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# Measurement of ageing effects on muscle tone and mechanical properties of rectus femoris and biceps brachii in healthy males and females using a novel hand-held myometric device

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ABSTRACT

*Background:* Age and gender effects on muscle tone and mechanical properties have not been studied using hand-held myometric technology. Monitoring changes in muscle properties with ageing in community settings may provide a valuable assessment tool for detecting those at risk of premature decline and sarcopenia.
*Objective:* This study aimed to provide objective data on the effects of ageing and gender on muscle tone and mechanical properties of quadriceps (rectus femoris) and biceps brachii muscles.
*Methods:* In a comparative study of 123 healthy males and females (aged 18–90 years; $n = 61$ aged 18–35; $n = 62$ aged 65–90) muscle tone, elasticity and stiffness were measured using the MyotonPRO device.
*Results:* Stiffness was greater and elasticity lower in older adults for BB and RF ($p < 0.001$). Tone was significantly greater in older adults for BB but not for RF when data for males and females were combined ($p = 0.28$). There were no gender differences for BB in either age group. In RF, males had greater stiffness (young males 292 vs females 233 N/m; older males 328 vs females 311 N/m) and tone (young 16.4 vs 13.6 Hz; older 16.7 vs 14.9 Hz). Elasticity in RF was lower in young males than females but did not differ between the older groups (both males and females log decrement 1.6).
*Conclusions:* Stiffness and tone increased with ageing and elasticity decreased. These findings have implications for detecting frailty using a novel biomarker. Age and gender differences are important to consider when assessing effects of pathological conditions on muscle properties in older people.


## 1. Introduction

Muscle strength is the most commonly used biomarker of musculoskeletal ageing and frailty (Sayer et al., 2006; Cooper et al., 2011b). However, strength measurements are not always feasible in older people due to e.g. pain from arthritis or impaired cognitive function from dementia. Tools for assessing muscle health are needed, that are not influenced by pain or cognition.

Sarcopenia, the age-associated loss of skeletal muscle mass and strength (Cruz-Jentoft et al., 2010; Rosenberg, 2011), is present when muscle mass decreases to a level less than expected for a specified age, gender and race (Baumgartner & Waters, 2006). Women have lower muscle mass and strength than age-matched males (Narici & Maffulli, 2010) but greater fatigue resistance (Wüst, Morse, De Haan, Jones, & Degens, 2008). These differences in functional capacity with age and gender reflect differences in muscle fibre-type composition. There is preferential loss of type 2 (fast twitch) fibres with ageing, which are predominantly distributed around the periphery of muscle fascicles (Manta, Kalfakis, Kararizou, Vassilopoulos, & Papageorgiou, 1995). Type 1 fibres do not change significantly with ageing (Kararizou, Manta, Kalfakis, & Vassilopoulos, 2009). Type 2 fibres have greater intrinsic strength and type 1 fibres are characteristic of endurance and slower contraction rate (Wüst et al., 2008).

Tone and mechanical properties of muscles (Blanpied & Smidt, 1993) and tendons (Scaglioni, Narici, Maffiuletti, Pensini, & Martin, 2003) change with ageing and are also altered in neurological conditions, such as stroke and Parkinson's disease (PD). Muscle tensile stiffness increases with ageing, as demonstrated using the resistance to a single stretch (Blanpied & Smidt, 1993) and sheer wave elastography (Eby et al., 2015). Stiffness is also reported to

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**Table 1**
Participant characteristics (total $n = 123$).

| | Young males ($n = 34$) | Young females ($n = 27$) | Older males ($n = 28$) | Older females ($n = 34$) |
|---|---|---|---|---|
| Age (years) | 24.5 ± 4.7 | 26.8 ± 4.7 | 74.2 ± 5.9 | 76.1 ± 6.4 |
| Height (m) | 1.8 ± 0.1 | 1.6 ± 0.1 | 1.7 ± 0.1 | 1.6 ± 0.1 |
| Weight (kg) | 72.6 ± 10 | 59.6 ± 7.8 | 78.4 ± 10.4 | 65.5 ± 8.7 |
| Body mass index (kg/m$^2$) | 23.2 ± 2.5 | 22.9 ± 2.7 | 25.9 ± 2.9 | 25.6 ± 2.7 |

increase with hypertrophy due to strength training (Kubo, Ikebukuro, Yata, Tsunoda, & Kanehisa, 2010) and with increasing muscle activation (Blanpied & Smidt, 1993). Gender differences in muscle stiffness measured using different laboratory based technologies are conflicting in the literature. For example, greater stiffness in males than females was found using the free oscillation technique (Wang, De Vito, Ditroilo, Fong, & Delahunt, 2015), which might be expected with greater strength in males. However, sheer wave elastography demonstrated greater stiffness in females (Eby et al., 2015). Differences may be due to methods used and muscles studied.

It is important to be able to distinguish the underlying effects of ageing from the specific effects of pathology when tone and mechanical properties are assessed in clinical conditions, such as musculoskeletal and neurological disorders. Clinical assessment of tone is subjective, using manual assessment by rating resistance to passive movement on scales such as the Modified Ashworth Scale (MAS) for stroke (Fleuren et al., 2010) and the Unified Parkinson's disease Rating Scale (UPDRS) for PD (Goetz et al., 2003). Laboratory techniques for assessing tone and mechanical properties objectively, such as ultrasound imaging with dynamometry (Narici et al., 1996; Muraoka, Chino, Muramatsu, Fukunaga, & Kanehisa, 2005) and magnetic resonance elastography (Dresner et al., 2001) are not clinically feasible. There is the need for objective, reliable, valid, robust, easy to use and cost effective ways of assessing skeletal muscle tone and mechanical properties in a clinical setting. Components of muscle tone at rest can be classified as neural or non-neural (intrinsic); neural aspects comprise active muscle tension and stretch reflex contractions, while non-neural components comprise passive stiffness and the inherent viscoelastic properties of the tissues (Britton, 2004).

Myoton technology (Myoton AS, Estonia) offers an in-vivo, non-invasive measurement of state of tension (non-neural tone) and mechanical properties of individual skeletal muscles, with the added advantage of portability and relatively low cost (Gavronski, Veraksits, Vasar, & Maaroos, 2007). It is necessary to establish normative data using the Myoton device to provide reference values for future assessment of skeletal muscle with ageing and in clinical conditions, as studies have indicated the potential use of Myoton technology to aid diagnosis and management of increased mechanical tone and stiffness in stroke (Chuang, Wu, & Lin, 2012) and PD (Rätsep & Asser, 2011; Marusiak, Jaskólska, Koszewicz, Budrewicz, & Jaskólski, 2012).

The aim of the present study was to establish normative data for resting stiffness, tone and elasticity, and identify age and gender differences in rectus femoris (RF) and biceps brachii (BB) muscles using the MyotonPRO device. It was hypothesised that muscle stiffness and tone would increase, and elasticity decrease, with ageing. Stiffness and tone would also be greater, and elasticity lower, in males than females.

## 2. Materials and methods

### 2.1. Participants

A convenience sample of 123 self-reported healthy participants were studied in four groups: young and older males and females (61 young; aged 18–35 years, recruited from the University, and 62 older participants; aged 65–90 years, recruited from the local community (see Table 1).

Young participants were included if they did not participate in sports or 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 (Washburn et al., 1993) to ensure only sedentary or moderately active participants were included.

Exclusion criteria for both age groups were: conditions known to affect muscle characteristics and functional ability; upper and lower limb pathology (fracture, surgery, neoplasm), skin disorder, neurological conditions and musculoskeletal injuries severe enough to require treatment or prevent activity for more than one week in the previous five years. Those taking medications, such as skeletal muscle relaxants, neuromuscular blocking drugs and those unable to understand study requirements were excluded. The study was approved by the Faculty of Health Sciences, University of Southampton Ethics Committee and was conducted in accordance with the Helsinki Declaration of 1975. All participants gave their written informed consent.

### 2.2. Experimental set-up

Participants were tested in supine lying for both muscles and lay relaxed for 10 min prior to testing (Bailey, Samuel, Warner, & Stokes, 2013). For BB, the participant lay supine with the shoulder externally rotated and elbows extended and wrist supinated. A rolled towel placed under the wrist to flex the elbow approximately 15° from the horizontal to take the stretch off the muscle and enable relaxation (Aarrestad, Williams, Fehrer, Mikhailenok, & Leonard, 2004). Measurements were taken at a point midway between the most anterior aspect of the lateral tip of the acromion and the mid cubbital fossa, following a gentle, resisted isometric muscle contraction to identify the middle of the muscle belly (Fig. 1). Rectus femoris measurement was achieved with the knee extended and hip in neutral, with sandbags placed either side of the ankle to maintain this position (Fig. 2). Measurements were

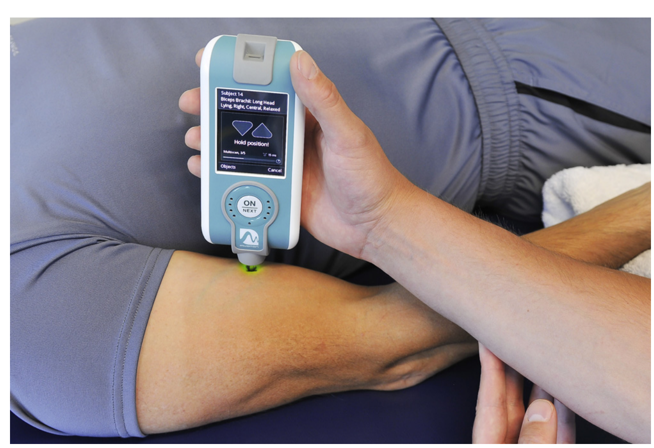


**Fig. 1.** MyotonPRO technique for measurement of biceps brachii (BB) stiffness, tone and elasticity.