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# Sex differences in knee extensor torque control

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## Abstract

There is currently equivocal evidence regarding sex-related differences in measures of muscle force and torque control. To that end, we investigated sex differences in knee extensor muscle torque control, using both magnitude- and complexity-based measures, across contraction intensities typical of activities of daily living. 50 participants (25 male, median age [and interquartile range] 23.0 [20.0 – 33.0]; 25 female, median age [and interquartile range] 21.0 [20.0 – 40.5]) performed a series of intermittent isometric knee extensor contractions at 10, 20 and 40% maximal voluntary contraction (MVC). Torque was measured in N·m and torque control was quantified according to the magnitude (standard deviation [SD], coefficient of variation [CV]) and complexity (approximate entropy [ApEn], detrended fluctuation analysis [DFA] α) of torque fluctuations. Males exhibited a significantly greater absolute magnitude (i.e., SD) of knee extensor torque fluctuations during contractions at 10% ($P$ = 0.011), 20% ($P$ = 0.002) and 40% MVC ($P$ = 0.003), though no sex differences were evident when fluctuations were normalised to mean torque output (i.e., CV). Males exhibited significantly lower ApEn during contractions at 10% ($P$ = 0.002) and 20% MVC ($P$ = 0.024) and significantly greater DFA α during contractions at 10% ($P$ = 0.003) and 20% MVC ($P$ = 0.001). These data suggest sex differences in muscle torque control strategies and highlight the need to consider both the magnitude and complexity of torque fluctuations when examining sex differences in muscle force control.

## Introduction

Motor units represent the final common pathway, transducing synaptic input from the central nervous system to muscle, which culminates in the generation of skeletal muscle force (or torque, when applied about a joint; Sherrington, 1925). Variance in the common modulation of motor unit discharge times results in a muscle torque output characterised by constant, inherent fluctuations (Farina & Negro, 2015), indicating that control of torque is not perfectly accurate. Metrics that quantify various aspects of muscle torque fluctuations (i.e., their magnitude and temporal structure, or "complexity") can be used as a paradigm to compare torque control between different conditions (e.g., contraction intensity; Slifkin & Newell, 1999) and populations (e.g., young vs. old adults; Pethick *et al*., 2022b). One comparison that has received relatively little attention is that between males and females, due to the historic underrepresentation, or even exclusion, of females in studies of motor control (Jakobi *et al*., 2018; Inglis & Gabriel, 2021; Jenz *et al*., 2022). Given known sex differences in motor unit recruitment strategies, including smaller motor unit size and greater firing rates (Guo *et al*., 2022), there is a need for systematic investigations of sex-related differences in muscle force/torque control and its underlying mechanisms (Lulic-Kuryllo & Inglis, 2022).

Classically, muscle force/torque fluctuations have been quantified according to their magnitude, either in absolute terms using the standard deviation (SD) or in relative terms (i.e., normalised to mean torqueoutput) using the coefficient of variation (CV; Pethick & Piasecki, 2022). Differences in these measures between conditions/populations reflect differences in torque steadiness, with the CV also providing an indication of variance in common modulation of motor unit discharge times (Enoka & Farina, 2021). Muscle torque fluctuations, however, also possess an irregular temporal structure ("complexity"); a characteristic that classical magnitude-based measures cannot quantify (Pethick *et al*., 2021a). Complexity-based

76 measures quantify the apparent randomness or regularity of muscle torque output (e.g.,
77 approximate entropy, ApEn; Pincus, 1991) and identify the presence of long-range fractal
78 correlations (e.g., detrended fluctuation analysis α, DFA; Peng *et al*., 1994). Differences in
79 these measures between conditions/populations reflect differences in the adaptability of torque
80 production; that is, the ability to adapt torque output rapidly and accurately in response to task
81 and/or environmental demands (Pethick *et al*., 2016). As magnitude- (SD, CV) and complexity-
82 based (ApEn, DFA α) measures quantify different aspects of torque control, it has been
83 recommended that they be used in conjunction to provide a more complete understanding of
84 force/torque control (Pethick *et al*., 2021b).
85
86 There is currently equivocal evidence regarding sex-related differences in the magnitude of
87 torque fluctuations. Studies on both upper and lower limb muscles have found significantly
88 greater CV in females during isometric contractions at intensities typical of activities of daily
89 living (ADLs), i.e., 2.5 to 40% maximal voluntary contraction (MVC; Brown *et al*., 2010;
90 Grunte *et al*., 2010; Inglis & Gabriel, 2021), as well as during higher intensity contractions up
91 to 100% MVC (Brown *et al*., 2010; Inglis & Gabriel, 2021). Such findings led Jakobi *et al*.
92 (2018) to conclude that there is clear evidence for reduced force/torque steadiness in females.
93 This conclusion is, however, challenged by numerous observations of no difference in muscle
94 force CV between males and females (Tracy & Enoka, 2002; Guo *et al*., 2022). There are very
95 few studies investigating sex-related differences in the complexity of torque fluctuations,
96 though current evidence suggests that entropic measures may be lower in females (Svendsen
97 & Madeleine, 2010; Duan *et al*., 2018; Mehta & Rhee, 2021), indicating poorer adaptability.
98 These studies on muscle torque complexity, however, were either limited to a single contraction
99 intensity, investigated only older adults, or were conducted in the upper limbs.
100

Differences in lower limb force/torque control between males and females could have important functional implications for ADLs, athletic performance and musculoskeletal injury (Pethick *et al*., 2022a; Clark *et al*, 2023). A greater magnitude and lower complexity of torque fluctuations has been linked to poorer performance in clinical tests of motor function (e.g., static and dynamic balance; Davis *et al*., 2020; Mear *et al*., 2022) and been speculated to increase the risk of muscle damage and injury (Svendsen & Madeleine, 2010). The aim of the present study was, therefore, to examine sex differences in knee extensor muscle torque control across contraction intensities typical of ADLs (Kern *et al*., 2001) using both magnitude- and complexity-based measures, which provide distinct information about torque steadiness and adaptability, respectively.

## Methods

### *Participants*

Twenty-five healthy male and twenty-five healthy female participants (see Table 1 for physical characteristics) provided written informed consent to participate in the study, which was approved by the ethics committee of the University of Essex (Ref. ETH2122-1278), and which adhered to the Declaration of Helsinki. Exclusion criteria were any history of lower limb musculoskeletal disease (e.g., osteoarthritis), injury (e.g., anterior cruciate ligament injury), surgery or diagnosed neurological condition (Pethick *et al*., 2022a). Neither stage of the menstrual cycle nor methods/type of hormonal contraception was assessed in the female participants. Participants attended the laboratory on a single occasion and were instructed to arrive in a rested state (i.e., no strenuous exercise in the preceding 24 hours) and to have consumed neither any food for caffeinated beverages in the three hours prior to arrival. On

arrival at the laboratory, participants body mass and height were measured for the calculation of body mass index (BMI).

*Dynamometry*

Participants were seated in the chair of a Biodex System 4 isokinetic dynamometer (Biodex Medical Systems Inc., Shirley, New York, USA), initialised and calibrated according to the manufacturer's instructions. Their right leg was attached to the lever arm of the dynamometer, with the seating position adjusted to ensure that the lateral epicondyle of the femur was in line with the axis of rotation of the lever arm. Participants sat with relative hip and knee angles of 85° and 90°, with full extension being 0°. The lower leg was securely attached to the lever arm above the malleoli with a padded Velcro strap, whilst straps secured firmly across both shoulders and the waist prevented any extraneous movement and the use of the hip extensors during the isometric contractions. The isokinetic dynamometer was connected via a custom-built cable to a CED Micro 1401-4 (Cambridge Electronic Design, Cambridge, UK). Torque (N·m) was sampled at 1 kHz and collected in Spike2 (Version 10; Cambridge Electronic Design, Cambridge, UK).

*Maximal torque*

Participants were familiarised with the dynamometer and testing procedure by performing a series of practice submaximal and maximal isometric knee extension contractions. After ten minutes rest, the isometric maximal voluntary contraction (MVC) of the knee extensors was assessed. Participants performed a series of 3-second MVCs, separated by 60-seconds rest, and continuing until three consecutive contractions were within 5% of each other. Participants were given a countdown, followed by strong verbal encouragement to maximise their effort. The highest instantaneous torque obtained from the three trials within 5% of each other was

designated as the MVC torque. In the majority of cases, participants achieved values within 5% of each other in the first three contractions performed. In no cases, did it take more than four contractions to achieve three consecutive contractions within 5% of each other.

*Torque control*

Ten minutes after the establishment of maximal torque, participants performed a series of targeted isometric knee extensor contractions at 10, 20 and 40% MVC; intensities typical of ADLs (Kern *et al*., 2001). The targets were determined from the highest instantaneous torque obtained during the preceding MVCs. Participants performed three contractions at each intensity, with contractions held for 12-seconds and separated by 8-seconds rest (Figure 1). The contraction intensities were performed in a randomised order, with two minutes rest between each intensity. Pilot testing indicated that this duty cycle followed by two minutes rest did not induce any fatigue, as measured by an MVC performed immediately prior to the next contraction intensity. Participants were instructed to match their instantaneous torque with a target bar superimposed on a display ~1m in front of them as quickly as possible at the start of the contraction and toto continue matching this target for as much of the 12-second contraction as possible.

*Data analysis*

Muscle torque data was analysed using code written in MATLAB R2017a (The MathWorks, Massachusetts, USA). The mean and peak torque for each contraction were determined. Measures of muscle torque control were calculated based on the steadiest five seconds of each contraction, identified by MATLAB as the five seconds containing the lowest SD (Pethick *et al*., 2015).

The absolute magnitude of torque fluctuations was quantified using the SD, while the normalised magnitude of fluctuations was quantified using the CV. The latter better facilitates comparisons between groups differing in maximal strength (Pethick & Piasecki, 2022), as is typically the case with males and females (Ansdell *et al*., 2017). As recommended by Goldberger *et al*. (2002), the complexity of torque fluctuations was examined using multiple metrics that analyse subtly different aspects of the output. The regularity of torque fluctuations was determined using ApEn (Pincus, 1991) and the temporal fractal scaling of torque was estimated using DFA α (Peng *et al*., 1994). Sample entropy (SampEn) was also calculated, though with regards to muscle torque this measure does not differ from ApEn when 5000 data points are used in its calculation (Pethick *et al*., 2015). The calculations of ApEn and DFA α are detailed in Pethick *et al*. (2015). In brief, ApEn was calculated with the template length, *m*, set at 2 and the tolerance for matching templates, *r*, set at 10% of the SD of force output. DFA α was calculated across time scales (57 boxes ranging from 1250 to 4 data points).

*Statistics*

Data were analysed in SPSS (version 28; IBM Corporation, USA). Figures were created using JASP (version 0.17.1; University of Amsterdam, Netherlands). All data are presented as means ± SD, unless otherwise stated. Data were tested for normality using the Shapiro-Wilk test. Physical characteristics (i.e., age, height, body mass, BMI) were all non-normally distributed. Sex differences in these parameters were, therefore, analysed using Mann-Whitney U tests. The MVC data were normally distributed, so sex differences were analysed using a Student's unpaired *t*-test. The torque control measures were also normally distributed and each of them (i.e., SD, CV, ApEn, DFA α) was analysed using two-way repeated measures ANOVAs to test for differences between contraction intensity, sex, and for a contraction intensity x sex interaction. When main effects were observed, Bonferroni-adjusted 95% confidence intervals

were used to identify specific differences. Results were deemed statistically significant when $P < 0.05$.

## Results

*Physical characteristics*

Participant's physical characteristics are presented in Table 1. There was no significant sex difference for age ($P = 0.907$). Significant differences between males and females were observed for height ($P < 0.001$), body mass ($P < 0.001$) and BMI ($P = 0.021$).

*Maximal torque*

A significant difference between males and females was observed for knee extensor MVC (264.1 ± 52.9 vs. 173.5 ± 55.7 N·m; 95% confidence intervals [CIs]: 59.7, 121.4 N·m; $P < 0.001$). This equates to a 34.3% difference in maximal torque.

*Torque control*

The SD for males and females across contraction intensities is presented in Figure 2. There was a significant effect of contraction intensity for SD ($F = 131.654$, $P < 0.001$). Both males and females exhibited the same pattern of change with increasing contraction intensity, whereby significant increases in SD were observed from 10 to 20% MVC and from 20 to 40% MVC (all $P < 0.001$). There was a significant contraction intensity x sex interaction for SD ($F = 7.084$, $P = 0.002$). Males exhibited greater SD than females at 10% MVC (0.76 ± 0.25 vs. 0.58 ± 0.24 N·m; 95% CIs: 0.01, 0.4 N·m; $P = 0.011$), 20% MVC (1.16 ± 0.42 vs. 0.82 ± 0.30 N·m; 95% CIs: 0.08, 0.6 N·m; $P = 0.002$) and 40% MVC (2.44 ± 1.11 vs. 1.64 ± 0.68 N·m; 95% CIs: 0.2, 1.4 N·m; $P = 0.003$).

The CV for males and females across contraction intensities is presented in Figure 3. There was a significant effect of contraction intensity for CV ($F$ = 16.570, $P$ < 0.001). Both males and females exhibited the same pattern of change with increasing contraction intensity, whereby CV significantly increased from 10 to 20% MVC (both $P$ < 0.001) but was not significantly different between 20 and 40% MVC (both $P$ > 0.05). There was no significant effect of sex ($F$ = 0.426, $P$ = 0.520) or a contraction intensity x sex interaction for CV ($F$ = 0.026, $P$ = 0.974).

The ApEn for males and females across contraction intensities is presented in Figure 4. There was a significant effect of contraction intensity for ApEn ($F$ = 211.631, $P$ < 0.001). Both males and females exhibited the same pattern of change with increasing contraction intensity, whereby ApEn significantly decreased from 10 to 20% MVC and from 20 to 40% MVC (all $P$ < 0.001). There was no significant contraction intensity x sex interaction ($F$ = 1.038, $P$ = 0.362), though there was a significant effect of sex ($F$ = 10.898, $P$ = 0.003). Males exhibited lower ApEn than females at 10% MVC (0.78 ± 0.09 vs. 0.86 ± 0.09; 95% CIs: −0.01, −0.1; $P$ = 0.004) and 20% MVC (0.68 ± 0.11 vs. 0.79 ± 0.12; 95% CIs: −0.02, −0.2; $P$ = 0.002). There was no difference in ApEn between males and females at 40% MVC (0.52 ± 0.09 vs. 0.59 ± 0.12; 95% CIs: −0.004, 0.1; $P$ = 0.024).

The DFA α for males and females across contraction intensities is presented in Figure 5. There was a significant effect of contraction intensity for DFA α ($F$ = 306.677, $P$ < 0.001). Both males and females exhibited the same pattern of change with increasing contraction intensity, whereby DFA α significantly decreased from 10 to 20% MVC and from 20 to 40% MVC (all $P$ < 0.001). There was a significant contraction intensity x sex interaction for DFA α ($F$ = 9.046, $P$ < 0.001). Males exhibited greater DFA α than females at 10% MVC (1.11 ± 0.09 vs. 1.02 ±

0.09; 95% CIs: 0.02, 0.1; $P = 0.003$) and 20% MVC (1.22 ± 0.09 vs. 1.13 ± 0.08; 95% CIs: 0.03, 0.2; $P < 0.001$). There was no difference in DFA α between males and females at 40% MVC (1.32 ± 0.07 vs. 1.31 ± 0.08; 95% CIs: −0.04, 0.06; $P = 0.602$).

## Discussion

Few previous studies have investigated sex differences in muscle force/torque control, with those that have often finding conflicting results. Moreover, only a handful of these studies have considered both magnitude- and complexity-based measures of force/torque control. Consequently, the aim of the present study was to examine sex differences in knee extensor torque control across contraction intensities typical of ADLs. With regards to classically assessed magnitude-based measures, males exhibited a greater absolute magnitude of knee extensor torque fluctuations (SD) across all contraction intensities (Figure 2), though no sex differences were evident when fluctuations were normalised to mean force output (CV; Figure 3). With regards to complexity-based measures, males exhibited lower complexity of knee extensor torque fluctuations (lower ApEn, greater DFA α; Figures 4 and 5) during contractions at 10 and 20% MVC. These data suggest sex differences in muscle torque control strategies and highlight the need to consider both the magnitude and complexity of torque fluctuations when examining sex differences in muscle force control.

### *Magnitude-based measures of torque control*

It has been demonstrated that the absolute magnitude of torque fluctuations (SD) increases in proportion to the mean torque exerted (Jones *et al*., 2002). As such, it seems reasonable to attribute the greater SD observed in males (Figure 2) to the fact that males were ~34% stronger and, therefore, were producing a greater absolute torque at each of the relative targets (10-40% MVC). Indeed, when the magnitude of torque fluctuations was normalised to mean torque

output (CV), no sex differences were evident (Figure 3), indicating similar steadiness in males and females; an observation in accordance with previous studies also conducted on the knee extensors (Tracy & Enoka, 2002; Clark *et al*., 2005; Guo *et al*., 2022). Previous studies observing sex differences in CV have largely been conducted in other muscle groups, e.g., elbow flexors (Brown *et al*., 2010), hip extensors (Grunte *et al*., 2010) and ankle dorsiflexors (Inglis & Gabriel, 2021), indicating that sex differences in steadiness may be muscle group specific. Interestingly, previous studies finding both significant differences (Inglis & Gabriel, 2021) and no differences (Guo *et al*., 2022) in muscle torque CV between males and females have reported significantly greater motor unit discharge rates and discharge rate variability in females. Motor unit discharge rates are an important contributor to the magnitude of muscle torque fluctuations (Enoka & Farina, 2021).

*Complexity-based measures of torque control*

To our knowledge, the present study is the first to examine sex differences in complexity-based measures of torque control at multiple contraction intensities in a lower limb muscle group. Males exhibited lower ApEn (Figure 4) and greater DFA α (Figure 5) during contractions at 10 and 20% MVC, indicating lower complexity and poorer adaptability of torque production (Pethick *et al*., 2016). No sex differences in ApEn and DFA α were observed at 40% MVC. Previous research finding sex differences in magnitude-based measures of torque control has suggested a similar contraction intensity dependence, whereby differences in CV are greatest at low intensities and progressively minimised as intensity increases towards ~40-50% MVC (Figure 1A in Jakobi *et al*., 2018). The lower ApEn observed in males contrasts with previous research, which has observed greater SampEn in males (Svendsen & Madeleine, 2010; Mehta & Rhee, 2021). Unfortunately, no mechanistic data was obtained which could account for the lower ApEn observed in males compared to females. Nevertheless, changes in motor unit

behaviour (i.e., recruitment, discharge rates, synchronisation) have been found to affect ApEn (Dideriksen *et al*., 2022). For example, the decrease in ApEn typically (and presently; Figure 4) observed with increasing contraction intensity has been postulated to be due to the recruitment of additional, larger motor units (Dideriksen *et al*., 2022). It has recently been demonstrated that during normalised force level contractions, at similar intensities to those performed in the present study, males are more reliant on recruitment of additional, larger motor units whereas females are more reliant on increases in motor unit discharge rates (Guo *et al*., 2022). Taken together, these previous findings suggest that the presently observed sex differences in knee extensor torque complexity were due to differing neuromuscular recruitment strategies, specifically greater motor unit recruitment for a given contraction intensity in males.

It is also possible that differences between the present and previous results could relate to signal acquisition and processing choices, to which entropic measures are highly sensitive (Forrest *et al*., 2014). The choice of sampling frequency, *m* (template length) and *r* (tolerance for matching templates) significantly affect the values obtained for ApEn and SampEn, as well as their relationship with contraction intensity (Forrest *et al*., 2014). The present study sampled data at 1,000 Hz, set *m* at 2 and *r* at 10% of the SD of torque output, as per previous studies (Pethick *et al*., 2015; Pethick *et al*., 2016; Mear *et al*., 2022); whereas Svendsen and Madeleine (2010), for example, sampled data at 500 Hz, set *m* at 2 and *r* at 20% of the SD of torque output. It may be advisable for future research to standardise signal acquisition and processing choices for entropic measures, in order to facilitate better comparison between studies.

*Implications*

Differences in CV between muscle groups, tasks and populations are indicative of differences in neural drive to muscle (Enoka & Farina, 2021). The similar CV values exhibited by males and females therefore indicate similar levels of knee extensor neural drive for contractions between 10 and 40% MVC, though potentially achieved through differing contributions of motor unit recruitment and discharge rates (Guo *et al*., 2022). The CV and SampEn of submaximal force have been demonstrated to explain significant amounts of variance in performance of tests of motor function. For example, lower CV and greater SampEn at the start of a fatigue test have been demonstrated to be predictive of longer endurance times (Duan *et al*., 2018). The greater ApEn in females at 10 and 20% MVC (Figure 4) is in accordance with previous observations that females exhibit longer endurance times than males during isometric contractions performed at the same relative intensity (Ansdell *et al*., 2017). In this case, the greater adaptability indicated by ApEn is reflected in the form of greater fatigue resistance. Any sex differences in CV or ApEn in other muscle groups could also contribute to variance in performance in tasks such as static (Davis *et al*., 2020) and dynamic (Mear *et al*., 2022) balance.

*Limitations and suggestions for future research*

Electromyographic data was not obtained during the present study, which could have provided mechanistic insight into the observed sex differences in torque control. For example, Inglis & Gabriel (2021) reported that lower muscle torque CV in females was associated with greater variability in motor unit action potential inter-pulse interval, while Dideriksen *et al*. (2012) demonstrated that torque variability was due to oscillations in neural drive, which have been shown to be greater in females compared to males (Pereira *et al*., 2019). Future research into sex differences in complexity-based measures of torque control should consider their relationship with motor unit behaviour. Studying the ApEn of the cumulative motor unit spike

train has been speculated to provide further insight (Dideriksen *et al*., 2022). However, as recently discussed, techniques such as high-density electromyography provide a smaller yield of motor units in females compared to males and it is unclear how this contributes to the accuracy of results (Taylor *et al*., 2022).

The hormonal status of female participants was not considered in the present study, though sex hormones have been suggested to mediate motor unit behaviour (Jenz *et al*., 2023). Tenan *et al*. (2013) reported an increase in initial motor unit firing rate after ovulation in naturally cycling females, as oestrogen and progesterone concentrations are expected to increase. Similarly, muscle force CV in an unfatigued state has been shown to be poorer in the luteal phase of the menstrual cycle (Tenan *et al*., 2016). Whilst it is unknown if hormonal status contributed to the sex differences in force control in the present study, future research in this field should consider this as a priority.

The present study only examined torque control during contractions at intensities typical of those of ADLs, i.e., 10 to 40% MVC (Kern *et al*., 2001). However, previous studies have demonstrated sex differences in the magnitude of force/torque fluctuations during contractions at both lower (Brown *et al*., 2010) and higher (Inglis & Gabriel, 2021) intensities than those presently measured. Future research investigating sex differences in the complexity of force/torque fluctuations should, therefore, examine contractions across the full range of voluntary forces.

*Conclusion*

The present study has demonstrated sex differences in knee extensor torque control during contractions at intensities typical of ADLs. Males exhibited a greater absolute magnitude of

force fluctuations (SD) during contractions at 10, 20 and 40% MVC, likely due to the greater absolute torque they were producing at each of the relative targets, as when fluctuations were normalised to mean torque output (CV) no sex differences were evident. Males also exhibited lower ApEn and greater DFA α during contractions at 10 and 20% MVC. This indicates lower adaptability of torque output and is likely due to sex differences in motor unit behaviour (Inglis & Gabriel, 2021; Lulic-Kuryllo & Inglis, 2022). The observation of sex differences in some, but not all, torque control measures provides further evidence that both the magnitude and complexity of fluctuations must be considered in order to provide a complete understanding of how force/torque control differs between populations.

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**Figure legends**

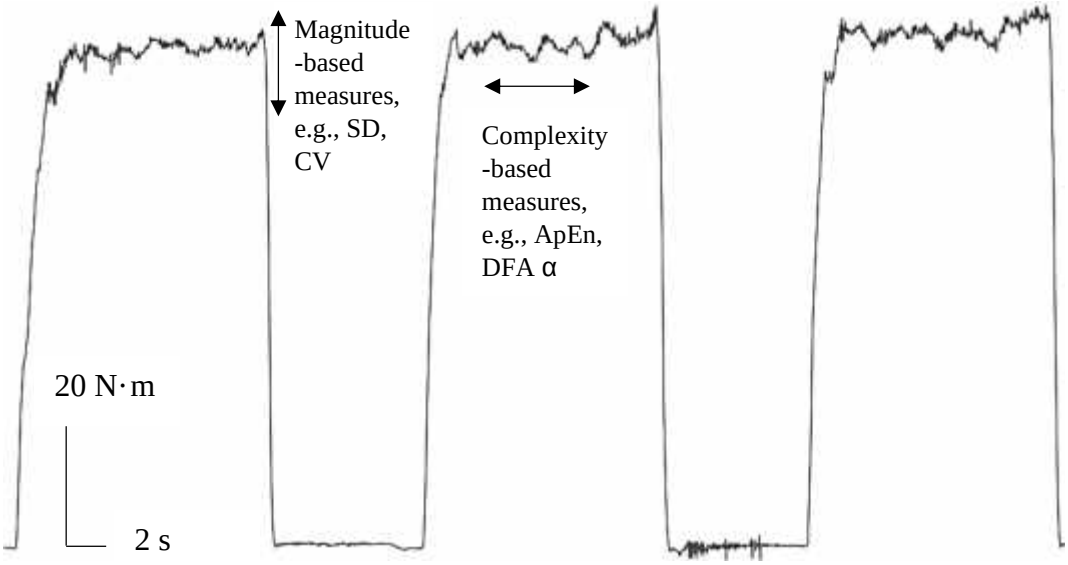
**Figure 1.** Contraction protocol for torque control task. Participants held contractions for 12 seconds, with eight seconds rest between contractions.

**Figure 2.** Box and jitter plot of standard deviation (SD) for 10% MVC (A), 20% MVC (B) and 40% MVC (C). SD was greater for both males and females at 20% compared to 10% MVC and at 40% compared to 20% MVC. * = significant difference from males.

**Figure 3.** Box and jitter plot of coefficient of variation (CV) for 10% MVC (A), 20% MVC (B) and 40% MVC (C). CV was lower for both males and females at 20% compared to 10% MVC, with no difference between 20% and 40% MVC. * = significant difference from males.

**Figure 4.** Box and jitter plot of approximate entropy (ApEn) for 10% MVC (A), 20% MVC (B) and 40% MVC (C). ApEn was lower for both males and females at 20% compared to 10% MVC and at 40% compared to 20% MVC. * = significant difference from males.

**Figure 5.** Box and jitter plot of detrended fluctuation analysis (DFA) α for 10% MVC (A), 20% MVC (B) and 40% MVC (C). DFA α was greater at 20% compared to 10% MVC and at 40% compared to 20% MVC. * = significant difference from males.


Magnitude
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measures,
e.g., SD,
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measures,
e.g., ApEn,
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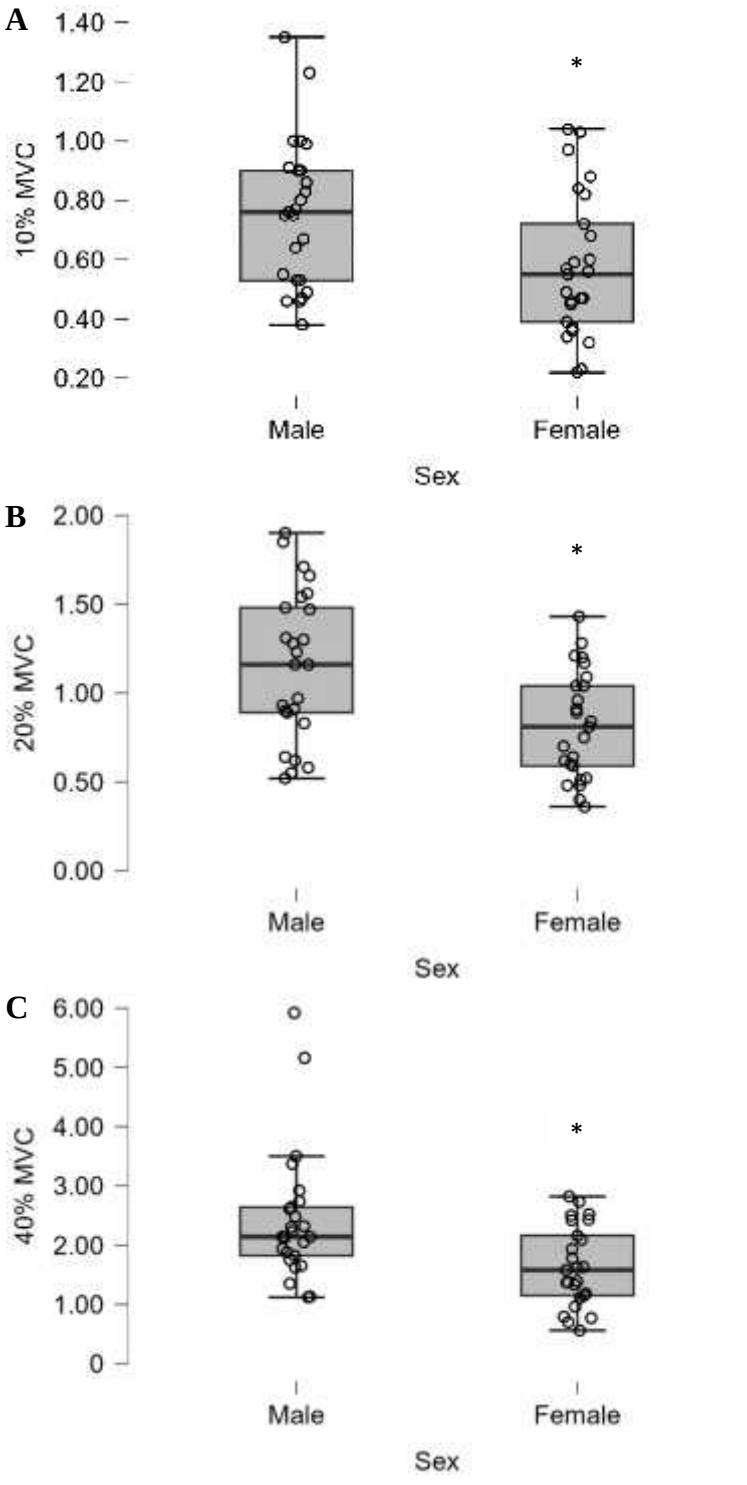
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0.20
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Female
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20% MVC
*
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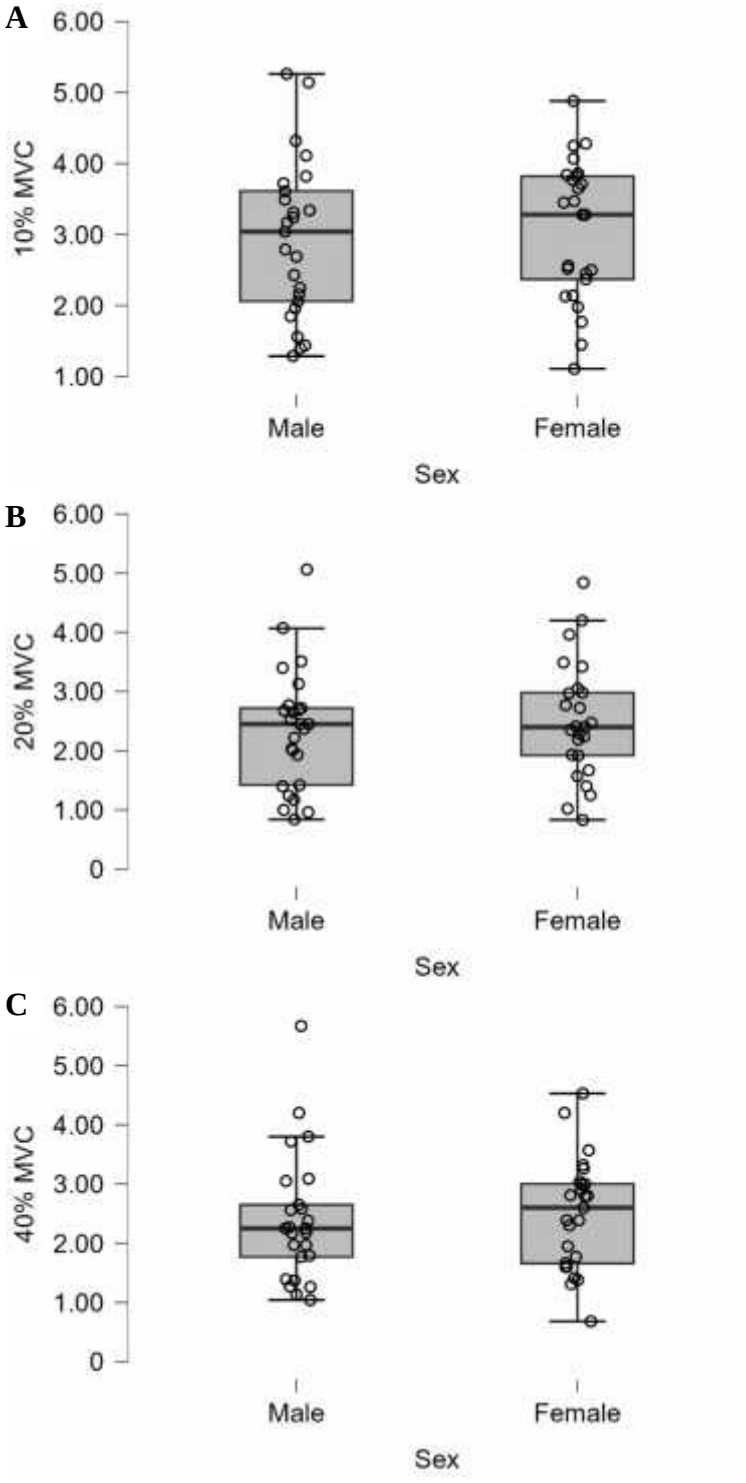
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20% MVC
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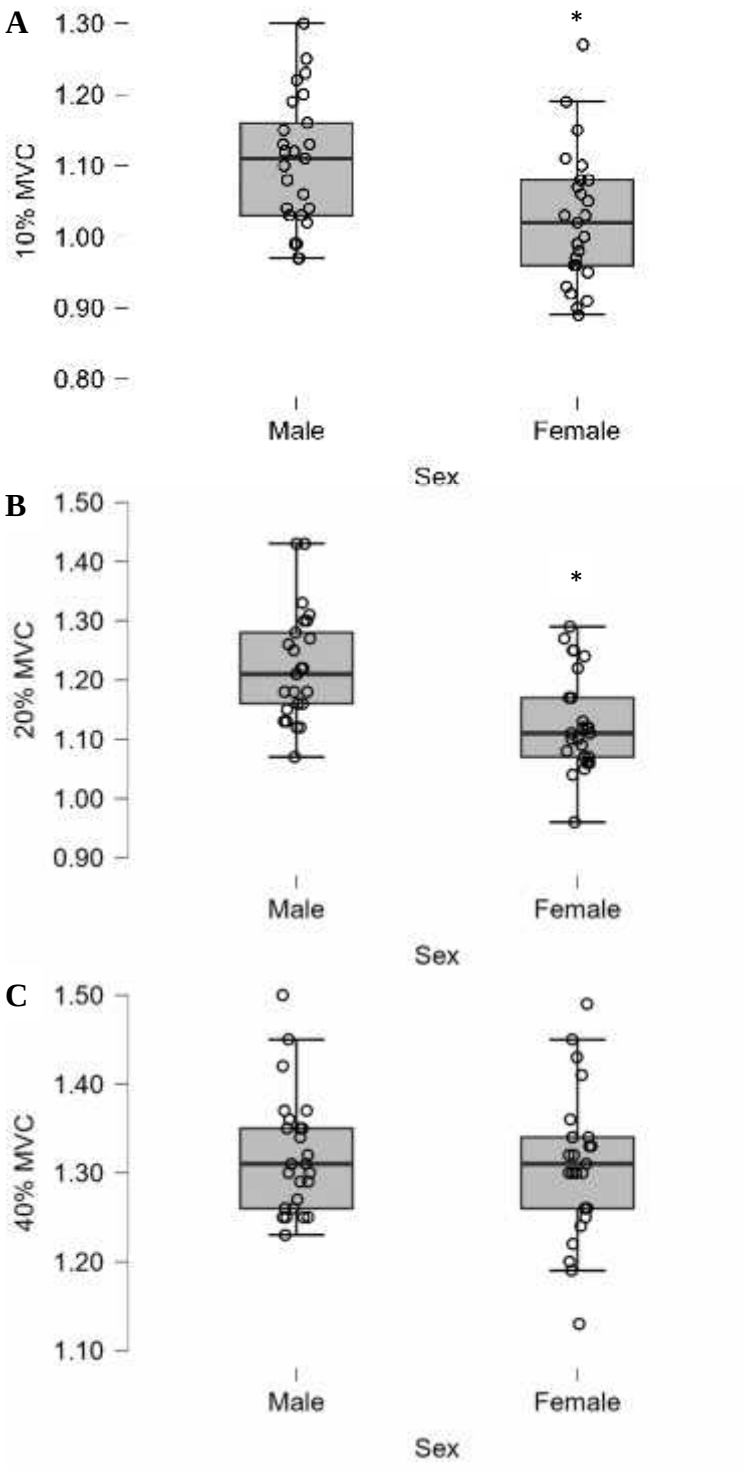
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Sex
C
1.50
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40% MVC
Male
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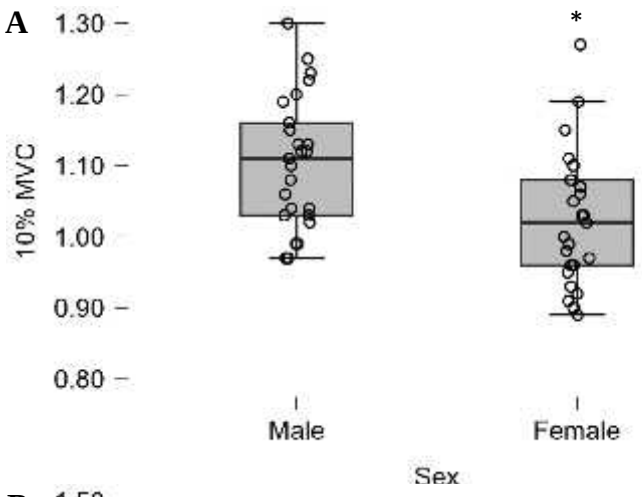
Sex


A
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Male
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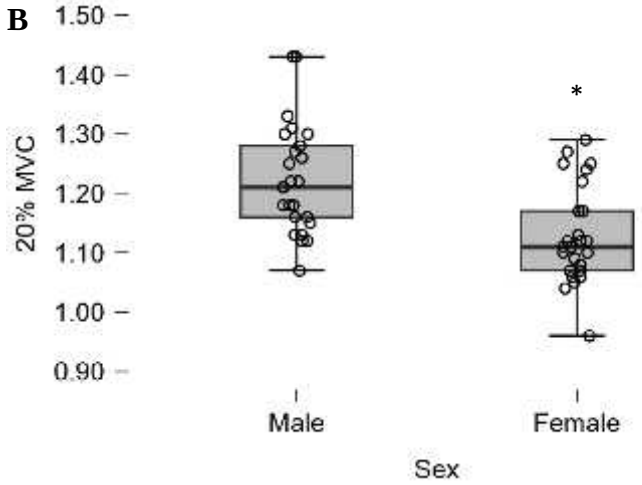
B
1.50
1.40
1.30
1.20
1.10
1.00
0.90
20% MVC
*
Male
Female
Sex


C
1.50
1.40
1.30
1.20
1.10
40% MVC
Male
Female
Sex

| Measure | Males (n = 25) | Females (n = 25) |
|---|---|---|
| Age (years) | 23.0 (20.0 – 33.0) | 21.0 (20.0 – 40.5) |
| Weight (kg) | 75.5 (71.7 – 85.3) | 59.5 (53.4 – 68.9)* |
| Height (m) | 1.73 (1.71 – 1.79) | 1.63 (1.58 – 1.71)* |
| BMI ($kg/m^2$) | 25.2 (24.3 – 27.5) | 22.4 (21.0 – 24.8)* |

Values are presented as medians (interquartile range) due to non-normal distribution. * indicates statistically significant difference ($P < 0.05$). BMI = Body mass index.