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ORIGINAL ARTICLE

The effect of sex and localised fatigue on triceps surae musculoarticular stiffness

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Abstract

Purpose: The main purpose of this study was to investigate the influence of fatigue on musculoarticular stiffness (MAS) of the ankle joint across sexes.

Methods: Twenty-seven males and 26 females participated in the study. After baseline assessment of MAS and related variables, localised fatigue was induced in triceps surae using the standing heel-rise test during which the subjects were instructed to lift and drop the heel at a frequency of 0.5 Hz. When subjects were unable to continue due to exhaustion the test was terminated and another MAS test was performed soon after.

Results: Significant higher triceps surae MAS was found in men compared to women (p < .01). MAS decreased (p < .01) between pre- and post-fatigue on average from 18.0 to 17.0 KN m⁻¹ and from 14.5 to 13.9 KN m⁻¹ in men and women, respectively. Percentage changes revealed, however, that in relative terms the changes in all the variables evaluated were similar (p > .01) between sexes, with MAS less than 5%. Conclusion: Despite the sex-related differences at baseline, fatigue seems to affect biomechanical properties of the ankle joint similarly in men and women.

Keywords: Fatigue, stiffness, ankle, gender, muscle-tendon unit

Highlights

• At baseline, men exhibit greater triceps surae MAS than women.
• Fatigue reduces triceps surae MAS in men and women.
• In relative terms fatigue induces similar MAS changes in men and women.

1. Introduction

There is evidence that fatigue, i.e. a transient decrease in force, power and working capacity of muscles after being active for a certain time (Williams & Ratel, 2009), can induce changes in biomechanical and neuromuscular factors. Such factors include rate of force development (Zhou, McKenna, Lawson, Morrison, & Fairweather, 1996), muscle activation patterns (Avela & Komi, 1998), co-activation (Weir, Keefe, Eaton, Augustine, & Tobin, 1998), proprioception and kinaesthesia (Allen & Proske, 2006). Likewise, the behaviour of the muscle spindle (Macefield, Hagbarth, Gorman, Gandevia, & Burke, 1991) and the Golgi tendon organ (Hutton & Nelson, 1986) can be affected, with repercussions for the associated reflex mechanisms including stretch sensitivity, electromechanical delay and myoelectric response amplitude (Avela & Komi, 1998; Granata, Orishimo, & Sanford, 2001). Fatigue also affects joint and lower limb stiffness, with some of the aforementioned factors having a role in it. For instance, in a group of five subjects (sex not reported) performing jumps until exhausting it was found an acute and prolonged reduction in knee and ankle joint stiffness (Kuitunen, Avela, Kyrolainen, Nicol, & Komi, 2002). Similarly, in a mixed group of 4 females and 11 males, it was
observed a reduction in both vertical and leg stiffness during treadmill running to exhaustion (Dutto & Smith, 2002).

Previous research has attempted to identify the mechanisms that could potentially contribute to any sex-related differences in fatigability, however, this phenomenon has yet to be fully elucidated (Williams & Ratel, 2009). In general, men have larger and stronger muscles than women but they are less able to sustain continuous and intermittent muscle contractions at low to moderate intensity levels (Wust, Morse, de Haan, Jones, & Degens, 2008). The greater fatigue resistance attributed to women is related to differences in muscle mass, substrate utilisation and muscle morphology (Wust et al., 2008). Even though it has been shown that fatigue affects stiffness, the sex-related differences in baseline joint stiffness may imply a different effect of fatigue on stiffness between males and females. To the best of the authors’ knowledge, only three studies have evaluated the influence of fatigue on stiffness across sexes. Padua et al. (2006) reported that lower extremity muscle fatigue induced during hopping tasks does not significantly alter vertical leg stiffness in both sexes. Wang, De Vito, Ditroilo, and Delahunt (2016) reported a decrease in knee musculoarticular stiffness (MAS) for both sexes after a cycling fatigue protocol and in another study the same authors observed that when fatigue was locally induced, by employing a continuous concentric-eccentric knee extension cycle at 90° s\(^{-1}\), a significant increase in knee MAS occurred only in females whilst a general treadmill fatigue protocol brought about a significant decrease in knee MAS in both sexes (Wang, De Vito, Ditroilo, & Delahunt, 2017). However, the study of Padua et al. (2006) employed a methodology to assess the stiffness of the lower limb as a whole (hopping test). The free-oscillation technique (Ditroilo, Watsford, Murphy, & De Vito, 2011) was utilised in the other two studies to analyse MAS of the knee joint. The aim of the present study was to examine the effect of sex and localised fatigue on MAS of the ankle joint assessed using the free-oscillation technique. It has been reported that sex differences in fatigue resistance are muscle group dependent (Avin et al., 2010), which may lead to different sex-related outcomes based on the joint evaluated. In addition, sonographic studies of human soleus and gastrocnemius muscles have shown sex differences in muscle architectures (i.e. fibre length, pennation angle and muscle thickness), particularly regarding the soleus muscle (Chow et al., 2000). It has also been suggested that the lower MAS found in women, when compared to men, may explain their higher incidence of injuries (Blackburn, Riemann, Padua, & Guskiewicz, 2004; Granata, Padua, & Wilson, 2002). If fatigue decreases MAS (as research seems to indicate) the risk of injury could potentially increase. On the other hand, women may have a protective mechanism on the grounds that they show greater fatigue resistance than men and with the assumption that their level of triceps surae MAS is not reduced by fatigue, as reported for knee joint (Wang et al., 2017). On the basis of previous findings with the ankle joint, it was hypothesised that: (1) men would show significant higher MAS than women; (2) fatigue would decrease MAS in both sexes; and (3) considering the greater fatigue resistance attributed to women, the fatigue-related reduction in MAS would be greater in men than in women.

2. Methods

2.1. Participants

Twenty-seven young men (age 22.6 ± 4.3 years, height 1.75 ± 0.06 m, body mass 72.2 ± 9.5 kg) and 26 young women (age 20.2 ± 1.5 years, height 1.60 ± 0.05 m, body mass 58.8 ± 6.7 kg) participated in this study. All subjects were healthy and had no injuries at the time of testing. The height and body mass of each subject were measured by a stadiometer (Seca 220, Hamburg, Germany) and conventional scales, respectively. An informed written consent was obtained once each subject was informed of the nature of the study. This research was performed in accordance with the Declaration of Helsinki and ethical approval was obtained from the ethics committee of the University of Beira Interior.

2.2. Maximal voluntary isometric contraction assessment

The participant sat in a chair, with no thigh support, with 90° between trunk-thigh, leg-thigh and leg-foot (Figure 1). The metatarsal-phalangeal joint of the barefoot was aligned with the edge of one wooden block fixed on top of a force plate (Kistler 9281B; Kistler Instruments, Amherst, NY, USA), while the calcaneus was supported by a different block. In this position, subjects maintained the arms folded across the chest. Since no bilateral differences in MAS have been reported for a similar healthy population (Murphy, Watsford, Coutts, & Pine, 2003) only data from the right lower limb were collected. On top of the right knee was then placed the Lever 1 and locked (Figure 1). Next, the subject was instructed to push the heel and the knee upwards against the locked lever as hard and as quickly as possible. Throughout this period verbal encouragement was given. Three measurements were obtained and the
best of the three attempts was taken as the maximal voluntary isometric contraction (MVIC) value.

2.3. MAS assessment

MAS was measured using the equipment illustrated in Figure 1 and the position reported in MVIC procedures. However, the Lever 1 placed on top of the right knee was unlocked and the wooden block that supported the calcaneus was removed to allow the foot to move freely in the sagittal plane. Standard weights were placed on top of Lever 1 (Figure 1). The load used was 30% of MVIC which is representative of gait activities (McNair & Stanley, 1996) and has been reported to produce the lowest coefficient of variance of MAS compared to other loads (i.e. 15%, 45% and 60%) yielding a good level of reliability in the assessment of MAS (Ditroilo, Watsford, Murphy, & De Vito, 2013). This load corresponded, on average, to 36.7 ± 6.8 and 36.4 ± 6.3% of the body mass for males and females, respectively. With the ankle in a neutral position the subject was then instructed to activate plantar flexors isometrically, maintaining the leg-foot at 90° and sustaining a steady muscle contraction for a period of 10 s. The foot-ankle angle was disrupted by dropping Lever 2 on top of Lever 1 producing a peak force of 200 N (Faria, Gabriel, Moreira, Bras, & Ditroilo, 2016). The test administrator then grabbed the Lever 2 when this rebounded after impact. The Lever 2 was dropped randomly, within 10 s, onto Lever 1 to prevent subjects to anticipate the impulse applied. The subjects were blindfolded to the application of the impulse and were instructed not to react to any stimulus (Faria, Gabriel, Abrantes, Bras, & Moreira, 2010). The vertical force applied to the ground was measured at 1000 Hz with the force plate linked to the software BioWare 4.0 type 2812A (Kistler Instruments, Amherst, NY, USA). The oscillations produced after perturbing the foot–ankle angle were recorded by the force plate and used to assess the MAS. The Matlab software (MATLAB R 2013a, MathWorks, Inc., Natick, MA, United States) was used to estimate stiffness parameters with the non-linear least squares method as well as the velocity and position-time curves through Simulink module. For each subject the average of two trials was obtained and used as the MAS value.

2.4. Fatigue protocol

After measuring MAS at baseline, fatigue was induced using the standing heel-rise test (Silbernagel,
Nilsson-Helander, Thomee, Eriksson, & Karlsson, 2010). Just after a short familiarisation period with the left leg, the fatigue exercise began with the right leg and during this phase verbal encouragement was given. This procedure was performed with the subjects standing on the right barefoot on a wedge tilted 10°. Subjects were instructed to lift the heel as high as possible and then drop it at a frequency of 0.5 Hz (Silbernagel et al., 2010). Participants maintained their balance by touching the wall with the fingertips of both hands at shoulder height and the left lower limb was kept still with the knee flexed. During the heel-rise of the right foot the knee angle was set at 0° (full extension). The occurrence of fatigue was assessed measuring the concentric work during the test. The T-Force Dynamic Measurement System (Ergotech Consulting, S.L., Spain) was used to assess kinetic and kinematic data while fatigue was being induced, and the software Metronome Plus 2.0.01 (M&M systeme, Braugasse, Germany) was employed to establish the frequency of 0.5 Hz during the standing heel-rise test. When the participant was unable to continue the heel-rise due to exhaustion the test was terminated and immediately another MAS test was performed.

2.5. MAS: variables analysed

The free-oscillation technique models the system under examination as a single degree of freedom mass-spring system with a damping element, as illustrated in the following equation:

\[ m\ddot{x} + Kx + C\dot{x} = 0, \quad (1) \]

where the total mass (kg) of the system (leg, foot, lever and standard weights), is given by \( m \), the acceleration (m s\(^{-2}\)) by \( \ddot{x} \), the velocity (m s\(^{-1}\)) by \( \dot{x} \), displacement (m) by \( x \), the damping coefficient (N s m\(^{-1}\)) by \( C \) and MAS (N m\(^{-1}\)) by \( K \). The general solution of this equation for an underdamped system allows the determination of MAS (N m\(^{-1}\)), ankle amplitude of movement (AM) (°) and ankle angular velocity (ω) (rad s\(^{-1}\)). Further mathematical details about the determination of MAS and related variables can be found in previous studies (Faria et al., 2016).

2.6. Statistical procedures

Statistical analysis of five dependent variables (i.e. work, MAS, C, AM and ω) was performed employing multivariate analysis of variance (MANOVA) and \( t \)-tests. Data were assessed across sexes at two time periods: immediately before (i.e. pre-fatigue) and after fatigue (i.e. post-fatigue), induced by the standing heel-rise test. The two conditions (i.e. pre-fatigue and post-fatigue) make up the within-subject factor time while sex (i.e. men and women) the between-subjects factor. After the dependent variables were tested for assumptions a between-within MANOVA was run to investigate differences across sex over time on the five dependent variables. When significant multivariate differences were detected, univariate analysis of variance (ANOVA) were used to determine where the differences lay. When a dependent variable showed a significant univariate interaction (sex × time) further analysis (i.e. \( t \)-tests) were performed (Mayers, 2013). Partial \( \eta^2 \) were used to calculate effect sizes (ES) (Mayers, 2013). Power and ES were computed using G*Power software (G*Power 3.1.7, University Kiel, Germany).

To examine the extent of fatigue-induced variations in men compared to women the percentage change was calculated as: \[((Post-fatigue − Pre-fatigue)/Pre-fatigue) \times 100\].

The percentage change was then used in independent \( t \)-tests to compare sex differences.

The variable work was evaluated by comparing the first and last measurements of concentric work (at 0% and 100% of task completed during heel-rises) performed during the fatigue test. The level of statistical significance has been adjusted for multiple comparisons employing a Bonferroni correction (0.05/5, \( p < .01 \)). Statistical analysis was performed using SPSS (IBM SPSS Statistics 24.0, Chicago, IL, USA).

3. Results

The Following dependent variables (i.e. work, MAS, C, AM and ω) were measured for men and women at two time-points (i.e. pre-fatigue and post-fatigue). Mixed MANOVA analysis confirmed that there was a statistically significant interaction effect between sex and time conditions on the combined dependent variables (Pillai’s Trace = 0.277, \( F(5, 47) = 3.607, p < .05, \eta^2 = 0.277 \)). It was also confirmed a significant multivariate effects for sex (Pillai’s Trace = 0.452, \( F(5, 47) = 7.741, p < .001, \eta^2 = 0.452 \)) and time (Pillai’s Trace = 0.874, \( F(5, 47) = 65.489, P < 0.001, \eta^2 = 0.874 \)).

Univariate between-group analysis revealed greater MAS and lower AM and ω in men than in women regardless of time condition (Tables I and II).

Within-group univariate analysis indicated that MAS and ω decreased significantly from pre-fatigue to post-fatigue, regardless of sex (Tables I and II). A significant univariate interaction effect (sex × time) was only found for the variable work (Table I). To determine the source of this interaction further statistical \( t \)-tests were performed (Mayers, 2013).
Paired t-tests indicated that the variable work decreased significantly from pre-fatigue to post-fatigue condition for men $t(26) = 14.181, p < .0005$ and for women $t(25) = 10.816, p < .0005$ (Table II). Higher values for work were also found for men than women at the pre-fatigue $t(51) = 5.211, p < 0.0005$, and post-fatigue conditions $t(51) = 3.971, p < 0.0005$, by independent t-tests (Table II).

As for the percentage change (Table II) the independent t-tests revealed no significant differences ($p > .01$) between men and women for all the variables analysed (i.e. work, MAS, $C$, $AM$ and $\omega$), indicating that the percentage of variation in all the variables was similar between sexes. Interestingly, no significant correlation ($r = -0.18, p = .19$) was found between percentage of MAS decline and body mass, therefore the fatigue protocol affected participants of different size in a similar way.

4. Discussion

The aim of this study was to investigate the effects of fatigue on triceps surae MAS across sexes. As hypothesised, men presented significantly higher triceps surae MAS than women and MAS significantly decreased for both sexes due to fatigue (Table I). The decrease in MAS between pre and post-fatigue was 18.0 to 14.5 KN·m$^{-1}$, for men and women, respectively. Percentage changes (Table II) show that the effects of fatigue were in fact similar in relative terms between sexes. This outcome refutes the third hypothesis where it was postulated that fatiguing would cause a greater MAS decrease in men than in women.

The greater stiffness demonstrated by men compared to women is in agreement with previous research. For instance, studies examining sex differences in stiffness of the plantar flexors (Blackburn, Padua, Weinhold, & Guskiewicz, 2006), knee flexors and extensors (Blackburn et al., 2004; Granata, Wilson, & Padua, 2002), as well as the whole leg (Granata, Padua, et al., 2002) found greater stiffness in men than in women. Structural stiffness and material modulus between sexes were assessed by Blackburn et al. (2006) which suggested that MAS differences were probably due to sex differences in tendon stiffness and muscle architecture. Several structures contribute to MAS, nonetheless most of series elastic stiffness is derived from the tendon and myofibrillar cross-bridges (Shorten, 1987). Material modulus and tendon stiffness were reported to be lower in females than in males (Kubo, Kancheisa, & Fukunaga, 2003). Additionally, both the soleus and gastrocnemius muscles differ across sexes in architectural parameters like the fibre length, pennation angle and muscle thickness. Overall males were found to have larger angles of pennation and thicker muscles (i.e. greater cross-section area) while females were found to have longer average muscle fibre bundle length (Chow et al., 2000; Kubo et al., 2003; Mademli & Arampatzis, 2005). Architectural parameters are related to force production (Mademli & Arampatzis, 2005), which can help explaining sex differences in MAS. One additional explanation is related with hormones which were reported to influence MAS (Bell et al., 2012; Granata, Wilson, et al., 2002). For instance, it has been reported a negative correlation between oestradiol and knee MAS as well as a positive correlation between free testosterone and knee MAS (Bell et al., 2012).

A decrease in MAS due to fatigue is also supported by previous research. Within these studies, triceps surae MAS decreased in 20 female students after two fatigue protocols employing a continuous isometric plantar flexion contraction (Rojhani-Shirazi & Saadat, 2014). The quadriceps MAS was assessed using the free-oscillation technique in 21 male

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**Table I.** Univariate analysis of the effect of Sex, Time and their interaction on work, MAS, damping coefficient, amplitude of movement and angular velocity.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Interaction (sex × time)</th>
<th>Sex (between factor)</th>
<th>Time (within factor)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F-value</td>
<td>p-value</td>
<td>ES</td>
</tr>
<tr>
<td>Work (J)</td>
<td>12.12</td>
<td>*</td>
<td>0.49</td>
</tr>
<tr>
<td>MAS (N·m$^{-1}$)</td>
<td>0.60</td>
<td>0.44</td>
<td>0.11</td>
</tr>
<tr>
<td>C (N·s·m$^{-1}$)</td>
<td>0.06</td>
<td>0.81</td>
<td>0.03</td>
</tr>
<tr>
<td>AM (°)</td>
<td>0.43</td>
<td>0.51</td>
<td>0.09</td>
</tr>
<tr>
<td>$\omega$ (rad·s$^{-1}$)</td>
<td>1.30</td>
<td>0.26</td>
<td>0.16</td>
</tr>
</tbody>
</table>

Notes: Work: work at pre- and post-fatigue; MAS: musculoarticular stiffness; C: damping coefficient; AM: amplitude of movement; $\omega$: angular velocity; ES: effect size; P: Power. Bold values indicate statistically significant effects.

\* $p < .01.$
cyclists which demonstrated a 12% reduction due to fatigue (Ditroilo, Watsford, Fernandez-Pena, et al., 2011). Employing dynamical perturbations the stiffness of the elbow joint was assessed in five subjects (sex not reported) by Zhang and Rymer (2001) which also revealed a significant decrease due to fatigue. The effects of repeated muscle contractions on tendon of seven males were explored by Kubo, Kanehisa, Kawakami, and Fukunaga (2001) which reported an increase in tendon compliance after fatigue. These studies substantiate the influence of fatigue on MAS, however, sex differences were not assessed. Padua et al. (2006) have examined the effect of fatigue on vertical leg stiffness across sexes. Notably, lower extremity muscle fatigue induced during hopping tasks did not significantly alter vertical leg stiffness for both sexes, which challenges the results formerly reported. According to the authors, once fatigued both males and females used an ankle-dominant strategy, with greater reliance on the ankle musculature and less on the knee musculature. To the authors’ knowledge, only two other studies have investigated the influence of fatigue across sexes using independent t-tests with no differences found (i.e. $p > .01$).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Sex</th>
<th>Time</th>
<th>Differences (%)</th>
<th>$p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work (J)</td>
<td>Male</td>
<td>Pre-fatigue</td>
<td>97.9 ± 21.0</td>
<td>51.1 ± 12.1</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>Pre-fatigue</td>
<td>70.4 ± 17.1</td>
<td>39.0 ± 10.0</td>
</tr>
<tr>
<td>MAS (N m$^{-1}$)</td>
<td>Male</td>
<td>Pre-fatigue</td>
<td>18041.9 ± 3101.3</td>
<td>17039.7 ± 2843.2</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>Pre-fatigue</td>
<td>14517.8 ± 2769.7</td>
<td>13921.7 ± 2926.3</td>
</tr>
<tr>
<td>C (N s m$^{-1}$)</td>
<td>Male</td>
<td>Pre-fatigue</td>
<td>245.9 ± 63.7</td>
<td>241.3 ± 59.0</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>Pre-fatigue</td>
<td>208.1 ± 58.3</td>
<td>207.0 ± 54.1</td>
</tr>
<tr>
<td>AM (°)</td>
<td>Male</td>
<td>Pre-fatigue</td>
<td>3.39 ± 0.65</td>
<td>3.34 ± 0.71</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>Pre-fatigue</td>
<td>4.42 ± 0.80</td>
<td>4.30 ± 0.86</td>
</tr>
<tr>
<td>$\omega$ (rad s$^{-1}$)</td>
<td>Male</td>
<td>Pre-fatigue</td>
<td>0.47 ± 0.09</td>
<td>0.46 ± 0.09</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>Pre-fatigue</td>
<td>0.61 ± 0.11</td>
<td>0.58 ± 0.11</td>
</tr>
</tbody>
</table>

Notes: Work: work at pre- and post-fatigue; MAS: musculoarticular stiffness; C: damping coefficient; AM: amplitude of movement; $\omega$: angular velocity. Percentage differences were compared across sexes using independent $t$-tests with no differences found (i.e. $p > .01$).
analysed it might be speculated that in both sexes fatigue is impairing similarly the mechanisms that specifically affects the variables studied. As previously mentioned such mechanisms can be related with a decrease in the net force produced by cross-bridges (Zhang & Rymer, 2001) or the enhancement of tissues extensibility due temperature (McNair & Stanley, 1996). Sex differences in fatigability can be muscle group dependent (Avin et al., 2010). It has been suggested that less sex difference in fatigability in some muscles (e.g. dorsiflexors) can be due the greater proportion of type I fibre which might restrain the expression of contractile fatigability (Hunter, 2014). The soleus muscle, which contribute substantially to the ankle MAS, contained predominantly slow twitch (Type I) fibres representing a mean of about 80% (Gollnick, Sjodin, Karlsson, Jansson, & Saltin, 1974). Even though absolute sex differences have been found, a substantial proportion of this fibre type might be enough to produce non-significant percentage change differences in the variables analysed. Studies investigating sex differences in muscle fibre type are limited, but it might be also possible that men and women show comparable proportions of fibre types, that are affected similarly by fatigue leading to non-significant percentage change results in the variables analysed. Interestingly, no sex differences were found in the fibre type composition of the soleus and tibialis anterior muscles in rats (Fox et al., 2003).

One acknowledged limitation in the current study was the use of only one load (30% MVIC) for the measurement of MAS. Even though this load has been consistently utilised in previous studies (e.g. Blackburn, Padua, & Guskiewicz, 2008; Faria, Gabriel, Abrantes, Bras, & Moreira, 2009; McNair & Stanley, 1996) the application of heavier loads may have resulted in a stronger and clearer effect of fatigue on triceps surae MAS.

In conclusion, males showed higher baseline MAS than females and fatigue affected MAS in both sexes. In relative terms fatigue induced the same changes in males and females in all the variables studied despite the greater fatigue resistance attributed to females.

Disclosure statement
No potential conflict of interest was reported by the authors.

References


