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1 **Contraction intensity and sex differences in knee-extensor fatigability**

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Abstract

Females are less fatigable than males during isometric contractions across various muscles and intensities. However, sex differences in knee-extensor fatigability remain relatively unexplored. **Purpose:** To determine the sex difference in performance fatigability for intermittent, isometric contractions of the knee-extensor muscles. **Methods:** Eighteen participants (10 males, 8 females) performed intermittent, isometric, knee-extensor contractions at 30% of their maximal voluntary force (MVC) for 30 min and in a separate session at 50% MVC until task-failure. During both fatiguing protocols a MVC was performed every 60 s and electromyography (EMG) was recorded during all contractions. **Results:** At task completion males had a larger reduction in MVC force for the 30% MVC task ($-32\pm 15\%$ vs. $-15\pm 16\%$, $P=0.042$) and the 50% MVC task ($-34\pm 8\%$ vs. $-24\pm 1\%$, $P=0.045$). Furthermore, for the 50% MVC task, females had a longer task duration (937 ± 525 s vs. 397 ± 153 s, $P=0.007$). The rise in EMG activity and force fluctuations were more rapid for the males than females ($P<0.05$). When participants were matched for strength *post-hoc* ($n=10$), a sex difference in fatigability for both tasks was still evident. **Conclusions:** Females were less fatigable than males during intermittent, isometric, knee-extensor contractions at moderate relative forces and this difference was independent of strength.

Words: 199

INTRODUCTION

70

71 Fatigue is a disabling symptom characterised by sensations of tiredness and weakness, underpinned
72 by multiple complex mechanisms (Enoka and Duchateau, 2016). The intricacies of fatigue vary
73 depending on circumstances, but during exercise, reductions in physical function [i.e., performance
74 fatigability (Hunter, 2017)] involves impaired force producing capacity of the working muscles. An
75 exercise-induced reduction in force capacity has been termed muscle fatigue (Gandevia, 2001),
76 mechanisms contributing to this reduction in force can occur at various and multiple sites along the
77 motor pathway, between neural activation and the contractile proteins of the working muscles (Enoka
78 and Duchateau, 2016). The contribution of these mechanisms and the magnitude of this fatigability
79 however, are dependent on the demands of the exercise task (Enoka and Stuart, 1992) such as the
80 contraction intensity (Place et al. , 2009). When submaximal tasks are performed at lower intensities
81 for a longer duration, impaired activation of the muscles can contribute substantially to fatigability
82 (Smith et al. , 2007) whereas contractile failure is often dominant for higher intensity–shorter duration
83 tasks with modest deficits in activation (Bigland-Ritchie et al. , 1986).

84 Performance fatigability is also modulated by the sex of the individual. Males have typically shown to
85 be more fatigable than females in several muscle groups (Hunter, 2014, Hunter, 2016) for both
86 continuous, and intermittent tasks (Hunter and Enoka, 2001, Hunter et al. , 2009, Yoon et al. , 2009).
87 However, the sex difference in fatigability and the contributing mechanisms can be specific to the
88 demands of the task including the contraction intensity and type, and the muscle groups involved. For
89 example, for lower intensity sustained contractions, there were sex differences for the elbow-flexor
90 muscles, but not in the ankle-dorsiflexor muscles (Avin et al. , 2010), and no sex differences for the
91 elbow-extensor muscles (Dearth et al. , 2010). The sex differences in fatigability are also greater at
92 lower intensities during sustained contractions that are held until task-failure for the elbow-flexor
93 muscles, forearm and the knee-extensor tasks (Maughan et al. , 1986, West et al. , 1995, Yoon et al. ,
94 2007), possibly in part due to perfusion-related differences between sexes, as males produce more
95 absolute force for the same relative intensity (Clark et al. , 2005). For intermittent tasks, when
96 perfusion related-differences are minimized, the sex difference is still apparent, even when the sexes
97 are matched for strength in elbow-flexor and forearm muscles (Hunter et al. , 2006, Hunter et al. ,
98 2004). In the *vastus lateralis*, females have been shown to have greater proportion of type-1 oxidative
99 fibres (Staron et al. , 2000) giving rationale for a more fatigue resistant muscle. Lower limb muscles
100 are important for locomotion and often exercise training regimes but there is less information on any

101 sex-related differences across different tasks. While the sex difference in fatigability is primarily
102 attributable to contractile and metabolic processes for the elbow-flexor muscles, for lower limb
103 muscles (ankle-dorsiflexors and knee-extensors), the sex difference has also been attributed to larger
104 reductions in voluntary activation in men during maximal tasks (Martin and Rattey, 2007, Russ and
105 Kent-Braun, 2003). Thus, the mechanisms of sex differences in performance fatigability are specific to
106 the task and muscle groups involved.

107 A sex difference in fatigability of the knee-extensor muscles was demonstrated for sustained isometric
108 and isotonic contractions (Clark, Collier, 2005, Martin and Rattey, 2007, Maughan, Harmon, 1986,
109 Senefeld et al. , 2013) but it is unknown if the fatigability of male and female knee-extensor muscles
110 also occurs for submaximal intermittent, isometric contractions across different contraction
111 intensities. Whilst Albert et al. (2006) purported to use this contraction style in the knee extensors
112 and found that females were less fatigable, the protocol used 30 s contractions with a 1:1 duty cycle.
113 Therefore, the long duration of contraction likely led to differential degrees of blood flow occlusion
114 between sexes, which might have been the reason for the sex difference reported (Clark et al., 2005).
115 In order to examine whether the sex difference was still apparent without occlusion difference, the
116 present study used a much shorter duration contraction (3 s), with a duty cycle previously reported to
117 negate the influence of occlusion (Hunter et al., 2004). The aim of this study was to determine sex
118 differences in fatigability for two submaximal intermittent contraction intensities performed with the
119 knee-extensors. It was hypothesised that females would exhibit less fatigability than males following
120 intermittent, isometric contractions.

121 **METHODS**

122 **Participants**

123 Eighteen recreationally active participants were recruited from University sports teams, 10 males,
124 (age, 21 ± 1 years; stature, 1.78 ± 0.04 m; mass, 78 ± 12 kg) and eight females (age, 21 ± 0 years,
125 stature, 1.64 ± 0.06 m; mass, 61 ± 10 kg) who regularly competed in sport of intermittent nature
126 (hockey, netball, rugby, and soccer) provided written informed consent to volunteer for the study.
127 Participants arrived at the laboratory rested and hydrated, having avoided strenuous exercise in the
128 preceding 48 h, and having refrained from caffeine for 12 h and alcohol for 24 h prior to each
129 experiment. The study received institutional ethical approval and was conducted according to the
130 Declaration of Helsinki.

131 **Experimental Design and Exercise Protocol**

132 Participants visited the laboratory on three separate sessions over a 10-day period that included one
133 familiarisation session (visit 1) followed by two experimental sessions. All sessions were a minimum
134 of 48 and a maximum of 72 hours apart. On visits 2 and 3, participants completed intermittent,
135 isometric, knee-extensor exercise at either 30 or 50% maximal voluntary contraction (MVC) in a
136 randomised, counterbalanced, crossover design. During the familiarisation session participants
137 practiced performing MVCs with their dominant knee-extensors, and two sets of the intermittent
138 contractions (3 s contraction, 2 s rest) at 30% MVC. One set comprised of 12 contractions followed by
139 a MVC (Figure 1).

140 Each experimental session began with three ~3-5 s MVCs with 30 s of recovery between each trial to
141 attain maximum MVC force. Participants then performed an intermittent fatiguing task either at 30%
142 or 50% MVC with the order of the tasks randomised across the two experimental days. Target forces,
143 based on the MVC achieved on each day, and real-time force were presented on a computer screen
144 placed in view of the participant. For the 30% MVC task, all participants exercised for 30 minutes and
145 for the 50% MVC task, each participant performed the intermittent contractions until task-failure.
146 Task-failure was defined as a failure to meet the target force by 5% three times within one set. A
147 metronome (Gymboss interval timer, Gymboss LLC, St Clair MI, USA) ensured the correct timing for
148 the start and end of each contraction during the fatiguing protocols.

149 **Force and Electromyography**

150 Knee-extensor force (N) was recorded using a calibrated load cell (MuscleLab force sensor 300,
151 Ergotest technology, Norway). The load cell was fixed to a custom-built chair and connected to a non-
152 compliant cuff attached around the participant's dominant leg, ~1-2 cm superior to the ankle malleoli.
153 Participants were instructed to sit upright in the chair with the hips and knees at 90° of flexion, this
154 position was maintained for the entire trial. The force signal was amplified (×300) with an isolated
155 pre-amplifier (1902, Cambridge Electronic Design, [CED] UK), digitised at 4 kHz (Power 1401, CED, UK)
156 and analysed offline with Spike2 v7.12 (CED, UK).

157 Electromyographic (EMG) activity was recorded from the *vastus lateralis* using surface electrodes
158 (Kendall, Ag/AgCl H87PG/F, Covidien, MA, USA). After the skin was cleaned and shaved, electrodes
159 were placed 2 cm apart over the muscle belly with a reference over the ipsilateral patella in
160 accordance with SENIAM guidelines (Hermens et al. , 2000). Electrode placement was marked with
161 permanent ink to ensure consistent placement between laboratory visits. From the recorded

162 interference EMG, root mean square EMG (rmsEMG) amplitude was calculated during the submaximal
163 and maximal (rmsMVC) contractions. The EMG signals were amplified ($\times 1000$) and band-pass filtered
164 (20-2000 Hz) with an isolated pre-amplifier (1902, CED, UK), digitised (4 kHz; Power 1401, CED, UK),
165 and analysed off line using Spike2 v7.12 (CED, UK).

166 **Data Analysis**

167 Maximal force was determined as the peak force achieved during the greatest of the three MVCs and
168 the rmsMVC was calculated from the corresponding time point centred over a 500 ms window. During
169 the fatiguing task, knee-extensor force, rmsEMG activity, and force fluctuations were measured over
170 a 1.5 s window during each contraction. The rmsEMG during sets of contractions was normalised to
171 the baseline rmsMVC at the beginning of each trial. Force fluctuations were quantified as the
172 coefficient of variation (CV) of force during each submaximal contraction. The same variables were
173 also analysed *post hoc* during the sets of submaximal contractions that were closest in time to the 25,
174 50 and 75% of task duration. Five males and five females were matched for strength; each pairing had
175 a baseline knee-extensor MVC within $\sim 10\%$ of the matched partner. This was included in the analysis
176 to compare the fatigability of the knee extensors to strength-matched pairs in the elbow flexors
177 (Hunter et al., 2004).

178 **Statistical Analysis**

179 Data are presented as mean \pm SD within the text and figures. To detect effects of sex (males, females),
180 time (start and end exercise) and any interactions, the data of the dependent variables were entered
181 into a separate two-way (2×2) Analysis of Variance (ANOVA) for each of the fatiguing protocols.
182 Dependent variables included force, rmsEMG, and CV of force. Assumptions of sphericity were
183 explored and controlled for all variables using the Greenhouse-Geisser adjustment, where
184 appropriate. Post-hoc paired sample *t*-tests were used to detect pre- to post-differences within
185 groups (SPSS v21, IBM, Chicago, USA) and effect sizes were calculated for the selected comparisons
186 using Cohen's *d*. Due to the small sample size of strength-matched pairs, ANOVAs and post-hoc tests
187 were not performed, however effect sizes were calculated for the differences between sexes.
188 Statistical significance was assumed at $P \leq 0.05$.

189

RESULTS

190
191 Males were 36% stronger than females (599 ± 139 vs. 384 ± 94 N, $P = 0.005$) consequently, target
192 forces for the men were higher for the 30% MVC task (169 ± 46 vs. 112 ± 29 N, respectively, $P = 0.007$)
193 and 50% MVC task (288 ± 69 vs. 195 ± 37 N, respectively $P = 0.003$). MVC force was not different
194 between the strength-matched males and females (438 ± 69 vs 423 ± 82 , $P = 0.77$; mean difference:
195 27 ± 4 N; $5 \pm 4\%$).

196
197 **30% MVC Fatiguing Task.** MVC force declined from pre- to post-exercise (time effect, $F_{1,7} = 28.65$; P
198 $= 0.001$, Figure 2A) and there was a greater reduction for the males compared with females (sex*time
199 interaction, $F_{1,7} = 6.13$, $P = 0.042$, $d = 1.87$). The average reduction in the males was 195 ± 125 N ($\Delta 32$
200 $\pm 15\%$; $P < 0.001$) and 57 ± 53 N for the females ($\Delta 15 \pm 16\%$; $P = 0.019$). In strength-matched pairs
201 (Figure 2B), smaller MVC decreases were evident in females compared with males ($\Delta 14 \pm 10\%$ vs. $\Delta 23$
202 $\pm 13\%$ respectively, $d = 0.78$).

203 The normalised rmsEMG activity (% baseline) increased across time (time effect, $F_{1,7} = 16.99$, $P =$
204 0.004). There was no difference in rmsEMG (% baseline) between the sexes during the fatiguing
205 exercise (group*time interaction, $F_{1,7} = 0.68$, $P = 0.436$, $d = 0.63$) with the males increasing by $46 \pm 39\%$
206 and the women by $17 \pm 17\%$ (Figure 2C). When participants were matched for strength (Figure 2D)
207 the males increased by $24 \pm 23\%$ and females by $11 \pm 10\%$ ($d = 0.73$).

208 Force fluctuations did not significantly increase throughout the trial (time effect: $F_{1,7} = 3.47$, $P = 0.105$,
209 $d = 1.41$). There was no difference in force fluctuations between sexes (group*time interaction effect:
210 $F_{1,7} = 0.39$, $P = 0.56$, $d = 0.47$). In strength-matched pairs (Figure 2F), males' CV increased by $37 \pm 63\%$
211 and females by $6 \pm 16\%$ ($d = 0.66$).

212
213 **50% MVC Fatiguing Task.** Time to task-failure was longer for females than males (937 ± 525 vs. $397 \pm$
214 153 s, $P = 0.007$). Of the participants who were strength-matched, all pairs showed that females
215 exercised for longer (1010 ± 546 s vs. 411 ± 211 s, Figure 3).

216 MVC force declined over time (time effect, $F_{1,7} = 99.39$, $P < 0.001$, Figure 4A) in both males ($\Delta 203 \pm 83$
217 N, $\Delta 34 \pm 8\%$) and females ($\Delta 96 \pm 43$ N, $\Delta 24 \pm 1\%$). Despite exercising for less time, the decline in MVC
218 force was greater for males (group*time interaction $F_{1,7} = 5.91$, $P = 0.045$, $d = 1.84$) and this was
219 reflected in the greater rate of MVC force loss for males compared with the females (34 ± 18 vs. $10 \pm$

220 8 N·min⁻¹, P = 0.003). The difference was also reflected in the strength-matched pairs ($\Delta 23 \pm 7\%$ vs.
221 $\Delta 30 \pm 8\%$, $d = 0.93$; Figure 4B).

222 The rmsEMG activity (% baseline) increased over time ($F_{1,7} = 27.33$, P = 0.001, Figure 4C), with an
223 increase of $56 \pm 40\%$ for males and $20 \pm 14\%$ for females. However, these increases were not different
224 between sexes when compared at the same relative time intervals (group*time interaction $F_{1,7} = 2.81$,
225 P = 0.138, $d = 1.27$). Due to females exercising for longer, the rate of rise in rmsEMG was lower than
226 the males (1.37 ± 1.59 vs. $5.45 \pm 4.77\% \cdot \text{min}^{-1}$, P = 0.035). In the strength-matched pairs (Figure 4D), 3
227 of the 5 females experienced smaller increases in rmsEMG ($\Delta 13 \pm 11\%$ vs. $\Delta 45 \pm 50\%$, $d = 0.88$).

228 Force fluctuations (CV of force) were not different ($F_{1,7} = 1.79$, P = 0.223) but increased over time (time
229 effect, $F_{1,7} = 8.20$, P = 0.024, Figure 4E). The increase was not different between the sexes when
230 compared at the same relative time intervals (group*time interaction $F_{1,7} = 3.91$, P = 0.088, $d = 1.49$).
231 However, due to the shorter time to task-failure for males, the rate of force fluctuation increase was
232 smaller in females (0.17 ± 0.11 vs. $0.39 \pm 0.14\% \cdot \text{min}^{-1}$, P = 0.001). In the strength-matched pairs (Figure
233 4F) 4 of the 5 females experienced smaller increases in CV than the males ($\Delta 52 \pm 13$ vs. $\Delta 17 \pm 32\%$, d
234 = 1.42).

235

236

DISCUSSION

237 The aim of the study was to determine the sex difference in fatigability of the knee-extensors during
238 short duration intermittent, isometric exercise at two submaximal contraction intensities. The data
239 illustrate that males show greater fatigability (reduction in MVC force) than females after intermittent
240 contractions at 30% MVC, and the same pattern was evident for intermittent contractions to volitional
241 exhaustion at 50% MVC. In line with the attenuated fatigue response, females exercised for more than
242 twice as long as the males whilst exhibiting smaller increases in EMG activity and force fluctuations
243 during the 50% task. When females and males were strength-matched (n = 5 pairs), the sex difference
244 in the decline in MVC force, and the time to task-failure, were still evident. Collectively, these data
245 demonstrate that a sex difference in fatigability exists for intermittent, isometric knee-extensor
246 exercise at both low and moderate intensities, and this sex difference is probably not explained by
247 absolute strength.

248

249 Our findings add to previous work in other muscle groups demonstrating that males are more fatigable
250 than females during intermittent, isometric contractions (Albert et al., 2006, Hunter et al., 2004,

251 Hunter et al., 2009). Furthermore, similar to when males and females were strength-matched for
252 performance of an intermittent isometric contraction task (Hunter et al., 2004), we showed that
253 females had a much longer time to task-failure (more than two-fold) compared with males for the
254 50% MVC task (937 vs. 397 s), however these results should be interpreted with caution as the small
255 sample size precluded inferential analysis. Despite the females exercising for longer, MVC reduction
256 was lower when compared with the males in our study, with a ~10% sex difference at task-failure.
257 Thus, the rate of decline for MVC force was over three times greater for males than females (34 vs. 10
258 $\text{N}\cdot\text{min}^{-1}$), a finding that was mirrored in the rmsEMG and force fluctuation (CV) data. The data from
259 the present study add to previous literature in other muscle groups showing that a sex difference in
260 performance fatigability following intermittent contractions is present in the knee-extensors. This
261 finding has implications for exercise training given the importance of the knee-extensors to
262 locomotion.

263

264 Mechanisms for the sex differences in fatigability during the intermittent tasks (when blood flow is
265 not occluded), include skeletal muscle metabolite accumulation, alterations in the contractile
266 properties and the reductions in voluntary activation (Hunter, 2014, Hunter, 2016). Although surface
267 EMG is not a direct indicator of neural drive (Farina et al. , 2014), we showed that the rate of rise in
268 motor unit recruitment during the 50% task was more gradual for the females than the males, despite
269 no differences at task-failure. During constant load contractions, EMG will typically increase, as we
270 observed in this study. Data in male populations show that increases in EMG activity during strenuous
271 exercise are closely linked with the contribution of anaerobic metabolism (Bundle et al. , 2006). This
272 is primarily caused by an increase in motor unit recruitment and reduced discharge rates (Garland et
273 al. , 1994) in response to compensatory increases in descending drive as the active muscle fibres
274 become progressively fatigued (McNeil et al. , 2011). Data from a similar study in the elbow-flexors
275 (Hunter, Critchlow, 2004) showed that males displayed greater increases in rmsEMG at task-failure
276 following a 50% MVC trial and greater reductions in MVC force. This trend was also seen in the
277 strength-matched pairs suggesting that motor unit activation for males and females were
278 compensating and increased at different rates to sustain the required force.

279

280 Similarly, the force fluctuations increased at greater rates for the males during both fatiguing
281 protocols. The magnitude of force fluctuations is primarily modulated by variability in the neural drive
282 of the motor unit discharge rate at low frequencies (1–2 Hz) and explains up to 70% of the force

283 steadiness (Farina and Negro, 2015). The absolute magnitude of force fluctuations (SD of isometric
284 force) increases with contraction intensity. To allow comparisons between contractions between
285 people of different strength, the fluctuations are normalized to the mean force and represented as
286 the CV of force (Enoka et al. , 2003). As we observed, the force fluctuations progressively increase
287 during fatiguing contractions for the knee-extensors during the 50% trial, a response which is observed
288 for other muscles (Hunter, Critchlow, 2004, Hunter and Enoka, 2001). Despite not reaching statistical
289 significance (interaction effect: $P = 0.088$), a trend for greater increases in force fluctuations in males
290 was observed during the 50% trial. As well as this, greater rates of increase (pre-post change divided
291 by time to task-failure, $\% \cdot \text{min}^{-1}$) in force fluctuations were observed for the males in this study.
292 Collectively, force fluctuation and EMG data suggest that motor unit recruitment and discharge rate
293 changed at varying frequencies in response to the muscle fibres fatiguing at different rates between
294 the sexes.

295

296 The greater rates of increase in the physiological adjustments reflected in the EMG and force
297 fluctuations likely reflect sex differences originating in the muscle (Hunter, 2014, Hunter, 2016). The
298 primary causes of a sex difference in fatigability during isometric contractions are mostly associated
299 with contractile and metabolic mechanisms. For instance, females typically have a greater proportion
300 of type I fibres (Staron et al., 2000), greater capillarisation of the knee-extensors (Roepstorff et al. ,
301 2006), and greater vasodilation during exercise in the femoral artery (Parker et al. , 2007) than males.
302 Thus, differences in skeletal muscle metabolism and contractile properties result in females exhibiting
303 a more fatigue resistant muscle than males. Even when strength-matched with females, the males
304 were more fatigable and the physiological adjustments reflected in the EMG and force fluctuations
305 followed the same pattern as overall group data.

306

307 The sex differences in fatigability were evident at both lower (30%) and higher intensities (50%) of
308 contraction. The time to task-failure of intermittent isometric knee-extensor contractions varies with
309 exercise intensity in a hyperbolic manner describing a force-duration relationship (Burnley et al. ,
310 2012). There is a critical force (intensity threshold) and above such an intensity, the development of
311 fatigue increases rapidly. It is possible that females were exercising lower on the hyperbolic force-
312 duration relationship relative to their critical intensity compared with males. Such that, females
313 fatigued at a slower rate and achieved longer times to task-failure. For dynamic contractions
314 performed with the knee-extensor muscles (cycling), the shape of the hyperbolic relationship does

315 not differ between the sexes (Sundberg et al. , 2017). Whether there are sex differences in the
316 intensity of this critical threshold for intermittent isometric fatiguing contractions is unknown.

317

318 There are several practical implications of the findings from this study for training and rehabilitation
319 in males and females. Because males and females fatigue at different rates during relatively short-
320 term exercise, males may need more time to recover than women between exercise training bouts.
321 However, differences in recovery of males and females after fatiguing exercise is relatively
322 unexplored. Furthermore, these results raise the possibility that females may need to train at a higher
323 intensity during training bouts to have similar fatigue effects over a given time and similar
324 neuromuscular adaptations with training. One path forward for future studies is to standardise
325 contraction intensities around a critical intensity, rather than comparing fatigability based on an
326 arbitrary percentage of MVC. This would enable the aetiology of the sex difference in fatigability to be
327 located, and consequently, training and rehabilitation could be optimised for each sex.

328

329 One limitation of this study was that menstrual cycle phase or hormonal contraceptives were not
330 controlled for in the group of females tested. While studies have demonstrated that MVC and
331 fatigability varied in the knee-extensors across the phases of the menstrual cycle (Sarwar et al. , 1996,
332 Tenan et al. , 2016), there is conflicting evidence showing no difference (de Jonge et al. , 2001).
333 However, in younger women, the differences in performance and fatigability between males and
334 females appear to be greater in effect size than possible difference across the menstrual cycle (Hunter,
335 2016).

336

Conclusion

337 We showed females to be less fatigable than males during intermittent, isometric knee-extensor
338 exercise at both 30% and 50% of MVC force. The physiological adjustments reflected in the EMG
339 activity and force fluctuations were more rapid for the males than the females. The sex differences in
340 fatigability observed could not be explained by differences in absolute strength between men and
341 women. These findings indicate that exercise performance that involves fatiguing contractions of the
342 knee-extensors muscles may differ for males and females because of fundamental differences in
343 muscle fatigability. Furthermore, understanding the sex differences in fatigability that are necessary
344 for neuromuscular adaptations will promote more targeted and effective strategies during exercise
345 training in males and females.

346

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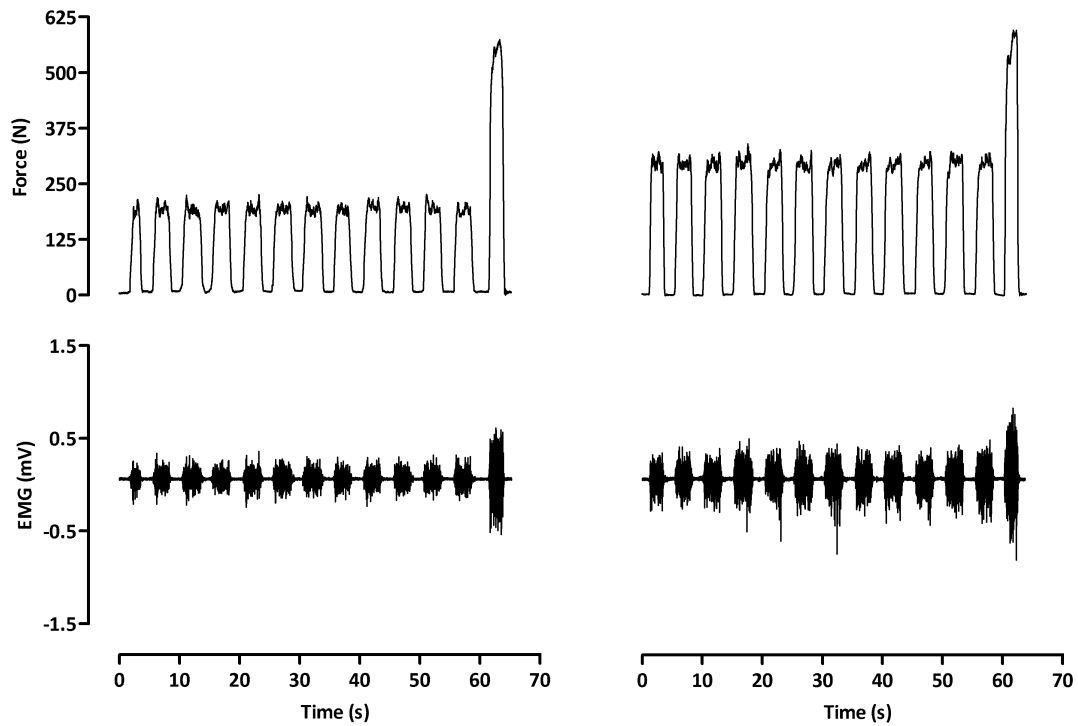
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Figure Legends



436 **Figure 1.** Force and EMG responses during one set of contractions in the 30% MVC (left hand panels)
437 and 50% MVC trials (right hand panels). All data are from the same, representative participant.

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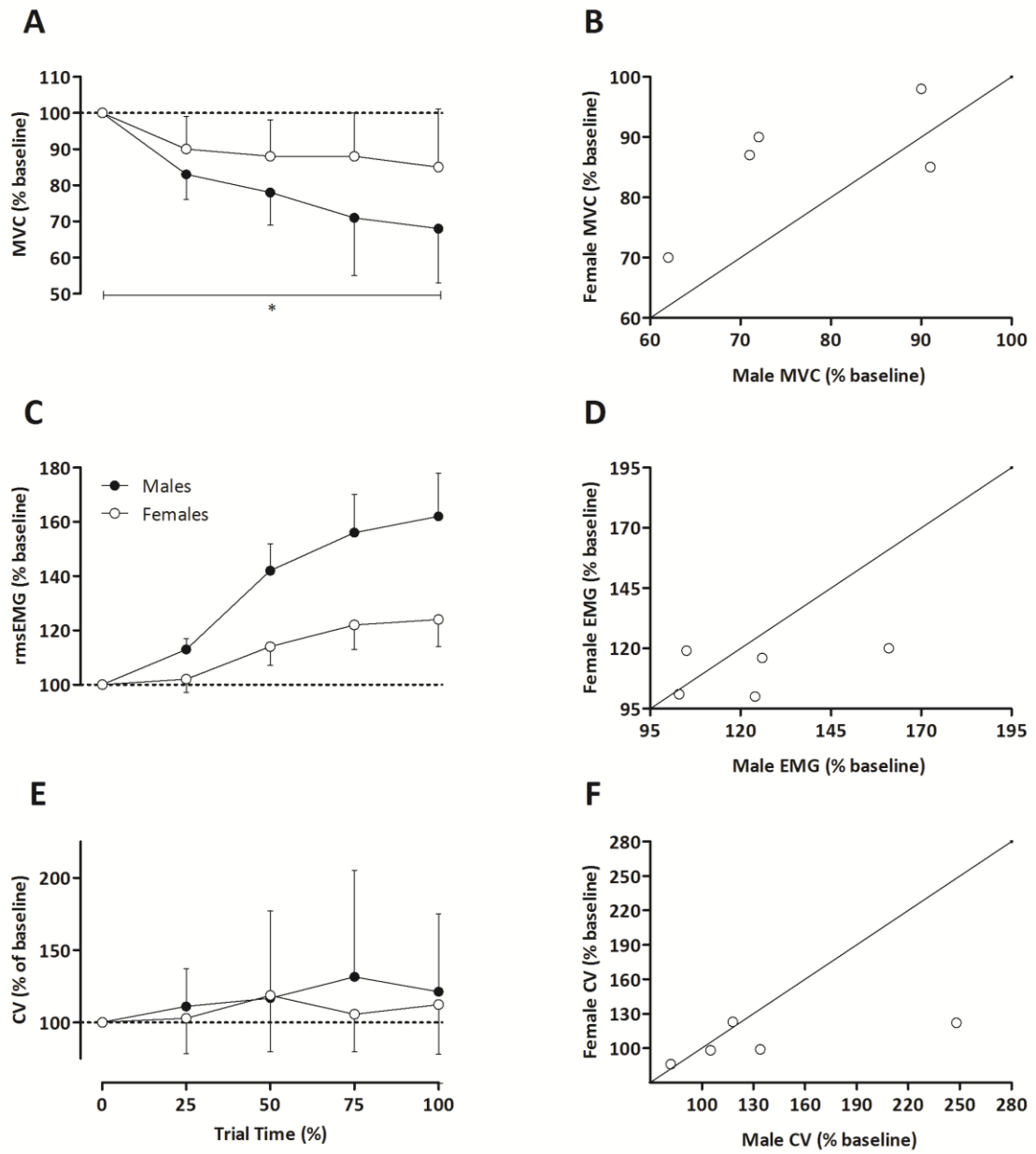
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453 **Figure 2.** Mean reduction in maximal voluntary contraction force (A), pre-post reductions in maximal
 454 voluntary contraction force for the matched pairs (B), change in rmsEMG (C), pre-post change in
 455 rmsEMG for the matched pairs (D), change in force fluctuation (CV; E), and pre-post change in force
 456 fluctuations for the matched pairs (F) throughout the 30% trial. Black circles: males, unfilled circles:
 457 females. In panels B, D, and F the line of equality represents where an equal change for males and
 458 females would lie. * = $P < 0.05$ male vs. female for the change in MVC from baseline.

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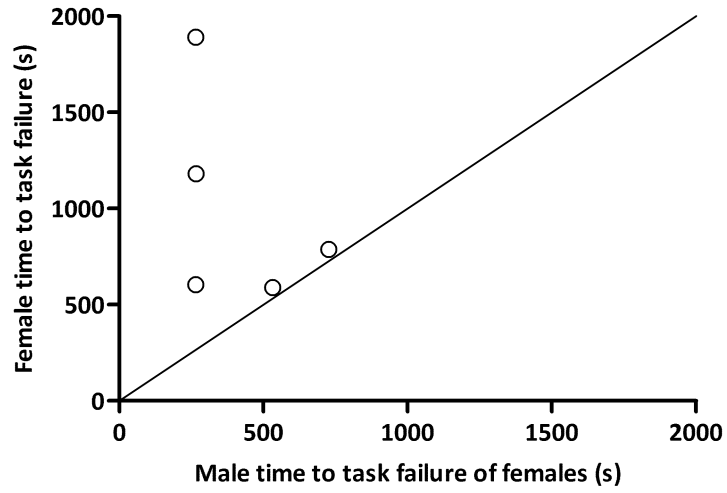
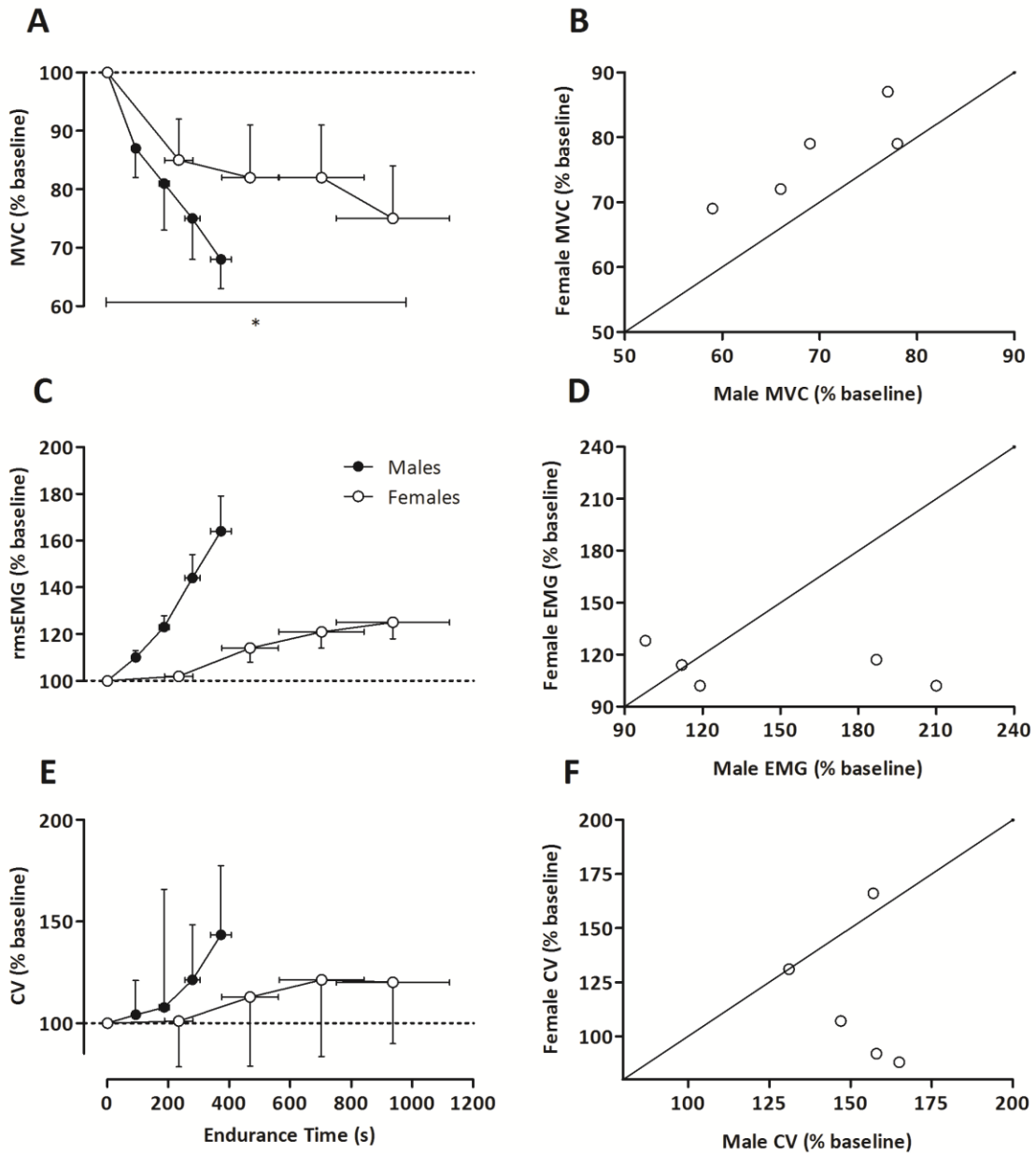


Figure 3. The relationship in time to task-failure in the 50% trial between strength-matched males and females (n = 5 pairs). The line of equality is shown to represent where an equal time in the pairs would lie.



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476 **Figure 4.** Mean reduction in maximal voluntary contraction force (A), pre-post reductions in maximal
 477 voluntary contraction force for the matched pairs (B), change in rmsEMG (C), pre-post change in
 478 rmsEMG for the matched pairs (D), change in force fluctuation (CV; E), and pre-post change in force
 479 fluctuations for the matched pairs (F) throughout the 50% trial. Black circles: males, unfilled circles:
 480 females. In panels B, D, and F the line of equality represents an identical change for males and females.
 481 * = $P < 0.05$ male vs. female for the change in MVC from baseline.