Symmetry and within-session reliability of mechanical properties of biceps brachii muscles in healthy young adult males using the MyotonPRO device

Kate Mooney, Martin Warner, Maria Stokes

Abstract

Background: Objective measurement of muscle tone and mechanical properties is generally challenging in clinical or sports settings and can be obtained using a novel hand-held device (MyotonPRO). Between-side comparison of muscle function and characteristics can assess abnormalities if normal symmetry is known, which this study investigated for biceps brachii (BB).

Objectives: To examine between-side symmetry of mechanical muscle parameters and within-session intra-rater reliability of testing the BB muscle.

Design: Methodological, observational, intra-rater reliability study.

Participants: Convenience sample (n=21) of healthy males, aged 18-35 years.

Methods: The participant lay supine with the elbow in slight flexion (10-15 degrees). The MyotonPRO applied brief, low force mechanical impulses over BB muscle belly eliciting damped oscillations, from which non-neural tone (frequency; Hz), dynamic stiffness [N/m] and elasticity (logarithmic decrement) were calculated automatically. Two sets of 10 impulses were applied bilaterally by a novice user. Actual, absolute and percentage differences between sides were calculated to assess symmetry. Within-session reliability was assessed using intra-class correlation coefficients (ICC), standard error of measurement (SEM), and Bland and Altman analysis.

Results: Mean and standard deviation (±) absolute and percentage differences were 14±11N/m (6 ± 5%) for stiffness 0.6 ± 0.4Hz (4 ± 3%) for tone, and 0.08 ± 0.08 logarithmic decrement (7.5 ± 7%) for elasticity. Within-session reliability was excellent for all three parameters (ICC3,2>0.95). The SEMs were 2.3N/m (stiffness), 0.1Hz (tone); and 0.03 for decrement (elasticity).

Bland and Altman analysis showed minimal systematic bias between sets ($\bar{d}$ =-1.9N/m, -0.1Hz; and 0.05 decrement).

Conclusions: Between-side symmetry was high for all three mechanical parameters of BB in healthy young males, with differences of less than 10%, and could be used for assessing abnormality. Reliability was excellent for all three parameters measured within the same session. Robustness of repeating the testing protocol needs to be established between days, as well as reference values of symmetry produced for different muscles and cohorts.

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Keywords:
muscle tone, mechanical properties, symmetry, reliability

Introduction

Long-term repetitive overloading of the upper limb is a major factor in the development of overuse injuries in overhead sports (Weldon and Richardson, 2001; Borsa et al., 2008; Wassinger and Myers, 2011). The ability to detect subclinical muscle injury or early maladaptation would be very useful to alert the athlete, coach, trainer or physiotherapist, so that injury prevention strategies could be employed. However, detecting such subtle changes in muscles objectively is currently challenging in sport and clinical settings.

Recent availability of portable diagnostic devices, such as tensiomyography (TMG; Ditroilo et al, 2011), a stiffness meter (Myotonometer; Leonard et al., 2004) and Myoton technology (e.g. Gavronski et al, 2007), offers the opportunity to monitor muscle adaptations non-invasively by measuring muscle tone and mechanical properties. The different technologies have their relative advantages. Myoton devices lend themselves to field testing, as they are compact and hand-held, measure various parameters and do not need to be connected to a computer for data collection. Myoton technology applies brief mechanical impulses to induce damped oscillations of muscle from which various parameters can be calculated, such as non-neural tone and mechanical properties of stiffness and elasticity (e.g. Gavronski et al, 2007). Studies have used Myoton devices to identify muscular adaptations to acute and chronic exercise training (Vain and Kums, 2002; Janecki et al, 2011).

The contralateral side is often used clinically to assess abnormalities of the injured side (Roberts et al., 2011). Such comparison requires knowledge of the normal level of symmetry for a given characteristic. For example, muscles of the dominant limb are generally found to be stronger in healthy individuals in the general population, which is the right hand for the majority (Roberts et al., 2011). It cannot be assumed that mechanical properties of muscle will show the same effect of limb dominance as muscle strength. When investigating between side symmetry using Myoton devices, two studies found no significant difference in parameters between the right and left side irrespective of limb dominance (Viir et al, 2006; Gavronski et al, 2007). In a recent study examining differences in limb dominance of the quadriceps muscle in healthy elderly participants, no significant differences between the dominant and non-dominant side were found (Aird et al., 2012). Although these studies suggest that no differences were observed between sides, the calculations used to make these comparisons assumed that asymmetry would be specific to a given side (right or left) or limb dominance, as is usually the case for strength, as mentioned above. Reference values for the absolute level of symmetry need to be established for specific muscles and populations, to enable assessment of asymmetry to indicate abnormalities for clinical and research purposes.

Measurement tools used for assessment and monitoring need to be valid, reliable and sensitive to clinically meaningful change (Syczewska et al, 2009). In validation studies, Myoton devices have produced similar results to more well established laboratory based diagnostic methods, such as electromyography and intramuscular pressure measurements) for quantifying muscle characteristics (Korhonen et al, 2005; Ditroilo et al, 2011). When compared with TMG, which elicits muscle oscillations by electrical stimulation, for measuring muscle contraction time and displacement, the Myoton device was found to be more reliable on repeated testing and more valid than TMG for detecting changes in muscle parameters at different muscle lengths (Ditroilo et al, 2011). Reliability of using prototypes of Myoton devices has generally been good and varied with the muscle studied (Bizzini and Mannion, 2003; Viir et al, 2006; Ditroilo et al, 2011; Janecki et al, 2011). Initial findings using the latest Myoton device (MyotonPRO), have indicated that reliability good reliability for rextus femoris in healthy young (Mullix et al 2012) and older (Aird et al 2012) people.

Myotonhand-held devices offer an objective, cost-effective method of detecting changes in muscle characteristics to aid assessment and monitoring of the health status of muscle in disease (Chuang et al, 2012) and with training (Janecki et al, 2011). The present study aimed to examine symmetry of in the BB muscle to determine whether arm dominance has an effect on mechanical properties in healthy young adult males, and to evaluate the intra-rater within-session reliability of using the MyotonPRO device.

Methodology

The design of this study was a methodological, observational, intra-rater reliability study.

Participants

Healthy young adult male participants (n=21) were recruited through poster advertising on the University of Southampton campus. For assessing symmetry, a sample of convenience was used and the sample size was based on recommendations of 20 participants as the minimum required for a reliability study (Atkinson and Nevill, 2001). Inclusion required that participants were male, aged ≥18 to ≤35 years to represent a young population, and right hand-dominant as determined by the Edinburgh Handedness Inventory (Oldfield, 1971). Exclusion criteria were conditions or medications known to affect muscle tone or injuries severe enough to require treatment or prevent activity for more than one week in the previous five years; body mass index (BMI) > 30 kg/m^2, so that measurement of the mechanical parameters of the muscle are not affected by excessive subcutaneous tissue (Gapeyva and Vain, 2008); participating in physical activity above average levels (at a vigorous intensity more than three times per week) (CDC, 2011). The study was approved by the Faculty of Health Sciences, University of Southampton Ethics Committee (FoHS-ETHICS-2011-049). All participants provided written consent before participating in the study.

Equipment

The MyotonPRO (Myoton Ltd, London and Myoton AS, Estonia) is a hand-held device designed to measure tone and mechanical properties of muscles. The tip of the probe (or testing end; 3mm diameter) is applied to the skin perpendicular to its surface over the muscle being tested at a constant pre-load (0.18 Newtons) to pre-compress subcutaneous tissues. An automatic system triggers a short electromagnetic impulse with constant force (0.4 Newtons) that is transmitted to the tissue, applying a brief mechanical impulse (15 milliseconds) with quick release (http://www.myoton.com/en/Technology/Technical-specification). The impulse causes elastic deformation to the muscle tissues, eliciting natural damped oscillations, which are recorded by the accelerometer at the other end of the probe. The device performs simultaneous computation of the tissue parameters, including its state of non-neural tension or tone (frequency; Hz), and mechanical properties of stiffness (N/m), indicating the ability to resist force that modifies its shape, and elasticity (logarithmic decrement), indicating the muscle's ability to recover its shape after being deformed (Figure 1). Frequency is defined as the maximum frequency ($F=f_{max}$) computed from the signal spectrum by Fast Fourier Transform (FFT). The higher the frequency of the dampened oscillations (natural oscillation frequency), the higher the tone (intrinsic state of resting tension without voluntary contraction). Frequency is known to increase with contraction (state of tension) and stretch (Viir et al, 2006; Gavronski et al, 2007). Stiffness is calculated as $S = m_{probe}\left(\frac{a_{max}}{\Delta l}\right)$ and the higher the N/m value, the stiffer the muscle is (Viir et al, 2006). Elasticity, characterised by logarithmic decrement of the dampened oscillations, is expressed in arbitrary units $\left[\theta = ln\left(\frac{a_1}{a_3}\right)\right]$ and indicates how much mechanical energy is lost in the tissue during a single oscillation cycle. The smaller the value for decrement, the smaller the dissipation of mechanical energy and higher the elasticity of a tissue (Viir et al, 2006). Decrement of zero would represent absolute elasticity and zero dissipation of mechanical energy.

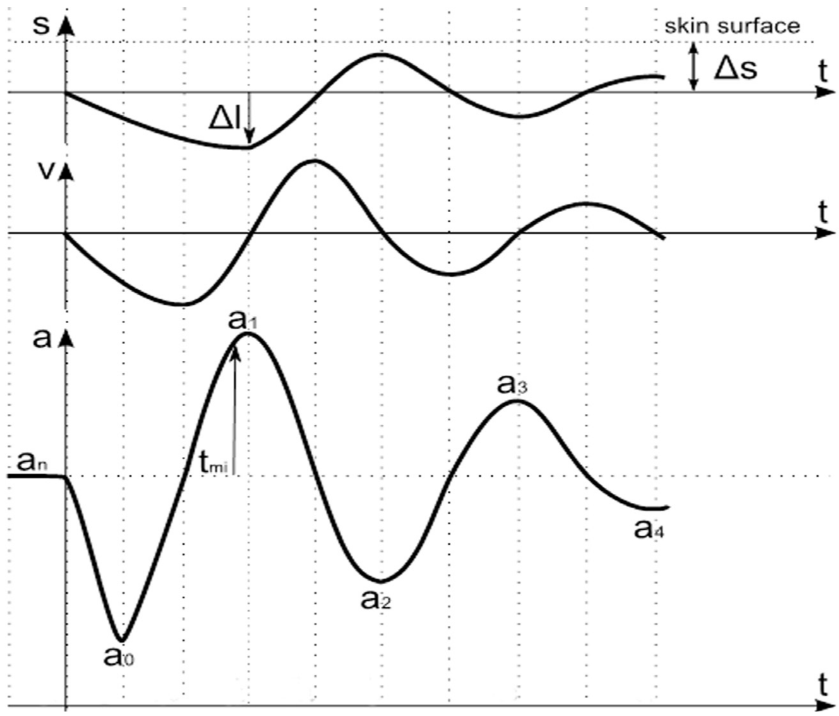

Figure 1

Waveforms illustrating muscle oscillation and its relative displacement (S), velocity (V) and acceleration (a). The mechanical impulse elicits a damped oscillation of muscle, causing co-oscillation of: the pre-compressed subcutaneous tissue; the probe; measurement mechanism; and accelerometer attached to the measurement mechanism. (Diagram provided courtesy of Myoton AS, Estonia.)

Key to symbols

ΔS Pre-compression of subcutaneous tissues above muscle being measured
Δl Maximum displacement of the tissue
S Displacement ; tissue oscillation (mm)
V Oscillation velocity (m/s)
a Acceleration of oscillation (mG)
t Time (ms)
a0 Maximum acceleration
t_{mi} End of mechanical impulse
a1 Maximum acceleration representing the maximum displacement of the tissue i.e. maximum tissue resistance measured in mG
a2 Maximum acceleration at the point of opposite displacement due to residual inertia of the tissue oscillation
a3 Maximum acceleration of the second period of oscillation, which takes place due to recuperation of stored residual mechanical energy in the tissue

Data collection procedure

Participants were asked to refrain from alcohol for ≥ 24 hours and avoid strenuous physical activity for ≥48 hours prior to testing, as both are known to affect muscle properties. Data were collected during one session by one investigator (KM), a physiotherapy student, who was a novice user of the MyotonPRO and underwent four hours of training with an expert from the Myoton company (Estonia). Independent practice was undertaken for a further four hours.

Participants lay on a plinth for 10minutes prior to data collection to aid relaxation and normalisation of muscle state. Measurements were recorded with the participant lying supine with their arms by their sides and forearms in mid-position between supination and pronation. A towel was placed under the wrist to slightly flex the elbow (10-15 degrees) to eliminate tension due to stretching BB. The test site was defined as 75% of the distance, distally, from the anterior aspect of the lateral acromion to the mid-cubital fossa and was located using a measuring tape and marked on the skin with a non-toxic marker. This test site was chosen to standardise the procedure of locating a reproducible site over the BB muscle belly. However, in some cases, the line used to locate the distance of 75% did not always intersect the middle of the muscle belly, in which case the testing site was marked medially or laterally of the line to be over the muscle belly. Recordings were only made at the adjusted position over the muscle belly, so no comparison was made. The device was held perpendicular to the skin surface and the tip of the probe placed on the testing site (Figure 2).

The device was set in the multi-scan mode, which consists of 10 mechanical impulses, one second apart, giving a mean, standard deviation and coefficient of variation (CV) for the 10 measurements, i.e. one measurement set (Gavronski et al, 2007). The participant was asked to relax. Two consecutive sets of 10 measurements were taken and the mean of the two sets was used for analysis of symmetry. The same procedure was performed on the right and left BB muscles. If the CV of a set exceeded 3%, as displayed on the device's screen, the set was erased and re-measured. This aimed to increase measurement consistency and stability on the part of the investigator, e.g. due to the sliding of the probe on the measurement surface during recording.

Figure 2

Recording of mechanical properties over biceps brachii muscle belly using the MyotonPRO

Statistical analysis

Data were downloaded from the MyotonPRO device into an Excel database and statistical analysis was performed using SPSS 19.0 (SPSS, Inc., Chicago, IL, USA).Normality of data was examined using Shapiro-Wilk's test. Means and standard deviations (SD) were calculated for each measurement set. The α significance level was set at 0.05. Right BB measurements were used for reliability analysis.

Descriptive statistics (mean, standard deviation, SD, and range) were calculated bilaterally for each parameter. A paired sample t-test determined the level of statistical significance between the two sides, as the data were normally distributed. The mean of the dominant (right) BB was compared to the mean of the non-dominant BB. The actual difference (non-dominant subtracted from dominant side), absolute difference (non-negative value of the actual difference) and percentage differences (absolute difference divided by the average of dominant and non-dominant value multiplied by 100) between limbs were calculated to assess symmetry. To examine whether true differences between sides were masked in the analysis considering dominance, the limb with the largest value was compared to the limb with the smallest value for each parameter. Paired t-tests were used to examine differences between sides for both types of comparison (dominant versus non-dominant and larger versus smaller), to examine whether the former was appropriate and did not mask true differences within the group mean data.

The association between repeated measurement sets was analysed using intra-class correlation coefficients (ICC) for each parameter, using an average measures ICC (3,2) model. Various classification scales exist for interpreting level of reliability from ICCs and the one used in the present study is from Fleiss (2007): Excellent ICC > 0.75; Good to Fair = 0.74–0.4; Poor < 0.4.

Standard error of measurement (SEM = SDxV1-ICC, where SD is the standard deviation and ICC the reliability coefficient) were calculated to provide an estimate of the error in the units of measurement, thus giving clinically relevant values for expected error in an individual (Portney and Watkins, 2000). Bland-Altman plots (Bland and Altman, 1986) were used to display graphically the variability and systematic bias between two measurement sets; the 95% limits of agreement (LOAs) evaluated the level of agreement between data sets (mean difference ± 1.96 SD of the difference).

Results

Participant demographics

Twenty-one participants completed the study and their demographic details are presented in Table 1.

Table 1.

Participant Demographics

n=21			
	Mean	SD	Range
Age (years)	25.8	4.1	20-35
Height (cm)	1.8	0.1	165-193
Weight (kg)	76.2	10.9	60-99
BMI (kg/m^2)	23.9	2.5	19.2-29.4

Within-session reliability

Reliability of repeated measures within the same session were classified (Fleiss, 2007) as excellent, with ICC 3,2 values of 0.99 for tone and stiffness and 0.95 for elasticity (Table 2). Bland-Altman analysis showed minimal systematic bias between sets for tone ($\bar{d}$ = -0.1Hz), stiffness ($\bar{d}$ =-1.9N/m) and elasticity ($\bar{d}$ =0.05 log decrement); which is illustrated graphically in Figure 3. Narrow LOA indicated high levels of agreement between the two data sets for each parameter (Table 2).

Table 2

Intra-rater reliability of within-session measurements of right biceps brachii. Descriptive values (mean and standard deviation) and estimates of relative reliability (ICC 3,2 and 95% CI) and absolute reliability (SEM; Bland & Altman analysis, and LOA).

Within-Session: between set 1 and set 2 (ICC 3,2).								
	Mean (SD)						LOA	
	Set 1	Set 2	ICC	95% CI	SEM	$\bar{d}$	Upper	Lower
Frequency (Hz)	14.8 (0.9)	14.9 (0.9)	0.99	(0.97-0.99)	0.1	-0.1	0.3	-0.5
Decrement	1.06 (0.12)	1.01 (0.10)	0.95	(0.87-0.98)	0.03	0.05	0.15	-0.06
Stiffness (N/m)	225.2 (28.0)	227.1 (27.0)	0.99	(0.97-1.0)	2.3	-1.9	7.2	-11

SD= Standard Deviation, ICC= Intraclass Correlation Coefficient, 95% CI= 95% Confidence intervals of ICC, SEM= Standard error of measurement, = mean difference between sets, LOA = Limits of Agreement (Lower limit, Upper limit)

Symmetry between sides

Descriptive statistics (mean and standard deviation) of the mechanical parameters (Fig 4) and differences between parameters for the two limbs are shown in Table 3. When the dominant and non-dominant sides were compared, the actual mean differences were 0.47N/m, 0.06Hz, and 0.00 log decrement for stiffness, tone and elasticity respectively and the percentage differences were all <1% (Table 3). Paired t-tests revealed no significant difference between sides (dominant vs. non-dominant) for any of the parameters; tone (p=0.731), stiffness (p=0.909) or elasticity (p=0.971). The absolute differences between sides were greater than the actual differences seen when considering limb dominance; 14.4N/m, 0.63HZand 0.08 for stiffness, frequency and decrement respectively (Figures 3a-c), which accounted for a 4%, 6% and 8% difference between sides (Table 3). When comparing the limb showing the larger value with the limb showing the smaller value (i.e. absolute difference) there was a significant difference between sides (p<0.001). Actual differences between-sides were within the SEM values from the reliability results for all three parameters but absolute differences were not (Tables 2 & 3).

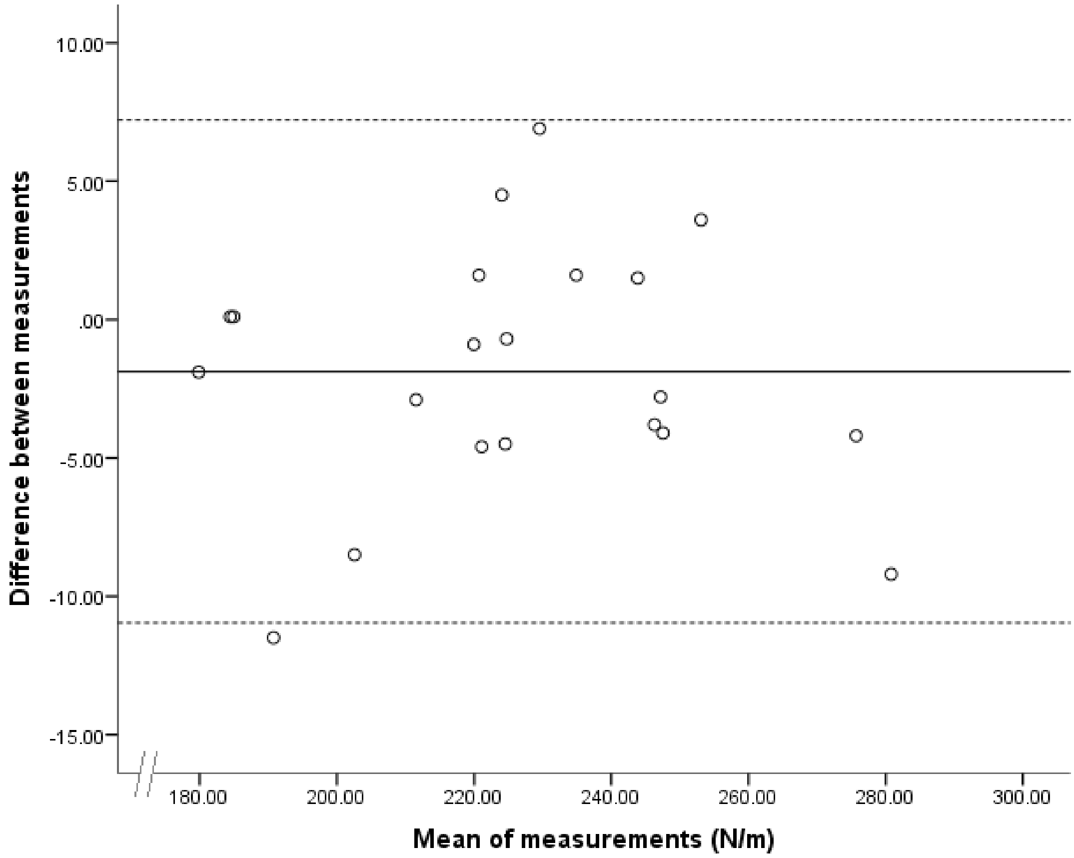

Figure 3

Bland & Altman plot illustrating level of agreement between the first and second set of measurements for stiffness on the dominant side. Mean difference shown as solid line, upper and lower limits of agreement shown as dotted lines. NB the magnitude of units of measurement (N/m) differs on the two axes, making the differences in values (y axis) appear large, relative to the x axis.

Table 3

Symmetry of parameters between sides, showing descriptive data (mean and standard deviation) for the mechanical parameters of tone, stiffness and elasticity. Differences are shown between dominant versus non-dominant, and side of larger versus smaller values for biceps brachii in healthy right-handed young males

Dominant vs non-dominant analysis						
	Tone (Frequency; Hz)		Stiffness (N/m)		Elasticity (Log Decrement)	
	D	ND	D	ND	D	ND
Mean (SD)	14.8 (0.8)	14.7 (0.8)	225.7 (27.3)	226.2 (21.3)	1.04 (0.11)	1.12 (0.05)
Range	13.1-16.4	13.3-16.0	179.9-280.8	187.7-260.0	0.83-1.26	1.02-1.21
p value	p = 0.731		p = 0.909		p= 0.971	
Actual difference	0.06 (0.76)		0.47 (18.48)		0.00 (0.12)	
Range	-1.14 – 1.49		-33.05 – 33.85		-0.35 – 0.23	
Absolute difference	0.63 (0.42)		14.4 (11.2)		0.08 (0.08)	
Range	0.03 – 1.49		0.25 – 33.85		0.00 – 0.35	
% Difference						
Actual	0.4% (5.2)		-0.5% (8.1)		-0.03% (10.4)	
Range	-7.9 – 9.8		-16.8 – 14.8		-28.5 – 20.4	
Absolute	4.3 (2.8)		6.3 (5.0)		7.5 (7.0)	
Range	0.2 – 9.8		0.1 – 16.8		0.4 – 28.5	
Larger vs smaller value analysis						
	Tone (Frequency; Hz)		Stiffness (N/m)		Elasticity (Log Decrement)	
	L	S	L	S	L	S
Mean (SD)	15.1 (0.8)	14.5 (0.7)	233.1 (25.2)	218.7 (22.8)	1.08 (0.13)	1.0 (0.1)
Range	13.6-16.4	13.1-15.6	184.7-280.8	179.9-253.1	0.89-1.40	0.83-1.15
p value[a]	p < 0.001		p < 0.001		p < 0.001	
For the mean differences for the largest vs. smallest analysis please see the absolute difference and percentage difference values for the dominance analysis above.						

D, Dominant side; ND, Non-dominant side; L, side on which largest values were found;
S, smallest values. [a]Significance level p< 0.05. Standard deviation in parenthesis.
Actual difference = non-dominant subtracted from dominant side
Absolute difference = non-negative value of the actual difference (i.e. larger vs smaller value)

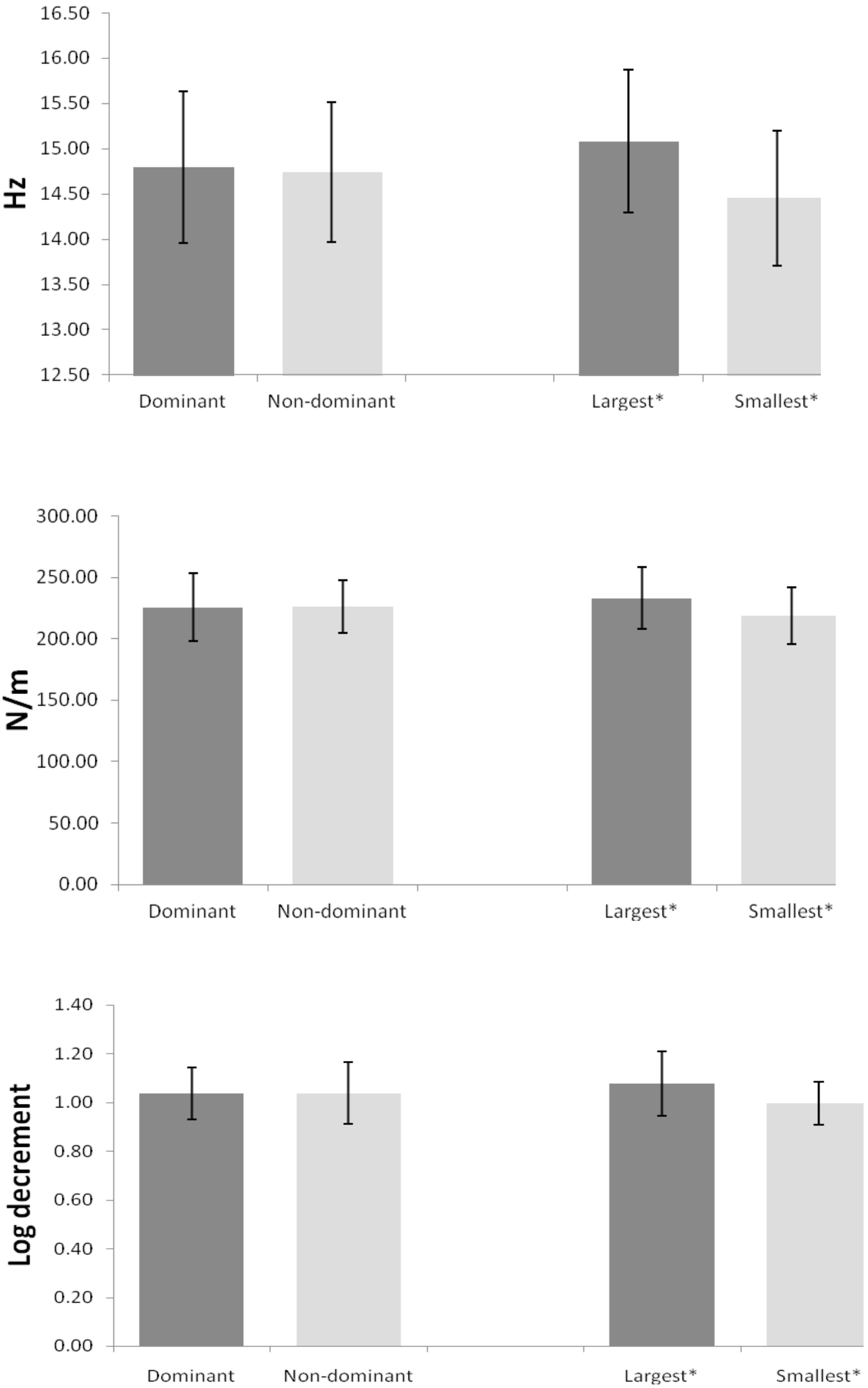

Figure 4

Symmetry of muscle tone and mechanical properties recorded over biceps brachii using the MyotonPRO, analysed according to dominant and non-dominant side (actual difference), and absolute difference between side of the largest and smallest values for non-neural tone (Hz; top panel); stiffness (N/m; middle panel); and elasticity (log decrement; lower panel). * Significant difference p<0.001

Discussion

The present results have demonstrated symmetry and within-session intra-rater reliability of measuring tone and mechanical properties of BB using the MyotonPRO in a group of healthy young males. Symmetry was not determined by limb dominance and the method of comparing values between sides influenced the level of symmetry found. The higher degrees of symmetry seen when analysed using limb dominance (actual difference) than comparing sides in terms of larger versus smaller values (absolute difference) were still all <10%, indicating the potential use of using asymmetry of Myoton parameters as a measure of abnormality, although this threshold of 10% needs to be confirmed in a larger sample and its clinical relevance determined. Intra-rater reliability of a novice user was excellent (ICC 3,2 >0.95) within the same session.

Symmetry reported in earlier studies, which found non-significant differences between sides, did not consider absolute differences, so may have overestimated the level of symmetry. For example, eight different muscles were studied in five junior triathletes using the Myoton-2, and comparison between the right and left sides of the body were not significant (Gavronski et al, 2007). Trapezius muscles parameters were tested using the Myoton-2 in 20 healthy females (aged 44.2, SD 14.7) compared right and left sides (Viir et al., 2006). Percentage differences were not reported in either of these earlier studies to enable comparison with the present findings. Actual differences between the dominant and non-dominant rectus femoris muscles in healthy older males were <2% for all parameters using the MyotonPRO (Aird et al. 2012), which were similar to the actual differences of <1% found in the present study (Table 3) and masked the larger differences seen for absolute symmetry (4-8%). Gapeyva and Vain (2008) suggested that differences between sides of up to 5% can be considered normal but such guidelines need to be based on reference data for absolute differences observed for specific muscles and cohorts.

Muscles of the dominant limb are generally found to be stronger than on the non-dominant side (Roberts et al., 2011) but in some sporting activities the association between limb dominance and strength is reversed. For example, in right handed professional golfers, left handgrip is stronger than the right (Barnes & Adams, 2008), presumably due to the nature of the golfing technique. It would be interesting to observe whether Myoton parameters have a similar bias between sides in golfers, suggesting an effect of habitual training. Such bias would be consistent with anecdotal observations using Myoton technology in highly trained athletes, which demonstrate greater stiffness in the primary muscles used in specific sports, e.g. quadriceps in cyclists (A Piepsi, by personal communication, included with permission). Unlike strength characteristics, the present results were not biased towards greater values being on the dominant side (Roberts et al, 2011), stressing the importance of using absolute differences for Myoton reference data against which to assess symmetry in individuals.

The excellent reliability found by a novice user within the same session (ICCs 3,2> 0.95) is consistent with the two other reliability studies of rectus femoris using the MyotonPRO published to date, in young (Mullix et al., 2012) and older (Aird et al., 2012) healthy males. A study of BB using the Myoton-3 also found a similar level of within-session reliability with an ICC of 0.92 (Janecki et al, 2011). The present Bland and Altman results showed minimal systematic bias for all three parameters, indicating good agreement between the two sets of 10 measures. Reliability between days is important for monitoring changes over time, so needs to be established using standardised testing protocols. Inter-rater reliability also needs to be established. Reliability of both applying the Myoton technique and locating the testing site need to be examined.

Another way of assessing abnormality rather than symmetry is to compare values from an individual with reference values from a comparative group of participants. The present study is the first to provide normative values for (non-neural) tone, stiffness and elasticity of the BB muscle in healthy young males using the MyotonPRO. The present values for stiffness (approx 226 N/m) were very similar to those in a previous study of BB in 14 healthy young (aged 22±2 years) right handed males using the Myoton-3 device (Janecki et al 2011), which reported mean resting stiffness of 223 N/m and did not report other parameters. The testing site was not located as precisely as in the present study and was described as being placed on the skin “overlying the central part of the biceps brachii”. This consistency in stiffness values reported between studies in different laboratories (earlier study in Poland), is encouraging.

Limitations must be considered when interpreting the present results. The level of symmetry documented between-sides for the BB muscles is only representative of the small group of healthy young males studied who were moderately active and may vary for males of different ages and levels of habitual activity (e.g. sedentary or in elite sports), as well as females and different muscles, all of which need to be studied. The present study was designed to be easily replicated in clinical and sports settings by using a measuring tape to locate the test site and towels to support the arm. Stricter control methods e.g. standardising elbow flexion angle using a goniometer, using muscle templates to mark testing site etc, may decrease measurement error of repeated measurements, particularly in later studies over different sessions. The method of locating the testing site in the present study was not always adhered to, as described above, when the line did not intersect the muscle belly. Since no comparison was made between the prescribed and adjusted locations, it is not known whether these would have differed and this could be explored in a future study. Our reliability estimates are specific to the context in which they were tested and cannot be generalised to other muscles, populations or raters.

Conclusions

Symmetry of mechanical parameters for the BB muscle in healthy young males were 4% for tone, 6% for stiffness and 8% for elasticity. Unlike muscle strength, the side of the greater value was not determined by limb dominance and the method of comparing values between sides influenced the level of symmetry found, so calculation of absolute rather than actual differences is recommended to reflect true symmetry. The findings indicate the potential for using asymmetry of Myoton parameters of >10% as a measure of abnormality for BB in young males but this threshold needs to be confirmed in larger numbers of participants and cannot be generalised to other muscles or participant groups. A novice user achieved excellent intra-rater reliability within the same session for all three parameters tested.Further research is warranted to determine the ability of the MyotonPRO to establish normal symmetry and variability within age, gender and sport-specific participant groups.

Key Points

- Normal between-side symmetry was below 10% for parameters measured with the MyotonPRO (non-neural muscle tone and mechanical properties) in BB muscle in a group of moderately active healthy young males
- This level of normal symmetry has the potential for measuring asymmetry to assess abnormalities of muscle parameters
- It is recommended that the absolute difference is used to calculate between-side difference for group mean data, rather than actual difference determined by limb dominance or side.

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