Effects of Intrasession Rest Interval on Strength Recovery and Reliability During High Intensity Exercise

Danny M. Pincivero¹, Scott M. Lephart¹, and Raj G. Karunakara³

¹Neuromuscular Research Laboratory, University of Pittsburgh, Pittsburgh, Pennsylvania 15261; ²Department of Physical Therapy, Eastern Washington University, Cheney, Washington 99004; ³Department of Medicine, St. Mary’s Hospital, Rochester, New York 14623.

Reference Data

ABSTRACT
This study examined the effects of intrasession rest interval on reliability and recovery of isokinetic quadriiceps and hamstring strength. Subjects were 15 healthy, college age volunteers with no recent weight training experience and no previous history of injury to the lower extremity. Each subject performed 4 sets of 10 reciprocal, concentric, maximal repetitions on the Biodesm System II isokinetic dynamometer at a preset angular velocity of 90°/sec. They were randomly assigned to either a short (40 sec) or a long (160 sec) rest interval group. Isokinetic values were obtained for peak torque, total work, and average power. Group 1 had a statistically significant (p < 0.05) reduction in quadriiceps and hamstring peak torque, total work, and average power. Group 2 had no significant changes in any dependent measure across the 4 sets of exercise. ICC coefficients and SEMs for quadriiceps and hamstring peak torque, total work, and average power ranged from 0.98-0.99 (SEM 2.2-4.7%) for Group 2, and 0.78-0.92 (SEM 5.1-7.7%) for Group 1. The findings indicate that a rest : exercise ratio of 2:1 may not be long enough to allow full recovery of isokinetic force capacity between exercise bouts.

Key Words: quadriiceps, hamstring, power, work torque

Introduction
The use of isokinetic exercise for assessing muscle function has been widely incorporated in orthopedic and sports medicine. Isokinetic exercise allows major muscle groups to exert maximal force throughout the full range of motion (21). However, training-induced strength gains may be confounded by inadequate muscle recovery during high intensity exercise. Furthermore, the reliability and precision of strength measurement via isokinetic methods is a critical factor for providing an accurate assessment of muscle function over repeated sets of exercise which may also be affected by inadequate muscle recovery. To date there is little information on the effects of rest interval length on isokinetic force production and reliability.

Rest is the recovery time after participation in heavy resistance activities, whereas the intrasession rest interval is the period of time between multiple sets of a single exercise or a series of exercises (30). Under conditions of maximal muscle contractions, the intrasession rest interval should allow enough time for the working muscle to replenish phosphocreatine (PCr), restore intramuscular pH, facilitate the removal of metabolic end products, and return impaired muscle membrane excitation to resting levels (2, 19, 28). Greater muscle fatigue due to a reduction of the intrasession rest interval may compromise the ability to generate maximal muscle tension, in turn interfering with valid measures of muscle strength (1, 7, 29, 30).

Although it has been shown that intrasession rest intervals lasting 2-3 minutes allow optimal muscle recovery (1, 13, 29), the reliability of strength measures following the manipulation of rest intervals remains in question. Using the Biodesm System II isokinetic dynamometer, Feiring et al (9) reported intraclass correlation coefficients (ICC) of r = 0.82 to 0.98 for isokinetic quadriiceps peak torque and single repetition work at angular velocities of 60, 180, 240 and 300° . sec⁻¹. Subsequently, ICCs ranging from 0.67 to 0.97 for nonwindowed peak torque and angular work at 60 and 180° . sec⁻¹ were demonstrated by Gross et al. (12).

Most recently, Pincivero et al. (22) found high test-retest ICCs of r = 0.88 to 0.97, and SEMs that ranged from 2.0 to 11.6% for isokinetic peak torque, total work, and average power at 60 and 180° . sec⁻¹. Although these previous reports demonstrate consistently high reliability coefficients at various velocities, they were performed under nonfatigued conditions. In addition, an intermediate velocity of 90° . sec⁻¹ lacks reliability even though it lies within the velocity spectrum of isokinetic dynameters. Since the recovery of muscle function following fatigue-inducing contractions is a time-dependant process, it is theorized that intrasession rest intervals that are too short may compromise the generating of muscle tension (4).

Therefore the purpose of this investigation was to examine the effects of intrasession rest intervals on isokinetic strength of the quadriiceps and hamstring muscles, and to examine the reliability and precision of these strength measures.
Methods

Serving as subjects for this study were 15 healthy, college-age volunteers (8 men, 7 women, mean age 21.7 ± 1.9 yrs, Ht 172.5 ± 8.5 cm, Wt 68.7 ± 9.8 kg) with no previous history of injury to the lower extremity and no resistance training during the last 6 months. Prior to participating in this study, each provided written informed consent approved through the Biomedical Institutional Review Board at the University of Pittsburgh. Each subject was randomly assigned to 1 of 2 groups: Group 1 (n = 8), short intrasession rest interval, or Group 2 (n = 7), long intrasession rest interval. For each subject, one leg was randomly selected to undergo concentric isokinetic exercise for reciprocal knee extension and flexion. Prior to strength testing, each subject completed a dynamic warm-up consisting of stationary cycling for 5 min at 60 rpm followed by quadriceps and hamstring stretching. All were instructed to stretch the quadriceps from a side-lying position with the hip in full extension and the ipsilateral hand pulling the knee into flexion. The hamstrings were stretched while the subject was upright and seated, with the knee fully extended and flexing forward at the hip. Each stretch was repeated 3 times and held for 20 sec.

Isokinetic Strength Assessment

Isokinetic strength was assessed with the Biodex System 2 isokinetic dynamometer (Biodex Medical, Shirley, NY). The subject sat upright in a comfortable position on the Biodex dynamometer chair and was secured with thigh, pelvis, and torso straps to minimize extraneous movements. The lateral femoral epicondyle was used as the bony landmark for matching the knee joint’s axis of rotation with that of the dynamometer resistance adapter.

Once the subject’s position allowed for a comfortable and unrestricted motion for knee extension and flexion from 90° of flexion to terminal extension, the following measurements were taken: seat height, seat inclination, dynamometer head height, and resistance pad level. These measures were recorded and stored in the Biodex Advantage software program, version 4.0, in order to standardize the testing position for each subject. Gravity was corrected by measuring the torque exerted on the dynamometer resistance adapter with the knee in a relaxed state at terminal extension. Values for the isokinetic variables measured were automatically adjusted for gravity by the software program.

The dynamometer was calibrated according to manufacturer specifications. During the test, the cushion setting on the control panel for the ends of the range of motion were set to their lowest (hard) setting to reduce the effect of limb deceleration on the reciprocal motion (27). Each subject was required to hold his or her arms across the chest and was given verbal encouragement, as well as visual feedback from the computer monitor in an attempt to elicit maximal effort (14). The same investigator conducted all testing procedures for all subjects.

Reciprocal concentric isokinetic knee extension and flexion was assessed at a preset angular velocity of 90° · sec⁻¹. Prior to testing, each subject completed 5 submaximal and 2 maximal reps to warm up. Each then performed 4 sets (~20 sec per set) of 10 maximal reps. Group 1 was given a 40-sec rest interval between sets (2:1 rest : exercise ratio) while Group 2 had a 160-sec rest interval (8:1 rest : exercise ratio). The ratios were based on anecdotal observations of protocols used in training and rehabilitation.

Values for peak torque (N·m), total work (N·m), and average power (Watts) for the quadriceps and hamstrings were computed by the software program. Peak torque was defined as the single maximal torque value generated during each set of exercise. Total work was defined as the amount of torque generated throughout the full range of motion during each set of exercise. Average power was defined as the amount of isokinetic work performed per unit of time during each set of exercise (21).

Statistical Analysis

A one-way repeated measures ANOVA was performed on each group to identify significant changes in isokinetic strength across the 4 sets of exercise. An alpha level of p ≤ 0.05 for significance was set. Intraclass correlation coefficients were then calculated for each isokinetic variable across the 4 sets of exercise to determine test-retest reliability (5, 24). To determine the precision of measurement for isokinetic variables, the SEM values were calculated and expressed as a percentage of the mean. SEM values were interpreted as a percentage in order to present the findings in a clinically applicable manner.

Results

The results revealed that Group 1 had a statistically significant reduction in quadriceps and hamstring peak torque (Figure 1), total work (Figure 2), and average power (Figure 3). Group 2 had no significant changes in quadriceps or hamstring peak torque, total work, or average power. The percentage decrements in peak torque, total work, and average power from Sets 1 to 4 were as follows:

<table>
<thead>
<tr>
<th>Group</th>
<th>Quadri</th>
<th>Hamstr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT</td>
<td>16%</td>
<td>12.3%</td>
</tr>
<tr>
<td>TW</td>
<td>19%</td>
<td>19%</td>
</tr>
<tr>
<td>Avg P</td>
<td>19%</td>
<td>18%</td>
</tr>
<tr>
<td>Group 2</td>
<td>PT</td>
<td>2.2%</td>
</tr>
<tr>
<td>TW</td>
<td>2.8%</td>
<td>5.7%</td>
</tr>
<tr>
<td>Avg P</td>
<td>2.4%</td>
<td>5.7%</td>
</tr>
</tbody>
</table>

The reduction in isokinetic strength for Group 1 ranged from 12.8 to 19%; the percentage decrements for Group 2 ranged from 2.2 to 5.7%.
ICC coefficients and SEM for quadriceps and hamstring peak torque, total work, and average power across the 4 sets of exercise are listed in Table 1. The results demonstrated higher reliability coefficients and lower SEM values for Group 2 (ICCs = 0.98–0.99, SEM = 2.2–4.7%) vs. Group 1 (ICCs = 0.78–0.92, SEM = 5.1–7.7%).

**Table 1**
Test-Retest Intracontract Correlation Coefficients and SEM Values for Both Groups

<table>
<thead>
<tr>
<th></th>
<th>Group 1 (40 sec rest)</th>
<th></th>
<th></th>
<th>Group 2 (160 sec rest)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ICC</td>
<td>SEM (%)</td>
<td>ICC</td>
<td>SEM (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quadriceps peak torque</td>
<td>0.83</td>
<td>6.5</td>
<td>0.99</td>
<td>2.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quadriceps total work</td>
<td>0.78</td>
<td>7.2</td>
<td>0.99</td>
<td>2.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quadriceps avg. power</td>
<td>0.84</td>
<td>7.5</td>
<td>0.99</td>
<td>2.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hamstring peak torque</td>
<td>0.92</td>
<td>5.1</td>
<td>0.98</td>
<td>3.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hamstring total work</td>
<td>0.80</td>
<td>7.5</td>
<td>0.98</td>
<td>4.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hamstring avg. power</td>
<td>0.85</td>
<td>7.7</td>
<td>0.98</td>
<td>4.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Discussion**

The major findings suggest that exercise protocols utilizing a rest : exercise ratio of 2:1 may not allow enough time for muscle recovery during isokinetic exercise, since there was a significant reduction in isokinetic strength of the quadriceps and hamstring muscles over 4 sets of exercise using an intraat session rest interval of 40 sec. Although other studies have examined muscle recovery patterns following fatigue-inducing contractions, the present study attempted to incorporate bouts of exercise that are often implemented during injury rehabilitation and training. Furthermore, the 20-sec duration of each set of exercises was an attempt to maximally stimulate the phosphocreatine system's contribution to ATP resynthesis (25).

It appears that an intraat session rest interval of 160 sec was long enough to allow full recovery of isokinetic quadriceps strength. These findings concur with those of Bilcheck et al. (1), who demonstrated that concentric and eccentric isokinetic strength of the quadriceps was fully recovered after 2-1/2 min of rest. Similarly, Touey et al. (29) found that isokinetic quadriceps and hamstring performance were optimized when utilizing intraat session rest periods of 120 sec. However, Touey et al., who also used 4 sets of 10 maximal repetitions of reciprocal concentric contractions, determined that a relatively longer intraat session rest interval of 240 sec maximized performance.

A reduced ability to exert maximal muscle tension because of inadequate recovery has been attributed to both metabolic and nonmetabolic factors. Metabolic factors, such as the rapid degradation of intramuscular PCr and the accumulation of muscle and blood lactate, have
been shown to affect exercise performance (2, 6, 15, 25, 26, 28). The increase in [H⁺] during prolonged high-intensity exercise has been shown to directly interfere with the contractile machinery of muscle by competing for the calcium-binding sites on troponin C (8, 11, 23).

Of the nonmetabolic factors implicated, reductions in force output of the quadriceps have been found to be positively related to decreases in the electromyogram (EMG) mean frequency following sustained isokinetic muscle contractions (10, 17, 20). These findings, as demonstrated within the first 20 sec of exercise, are thought to be due to a reduction in the conduction velocity of the muscle fiber membrane, which in turn can be attributed to an increased [K⁺] in the extracellular compartment, a decrease in [K⁺] inside the muscle cell, and an increase in extracellular [Na⁺] (3, 19).

The time dependency of muscle recovery, as shown in the present investigation, suggests that the restoration of these various metabolic and nonmetabolic factors is critical for enhancing the force-generating capacity of muscle. Since the primary stimulus for strength development appears to be a muscle’s ability to generate maximum tension when fatigue is minimized, optimal muscle recovery through relatively longer rest periods seem prudent (16, 18, 30).

Quantifying muscle strength objectively is important for clinicians in sports medicine and orthopaedic rehabilitation. The results from the present study reveal that test-retest reliability of isokinetic strength of the quadriceps and hamstrings is higher when using longer intrasession rest intervals. Furthermore, more precise measures, as indicated by the SEM values in Table I, were also found for Group 2. As noted earlier, high interday ICC coefficients for isokinetic strength were found by Feiring et al. (9), Gross et al. (12), and Pincivero et al. (22). It was also concluded from those studies that the use of windowed data as well as adequate calibration, gravity correction, and patient set-up procedures are the most important factors for improving a test’s reliability (9, 12, 22, 31).

The present study suggests that intrasession rest periods are also critical for improving the reliability of isokinetic strength assessment. Oftentimes in the clinical setting, repeated bouts of muscle contractions (sets) may provide a valid index for muscle fatigue. In the present study, an intrasession rest interval corresponding to a 2:1 rest:exercise ratio produced ICC coefficients and SEM values comparable to interday measurements (9, 12, 22). Although these previous studies presented high test-retest coefficients, intrasession reliability in the present study was found to be maximized (r = 0.98 to 0.99) with adequate muscle recovery of 160 sec.

Practical Applications

The present study demonstrated the importance of rest intervals of sufficient length (160 sec) for isokinetic muscle recovery and reliability measures. An understanding of the physiological recovery patterns of skeletal muscle following fatiguing contractions is vital to developing a good rehabilitation and training program. The restoration of muscle function as a result of adequate rest was shown to be a key factor for accurate and reliable measures of strength testing during a single session. Since these findings appear to concur with those of other investigators with respect to muscle recovery, the duration of the rest interval and its impact on force production may influence strength development. Such a hypothesis, however, warrants continued investigation into the area of training and rehabilitation.

References


