The Effect of Recovery Time on Strength Performance Following a High-Intensity Bench Press Workout in Males and Females

Lawrence W. Judge and Jeanmarie R. Burke

Purpose: To determine the effects of training sessions, involving high-resistance, low-repetition bench press exercise, on strength recovery patterns, as a function of gender and training background. Methods: The subjects were 12 athletes (6 males and 6 females) and age-matched college students of both genders (4 males and 4 females). The subjects completed a 3-wk resistance training program involving a bench press exercise, 3 d/wk, to become familiar with the testing procedure. After the completion of the resistance training program, the subjects, on three consecutive weeks, participated in two testing sessions per week, baseline session and recovery session. During the testing sessions, subjects performed five sets of the bench press exercise at 50% to 100% of perceived five repetition maximum (5-RM). Following the weekly baseline sessions, subjects rested during a 4-, 24-, or 48-h recovery period. Strength measurements were estimates of one repetition maximum (1-RM), using equivalent percentages for the number of repetitions completed by the subject at the perceived 5-RM effort of the bench press exercise. Results: The full-factorial ANOVA model revealed a Gender by Recovery Period by Testing Session interaction effect, $F(2, 32) = 10.65; P < .05$. Among male subjects, decreases in estimated 1-RM were detected at the 4- and 24-h recovery times. There were no differences in muscle strength among the female subjects, regardless of recovery time. Conclusions: For bench press exercises, using different recovery times of 48 h for males and 4 h for females may optimize strength development as a function of gender.

Keywords: fatigue, gender differences, training volume

Muscular strength is one essential component underlying optimal athletic performance. The development of strength typically involves high-resistance, low-repetition exercises using larger muscle masses to increase the maximal force generation by a muscle or muscle group. The ability of individuals to adapt positively to increasing training loads requires careful consideration of the volume and intensity of the exercises. However, if there is an inappropriate amount of recovery time between training sessions than the duration of postexercise fatigue may impair maximal force

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generation by a muscle. Postexercise fatigue may limit the effectiveness of the resistance training program as an adaptive physiologic stimulus for strength gains.

Although much research has addressed the observed differences in muscle fatigue between genders (cf.9,10), the influence of gender on strength recovery patterns during high-resistance training programs has received little attention.11,12 The strength recovery patterns in males indicate that recovery times should be at least 48 h between training sessions involving high-resistance, low-repetition exercises,11–13 whereas strength recovers within 24 h in females.11,12 Gender differences in fatigue resistance may be an important consideration when determining recovery times between training sessions to optimize strength development in females. Furthermore, gender differences in muscle fatigability may impact the role of resistance training to failure versus not to failure and the effects of single set versus multiple sets for optimizing strength gains.7,8

There has not been much research to date on postexercise recovery of strength as a function of gender, with studies only examining leg extension11,12 Maximal bilateral isometric leg extension force (MVC) in male and female athletes was measured after heavy resistance squat-lift exercise at the following time points: preexercise, and 0, 1, 2 h, and 1 and 2 d postexercise.11,12 Consequently, task specificity of strength and fatigue are limited to laboratory-based measurements and are dependent upon the transfer of exercise performance from training regimens to isometric MVC force generation. Maximum weight lifted during a bench press exercise is a commonly accepted quantitative measure of upper extremity strength, even though, the ability to exert maximal muscle force depends upon numerous conditions related to body position, task demands, movement type, and movement speed.2 The bench press exercise was used in the current study to extend previous research findings on strength and fatigue of the leg extensors to the upper extremity using a well-studied muscle group, the elbow flexors. The female advantage in fatigue resistance for the elbow flexors is dependent upon type and intensity of the contraction and related to the absolute contraction intensity.14–16

There are gender differences in resistance training physiology and performance which have been reported throughout the literature.5,17–20 Similar to different training loads to optimize power output in males and females,20 using different recovery times between training sessions may optimize strength development in males and females. It is necessary to directly compare recovery times between genders to test this hypothesis. It is also not clear whether training background may influence gender differences in fatigue resistance. The comparison of highly trained female athletes with recreationally active males will allow us to match strength, independent of gender, and address the influence of training background on muscle fatigability. Therefore, the purpose of the study was to determine the effects of training sessions, involving high-resistance, low-repetition bench press exercise, on strength recovery patterns, as a function of gender and training background.

Methods

Subjects

The subjects were males (n = 7) and females (n = 6) who participated in resistance training to enhance athletic performance in collegiate field events. Years of resistance training were 6.5 ± 0.9 y for the male athletes and 4.6 ± 0.9 y for the female athletes.
Age-matched college students of both genders (4 males and 5 females) were the control group. The controls were recruited from an intermediate level weight training class. Years of recreational weight lifting experience were 3.8 ± 1.1 y for male controls and 1.4 ± 0.5 y for female controls. Their recreational weight lifting experiences were geared toward physical fitness. Although not clearly evident in the years of training, it was assumed that the quality of training by the athletes was better than by controls due to presence of coaching and their inherent motivation to improve competitive performance. Based upon their years of experience, it was assumed that the female controls began weight lifting in college. Table 1 summarizes the physical characteristics of the subjects. Figures 1 and 2 indicate that strength values for the male controls and female athletes were matched, despite differences in group means (cf. Table 1 and Results).

Each subject was informed of the risks and benefits of the study. Informed consent was obtained from each subject in accordance with the policy statement of the American College of Sports Medicine and guidelines established by the University’s Institutional Review Board for human subjects in research.

**Design**

The experimental approach involved a repeated measure, cross-sectional research design comparing strength recovery patterns between males and females as a function of training background.

![Figure 1](image-url) — Scatter plot of perceived 5-RM (kg) versus body mass (kg) (6 male athletes, 4 male controls, 6 female athletes, 4 female controls, n = 20). Linear regression line and regression equation of all 20 data points. The oval includes the distribution of scores for the 4 male controls and 6 female athletes to depict matched strength.
Table 1 Physical characteristics of the subjects (means ± SD)

<table>
<thead>
<tr>
<th>Group by Gender</th>
<th>n</th>
<th>Age (y)</th>
<th>Body Mass (kg)</th>
<th>Body Fat (%)</th>
<th>5-RM (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Athletes</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>6</td>
<td>20.3 ± 0.52</td>
<td>110.5 ± 14.47</td>
<td>16.2 ± 3.60</td>
<td>144.5 ± 26.85</td>
</tr>
<tr>
<td>Females</td>
<td>6</td>
<td>20.5 ± 1.23</td>
<td>92.0 ± 13.30</td>
<td>20.8 ± 4.07</td>
<td>73.5 ± 14.43</td>
</tr>
<tr>
<td>Controls</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>4</td>
<td>19.5 ± 1.29</td>
<td>96.5 ± 17.25</td>
<td>19.3 ± 4.35</td>
<td>90.0 ± 21.23</td>
</tr>
<tr>
<td>Females</td>
<td>4</td>
<td>19.8 ± 0.96</td>
<td>75.8 ± 15.63</td>
<td>23.0 ± 4.32</td>
<td>38.3 ± 12.61</td>
</tr>
</tbody>
</table>

* One male athlete dropped out after the second week of testing (20 y, 83.6 kg, 15%, and 88.6 kg, respectively).

* One female control subject dropped out after the first week of testing (21 y, 75 kg, 18% and 34.1 kg, respectively).

Figure 2 — Normalized strength (%): means and upper and low limits of the 95th confidence intervals for perceived 5-RM (kg) normalized to body mass (kg) as function of gender and training background. The mean is shown as a line across the box. The upper limit of the 95th confidence interval is the top border of the box. The lower limit of the 95th confidence interval is the bottom border of the box. The box is shaded to represent the lower and upper halves of the 95th confidence interval.
Training Protocol

The subjects in both groups completed a 3-wk resistance training program involving the bench press to become familiar with the testing procedure. The subjects participated in the resistance training program 3 d/wk. Each training session consisted of four sets of five repetitions. The intensities of training loads for each training session were alternated between 60% and 80% of subjects’ perceived five-repetition maximums (5-RM) on the bench press. A strength and conditioning coach, who was one of the investigators, supervised the training sessions to assess that each repetition was performed correctly. One successful repetition consisted of the subject lowering the bar until the bar came in contact with the chest musculature and then lifting the bar until the elbows were fully extended with the wrists rigid and directly above the elbows. The training regimen was performed with progressively heavier loads as determined by the strength and conditioning coach. All subjects admitted to being devoid of the use of performance-enhancing drugs and the athletes were subject to institutional random drug testing.

The rationale for our 3-wk familiarization period was to mimic the preparatory phase of a resistance training regimen, because the initial training status of a participant plays an important role in the rate of strength development during resistance training regimens. During the 3-wk resistance training program, the athletes participated in their normal practice regimen for throwing their field implements and other resistance training and fitness activities. The control subjects were instructed to maintain their current level of participation in activities of daily living, recreational sports activities and physical fitness activities, eg, asked not to increase their daily step counts and/or training volumes.

Strength Testing

After the completion of the resistance training program, the subjects, on three consecutive weeks, participated in two strength testing sessions per week, a baseline session and a recovery session. The subjects performed a five-set bench press testing protocol during each session. Table 2 outlines the strength testing protocol, which progressed from 10 repetitions of 50% of perceived 5-RM effort to the maximum number of repetitions at 100% of perceived 5-RM effort. There was a timed 3-min rest period between each bench press set. Following the baseline sessions, subjects rested during a 4-, 24-, or 48-h recovery period. During the recovery period, the

<table>
<thead>
<tr>
<th>Bench Press Sets</th>
<th>Perceived 5-RM (%)</th>
<th>Repetitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50%</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>70%</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>85%</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>95%</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>100%</td>
<td>Until failure</td>
</tr>
</tbody>
</table>

Note. There was a timed 3-min rest period between each bench press set.
subjects refrained from participating in any training activities or recreational physical activities. In other words, the subjects were instructed to limit their physical activity to activities of daily living during the recovery period. After the recovery period and before the baseline testing of the subsequent week, the subjects resumed their normal training activities or recreational physical activities, with the exception of bench press exercises. During the 3-wk strength testing period, the subjects only performed bench press exercises at their weekly baseline measurement sessions and recovery measurement sessions.

The administrations of the recovery period durations were not random and all subjects received 4-, 24-, or 48-h recovery periods on consecutive weeks from week one to week three. The scheduling of the recovery durations was chosen based on the availability of facilities and subjects’ availabilities. The use of the facilities required that the investigators preschedule the facilities for the testing sessions. The recovery durations had to be factored into the athletes’ practice schedules and training programs and the investigators were limited in this area by the cooperation of the athlete’s coaching staff. Having all subjects receive 4-, 24-, or 48-h recovery periods on consecutive weeks from week one to week three allowed us to meet the constraints of these scheduling requirements.

At the baseline session of each test week, the subject’s perceived 5-RM effort was set as the test load for performing the strength testing protocol. This methodological decision used the same test load for baseline and recovery testing sessions within each test week, but allowed for variations in the subjects’ perceived 5-RM efforts that may have occurred during the 3-wk strength testing protocol (Table 3). Strength maintenance, decrements and increments that occurred during the 3-wk strength testing protocol and as a function of the durations of the recovery periods, were normalized to subject’s perceived 5-RM effort at the beginning of each test week.

Testing protocols designed to determine the maximal 5-RM strength would have provided a more objective measurement of strength loss. However, the testing protocol was designed to optimize transfer of strength performance from the training regimen to the testing protocol, ie, control for task specificity and strength performance. In addition, the use of perceived 5-RM as the testing load may further enhance the practical applications of our study findings, because the progressions of training loads that occur during resistance training programs are typically determined by strength and conditioning coaches and not by testing protocols designed to determine maximal strength. Thus, the perceived 5-RM was chosen as the testing load during strength testing sessions to mimic the training loads used during resistance training sessions.

**Calculation of Primary Dependent Variable: Strength**

Strength measurements were estimates of 1-RM, using equivalent percentages for the number of repetitions completed by the subject at 100% of the perceived 5-RM effort of a bench press exercise. The equivalent percentages to estimate 1-RM were from Baechle and Earle, Table 18.8.2 Strength maintenance, decrements and increments during the 3-wk strength testing period were estimates of 1-RM using equivalent percentages for the number of repetitions completed by the subject at 100% of their perceived 5-RM effort.
A full factorial ANOVA model was used to reveal differences in strength over measurement periods as a function of gender and athletic training background. The between-subject factors were athletic group and gender and the within-subject factors were recovery condition (4, 24, or 48 h) and time (weekly baseline and recovery measurements). Post hoc $t$ test procedures with correction for multiple comparisons were used to detect pairwise differences, when appropriate. The criterion for statistical significance was $P < .05$.

### Table 3  Estimated 1-RM strength (means ± SD)

<table>
<thead>
<tr>
<th>Group × Gender Interaction and Recovery Time</th>
<th>Baseline Strength (kg)</th>
<th>Recovery Strength (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male athletes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 h</td>
<td>165.9 ± 30.81</td>
<td>161.9 ± 28.35*</td>
</tr>
<tr>
<td>24 h</td>
<td>165.6 ± 28.24</td>
<td>159.1 ± 25.88*</td>
</tr>
<tr>
<td>48 h</td>
<td>165.6 ± 28.24</td>
<td>165.0 ± 25.98</td>
</tr>
<tr>
<td>Female athletes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 h</td>
<td>84.5 ± 16.33</td>
<td>84.0 ± 16.75</td>
</tr>
<tr>
<td>24 h</td>
<td>85.8 ± 17.30</td>
<td>85.7 ± 16.27</td>
</tr>
<tr>
<td>48 h</td>
<td>86.8 ± 15.89</td>
<td>87.1 ± 15.20</td>
</tr>
<tr>
<td>Male controls</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 h</td>
<td>103.9 ± 24.46</td>
<td>101.1 ± 22.79*</td>
</tr>
<tr>
<td>24 h</td>
<td>104.5 ± 23.67</td>
<td>99.2 ± 21.17*</td>
</tr>
<tr>
<td>48 h</td>
<td>103.4 ± 21.43</td>
<td>103.0 ± 21.27</td>
</tr>
<tr>
<td>Female controls</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 h</td>
<td>43.8 ± 14.55</td>
<td>43.3 ± 14.09</td>
</tr>
<tr>
<td>24 h</td>
<td>45.7 ± 13.93</td>
<td>45.4 ± 12.99</td>
</tr>
<tr>
<td>48 h</td>
<td>47.2 ± 12.59</td>
<td>47.5 ± 12.40</td>
</tr>
</tbody>
</table>

* Strength differences between baseline and recovery, $P < .05$.

### Statistical Analyses

A full factorial ANOVA model was used to reveal differences in strength over measurement periods as a function of gender and athletic training background. The between-subject factors were athletic group and gender and the within-subject factors were recovery condition (4, 24, or 48 h) and time (weekly baseline and recovery measurements). Post hoc $t$ test procedures with correction for multiple comparisons were used to detect pairwise differences, when appropriate. The criterion for statistical significance was $P < .05$.

### Results

### Study Population

There was a total of 22 subjects who participated in the training protocol and initiated the strength testing protocol. One male athlete voluntarily withdrew from participation after completing the first four strength testing sessions, weekly baselines and 4- and 24- h recovery periods. One female control subject withdrew from the University after completing the first two strength testing sessions, baseline and 4-h recovery period. The data were not included in the statistical analyses. Descriptive statistics and intention-to-treat analyses were conducted with their data to address
any potential bias in the results that may occur when subjects fail to complete the testing protocol.

Table 1 summarizes the physical characteristics of the subjects who completed the strength testing protocol (n = 20). There were no interaction effects between athletic training background and gender for any of the physical characteristics (P > .05). The ages of subjects were similar among the group and gender cells. Body mass (F(1,16) = 4.94) and perceived 5-RM strength (F(1,16) = 23.88) of the athletes were greater than the controls (P < .05). Body mass (F(1,16) = 8.32) and perceived 5-RM strength (F(1,16) = 44.67) of the males were greater than the females with percent body fat (F(1,16) = 5.22) of males being less than females (P < .05).

When normalizing strength to body mass, males (116 ± 23.6%) lifted significantly more mass than females (68 ± 18.5%; F(1,16) = 69.27, P < .05) and athletes (105 ± 30.0%) lifted significantly more mass than control subjects (71 ± 25.0%; F(1,16) = 35.79, P < .05). Figure 1 shows the scatter plot of perceived 5-RM strength as a function of body mass. There was a significant correlation between perceived 5-RM strength and body mass (r = .84, P < .05) with the partial correlation coefficient being pr_athletes and genders = .72, P < .05. Using the 95th confidence interval as the criterion, the distributions of perceived 5-RM strength values normalized to body mass were similar for female athletes and male controls; whereas, distributions of perceived 5-RM strength values normalized to body mass for male athletes and female controls were exclusive (Figure 2).

**Estimated 1-RM**

The full-factorial ANOVA model revealed a Gender × Condition × Time interaction effect (F(2,32) = 10.65; P < .05). This interaction effect is illustrated in Figure 3 and revealed decreases in muscle strength among male athletes and male controls when asked to perform the strength testing protocol within 24 h of each other. Paired t tests between baseline strengths and recovery strengths of the male subjects were conducted with data from the 4-, 24-, or 48-h recovery periods. The level of significance was adjusted to .01 to account for the three post hoc comparisons and to maintain the experiment-wise error rate at .05 (.05/4 = .0125; conducted four statistical procedures: ANOVA plus three paired t tests). Among male subjects, estimated 1-RM decreased by 2.5%, from 141.1 ± 41.86 to 137.6 ± 40.10 kg, after recovery period of 4 h (t9 = 4.12; P < .01) and decreased by 4.3%, from 141.2 ± 40.31 to 135.1 ± 38.46 kg, after of recovery period of 24 h (t9 = 6.43; P < .01). Decrements in muscle strength were not observed, when male subjects were allowed to recover for a period of 48 h (t9 = 0.55; P > .05). There were no differences in muscle strength among the female subjects, regardless of the durations of the recovery periods. Table 3 summarizes the estimated 1-RM strength by group and gender.

**Dropouts and Recovery Profiles**

The 5-RM strength was maintained for the one female control subject at baseline and after 4 h of recovery time (34.1 kg). Her recovery profile was similar to the averaged recovery profile of muscle strength for female subjects after 4 h of rest.

The estimated 1-RM strength was maintained for the one male athlete at baseline and after a recovery period of 4 h (101.8 kg), but there was a 3.3% decrement in estimated 1-RM strength between baseline (104.5 kg) and after a recovery period of 24 h
The decrease in muscle strength observed when asked to perform the strength testing protocol before and after a 24 h recovery period, without a concomitant decrease being observed for the 4-h recovery period, may be due to inherent fluctuations in the measurement of his baseline muscle strength from week one testing to week two testing. An intention-to-treat analysis was completed, because his recovery profile was not similar to the averaged recovery profile of muscle strength for male subjects after recovery periods of 4 and 24 h. The intention-to-treat analysis entered the mean (102.3 kg) of his estimated 1-RM values into the full-factorial ANOVA model and paired t test post hoc analyses. The intention-to-treat analysis revealed the same significance findings ($F_{(2,34)} = 8.45; P < .05$), but the effect sizes were slightly smaller. The detected muscle strength decrements among males were 2.3% after the 4-h recovery period ($t_{10} = 3.83; P < .01$) and 4.0% after the 24-h recovery period ($t_{10} = 5.43; P < .01$).

**Discussion**

Strength recovery patterns were affected by gender independent of training background. Following a training session involving five sets of a high-resistance, low-repetition bench press exercise, the strength recovery patterns of females ($n = 10$)
occurred within 4 h; whereas, the strength recovery patterns of males \((n = 10)\) did not occur until after 24 h. When matched for strength (four male controls and six female athletes), the female advantage in fatigue resistance was still evident in the strength recovery patterns. Fatigue, the inability of a muscle or muscle group to generate maximal force/torque, was evident as a decline in strength of elbow flexors following a baseline bench press exercise session that persisted until 48 h in male subjects. The results extend findings on the female advantage in fatigue to include appropriate durations of recovery periods between training sessions for a bench press exercise.

Mechanisms underlying gender differences in muscle fatigability, as opposed to muscle damage, are the most likely explanations for our data findings. Women are more prone to exercise-induced muscle damage than are men and the strength-loss response after eccentric exercise is greater in females as compared with males.\(^{19,21}\) Unlike men, women did not demonstrate any strength loss after participating in the baseline, weekly strength testing session. Adaptations to a second bout of eccentric exercise include fewer signs of exercise-induced muscle damage with this adaptive response being consistent with a training effect.\(^{21}\) The effects of muscle damage and soreness as function of gender would have most likely occurred during the 3-wk resistance training program that preceded the 3-wk strength testing protocol, because muscle damage and muscle soreness occur at onset of unaccustomed exercise regimens.

There is no single mechanism responsible for muscle fatigue and muscle fatigability is task dependent.\(^{22}\) In the current task involving sets of a high-resistance, low-repetition bench press exercise, there was a female advantage in muscle fatigability. The muscle mass and strength hypothesis does not appear to contribute predominately to the fatigue advantage of females during dynamic muscle contractions involving the bench press exercise for the following reasons. Control males experienced more muscle fatigue than strength-matched athletic females when performing sets of a high-resistance, low-repetition bench press exercise. Training background, ie, increased muscle mass and strength, did not influence gender differences in muscle fatigability, because the female advantage in fatigue was evident, regardless of training background.

Gender differences in fatigue are dependent upon intramuscular blood flow, but the effects of ischemic and hypoxic conditions on fatigue responses depend upon the preferential utilization of oxidative metabolism by women rather than blood flow per se.\(^{23-26}\) Specifically, muscle blood flow is sufficient in both genders to maintain force output during fatiguing isometric contractions, but when oxygen is absence, as in ischemia conditions, there is no female advantage in fatigue resistance.\(^{24-26}\) When oxygen availability is reduced, as in hypoxic conditions, the female advantage in fatigue resistance is still evident and is most likely related to their preferential utilization of oxidative metabolism.\(^{23-26}\)

With regards to this study, clearance of the metabolic by-products after the baseline, weekly strength testing session would require less time for females than males, because females possess a greater capacity for utilizing oxidative metabolism with a reduced reliance on glycolytic pathways.\(^{27}\) However, the prolonged postexercise hyperemia that persists for approximately 25 min with a high-intensity forearm exercise should have allowed for the clearance of metabolic by-products within 4 h of our baseline, weekly strength testing session for both genders.\(^{28}\)
Thus, gender differences in strength recovery patterns that occurred at the 4- and 24-h time points may be related to prolonged time needed by males for muscle glycogen resynthesis after the baseline, weekly strength testing session due to their greater reliance on anaerobic metabolic (glycolytic) pathways as compared with females during resistance exercise. Although our study design did not address the neural activation hypothesis, altering the level and pattern of muscle activation by females as compared with males during fatiguing contractions has not been conclusively documented in the literature. Furthermore, the relationship between muscle morphology and fatigability, to include measurements of muscle capillarization, must be more fully established to understand the contributions of muscle morphology to the female advantage in fatigue.

There is a potential that order effects confounded the results, because the recovery periods were not randomized. Baseline strengths for the males were similar across the three strength testing weeks (Table 3); therefore, adaptations to the strength testing protocol over the 3 wk did not seem likely among the males. Among the male subjects, the duration of the recovery period and not familiarization and/or adaptations to the strength testing protocols is the likely explanation for strength decrements at the 4-h and 24-h recovery periods. Among the females, there were progressive increases in baseline strengths from testing week one (4-h recovery period) to testing week three (48-h recovery period), which were significant (P < .05); 4% increase from week one to week three. However, the consistency of data responses within a test week (Table 3) suggests that females were fatigue-resistant, even though they may have been improving their perception of a 5-RM testing load across the 3 wk.

**Practical Applications**

Postexercise fatigue may limit the effectiveness of the resistance training program as an adaptive physiologic stimulus for strength gains. This study shows that determining the optimal recovery time between resistance training sessions may depend upon the gender of the participants. Strength and conditioning coaches may be able to increase the frequency and intensity of the resistance training sessions that females perform each week to optimize strength gains. Similar to the concept of using different training loads to optimize power output in males and females, using different recovery times may optimize strength development in males and females.

In females, the distribution of the volume of high resistance training into two daily sessions may take advantage of their shorter postexercise recovery times to optimize their strength development. In males, optimal strength development may occur with one daily session that is followed by a postexercise recovery period of 48 h. Increasing the intensity of the training stimulus relative to body mass may be another variable that strength and conditioning coaches may manipulate to optimize strength gains in females and take advantage of the greater fatigue resistance in females. Strength relative to body mass was less in females than in males as shown in this study and previous studies. This latter finding supports the recommendation to increase the intensity of the training stimulus relative to body mass for females to optimize their strength development. The female advantage in fatigue resistance may also allow for the inclusion of two to three
additional weight lifting exercises per session to increase total training volume and/or improve the effectiveness of periodization models.

Future research needs to further establish the relationship between gender differences in muscle fatigability and exercise training and prescription to optimize strength development in males and females. For optimizing strength gains, gender differences in muscle fatigability may affect exercise training and prescription in males and females as it relates to resistance training to failure versus not to failure or the effects of single set versus multiple sets.

**Conclusion**

The strength recovery patterns for a high-intensity bench press exercise were within 4 h for females and within 48 h for males. For bench press exercises, using different recovery times of 48 h for males and 4 h for females may optimize strength development as a function of gender.

**References**


