Gender Muscle Recovery During Isokinetic Exercise

Abstract

The purpose of this study was to examine the effect of two between set rest intervals (RI) on isokinetic knee extension peak torque (PT) produced by sedentary women and men. Seventeen young women (27.18±4.05 yrs) and 16 young men (26.75±4.73 yrs) performed 3 sets of 10 unilateral isokinetic knee extension at 60° and 180°/s. The RI between sets was 60 and 120s, counterbalanced across 2 testing days. Statistical evaluation of the data was performed using a 3-way mixed factor ANOVA (gender×rest interval×sets). Males and females exhibited decreases (p<0.05) in PT with 120s RI at 60°/s. There was no significant decline in PT in the female group during both RI at 180°/s. Men showed a significant decrease in PT only with 60s RI. Young women and men require more than 120s of RI to recover full PT at 60°/s. However, full quadriceps’s muscle strength recovery can be attained with a 60 and 120s at 180°/s in women, but in men only with a 120s at the same velocity.

Introduction

Muscle fatigue can be defined as a decline in muscle force or power output [10,36]. Different factors such as muscle mass, contraction type, and muscle fiber type can influence muscle fatigue [20,26]. Gender may also be an inherent factor that can affect muscle fatigue [23]. Some studies reported that females have less fatigue rate than males [19,23,25,28]. However, other studies reported no gender differences in muscle fatigue [16–18,20]. These differences may relate to the differences in protocols, muscle groups (i.e., upper and lower body), intensity (i.e., maximal and submaximal loads), contraction type (i.e., isotonic, isometric and isokinetic), or rest interval between sets. Bottaro et al. [4], Ratamess et al. [31] and Willardson and Burckett [39] found that rest interval (RI) between sets is an important variable that can be manipulated to fit the goal of a resistance exercise training program. A short RI can affect the total training volume, which may affect subsequent strength adaptation [32]. However, RI is one of the most neglected variables when a training program is structured [31].

Many authors have studied the effect of different RI on strength gains and isokinetic fatigue rates in young male subjects [8,9,21]. However, these results may not be applied to female subjects [19,26]. To date, only a few studies have considered the female subject when investigating the effect of different RI on muscle fatigue [29,37]. Pincivero et al. [29] reported that a RI of 40s may not be long enough to allow full recovery of isokinetic force in 15 (8 men and 7 women) healthy college-age volunteers. Theou et al. [37] compared the effect of rest interval in 20 young and 16 older women and reported that active younger and older women require similar RI (60s) between sets of an isokinetic knee extensor exercise for complete recovery.

We are currently unaware of any published studies comparing the influence of rest interval recovery on the performance of young men and women in isokinetic exercise. Thus, the purpose of this study was to compare the effect of two different RI between sets of isokinetic knee extension exercise on muscle performance in young men and women.
Methods

This study was approved by the University Institutional Review Board and was performed in accordance with the ethical standards of Int J Sports Med [14].

Experimental procedures

To test the effect of RI length on isokinetic knee extensor torque, subjects performed an isokinetic training protocol on two separate days with a minimum of 72 and a maximum of 96 h between test sessions. Volunteers performed three sets of 10 isokinetic concentric repetitions at 60°/s and 180°/s on each of the two visits with the interset rest interval (60 and 120 s) varying between visits. These intervals had work-to-rest ratios of approximately 1:3 (60 s) and 1:6 (120 s) for 60°/s, and 1:6 (60 s) and 1:12 (120 s) for 180°/s. The order of the RI and the number of sets were selected according to the ACSM recommendations for muscle strength gains [2]. The velocities of 60°/s and 180°/s are often used for isokinetic testing. The RI and the number of sets were selected according to the ACSM recommendations for muscle strength gains [2]. The velocities of 60°/s and 180°/s are often used for isokinetic testing in young people [38]. To avoid any effect of menstrual cycle on results, the testing days were scheduled during the follicular phase, 1st and 13 days of menstrual cycle [1,34]. The menstrual cycle phases were reported during the recruiting process.

Subjects

Thirty-three subjects, seventeen young women (27.18 ± 4.05 yrs; 56.84 ± 9.63 kg; 162.56 ± 7.02 cm) and sixteen young men (26.75 ± 4.73 yrs; 79.06 ± 9.38 kg; 175.69 ± 4.66 cm) who were non-resistance trained (i.e., no participation in resistance training during the past 12 months) volunteered for the study. Volunteers were informed of the purpose, procedures, possible discomfort, risks, and benefits of the study prior to signing a written informed consent. Participants were excluded from the study if they reported any history of cardiovascular disease, hypertension, or orthopedic disease. Subjects were instructed not to drink alcohol 48 h, or exercise 24 h prior to testing.

Warm up and familiarization

Subjects warmed-up on a cycle ergometer at 25–50 W for 5 min at a self-selected cadence. Following the cycle warm-up, they were seated on the isokinetic dynamometer and actively warmed-up the involved quadriceps muscles by performing ten to twelve submaximal knee extension repetitions at 300°/s [5]. For familiarization with isokinetic exercise, subjects performed 2 sets of four maximal repetitions at 60°/s with 60 s rest between sets [21]. The familiarization session was performed between 48 and 72 h before the first isokinetic testing session. However, to exclude any learning or fatigue effect, a 5% difference in peak torque (PT) was not allowed between the familiarization and experimental sessions in the first set. In the case of a difference, the session was repeated 72 h later. Only two subjects were rescheduled due to PT variation.

Measurement of isokinetic torque

Isokinetic peak torque was measured on the Biodex system 3 Isokinetic Dynamometer (Biodex Medical, Inc., Shirley, NY). Calibration of the dynamometer was performed according to the manufacturer’s specifications before every testing session. Subjects sat upright with the axis of rotation of the dynamometer oriented with the lateral femoral condyle of the right knee. Belts were used to secure the thigh, pelvis, and trunk to the dynamometer chair to prevent additional body movement. The chair and dynamometer settings were recorded to ensure the same positioning for all tests. The flexor torque produced by the relaxed segment was used for gravity correction. Concentric contractions were performed isokinetically at 60°/s and 180°/s between 5° and 90°, with full extension acting as the reference point. Subjects were instructed to fully extend and flex the knee and to work maximally during each set of exercises. Verbal encouragement was given throughout the testing session. After each set, subjects were required to take 60 or 120 s of rest before the onset of the next set. The knee strap was released during each rest period to ensure unrestricted blood flow to the quadriceps. The procedures were administered to all subjects by the same investigator [6].

Statistical analyses

Descriptive statistics were expressed as means (±SD). The normality of data was tested by Smirnov-Kolmogorov test. The statistical power for this study was 0.8 (β = 0.2). The possible effects of gender, rest intervals and sets on PT were tested by a 3-way mixed factor ANOVA [gender (men and women) × rest interval (60 and 120 s) × sets (1st, 2nd, 3rd)], followed by the Bonferroni post-hoc procedure whenever necessary. The probability level of statistical significance was set at α < 0.05. All calculations were performed using SPSS (version 13.0).

Results

PT was significantly (p = 0.001) greater in men than women for all exercise sets regardless of the rest period. There were no significant differences within gender in PT in the first set regardless of the rest period (60 vs. 120 s), and there was no significant (p > 0.05) interaction of rest by set by gender for either contraction velocity. For PT of the knee extensors there was no significant interaction of rest by gender (p > 0.05) or set by gender (p > 0.05), but there was a significant interaction of rest by set (p = 0.001).

Fig. 1 shows PT during all three sets at 60°/s with 60 and 120 s RI for both genders. A significant decline in PT was observed between the 3 sets on both rest intervals and genders. When comparing to 60 s RI, 120 s RI allowed greater recovery during the second (p = 0.025) and third sets (p = 0.017) in both genders. The percent decline of PT between first, second and third sets for both gender groups and both rest intervals (60 and 120 s) at 60°/s is presented in Table 1.

Fig. 2 shows PT during all three sets at 180°/s with 60 and 120 s RI for both genders. There was no significant decline in PT...
Bottaro et al. [5] studying older men, and Parcell et al. [21] studying younger men, found that 30 s and 60 s RI, respectively, were sufficient to recover quadriceps PT during isokinetic testing. However, it is important to emphasize that these studies used a less demanding protocol with less volume (i.e., 2 sets with 4–5 repetitions) than the one used during our present study (i.e., 3 sets of 10 repetitions).

Bottaro et al. [3] also compared the effect of two different rest intervals between sets of isokinetic knee extension exercise on PT between untrained younger and older men. They concluded that young men might require longer rest intervals to recover full PT when compared to older men. In agreement with our present study, they showed that 60 s was not sufficient to maintain quadriceps muscle strength in young subjects. Some studies have shown that gender can affect muscle fatigue and also affect muscle performance [19, 25, 26, 28]. In a recent study with young and old women, Theou et al. [37] found that 60 s was sufficient to recover quadriceps PT after three sets of 8 repetitions at 60°/s in young subjects. In our present study, 60 s was not sufficient to recover PT at 60°/s in young female subjects. The differences between studies can be related to the differences in subject strength. The mean PT of Theou et al. [37] young subjects was 128N.m while the mean PT in our present study was 162N.m. Faigenbaum et al. [13] and Pincivero et al. [28] have shown that greater force production is correlated with greater fatigue. One explanation for this is probably due to stronger individuals experiencing greater intramuscular pressures [33], blood flow occlusion, accumulation of metabolites, impairment of oxygen delivery to the muscle, and an earlier onset of task failure during a sustained contraction [20, 22].

When we compared muscle torque recovery during higher velocity muscle actions (180°/s), we found that women recovered faster than men. These results can be in part due to males exhibiting less acceleration range of motion and greater isokinetic load range than females at fast contraction velocities [7]. By the same token, a review and analysis of isokinetic data published in the literature demonstrates significantly different PT with increased isokinetic velocity between males and females [15]. The gender-related differences in muscle fatigue may also be associated with metabolic, mechanical, morphology and muscle fiber type distribution, neural activation, and hormone concentration [15, 17, 27, 28]. Recently, Wust et al. [40] concluded that gender-related muscle fatigue may be addressed by muscle fiber characteristic. Females have more type I fibers and less type II fibers when compared with males [24]. Conversely, Staron et al. [35] reported no gender-differences in fiber type distribution in vastus lateralis muscle. However, they reported gender differences in percent fiber type areas that relate to differences in the hierarchy of cross-sectional areas of the major fiber types. Although the percentages of fast and slow fiber types are similar between young men and women, the slow fibers occupy a greater area in women while fast fibers occupy a greater area in men.


development of the cross-sectional area of women when compared to men in type I fibers.

development of muscle fatigue may also be associated with metabolic, mechanical, morphology and muscle fiber type distribution, neural activation, and hormone concentration [15, 17, 27, 28].

Table 1 Decline (%) of Peak Torque (Nm) between 1st, 2nd, and 3rd sets for both gender groups and rest intervals at 60°/s.

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<th>Female (n=17)</th>
<th>Male (n=16)</th>
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<td>1st set vs 2nd set</td>
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<td>Females</td>
<td>7.7% 6.0% 8.8% 4.5%</td>
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<td>Males</td>
<td>8.6% 5.9% 10.7% 7.1%</td>
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<td>1st set vs 3rd set</td>
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<tr>
<td>Females</td>
<td>15.7% 11.6% 18.6% 11.3%</td>
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<td>Males</td>
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Table 2 Decline (%) of Peak Torque (Nm) between 1st, 2nd, and 3rd sets for both gender-groups and rest intervals at 180°/s.

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<th>Female (n=17)</th>
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<td>1st set vs 2nd set</td>
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<td>Females</td>
<td>1.7% 1.6% 3.7% 0.4%</td>
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<td>Males</td>
<td>2.0% 0.8% 2.8% 2.5%</td>
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in females at 180°/s and no significant (p>0.05) differences were observed in PT between 60 and 120 s RI. On the other hand, with 60 s RI, males exhibited a significant decline of PT between the first and second set (p=0.001), between the first and third set (p=0.001) and between the second and third set (p=0.016). No significant decline between sets (p>0.05) was observed in males at 120 s RI. The percent decline of PT between first, second and third sets for both gender groups and both rest intervals (60 and 120 s) at 180°/s is presented in Table 2.

**Discussion**

The purpose of this study was to compare the effect of two different RI (60 and 120 s) on muscle torque recovery during three sets of 10 repetitions in isokinetic exercise between non-resistance trained females and males. The main finding was that at 60°/s the recovery from 60 s and 120 s RI was similar between males and females. The results also showed that 120 s RI exhibits greater maintenance of muscle torque during three sets of isokinetic knee extension than 60 s in both genders. However, it appears that at higher velocities (e.g., 180°/s) women recover more quickly than men.

Our results are similar to others reported in the literature. Pincivero et al. [29, 30] and Touey et al. [38] showed that short RI (30 s and 60 s) did not allow complete muscle recovery in isokinetic quadriceps PT in young men. Different than our results, Esbjörnsson-Liljedahl et al. [12] reported that slow-twitch fibers have lower contraction velocity, less energetic cost and, consequently, different fatigue rates than fast-twitch fibers [12]. However, Esbjörnsson-Liljedahl et al. [11] later reported no differences in energy cost in type II fibers during high intensity and short duration exercise between genders. These authors emphasized that the gender differences are related to less glycogen reduction, and lactate content in women when compared to men in type I fibers.
In summary, it is well established that repeated contractions, and/or multiple sets, result in muscular fatigue, usually expressed as a reduction in force producing capacity, and that muscle fatigue response is influenced by the manipulation of the resistance training variables such as rest interval between sets. Thus, it should be interesting for a future study to analyze the hypothesis that multiple sets might have different RI, like short RI between the firsts sets and longer RI between the lasts sets.

**Conclusion**

This study indicated that, within typical isokinetic resistance training protocols, young women and men require more than a 1:6 work-to-rest ratio to recover full PT at 60°/s. However, full muscle strength recovery can be attained with a 1:6 and 1:12 work-to-rest ratio at 180°/s in women. In summary, the present study indicated that non-resistance trained young men and women may require more than 120 s rest intervals to recover full work-to-rest ratio at 180°/s in women. In summary, this study indicated that repeated contractions, and/or multiple sets, result in muscular fatigue, usually expressed as a reduction in force producing capacity, and that muscle fatigue response is influenced by the manipulation of the resistance training variables such as rest interval between sets. Thus, it should be interesting for a future study to analyze the hypothesis that multiple sets might have different RI, like short RI between the firsts sets and longer RI between the lasts sets.

**References**
