Potentiation and Recovery Following Low- and High-Speed Isokinetic Contractions in Boys

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The objective of this study was to examine the response and recovery to a single set of maximal, low and high angular velocity isokinetic leg extension-flexion contractions with boys. Sixteen boys (11–14 yrs) performed 10 isokinetic contractions at 60°.s⁻¹ (Isok60) and 300°.s⁻¹ (Isok300). Three contractions at both velocities, blood lactate and ratings of perceived exertion were monitored pretest and at 2, 3, 4, and 5 min of recovery (RI). Participants were tested in a random counterbalanced order for each velocity and recovery period. Only a single contraction velocity (300°.s⁻¹ or 60°.s⁻¹) was tested during recovery at each session to remove confounding influences between the recovery intervals. Recovery results showed no change in quadriceps’ power at 300°.s⁻¹, quadriceps’ power, work and torque at 60°.s⁻¹ and hamstrings’ power and work with 60°.s⁻¹. There was an increase during the 2 min RI in hamstrings’ power, work and torque and quadriceps’
torque with isokinetic contractions at 300°.s⁻¹ suggesting a potentiating effect. Performance impairments during recovery occurred for the hamstrings torque at 60°.s⁻¹ and quadriceps work with 300°.s⁻¹. In conclusion, 10 repetitions of either low or high velocity isokinetic contractions (Isok60 or Isok300) resulted in full recovery or potentiation of most measures within 2 min in boys. The potentiating effect predominantly occurred following the hamstrings Isok300 which might be attributed to a greater agonist—antagonist torque balance and less metabolic stress associated with the shorter duration higher velocity contractions.

There are a number of important variables associated with resistance training prescriptions including the intensity, volume or duration, frequency and recovery intervals (RI; 1). The adult resistance training literature provides between set RI recommendations based on phosphocreatine resynthesis (32), hormonal responses (14), strength restoration (64), jump performance (47), and sprint time (15) and other measures. Review articles and textbooks in general recommend 2–5 min of recovery between resistance training sets for adults (1,69). However, there is very little information in the literature regarding potentiation and fatigue during RI for children and adolescents. A number of review articles, position stands and training prescription papers recommend or suggest ranges of intensities and volumes of resistance training for children and adolescents but do not mention recommended RI (6,24,37,40,68).

There is a complex interplay between muscle fatigue and potentiation (3). Potentiation can be defined as a temporary improvement in muscle performance following a conditioning activity due to mechanisms either within the muscle or neural factors (58). The ability to sustain forces can be viewed as a compromise between fatigue-inducing impairments and neuromuscular strategies to enhance or sustain performance (3). While the effect of an initial bout of high intensity contractions has been shown to produce force facilitation or potentiation in some adult studies (5,35,58), there are few studies examining recovery and potentiation in children and adolescents. Jump performance has been enhanced following dynamic warm-ups in high school female athletes (28), male adolescent athletes (27) and elite youth soccer players (42). Both Faigenbaum et al. (26) and Duncan and Woodfield (20) speculated that improvements in shuttle run and vertical jump performance respectively may have been due to enhanced excitability of fast twitch motor units. Muscle postactivation potentiation has been demonstrated in healthy pre- and postpubertal children (9,44,45). The mechanisms of potentiation and fatigue can occur simultaneously (51). A typical volume of resistance training which can induce fatigue for an adult (7,57) could result in no appreciable signs of fatigue in children or adolescents. Whether the response to a conditioning stimulus is fatigue or potentiation is also dependent upon the trained state of the individual (58).

According to the concept of training specificity (4), for sports that involve explosive and high speed contractions, training should involve similar contraction velocities and intensities. As the few previous studies in children and adolescents that have investigated RI used moderate or slower speed contractions, it is unknown how youth respond to high and low speed, high intensity contractions. Youth are reported to have a greater resistance to fatigue (19,52,53) and have been shown to recover more rapidly than adults from three sets of a 10 repetition maximum load (29) and repeated bouts of high intensity 120°.s⁻¹ isokinetic contractions (19,70). In fact, there are very few adult studies comparing the fatigue effects between high
and low speed contractions. Celes et al. (16) reported greater losses in peak torque and total work with 3 sets of 10; 60°.s\(^{-1}\) versus 300°.s\(^{-1}\) isokinetic knee extensions in young men (~22 years). In a study using older men (60–74 years), there was no difference in recovery of peak torque following 2 sets of 4 repetitions of 90°.s\(^{-1}\), and 120°.s\(^{-1}\) isokinetic contractions (30, 60 and 90s recovery; 12).

Thus it was the objective of this study to investigate the extent of potentiation or fatigue during the recovery of boys’ quadriceps and hamstrings following a set of 10 repetitions of low and high velocity leg extension and flexion isokinetic contractions. As the 60°.s\(^{-1}\) isokinetic contractions can generate greater torques over longer durations than the 300°.s\(^{-1}\) contractions, it was hypothesized that the lower speed contractions would provide greater force impairments during the recovery.

**Methods**

**Subjects**

Sixteen male competitive martial arts practitioners, between 11–14 years volunteered to participate in this study. Subject characteristics were 12.2 ± 0.9 years, 151.1 ± 8.6 cm, 42.5 ± 9.7 kg with mean body fat percentage and fat free mass of 17.1 ± 4.2% and 34.9 ± 6.6 kg respectively. All of them had been practicing their sport for at least 3 years with a mean training schedule of 6–8 hr per week. A pubertal assessment was conducted using the composite score of the widely used method of pubertal stage assessment described by Tanner (63). These data are in respect to the available published data about puberty onset and development in Tunisian schoolchildren aged between 8 and 16 years (66). In this regard, all the study subjects ranged from stage 2 to stage 4 of Tanner score.

Following written consent and before experimental participation, volunteers were examined by a physician in the National Center of Medicine and Science in Sports, Tunis, and were assessed as having no injury to their lower limbs, orthopedic limitations or illness that put them at risk while performing the testing exercises or would influence performance or measurements. Body fat measurements were conducted according to Deurenberg et al. (18) who reported similar prediction errors between adults and young adolescents. The study was conducted according to the Declaration of Helsinki and the protocol was fully approved by the Clinical Research Ethics Committee and the Ethic Committee of the National Centre of Medicine and Science of Sports of Tunis (CNMSS).

**Experimental Protocol**

Each subject completed 11 laboratory visits including a 2-part orientation session. During the orientation phase, approximately 1 week before testing, each subject was familiarized with the equipment (isokinetic dynamometer: Cybex NORM; Henley Healthcare, Cybex International, Inc., Medway, MA) and procedures and participants’ height, body mass, and skinfold thickness were measured. During this sessions, subjects performed five submaximal and ten maximal isokinetic efforts of the knee extensors and flexors at 300°.s\(^{-1}\) and 60°.s\(^{-1}\). The remaining 8 sessions were completed during the course of the subsequent 16 days, so that approximately 48 hr separated each test-day.
Sixteen boys were tested with 3 maximal isokinetic contractions at 60°.s\(^{-1}\) and 300°.s\(^{-1}\) before and following an intervention of 10 isokinetic contractions at 60°.s\(^{-1}\) or 300°.s\(^{-1}\) (Isok60 and Isok300, respectively). Ten isokinetic contractions were chosen for their ecological validity as this number is within the recommended range of repetitions (6–15 repetitions) reported in a number of position stands and reviews for children’s resistance training (6,25,34,39,40,68). During each of the 8 follow-up sessions, subjects were tested at 300°.s\(^{-1}\) or 60°.s\(^{-1}\) for peak torque, mean power, and total work during the recovery periods at 2, 3, 4 or 5 min to eliminate the potentially confounding influence of the testing of various testing velocities on subsequent recovery interval measures.

Ratings of perceived exertion (RPE) were monitored during the pretest, isokinetic resistance protocols and RI. Blood was taken immediately before Isok60, Isok300 and the RI tests for the measurement of blood lactate.

The athletes did not participate in their regular TKD training for 24 hr before testing. This procedure was chosen to minimize any performance changes that could occur over a longer time period and to ensure adequate functional recovery. Each subject was tested at approximately the same time of day (within 2 hr) over the 8 sessions to nullify diurnal variations.

**Testing Protocol**

At all testing sessions, each subject started the experimental trial by completing a standardized procedure including a 5-min cycling warm-up at 70 W at 70 rpm on a cycle ergometer before the initial isokinetic testing. As part of the warm-up, the subjects sat on the Cybex Norm dynamometer (Cybex NORM; Henley Healthcare, Cybex International, Inc., Medway, MA) and were secured to both the dynamometer and the corresponding chair according to manufacturer’s specifications to minimize extraneous movements and to maintain a constant hip joint angle (90°). Only the dominant limb, determined from the kicking preference of the athlete, was tested. After height, limb mass, gravity correction, and individual specific full range of knee motion were recorded, subjects performed a set of four to five submaximal leg extension and flexion contractions on the isokinetic dynamometer at 180°.s\(^{-1}\) as a specific warm-up. After a 3-min rest, the participants performed the pretesting protocol which was randomly allocated consisting of three maximal intensity leg extension and flexion repetitions on an isokinetic dynamometer at 300°.s\(^{-1}\) and 60°.s\(^{-1}\) respectively, with 3 min rest between sets of testing contractions. Subjects were instructed to not rest between the 3 repetitions. They were instructed to continuously push the lever-arm through a full range of motion, as hard and as fast as possible for three maximal efforts in both directions of the movement, with extension always undertaken first. Three repetitions were chosen pretest and during recovery as it is acknowledged in the literature that no more than 3–5 repetitions are necessary when assessing strength (13). Following a 3-min rest period, the subjects performed a resistance exercise protocol consisting of 10 maximum intensity, full range of motion, isokinetic leg extension and flexion contractions at either 60°.s\(^{-1}\) (Isok60) or 300°.s\(^{-1}\) (Isok300) depending on the testing session day. This protocol was selected due to its similarity to isokinetic strength testing protocols in the literature (46). The order of the isokinetic resistance protocol was randomized as was the RI (2, 3, 4, and 5 min) for each testing session. After the isokinetic protocol, the
testing protocol was the same as that used before the intervention. The participant’s were verbally encouraged to produce maximal effort.

The parameters used for analysis were peak torque measured in Nm, mean power and total work measured in Joules. Isokinetic measurements in children have been reported to be reproducible (41). Table 1 illustrates the excellent isokinetic measurement reliability attained in the current study. Between session reliability was calculated by comparing multiple pretest measures.

Each young athlete was asked to state the respective RPE at the end of each exercise set to ensure that the perceived effort was referred to this exercise-set only. With every exercise set a copy of Borg’s CR10 scale (11) modified by Foster et al. (33) was used to assist the young athletes in making their responses. The predictive efficacy and validity of the Borg RPE has been demonstrated in children (22,23).

To assess blood lactate with the isokinetic resistance protocols, fingertip blood samples were taken immediately before the isokinetic protocol and each RI. A blood sample (5 µl) was obtained from the fingertip and analyzed for lactate concentration (mmol·l⁻¹) using portable blood lactate analyzer (LactatePro, Arkray, Tokyo, Japan). Before each testing session and before each blood sampling, the lactate analyzer was calibrated and used according to the manufacturer guidelines. The portable blood lactate analyzer used in this study has been reported to be reliable and valid (50).

Table 1  Reliability Obtained From Preintervention Values of Isokinetic Measures. The Parameters Used for Analysis Were Peak Torque Measured in Nm, Mean Power and Total Work Measured in Joules.

<table>
<thead>
<tr>
<th>Velocity</th>
<th>Muscle group</th>
<th>Parameters Pretest</th>
<th>ICC</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>300°.s⁻¹</td>
<td>Hamstring</td>
<td>Peak torque 38.7 ± 11.2</td>
<td>0.962</td>
<td>0.793</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean power 102.1 ± 28.6</td>
<td>0.955</td>
<td>2.534</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total work 47.8 ± 13.1</td>
<td>0.951</td>
<td>1.257</td>
</tr>
<tr>
<td></td>
<td>Quadriceps</td>
<td>Peak torque 48.4 ± 12.1</td>
<td>0.928</td>
<td>1.990</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean power 124.9 ± 34.8</td>
<td>0.952</td>
<td>3.408</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total work 58.4 ± 15.4</td>
<td>0.947</td>
<td>1.674</td>
</tr>
<tr>
<td>60°.s⁻¹</td>
<td>Hamstring</td>
<td>Peak torque 60.4 ± 15.8</td>
<td>0.991</td>
<td>0.306</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean power 39.7 ± 10.3</td>
<td>0.988</td>
<td>0.253</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total work 73.6 ± 20.1</td>
<td>0.950</td>
<td>1.838</td>
</tr>
<tr>
<td></td>
<td>Quadriceps</td>
<td>Peak torque 88.6 ± 19.2</td>
<td>0.987</td>
<td>0.541</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean power 57.3 ± 14.8</td>
<td>0.980</td>
<td>0.553</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total work 99.6 ± 20.1</td>
<td>0.994</td>
<td>0.280</td>
</tr>
</tbody>
</table>
Statistical Analysis

The kinetic and RPE data were analyzed using 3 way repeated-measures ANOVA (2 × 4 × 4; GB-Stat V. 7, Dynamic Microsystems, Maryland USA). Factors included velocity of the isokinetic intervention contractions (Isok60 and Isok300), pretest (separate pretests were performed with each of the 4 recovery intervals) and recovery time (2, 3, 4, and 5 min RI). The preintervention and recovery testing velocities (3 contractions each at 60°.s⁻¹ and 300°.s⁻¹) were not compared or analyzed as a third factor in the ANOVA as it is well known that forces, work and power outputs differ between 60°.s⁻¹ and 300°.s⁻¹ isokinetic contractions. Thus the preintervention and recovery testing velocities were analyzed with separate 3 way ANOVAs. The blood lactate data were analyzed using a repeated measures 2 way ANOVA (2 × 2). Factors included velocity of contractions (Isok60 and Isok300) and time (precontractions and recovery). If significant interactions were detected a Bonferroni-Dunn’s correction procedure post hoc test was used. Significance was considered to be achieved at \( p < .05 \). Effect sizes (ES = mean change / standard deviation of the sample scores) were also calculated and reported (17). Data are described as means ± SD (SD).

Results

Hamstrings Kinetics

Following the Isok300 intervention, there was a significant main effect for 300°.s⁻¹ testing with 3.5%, 2.7% and 5.6% increases in hamstrings mean power \( (p = .006, \text{ES} = 0.12) \), total work \( (p = .003, \text{ES} = 0.1) \) and peak torque \( (p < .0001, \text{ES} = 0.2) \) respectively comparing the pretest to the combined recovery periods (Table 2).

After the Isok60 protocol, there were no main effects for hamstrings mean power or total work for the 60°.s⁻¹ testing. However, hamstrings peak torque decreased by 3.4% when comparing the pretest to the combined recovery periods for the 60°.s⁻¹ isokinetic testing \( (p = .003, \text{ES} = 0.2) \). A main effect \( (p = .02, \text{ES} = 0.35) \) for RI showed an 11.4% increase in hamstrings peak torque from 2 (55.5 Nm ± 19.6) to 3 (61.8 Nm ± 17.6) minutes of recovery. There were no other significant differences between the other recovery periods’ measurements.

| Table 2 | Illustrates the Significant (*) Main Effect for Time (Pre- to Posttesting) With 300°.s⁻¹ Testing With Hamstrings Mean Power \( (p = 0.006) \), Total Work \( (p = 0.003) \) and Peak Torque \( (p < 0.0001) \) Respectively. |
|-----------------|------------------|------------------|------------------|
| **Hamstrings Mean Power** | **Hamstrings Total Work** | **Hamstrings Peak Torque (Nm)** |
| Pretest | 98.6 ± 27.4 | 46.3 ± 13.7 | 38.7 ± 11.9 |
| Posttests (data combined over all recovery periods) | 102.1 ± 29.5 * | 47.6 ± 13.3 * | 40.9 ± 11.3 * |
Quadriceps Kinetics

With the Isok60 intervention, there were no significant changes from 300°.s⁻¹ pre-test to recovery for mean power or between 60°.s⁻¹ pretest and recovery for mean power, total work or peak torque. The amount of total work by the quadriceps decreased 2.6% ($p = .003$, ES = 0.1) when comparing the pretest to the combined recovery 300°.s⁻¹ testing.

Following the Isok300 intervention, there was a main effect ($p = .002$) for 300°.s⁻¹ peak torque testing RI with the 2 min RI having 5.5%, 5.6%, 8.2% and 8.1% greater peak torque than the pretest, as well as 3 (ES = 0.2), 4 (ES = 0.3), and 5 (ES = 0.3) minutes of recovery respectively (Figure 1).

Blood Lactate

A significant ($p < .0001$) main effect for testing showed that RI (3.15 ± 0.9 mmol·l⁻¹) blood lactate values were 38.1% (ES = 1.4) greater than preintervention (2.28 ± 0.6 mmol·l⁻¹) values. A second significant ($p < .0001$) main effect for contraction velocity illustrated that the Isok60 (2.95 ± 0.9 mmol·l⁻¹) blood lactate values were 18.9% (ES = 0.8) greater than the Isok300 (2.48 ± 0.6 mmol·l⁻¹) values. Interaction effects ($p < .0001$) indicated that overall recovery blood lactate values for both the Isok60 and Isok300 exceeded the pretest values by 47.8% (ES = 1.65) and 27.9% (ES = 1.07) respectively (Figure 2). Whereas there was no difference between the pretest values, the blood lactate recovery values were significantly ($p < .0001$) higher for the Isok60 than the Isok300 (Figure 2).
Ratings of Perceived Exertion (RPE)

A main effect for testing indicated significantly \( (p < .0001) \) higher mean RPE scores for the combined isokinetic protocols (Isok60 and Isok300 combined RPE: \( 3.9 \pm 0.8 \)) and recovery (RPE: \( 3.6 \pm 0.7 \)) periods compared with the pretests (RPE: \( 3.1 \pm 0.6 \)). The isokinetic interventions (Isok60 and Isok300 combined) and RI RPE scores exceeded the pretest scores by 24.7\% (interventions: ES= 1.4) and 13.7\% (RI: ES = 0.89) respectively. The set of 10 isokinetic contractions’ RPE score (Isok60 and Isok300 combined) was 9.8\% (ES = 0.4) greater than the RI score.

Whereas the Isok60 intervention RPE was 48.5\% higher \( (p < .0001) \) than the Isok60 pretest contractions, the Isok300 intervention showed a nonsignificant 1.5\% higher RPE score than the Isok300 pretest contractions (Table 3). Other significant \( (p = .0008) \) interactions indicated that RPE scores for all RI following the Isok60 were higher than the 2 min RI following the Isok300 intervention. The RPE scores following the Isok60 RI were 25.1\% (ES = 0.88), 16.3\% (ES = 0.85), 17.5\% (ES = 1.25) and 15.3\% higher than the 2 min RI following the Isok300 respectively. There were no significant differences between the 3, 4, and 5 min RI following the Isok300 and any of the recovery periods for the Isok60 (Table 3).
The most significant findings of this study were the potentiation of the boys’ hamstrings’ mean power, total work, and peak torque and quadriceps’ peak torque following 10 maximal isokinetic repetitions at 300°.s⁻¹ (Isok300). The present study has also shown a lack of impairment during RI in quadriceps mean power at 300°.s⁻¹, quadriceps mean power, total work or peak torque at 60°.s⁻¹ and hamstrings mean power or total work with 60°.s⁻¹ contractions.

In the current study, there was an increase of hamstrings mean power, total work and peak torque and quadriceps peak torque (2 min recovery) following Isok300. This potentiation may be attributed to a variety of neural responses. For example, neural potentiation has been documented at the supraspinal level with motor evoked potential facilitation occurring following varying durations and contraction intensities (2). In that study the greatest potentiation was achieved with the shortest and strongest contractions. At the level of the motoneuron, improved H-reflex amplitudes (36) can persist for 10 min following conditioning contractions (67). At the muscle level, increased muscle stiffness has been shown to persist for 90 min following 5 repetitions of 8s contractions (65). Other peripheral factors such as increased sensitivity to Ca++ release or increases in muscle stiffness due to residual crossbridge attachments (59) might also contribute to the facilitation or potentiation of contractions.

It is unlikely that the mechanisms associated with muscle postactivation potentiation (PAP) played a significant role in the recovery potentiation. PAP has been defined as an increase in the efficiency of a muscle or a decrease in the energy needed to produce a submaximal force following a voluntary contraction (3). Furthermore PAP can also positively affect rate of force development (58), however as the velocity of movement was limited by the dynamometer, it would not be a factor. As the current study’s recovery testing involved maximal contrac-

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### Table 3 Illustrates the Mean Ratings of Perceived Exertion (RPE) Measures for Pretest, Intervention (Isok60 and Isok300) and Recovery Tests. The Asterisk (*) Indicates that the Isok60 Pretest RPE Measure was Significantly Lower than the Corresponding Isok60 Intervention and Recovery Scores. The Omega (Θ) Symbol Indicates Significant Differences Between the Single and Double Omegas (Θ Θ) Measures.

<table>
<thead>
<tr>
<th></th>
<th>Isok60 intervention</th>
<th>Isok300 intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>3.1 ± 0.7 *</td>
<td>3.1 ± 0.7 Θ Θ</td>
</tr>
<tr>
<td>Intervention (10 isokinetic contractions)</td>
<td>4.6 ± 0.8 Θ</td>
<td>3.2 ± 0.5</td>
</tr>
<tr>
<td>2 min recovery</td>
<td>3.9 ± 0.9 Θ</td>
<td>3.1 ± 0.9 Θ Θ</td>
</tr>
<tr>
<td>3 min recovery</td>
<td>3.7 ± 0.7 Θ</td>
<td>3.7 ± 0.5</td>
</tr>
<tr>
<td>4 min recovery</td>
<td>3.7 ± 0.7 Θ</td>
<td>3.7 ± 0.8</td>
</tr>
<tr>
<td>5 min recovery</td>
<td>3.6 ± 0.4 Θ</td>
<td>3.4 ± 0.6</td>
</tr>
</tbody>
</table>
Potentiation and Recovery Responses of Youth

Potentiation forces, the PAP mechanisms (i.e., regulatory light chain phosphorylation) (62) typically are only present with lower frequency muscle stimulation such as twitches, unfused tetanus and submaximal voluntary contractions. Furthermore children are reported to have lower proportional area of type II muscle fibers (10,53). As PAP is reported to occur more predominantly in type II fibers (58), the mechanisms underlying the improvement in recovery measures are more likely to be associated with neural responses. However, if particular subjects did not produce maximal exertion throughout the protocol, the increased muscle efficiency associated with PAP could have reduced possible fatigue effects.

However, adult literature PAP studies have shown greater potentiation responses in trained individuals (58). As the boys in this study were trained martial artists who engaged regularly in power and strength activities, they may have been more likely to emphasize potentiation rather than fatigue responses than untrained youth.

In the current study, there seemed to be a greater potentiation response by the hamstrings compared with the primarily lack of change with the quadriceps variables. Forbes et al. (31) reported a more equitable torque balance between hamstrings and quadriceps in younger football players (under 12–16 years) as compared with the greater predominance of quadriceps concentric torque with 17–18 year old football players. They suggested that the hamstrings-quadriceps inequality with 17–18 year old players may be reflective of a limited focus on hamstrings training or a greater focus on quadriceps training. They reported concentric hamstrings to quadriceps peak torque ratios of 0.5–0.62. The young athletes in the current study had even more balanced hamstrings to quadriceps concentric torque ratios of 0.8 for the pretest 300°.s⁻¹ isokinetic contractions and 0.67 for the 60°.s⁻¹ contractions. In the current study, the greater relative potentiation of the hamstrings may be related to better hamstrings-quadriceps torque balance.

Other than RI hamstrings peak torque at 60°.s⁻¹ and quadriceps total work with 300°.s⁻¹ isokinetic contractions, all other recovery measures following the Isok60 and Isok300 showed full recovery by 2 min. However it could be argued that there was a tendency for velocity specificity with augmented or potentiated measures only occurring following the Isok300 (i.e., RI hamstrings mean power, total work and peak torque and quadriceps’ peak torque at 300°.s⁻¹). There was no potentiation following Isok60. There is a physiological compromise or balance between fatigue-inducing responses and neuromuscular strategies to enhance or sustain performance (3). The 60°.s⁻¹ contractions (Isok60) were of longer duration (each repetition was approximately 1.5 s compared with ~0.3 s for the 300°.s⁻¹ contractions). This increased duration and work involved a greater metabolic stress as evidenced by the significantly greater blood lactate values as compared with the Isok300. We would hypothesize that the greater work and duration-induced metabolic disruptions with Isok60 and the subsequent metabolic stress counterbalanced the neuromuscular mechanisms that might contribute to a potentiated response during recovery. Future research must investigate different velocities of isokinetic contractions with similar durations of work to determine specifically whether it was the duration or velocity of the exercise that was the prime determinant of performance facilitation or potentiation.

With the evidence of muscle stress (increased RPE and blood lactate), the lack of change in RI quadriceps power at 300°.s⁻¹, quadriceps power, total work or peak torque at 60°.s⁻¹ and hamstrings power or work with 60°.s⁻¹ contractions would
seem to indicate that the effects of potentiation and metabolic stress were relatively balanced. Internal fatigue manifestations such as metabolic disruptions may be experienced during repetitive contractions without a decrement in the targeted force (3). This type of fatigue may be defined as an increase in the perceived effort needed to exert a desired force and an eventual inability to produce this force (21). Fatigue effects may have been more predominant with the decreases in the Isok60 RI hamstrings peak torque with 60°.s⁻¹ isokinetic contractions and quadriceps total work with 300°.s⁻¹ contractions.

Although, most of the measured variables in the current study did not decrease and some even increased following the exercise protocol there was conceivably counterbalancing effects between potentiating and fatigue-inducing factors. Evidence illustrating the presence of physical stress includes RPE scores that were significantly higher during the Isok60, Isok300 and RI than the pretest; as well; the RPE scores were significantly higher during the Isok60 and Isok300 than during the RI. Blood lactate measures demonstrated that the Isok60 and Isok300 placed a metabolic stress upon the participants’ muscles. The accumulation of blood lactate during the recovery intervals is similar to the values reported in both adult (56,61) and pubescent boys’ (49) resistance exercise. Thus, the ability to sustain forces may be viewed as a compromise between a physical or metabolic stress and neuromuscular strategies to enhance or sustain performance (3).

The lack of external manifestations of fatigue (with the exception of Isok60 hamstrings peak torque at 60°.s⁻¹ and quadriceps total work with 300°.s⁻¹ contractions) exhibited throughout the RI may be attributed to a number of factors. Although the intent of each participant was to contract maximally, the contraction intensity and muscle activation may have been submaximal. Perry-Rana et al. (48) had adult subjects perform 25 maximal intent, eccentric, isokinetic contractions and illustrated that the average torque for the first contraction was approximately 75% of maximum and increased to approximately 85% of maximum by the end of the set. Children do not activate their knee extensors to as great an extent as adults (children ~65–70% (43,60) vs. adults ~85% (8)). Although the intent was for maximal contractions, the possibly lower agonist activation levels of the boys could result in less fatiguing submaximal contractions with the resultant response being an increase in muscle activation and potentiation (3).

Other explanations for the lack of recovery impairments could be related to lower anaerobic capacities (10), lactate concentrations (10,70), and muscle glycogen levels (10), faster phosphocreatine resynthesis (53,55) and higher oxidative capacities (55) of children and adolescents. Youth are also reported to have lower proportional area of type II muscle fibers (10,53) which would provide greater relative endurance capacities. Youth are reported to have a greater fatigue resistance (19,52,53) and recover faster from high intensity exercise than adults due to their lower maximal power output (30). They have been shown to recover more rapidly from Wingate anaerobic tests (38), 3 sets of a 10 repetition maximum load (29) and repeated bouts of high intensity 120°.s⁻¹ isokinetic contractions (70). Similarly, other studies using either isokinetic contractions (19) or sprints (54) have also shown greater fatigue resistance in children and adolescents when compared with adults. These findings may be a reflection of a lower reliance on glycolysis, more rapid removal of metabolites and/or lower muscle activation levels. As the boys in the current study were 11–14 years of age and transitioning from and through
Potentiation and Recovery Responses of Youth

Pubescence, the aforementioned metabolic factors may have ranged from child-like to more adult responses dependent upon physiological maturation. However there were no apparent or significant differences within the group. Finally the findings of trained boys may not translate to untrained boys. A future study is needed examining both trained and untrained children subjected to similar durations of high and low speed isokinetic contractions.

Conclusion

The present study showed that athletic boys were fully recovered (10 out of 12 measures) 2 min following 10 maximal repetitions using either 60°.s⁻¹ or 300°.s⁻¹ isokinetic contractions (Isok60 and Isok300). There was an indication for a velocity and muscle specific potentiation effect during recovery following the hamstrings Isok300 which might be attributed to a greater agonist—antagonist torque balance in boys and less metabolic stress associated with the shorter duration higher velocity contractions. Based on this study and previous research (6,29), it is recommended that a rest interval of less than 1–2 min may be necessary to induce fatigue (i.e., decreases in force, work or power) in youth following a set of maximal intensity resistance training. Conversely to improve subsequent performance, muscle potentiation may be achieved two or more minutes following a set of maximal intensity higher velocity resisted contractions.

Acknowledgments

This study was financially supported by the Tunisian Ministry of Scientific Research, Technology and Development of Competences, Tunisia. The authors would like to thank the staff of the National Centre of Medicine and Science in Sports, as well as the young athletes for their participation in this study. We especially thank Mme Touati Narjess and Mr Kasmi Sofiene for their assistance with Cybex devise.

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