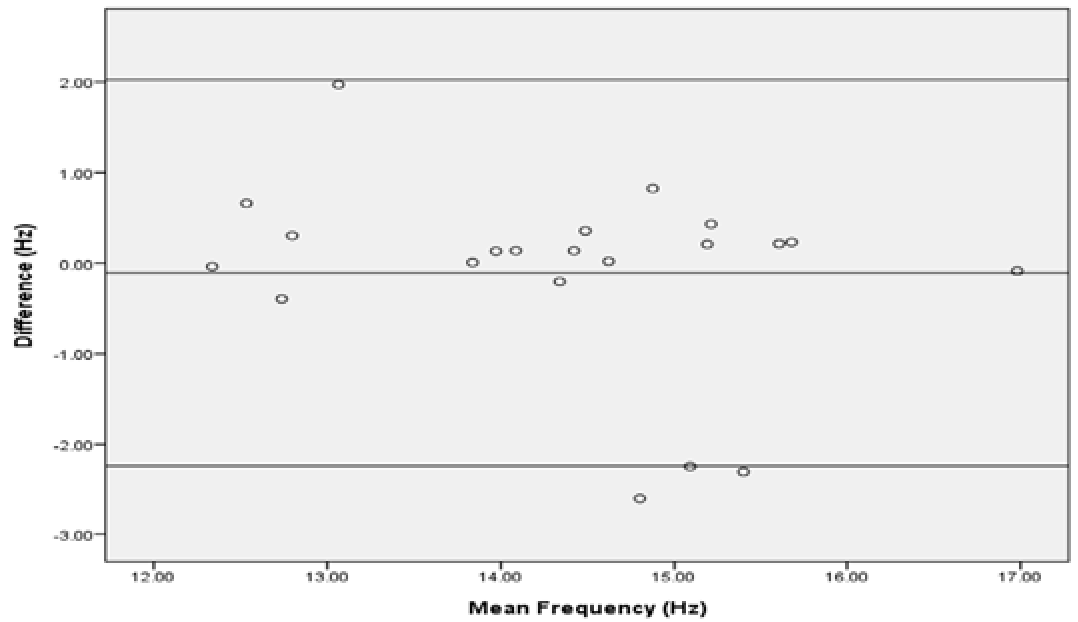

Figure 3 Bland and Altman plot showing agreement between raters for biceps brachii tone (frequency) in older males. The difference in tone values between raters is plotted against mean values for each participant. The middle line shows the mean difference (-0.11). The 95% upper and lower limits of agreement represent 2 standard deviations above and below the mean difference.

>0.9) according to Portney and Watkins (Portney and Watkins 2000). Interrater reliability for measuring all three parameters of the RF muscle was equally robust in younger males. For older males, all RF parameters were excellent, with tone and stiffness ICCs >0.9 and elasticity 0.86. Overall, logarithmic decrement, as an indication of muscle elasticity, which is its ability to recover its shape (Özkaya et al. 1999), demonstrated the most consistently robust reliability of the three parameters studied (ICCs 0.78-0.95), across the two muscles and age groups. It is worthy of note that despite tone and stiffness of BB measurements in older males demonstrating good interrater reliability (ICC 0.68 and 0.67 respectively), elasticity showed excellent reliability (0.89). Furthermore, all ICC values for RF

Table 4 Bland and Altman analysis between raters; mean differences and limits of agreement

Muscle	P	Young Males n=21			Older Males n=21		
		$\bar{d}$	UL	LL	$\bar{d}$	UL	LL
BB	Tone (Hz)	-0.1	0.83	-1.04	-0.11	2.02	-2.24
	Stiffness (N/m)	-2.65	15.9	-21.19	-1.09	42.39	-44.57
	Elasticity (Log)	0.04	0.19	-0.12	0.01	0.23	-0.22
RF	Tone (Hz)	0.6	1.38	-0.18	0.18	1.31	-0.95
	Stiffness (N/m)	11.55	28.45	-5.34	3.83	23.67	-16.0
	Elasticity (Log)	0.08	0.21	-0.06	0.09	0.46	-0.28

P = Parameter measured; $\bar{d}$ = Mean difference between raters; UL = Upper limit; LL = Lower limit BB = Biceps Brachii; RF = Rectus Femoris

in the older group were excellent, with both tone and stiffness >0.90 and elasticity 0.86, so reliability varied in specific situations.

Interrater reliability for tone of BB was excellent in the younger participants (ICC 0.84) and good in older participants (0.67). Difficulties were encountered by the raters when locating the BB test site in older participants, as the muscle was less well defined and the muscle belly was not always centrally located on the upper arm, often falling medially. The attempt to standardise the test site by measuring the distance between anatomical landmarks may not have been as reliable as the more subjective method recommended in the MyotonPRO users' manual, which instructs the user to identify the muscle belly by palpation during a low force contraction of biceps. The more subjective method was not considered appropriate for scientific use but, in fact, may prove to be more reproducible than the measurement method selected. Future studies are required to explore different methods of relocating the test site for improving the reliability of repeated measurements from BB that is not influenced by ageing. A compromise between objective and subjective methods of locating the test site may be needed, so that measurements are taken at the same longitudinal distance but palpation and visual inspection could be used during a slight contraction to locate the bulk of the muscle belly. The RF muscle on the other hand has more room for error and it would be helpful to quantify how far from the original testing site is permissible before inaccurate readings are obtained. Such a study is in progress in the authors' laboratory.

While the present findings suggest that measuring tone, stiffness and elasticity in asymptomatic participants using the MyotonPRO is more reliable between raters for RF than for BB, and in younger than older males, further studies are needed in other asymptomatic groups, clinical populations and muscles, as well as in females. Previous literature on interrater reliability of earlier Myoton prototypes is of interest for comparison with the present findings. In a study of 20 adult females; 5 healthy and 15 with musculoskeletal disorders (mean age 44.2±14.7 years), reliability of measuring tone, stiffness and elasticity of the relaxed trapezius muscle was assessed using the Myoton-2 device (Viir et al. 2006). They found excellent ICC values for tone (0.99), stiffness (0.99) and elasticity (0.97) (Viir et al. 2006). Bizzini and Mannion carried out similar reliability testing using Myoton-2 in lower limb muscles: vastus lateralis (VL), rectus femoris (RF) biceps femoris (BF), lateral gastrocnemius (LG) and medial gastrocnemius (MG), in 10 healthy adult males and females (mean age 40±13 years); their focus was, however, on muscle stiffness (Bizzini and Mannion 2003). They equally recorded excellent interrater reliability for RF (0.84-0.85), BF (0.80-0.91), LG (0.86-0.93) and MG (0.80-0.88) but for VL, the ICCs ranged from poor to excellent (0.40-0.93).

Generally, the previous studies above reported excellent reliability for muscles assessed within the same session, using earlier Myoton prototypes. The MyotonPRO also showed excellent within session reliability for all three parameters and has the potential to be a useful

tool for obtaining objective measurements of muscle tone, stiffness and elasticity. A key factor is to establish reliability of the operator between-days, as changes over time are used to monitor the effects of interventions. It is also necessary to know the amount of error in order to establish the degree of clinically important change. Intra-rater studies by the present group show acceptable reliability using the MyotonPRO, which vary for muscle and age (Aird et al. 2012; Bailey et al. 2013; Mooney et al. 2013; Mullix et al. 2012). Between-day reliability was better for quadriceps than biceps brachii and in young than older participants.

Absolute values for tone, stiffness and elasticity

Due to the small numbers of participants in the present study groups (n=21 young, n=21 older), the data for absolute values obtained by the same rater (Rater 1) are only used to indicate differences between muscles and age groups, which need to be confirmed in larger studies for statistical analysis. Muscle tone (frequency) varied little between participant groups and muscles studied. The range of tone values recorded for BB and RF in the healthy males were 14.29 (1.1) to 14.73 (0.8) Hz and 16.09 (1.2) to 16.36 (1.71) Hz respectively. Muscle stiffness, which is an indication of the muscle's ability to resist changes of its shape caused by an external force, appeared to be greater in older than younger participants for RF but not for BB. The absolute values recorded for stiffness were greater in RF than BB (Table 1). Similar values to those in the present study for RF stiffness were found using the Myoton-2 in 10 young participants (5 females and 5 males, aged 40±13 years), with mean stiffness of 268 (±31) N/m in the right quadriceps (Bizzini and Mannion 2003). In the current study, mean RF stiffness was 288 (±23) N/m and 322 (±28) for young and older males respectively. The large standard deviations in the data sets from the two studies, and the small participant numbers, indicate that these findings are similar between the two studies.

Muscle values of logarithmic decrement were relatively higher in the older males (indicating lower elasticity) for both RF and BB. In both muscles elasticity appeared to be greater in the young than the older participants (RF 1.4 ±0.2 and 1.8 ± 0.3; and BB 1.1 ± 0.1 and 1.3 ±0.2. As mentioned above, larger studies are required to establish age related changes in these parameters.

Limitations of the study

A limitation of the methodology that may have caused the lower reliability results in BB was the method of locating the testing site. Measuring multiple sites and ways of relocating them, particularly in older people, could be explored to determine the most reliable ways of locating the site for research purposes and clinical use. Muscle activity in the relaxed position was not assessed and instructing participants to relax and providing support for the limb in the testing position could have eliminated active contractions but does not rule this out as a potential confounding variable. This may be one of the reasons for variability in the measurements within or between raters and therefore could affect reliability. Future studies could use electromyography to objectively measure the state of the muscle rather than relying on participants to relax fully.

The number of participants was sufficient to examine reliability (n=20) but too small to allow definitive conclusions to be drawn about differences in parameters between the RF and BB muscles or changes with ageing but the findings indicate that larger studies are warranted to establish reference data for the different groups and muscles.

Potential clinical implications and future research

Further patient studies need to be conducted, particularly those presenting with neurological conditions, e.g. assessing tone in stroke (Chuang et al. 2012), Parkinson's disease (Rätsep and Asser 2011), and compared with normative data to help inform clinical decision making. Also the device could be used as an evaluation tool in musculoskeletal and neurological conditions to assess muscle disease and injury and effects of rehabilitation.

CONCLUSIONS

This present study confirms the interrater reliability of the MyotonPRO for objective assessment of skeletal muscle tone, stiffness and elasticity in the RF and BB muscles. The observed trend in absolute values forms the basis for larger studies to produce reference data and establish conclusive evidence of effects of ageing. Further research is needed to add to the existing literature to establish Myoton technology as a valid and reliable clinical research tool for examining the effects of injury, disease and interventions. Studies need to include various muscles in healthy groups with different levels of habitual physical and clinical populations, such as neurological and musculoskeletal conditions.

Conflict of interest statement

There were no conflicts of interest within the present study, which was conducted independently of the company providing the equipment (Myoton Ltd, London).

Key points

1. Different raters obtained acceptably similar results in rectus femoris demonstrating the potential for MyotonPRO to be used for objective assessment of mechanical muscle properties
2. Protocol for testing biceps brachii in older participants could be modified to improve reliability.
3. The MyotonPRO device could be used as an evaluation tool in musculoskeletal and neurological conditions to assess muscle disease and injury and effects of rehabilitation.
4. The observed trend in absolute values forms the basis for larger studies to produce reference data and establish conclusive evidence of effects of ageing.

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