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Fatigue and Recovery from Dynamic Contractions in Men and Women Differ for Arm and Leg Muscles

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FATIGUE AND RECOVERY FROM DYNAMIC CONTRACTIONS IN MEN AND WOMEN DIFFER FOR ARM AND LEG MUSCLES

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Abstract

Introduction—Whether there is a gender difference in fatigue and recovery from maximal velocity fatiguing contractions and across muscles is not understood.

Methods—Sixteen men and 19 women performed 90 isotonic contractions at maximal voluntary shortening velocity (maximal velocity concentric contractions, MVCC) with the elbow flexor and knee extensor muscles (separate days) at a load equivalent to 20% maximal voluntary isometric contraction (MVIC).

Results—Power (from MVCCs) decreased similarly for men and women for both muscles ($P > 0.05$). Men and women had similar declines in MVIC of elbow flexors, but men had greater reductions in knee extensor MVIC force and MVIC electromyogram activity than women ($P < 0.05$). The decline in MVIC and power was greater, and force recovery was slower for the elbow flexors compared with knee extensors.

Conclusions—The gender difference in muscle fatigue often observed during isometric tasks was diminished during fast dynamic contractions for upper and lower limb muscles.

Keywords

elbow flexors; gender; knee extensors; sex differences; women

There is limited information on whether gender differences in fatigue exist during dynamic contractions, despite the potential implications for rehabilitation. Some studies show less fatigue of lower limb muscles in women than men for isokinetic dynamic contractions, and this is related to greater mechanical work performed by men.[1–3] For isometric fatiguing contractions, women are typically less fatigable than men,[4] although the gender difference is greater for some muscle groups such as the elbow flexors compared with the ankle dorsiflexors.[5–8] The mechanism for the gender difference is related to a more oxidative muscle of women and strength related-differences in perfusion.[9–11] Recent findings in the aging-fatigue literature, however, indicate that older muscles are typically *less* fatigable during isometric and slow-to-moderate velocity contractions[12,13] and are *more* fatigable for fast or maximal velocity contractions.[14–16] Here, we extend our understanding of the task specificity of gender differences in fatigue by comparing muscle fatigue of young men and women elicited during a maximal velocity fatigue task. Upper and lower limb muscles that show large gender differences for isometric fatiguing contractions[5,7–9,17–19] were assessed.

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We also determined recovery in men and women, which is a unique aspect that has received minimal attention in the fatigue and rehabilitation literature.

MATERIALS AND METHODS

Thirty-five adults (16 men, 20 ± 1 years and 19 women, 21 ± 1 years) performed a dynamic isotonic, fatigue task with a load equivalent to 20% of MVIC on the Biodex System 4 dynamometer (Biodex Medical, Shirley, New York). The fatiguing protocol involved 3 sets of 30 MVCCs with 1 MVCC every 3 s. Subjects were asked to move their limb as fast as possible through the required range of motion; a 20% of MVIC load moved at maximal velocity closely corresponds to peak power production on the force-power curve.[20] Each set of MVCCs was separated by an MVIC. An MVIC and a set of 6 MVCCs were assessed before and in recovery (2.5, 5, 7.5, and 10 min post) from the fatiguing protocol. The right limb elbow flexor and knee extensor muscles were tested on separate days (counterbalanced). Subjects were seated at 90° hip flexion, and for both muscle groups, full extension is considered 0°. For knee extensor muscles, MVICs were performed at 75° and dynamic contractions between 90° to ~5° of knee extension. For elbow flexor muscles, the arm was abducted ~90°, and MVICs were performed at 90° and dynamic contractions between 125° to 35° elbow extension. Joint angle, torque, and velocity signals were digitized at 500 samples/s (Power 1401) and recorded to Spike2 software (Cambridge Electronics Design, Cambridge, UK). The electromyogram (EMG, Coulbourn Instruments, Allentown, Pennsylvania) of knee extensors (vastus lateralis, vastus medialis, rectus femoris) and elbow flexors (biceps brachii, brachioradilis) were recorded with bipolar surface electrodes, bandpass filtered (13–1,000 Hz), and sampled at 2,000 Hz. Rating of perceived exertion (RPE, on a scale of 0 to 10),[21] heart rate, and blood pressure (Omron Healthcare Inc, Illinois) were monitored. Physical activity levels were estimated from a questionnaire.[22]

Repeated-measure analyses of variance over time with gender as a between-subject factor and independent *t*-tests compared dependent variables. Significance was identified at $P < 0.05$.

RESULTS

Men and women were similar in physical activity levels (89.5 ± 10.7 vs. 85.5 ± 11.1 MET.hr/week, $P = 0.70$). Men were stronger and more powerful than women for both muscle groups ($P < 0.05$; Fig. 1A,B). Knee extensors were stronger and more powerful than elbow flexors for both genders ($P < 0.05$; Fig. 1A,B).

Men and women had similar reductions in elbow flexor MVIC after the dynamic contractions ($P > 0.05$), but men had greater reductions than women in both knee extensor MVIC ($P = 0.046$; Fig. 1C) and MVIC EMG activity (80.0 ± 17.3% vs. 88.2 ± 14.3% of baseline MVIC, $P = 0.034$). There was no gender difference in reduction of power for the knee extensors ($P = 0.102$) or elbow flexors ($P = 0.50$; Fig. 1D).

Elbow flexors had greater declines than knee extensors for MVIC (16% difference, genders pooled) and power (7% difference; Fig. 1E,F). Recovery of MVIC was slower for elbow flexors than knee extensors, but power had a similar recovery for the muscles.

During the dynamic fatiguing task, EMG activity decreased for men and women similarly for the knee extensors ($P = 0.101$) and elbow flexors ($P = 0.23$). RPE, blood pressure, and heart rate increased similarly for the genders ($P > 0.05$).

DISCUSSION

There are several novel observations. First, there was no gender difference in the power reduction (fatigue) during repeated maximal velocity contractions or in the subsequent recovery for the elbow flexor and knee extensor muscles. Thus, the less fatigable muscles of women often observed for isometric fatiguing tasks[4] was shown here to be diminished for maximal velocity contractions when we assessed the muscles with a sub-maximal load that usually corresponds to peak power.[20] The rate-limiting mechanisms of maximal velocity (speed of cross-bridge cycling and calcium kinetics in the fiber[23]) was likely impaired similarly for both genders.

Second, fatigue of knee extensor MVIC was greater for men than women at the end of the fatiguing task, while the genders had similar reductions in MVIC for the elbow flexor muscles. Fatigue of maximal force is due to fewer high force cross-bridges and/or less force per cross-bridge[23] and a loss of voluntary drive (central fatigue).[9,24] Men previously showed greater central fatigue of knee extensor MVICs after isometric fatiguing contractions[19] but no gender differences for elbow flexors.[9,25,26] Central fatigue could explain the greater loss of knee extensor MVIC of the men than women, and the greater loss of MVIC EMG activity for the men than women in this study support this explanation.

Third, elbow flexor muscles exhibited greater relative fatigue (both reductions in MVIC and power) than knee extensors and slower recovery of MVIC torque. Elbow flexors can have larger proportions of fast more fatigable (type II) fibers than the knee extensors.[27] Both muscle groups were placed horizontally, so posture and perfusion likely did not contribute to the muscle group differences, and the cardiovascular responses corroborate this interpretation.

Thus, the greater fatigue resistance of women compared with men during isometric contractions was diminished for fatigue of power during maximal velocity dynamic contractions of arm and leg muscles. The mode of testing to evaluate fatigue after dynamic fatiguing contractions, however, can yield varying results for men and women in the lower and upper limb muscles. Because fatiguing contractions are required for neuromuscular adaptation,[28,29] there are significant implications for methods of muscle function assessment during training and rehabilitation in men and women.

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Abbreviations

EMG	electromyogram
MET	metabolic equivalents
min	minutes
MVCC	maximal velocity concentric contraction
MVIC	maximal voluntary isometric contraction
RPE	rating of perceived exertion
s	seconds

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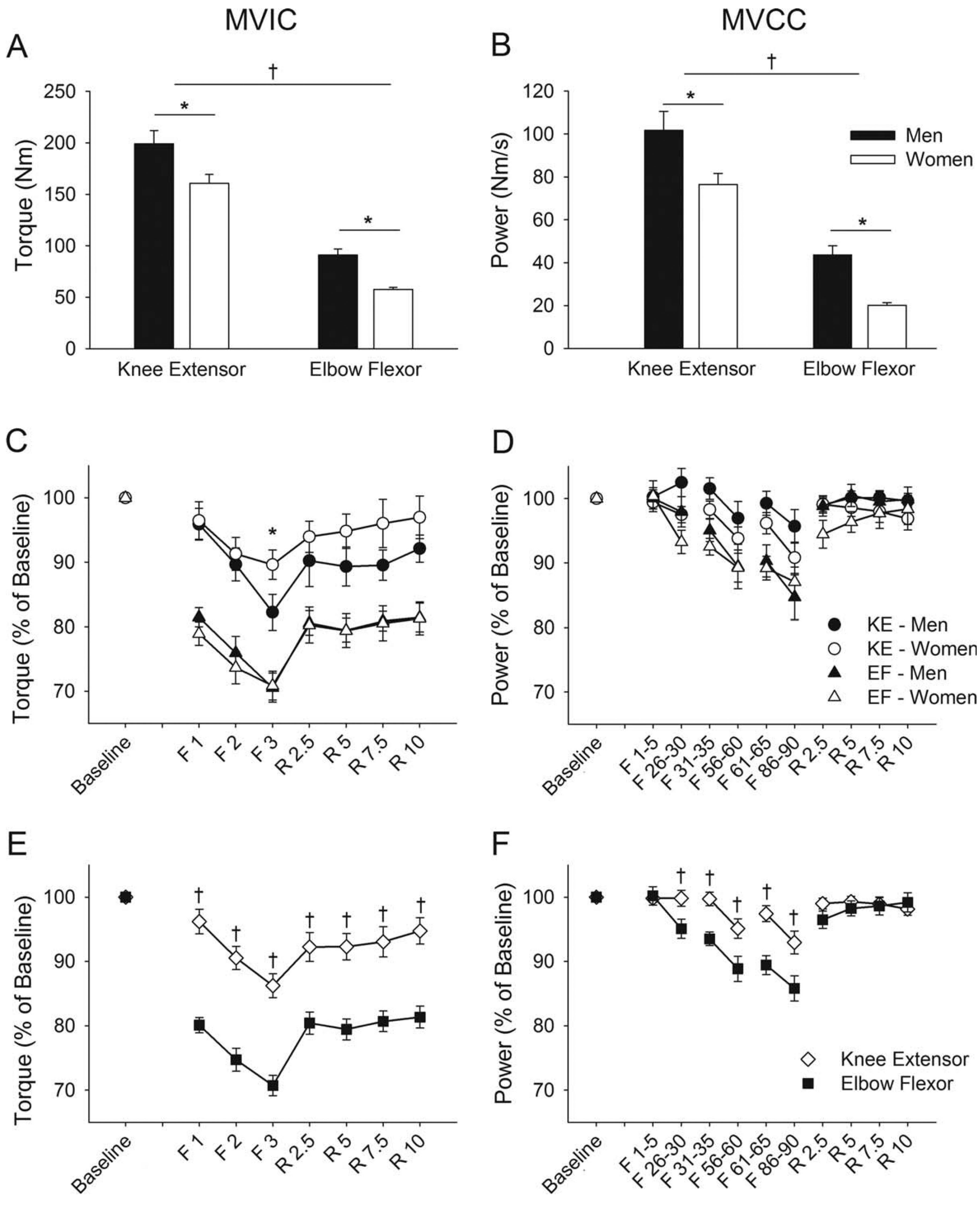

FIGURE 1.

Maximal voluntary isometric contraction (MVIC) torque and maximal velocity concentric contraction (MVCC) power during knee extension and elbow flexion of young men and women. **A,B:** Baseline (control) values of MVIC torque (A) and MVCC power with 20% MVIC load (B) for the knee extensor and elbow flexor muscles. Shown are the mean (±SEM). **C:** MVIC torque (% of baseline) immediately after each of the 3 sets of 30 dynamic contractions (F1, F2, and F3) and recovery measures at 2.5, 5, 7.5, and 10 min (R2.5, R5, R7.5, and R10) for each of the muscle groups. **D:** Power (% of baseline) at the start and end of each of the 3 sets of fatiguing dynamic contractions (mean ±SEM of 5 contractions) and for recovery measures at 2.5, 5, 7.5, and 10 minutes (R2.5, R5, R7.5, and

R10) for each of the muscle groups. **E,F:** MVIC torque (E) and power (F) relative to control for the same time intervals (x axis) as panels C and D for the knee extensor (KE) and elbow flexor (EF) muscles. Gender difference indicated by * at $P < 0.05$, and muscle group differences indicated by † at $P < 0.05$.

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