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Increase in post activation potentiation in females following a cycling warmup

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ABSTRACT

Post activation potentiation (PAP) is a phenomenon in which muscular force is acutely enhanced as a result of prior contractile activity. The net augmentation is dependent upon the intensity of the preceding conditioning contraction influencing calcium release and phosphorylation of the regulatory myosin light chain. This phenomenon has been recorded after various types of conditioning contractions, however the interaction of a warmup on PAP remains uncertain and whether this differs between males and females requires consideration. We investigated the effect of a cycling warmup on twitch contractile properties and PAP of the plantar flexors on males and in females using oral contraceptives. A maximal voluntary contraction (MVC) of the plantar flexors preceded and followed a 10-min cycling warmup, where supramaximal twitches were administered prior to, during and after the conditioning contractions. Twitch contractile properties of peak tension (PT), time to peak tension (TPT), half relaxation time (HRT) and contraction duration (CD) were compared between resting and potentiated twitches before and after the warmup. Ultrasonography was used to measure *in vivo* Achilles tendon architecture. Males were $\sim$30% stronger, but voluntary activation did not differ from females ($p = .37$). In males and females PT increased following the conditioning MVC ($p = .03$). The degree of potentiation was higher following the warmup in females (25.01%, $p = .02$) but not males ($p = .24$). TPT, HRT and contraction duration ($p < .05$) were faster after the warmup and in males ($p < .001$). Achilles tendon elongation was unchanged by the warmup ($p = .11$). Ten minutes of a cycling warmup reduced TPT, HRT, and CD in both males and females without altering the tendon. The degree of PAP was higher in females than males following the warmup. This difference might be associated with altered calcium kinetics of females on oral contraceptives as well as higher proportion of type I fibres in the active muscles.

1. Introduction

Optimization of force production is integral to movement success. It is well known that skeletal muscle force production is history dependent and this can be observed in acute situations in both males and females (Herzog, 2004; Hunter, Duchateau, & Enoka, 2004, Hunter, 2014). In instances where prior activity results in an attenuation of force, muscle fatigue can be quantified through neural and contractile responses where differences between males and females are well described from perspectives of motivation,

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descending drive, blood flow and fibre composition (Costill, Daniels, Evans, et al., 1976; Hunter et al., 2004; Wüst et al., 2008). Contractile history can also enhance force output and this is described as post activation potentiation (PAP) (MacIntosh, Robillard, & Tomaras, 2012). PAP can be observed acutely as an increase in twitch force and rate of force generation following a maximal voluntary contraction (MVC). Little is understood about sex-related differences in PAP; however, given that PAP is a consequence of balancing the contractile mechanisms that enhance force with those that limit force output, such as fatigue, and the latter differs between sexes it is likely that PAP would also have unique features between males and females.

PAP is evoked when actin and myosin are rendered more sensitive to calcium by phosphorylation of the myosin regulatory light chains (Sweeny, Bowman, & Stull, 1993). Paasuke et al. measured PAP in males (Paasuke, Ereline, & Gapeyeva, 1998) and females (Paasuke, Ereline, Gapeyeva, & Torop, 2002) of different training backgrounds and concluded that PAP was present for both sexes. The males experienced ~10% greater PAP than what was reported in the female study (2002). In both studies the mechanisms underlying augmentation in plantar flexion twitch force was phosphorylation of the myosin regulatory light chain; however, males are generally stronger and possess a greater number of type II fibres than females (Seitz, De Villarreal, & Haff, 2014; Hicks, Kent-Braun, & Ditor, 2001; Trappe, Gallagher, Harber, et al., 2003) which predisposes males to experience greater PAP. Thus, these factors should be considered within a direct assessment of PAP between sexes. The effect of sex on PAP might also be complicated by tendon compliance. Greater compliance was observed in females (Onambele, Burgess, & Pearson, 2007), and is negatively correlated with muscle contractile speeds and force production (Gago, Arndt, Tarassova, et al., 2014; Onambele et al., 2007) and this could limit PAP in females relative to males. Whether tendon compliance is altered with conditioning contractions is equivocal (Gago et al., 2014; Kay & Blazevich, 2009); however, an increase in tendon compliance either through sex hormones, conditioning contractions or both, would likely reduce the prevalence of PAP. Thus, a direct evaluation of PAP between sexes is warranted as the potential effect of compiling factors of strength, fibre type, and tendon compliance are likely contributors to sex-related differences. The magnitude of PAP is clearly dependent upon the intensity of a conditioning contraction (Sale, 2002; Vandervoot, Quinlan, & McComas, 1983). However, the conditioning activity to induce PAP is often confounded with warmup, which is nearly universally recommended for optimization of performance (MacIntosh et al., 2012). How a warmup interplays with a conditioning contraction and subsequently alters the magnitude of PAP is difficult to ascertain as warmup techniques applied to stimulate PAP are wide-ranging and span static stretching to dynamic sport and non-sport specific movements and these are studied in males (MacIntosh et al., 2012). Generally, the consistent element of studies indicates that the effect of a static warmup is negligible whereas dynamic exercises show promise (Ce, Rampichini, Maggioni, et al., 2008; Skof & Strojnik, 2007) for inducing adaptations in muscle and tendon that would culminate in a positive history dependent response. Warmup increases muscle temperature (Sargeant, 1987) which creates a better environment for diffusion and enzymatic activity both of which are related to increased performance. Sale (2002) reported that cycling increases low frequency tetanic force through heightened sensitivity of actin and myosin to calcium, but there was no differentiation between sexes in this study. Tomaras and MacIntosh (2011) reported greater anaerobic performance after a lower, when compared to higher, intensity warmup as this could be performed without fatiguing the muscles. Therefore, it remains difficult to fully extract PAP from the warmup effect. Overall, there is ambiguity surrounding warmup and uncertainty in whether PAP has sex dependent responses thus, the purpose of this study was to quantify the effect of a cycling warmup on twitch contractile properties and PAP of the plantar flexors in males and females. It was hypothesized that PAP would be greater in males when compared to females and that following a cycling warmup PAP and twitch contractile times would be enhanced in both sexes provided the tendon remained unchanged by the warmup.

2. Methods

Eleven males (22 ± 3 years, 181.7 ± 9.1 cm, 86.0 ± 11.1 kg) and eleven females (21 ± 1 years; 165.9 ± 7.0 cm, 59.5 ± 8.8 kg) participated in the study which was approved by the local university human ethics review board and conformed to the 1964 Declaration of Helsinki. Written informed consent was acquired prior to participation. All participants were recreationally active, but were not committed to a formal exercise training plan and participated in < 150 min per week of organized, intentional moderate to high level physical activity such as jogging, spin class etc. Females were taking an ethinyl-estradiol blend monophasic oral contraceptive pills (MOCP) for a minimum of 6 months prior to the study and were tested during the luteal phase of the menstrual cycle.

The experiment involved assessment of the length of the Achilles tendon (AT) at rest, with a continuous longitudinal ultrasound scan (Simpson, Kim, Bourcet, Jones, & Jakobi, 2016) using the ML6-15 probe (4.5–15.0 MHz linear array, 13 × 58 mm foot print, 30 frames per second, 50 mm field of view, 8 cm depth of field, LOGIQview, GE©, Connecticut, USA). Participants were familiarized with the protocol through four submaximal contractions separated by 1 min. Supramaximal stimuli was established through progressive increases of the stimulation intensity (200 μs pulse width, 400 Vs, Digitimer Constant Current Stimulator, DS7AH, Hertfordshire, United Kingdom) until a plateau of the M-wave was achieved and then the intensity was increased a further 10%. This supramaximal intensity was used to induce twitch responses prior to, during, and following a conditioning MVC. During these contractions video ultrasonography was used to record the muscle tendon junction (MTJ). The conditioning MVC was undertaken by contracting as fast and as hard as possible, and holding the maximal force for ~5 s. This procedure of scanning the AT at rest, and video recording of the MTJ during twitches and MVC was repeated prior to and following a 10-min cycling warmup (Fig. 1).

Participants were positioned into the Biodex dynamometer (Biodex Medical Systems, New York, USA) with the hips at 100°. The self-identified dominant foot was secured into the footplate with the medial malleolus aligned with the center of rotation of the dynamometer. The leg was extended and the knee positioned to ~170°, with the ankle angle at 90° (Kay & Blazevich, 2009). Torque was sampled at 496 Hz, converted from analogue to digital format (Power 1401, Cambridge Electronic Design (CED), Cambridge,