Effect of Remote Voluntary Contractions on Isometric Prime Mover Torque and Electromyography

Luke R. Garceau¹, Erich J. Petushek², McKenzie L. Fauth³, William P. Ebben⁴

¹Department of Physical Therapy, Marquette University, Milwaukee, WI, ²Cognitive and Learning Sciences, Michigan Technological University, Houghton, MI, ³Wexner Medical Center, Sports Medicine, Ohio State University, Columbus, OH, ⁴Department of Health, Exercise Science and Sport Management, University of Wisconsin-Parkside, Kenosha, WI

ABSTRACT

Garceau LR, Petushek EJ, Fauth ML, Ebben WP. Effect of Remote Voluntary Contractions on Isometric Prime Mover Torque and Electromyography. JEPonline 2012;15(4):40-46. Remote voluntary contractions (RVCs) are contractions remote from the prime mover, and have been demonstrated to increase muscular performance. This study assessed the effect of remote voluntary contractions (RVC) on isometric peak torque (PT), rate of torque development (RTD), muscle activation of the prime movers, their antagonist, contralateral homologous muscle, and the muscles involved in the RVC, and gender differences. Thirteen men and 15 women performed isometric knee extension tests on a dynamometer in RVC and non-RVC (NO-RVC) conditions. The RVC condition included jaw clenching, hand gripping, and the Valsalva maneuver. Electromyography was used to quantify muscle activation. A two-way mixed ANOVA with repeated measures for RVC condition was used to evaluate the main effects for PT, RTD, muscle activation, and the interaction between RVC condition and gender. Remote voluntary contractions resulted in a significant 6.1% and 13.9% enhanced performance of men’s knee extension PT and RTD, respectively. Concurrent activation potentiation is an effective ergogenic aid for men.

Key Words: Concurrent Activation Potentiation, Power Development, Gender Differences
INTRODUCTION

Enhancing muscular performance is one of the primary goals of muscular conditioning programs. Ergogenic methods have been sought and concurrent activation potentiation (CAP) has emerged. Concurrent activation potentiation is a type of potentiation phenomenon that is proposed to increase prime mover activation via simultaneous contractions remote from the prime mover (2). Such contractions have been referred to as remote voluntary contractions (RVC). Previous reports have demonstrated RVC mediated muscular performance augmentations during open (3) and closed (4-7) kinetic chain exercises. Increased prime mover muscle activation has also resulted from CAP strategies (3).

Combined RVC of jaw clenching, hand gripping, and the Valsalva maneuver have been shown to augment isometric knee extensor average and peak torque (PT) (6), isokinetic knee extension PT, rate of torque development (RTD), power, and work (3) when compared to control test conditions with no RVC. Jaw clenching has produced an enhancement in peak force and rate of force development during the countermovement jump (4), squat jump (5), and back squat (5). However, the gender response and role of muscle activation during isometric exercise, in response to CAP strategies, has yet to be investigated.

Gender differences in isometric strength have been documented, with women achieving 44.5% to 52.2% of their male counterparts (1). Gender differences in response to RVC remain uncertain. Previous reports have either only assessed men (5) having chosen not to examine gender differences (4,7) or examined gender differences during isokinetic knee extension but revealed differences in RTD and not PT (3). Additionally, gender differences were seen in the level of muscle activation during RVC and non-RVC conditions of isokinetic knee extension and flexion (3). As such, it was the purpose of this study to assess the effect of RVC on PT, RTD, and muscle activation of the prime movers, their antagonist, contralateral homologous muscle, and muscles involved in the RVC, during isometric knee extension, and to assess gender differences therein.

METHODS

Subjects
Thirteen men (mean ± SD, age 20.9 ± 1.4 yrs; body mass 81.9 ± 11.3 kg) and 15 women (mean ± SD, age 21.6 ± 1.6 yrs; body mass 68.5 ± 8.2 kg) NCAA D1, club, or intramural athletes participated in this study. Inclusion criteria included biweekly participation in lower body resistance training with exercises that included knee extension for 2 months. Exclusion criteria included any history of muscle pathology that resulted in functional limitations of the RVC or right leg assessed. The women participants demonstrated NO-RVC isometric knee extension torque that was an average of 73.8% of the values of the men, suggesting the women participants had a similar training background as the men and a lower than average gender difference in lower body strength (9-11). Participants refrained from resistance training for at least 48 hrs prior to the test session. All were informed of the risks associated with the study and provided informed written consent. The study was approved by the institution’s internal review board, and was designed in accordance with the ethical standards of the Helsinki Declaration.

Procedures
The participants were habituated and tested. Prior to each session, the participants warmed-up and performed dynamic stretching exercises for the lower body for approximately 15 secs for each major muscle group. Then, the participants were positioned and secured in a dynamometer (System 4, Biodex Inc., Shirley, NY, USA) according to the manufacturer specifications. The knee joint was
tested at 60° of flexion where test specific warm-up sets of an isometric leg extension exercise in the RVC and NO-RVC conditions were performed. The RVC condition included maximal jaw clenching on a dental vinyl mouth guard (Cramer Products Inc., Gardner, KS, USA), maximal bilateral hand gripping using hand dynamometers (model 78010, Lafayette Industries, Lafayette, IN, USA), and the performance of the Valsalva maneuver. The NO-RVC condition included performing the exercises with an open mouth and pursed lips to limit the likelihood of jaw clenching, and a consistent cycle between inspiratory and expiratory flow in order to reduce the Valsalva effect. The participants also grasped handheld dynamometers which were used to confirm the absence of hand gripping.

During the habituation session, the participants performed 1 isometric knee extension for 5 secs in both RVC and NO-RVC conditions at 75% and at 100% of their self-perceived maximum ability. All habituation session sets were counterbalanced between conditions. The participants were given 4-min rest periods between all sets. All warm-up and test sets were performed with the right leg. Participants recovered for at least 72 hrs prior to returning for the test session.

During the test session, the participants completed the dynamic warm-up as well as the test specific warm-up by performing 1 isometric knee extension for 5 secs in both the RVC and the NO-RVC conditions at 90% of their self-perceived maximum ability. Participants rested for 5 min between the warm-up and test sets. During this time, surface electromyography electrodes were placed on the muscles to be assessed. The participants then performed 2 sets of maximal isometric right knee extension for 5 secs on the dynamometer with 1 set in the RVC condition and 1 set in the NO-RVC condition. Randomization and 4 min of recovery between all test sets were used to reduce the order and fatigue effects. Participants were instructed to perform maximally and equally encouraged for all test sets.

Electromyography was used to quantify muscle activation using an 8 channel telemetered EMG system (Myomonitor 4, DelSys Inc., Boston, MA). The input impedance was 1015 Ohms and the common mode rejection ratio was >80 dB. Electromyographic data were recorded at 1024 Hz using rectangular shaped (19.8 mm wide and 35 mm long) bipolar surface electrodes with 1 x 10 mm 99.9% Ag conductors, and an inter-electrode distance of 10 mm. Electrodes were placed on the longitudinal axis of the muscles in order to quantify the activation of the right rectus femoris (R-RF), left rectus femoris (L-RF), right hamstring belly (R-H), rectus abdominus (RA), right flexor digitorum superficialis (R-FDS), left flexor digitorum superficialis (L-FDS), and right masseter (R-M) (3). A common reference electrode was placed on the lateral malleolus of the fibula. Electrode placement was chosen in order to assess the potential differences in muscle activation between test conditions associated with the muscles invoked in the RVC and to evaluate the potential augmentation in muscle activation in the prime mover, its antagonist, and the contralateral prime mover. Skin preparation included shaving hair if necessary, abrasion of the skin, and cleaning the surface with alcohol. Elastic tape was applied to ensure electrode placement and prove strain relief for the electrode cables. Surface electrodes were connected to an amplifier and streamed continuously through an analog to digital converter (DelSys Inc., Boston, MA) to an IBM-compatible notebook computer.

Torque curves for each subject were analyzed using manufacturer’s software. Peak torque and RTD were calculated for each 5-sec sample per test condition. Rates of torque development were calculated for the first 300 ms of each test exercise performance and normalized to 1 sec, consistent with previous methods (3). All EMG data were filtered with a 10-450 Hz band pass filter, saved, and analyzed with the use of software (EMGworks® 3.5, DelSys Inc., Boston, MA). Raw root mean square (RMS) EMG data were analyzed for each muscle for the duration of each test exercise. A normalization procedure was not used since no comparison between participants or muscles was sought and all testing was conducted in a single session.
Statistical Analyses
All data were analyzed using SPSS 18.0. A two-way mixed ANOVA with repeated measures for RVC condition was used to evaluate the interaction between RVC and NO-RVC conditions and gender, and to assess the main effects of PT, RTD, and muscle activation. Significant main effects were further evaluated with a paired samples t-test. Additionally, in order to obtain a general measure of subject characteristics with respect to gender differences in strength, isometric torque in the NO-RVC condition was assessed with an independent samples t-test. Assumptions for linearity of statistics were tested and met. P-values ($p$), effect size ($\eta^2$), and statistical power ($d$) are reported and all data are expressed as means ± SD. The a priori alpha level was set at $P = 0.05$.

RESULTS

Peak Torque and Rate of Torque Development
Data analysis revealed significant main effects for RVC condition ($P = 0.01$, $\eta^2 = 0.27$, $d = 0.76$) and the interaction between the RVC condition and gender ($P = 0.049$, $\eta^2 = 0.16$, $d = 0.46$) for peak torque. Analysis of the RTD demonstrated significant main effects for the RVC condition ($P = 0.046$, $\eta^2 = 0.17$, $d = 0.49$) and the interaction between RVC condition and gender ($P = 0.001$, $\eta^2 = 0.46$, $d = 0.98$). Significant main effects are shown in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>RVC</th>
<th>Men (n=13)</th>
<th>%</th>
<th>RVC</th>
<th>Women (n=15)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT (N·m⁻¹)</td>
<td>191.1 ± 47.5</td>
<td>179.4 ± 40.1</td>
<td>6.1*</td>
<td>134.5 ± 20.0</td>
<td>132.4 ± 20.5</td>
<td>1.6</td>
</tr>
<tr>
<td>RTD (N·m⁻¹)</td>
<td>388.5 ± 112.3</td>
<td>334.5 ± 88.4</td>
<td>13.9¥</td>
<td>289.5 ± 90.9</td>
<td>308.4 ± 92.7</td>
<td>-6.5</td>
</tr>
</tbody>
</table>

*$\text{PT} = \text{peak torque, RTD = rate of torque development, } \% = \text{percent difference between the RVC and NO-RVC condition,}$

$*\text{Significantly different (P = 0.05), ¥ Significantly different (P = 0.001)}$

Electromyography
The ipsilateral rectus femoris was analyzed to evaluate the potential effect of RVC on prime mover activation during isometric knee extension. Analysis of the R-RF activation revealed no main effects for the condition ($P = 0.37$), but main effects for gender ($P = 0.04$, $\eta^2 = 0.23$, $d = 0.50$). The ipsilateral hamstring muscle group was evaluated in order to understand the effect of RVC on the activation of the antagonist to the prime mover. Results revealed no significant main effect for condition ($P = 0.17$) or the interaction of condition and gender ($P = 0.52$). The L-RF was evaluated in order to assess the effect of RVC on the contralateral homologous muscle group. The results demonstrated no significant main effect for condition ($P = 0.36$) or the interaction of condition and gender ($P = 0.18$). The activation of the R-M, R-FDS, L-FDS, and RA were also evaluated in order to provide a measure of activation of muscles involved in the RVC. Significant main effects for condition were found for each of these muscles ($P = 0.01$). Analysis of the interaction between condition and gender indicated there were no significant effects of the R-M ($P = 0.94$) and RA ($P = 0.37$), though a significant interaction was found for the L-FDS ($P = 0.04$, $\eta^2 = 0.19$, $d = 0.57$) and R-FDS ($P = 0.039$, $\eta^2 = 0.19$, $d = 0.56$). Significant main effects are shown in Table 2.
Table 2. Electromyographic Data (mean ± SD, millivolts) for Isometric Knee Extension in RVC and NO-RVC Conditions for Men and Women.

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Men (n=13)</th>
<th>Women (n=15)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RVC</td>
<td>NO-RVC</td>
</tr>
<tr>
<td>R-RF</td>
<td>0.119 ± 0.076</td>
<td>0.114 ± 0.084</td>
</tr>
<tr>
<td>L-RF</td>
<td>0.013 ± 0.030</td>
<td>0.003 ± 0.005</td>
</tr>
<tr>
<td>R-H</td>
<td>0.009 ± 0.014</td>
<td>0.003 ± 0.003</td>
</tr>
<tr>
<td>RA</td>
<td>0.023 ± 0.029</td>
<td>0.012 ± 0.016</td>
</tr>
<tr>
<td>R-FDS</td>
<td>0.226 ± 0.151</td>
<td>0.008 ± 0.013</td>
</tr>
<tr>
<td>L-FDS</td>
<td>0.252 ± 0.204</td>
<td>0.009 ± 0.028</td>
</tr>
<tr>
<td>R-M</td>
<td>0.097 ± 0.082</td>
<td>0.002 ± 0.001</td>
</tr>
</tbody>
</table>

R-RF = right rectus femoris, L-RF = left rectus femoris, R-H = right hamstring belly, RA = rectus abdominis, R-FDS = right flexor digitorum superficialis, L-FDS = left flexor digitorum superficialis, R-M = right masseter, % = percent difference between the RVC and NO-RVC condition, *Significantly different than NO-RVC condition (P = 0.05), ¥Significantly different (P = 0.001)

**DISCUSSION**

This is the first known study to examine the effect of RVC on isometric knee extensor PT and RTD using dynamometry and EMG. Men exhibited a statistically significant mean performance increase of 6.1% to 13.9% in the RVC compared to the NO-RVC condition for PT and RTD, respectively. Women exhibited no statistically significant difference in PT or RTD. Thus, based on the findings of this study, the effect of CAP appears to be ergogenic for men and not for women. The prime mover, antagonist, and homologous muscle contralateral to the prime mover demonstrated greater mean muscle activation in the RVC compared to the NO-RVC condition, but failed to reach statistical significance. Analysis of muscle activation via EMG confirmed that all of the muscles involved in the RVC (R-FDS, L-FDS, R-M, and RA), except the RA of male subjects, were significantly more active in the RVC compared to the NO-RVC condition. Men and women demonstrated differences in the response to CAP, which were potentially due to the women’s reduced magnitude of flexor digitorum superficialis activation in the RVC condition.

**Peak Torque and Rate of Torque Development**

The results of the present study confirmed the ergogenic effect of CAP for men for the kinetic variables assessed, which is consistent with previous research (3-7). Men demonstrated 6.1% higher isometric knee extension PT in the RVC compared to NO-RVC condition, which is consistent with a recent report that demonstrated a 10.6% performance enhancement of isokinetic peak knee extensor torque (3). Previous research (6) that employed numerous RVC testing conditions that potentially stimulated post-activation potentiation (8), when compared to the present study, may help to explain the considerably higher performance differences in test participants.

In the present study, men demonstrated 13.9% higher isometric knee extensor RTD in the RVC compared to the NO-RVC condition. Previous reports assessing the same array of RVC on isokinetic knee extensor performance, demonstrated a smaller performance enhancement of 6.2% faster RTD (3). However, larger performance gains in rate of force development such as 19.5%, 23.1%, and 32.2% have been demonstrated in previous research assessing RVC during lower body sport specific movements such as the countermovement jump (4) back squat (5), and squat jump (5), respectively. Regardless, it is clear that RVC have been purported to ergogenically improve men’s lower body kinetic performance in a range of 6.2% to 32.2%.
Electromyography
Muscle activations of the RVC muscles were 66.4% to 97.9% greater in the RVC compared to the NO-RVC condition. The predictable increases in activation of the RVC muscles, in addition to the non-significant prime mover muscle activation enhancement, coincided with a 6.1% to 13.9% mean performance enhancement of men’s PT and RTD, respectively. The increases in muscle activation of the present study are similar to those in a previous report that demonstrated a 62.1% to 96.1% increase in men and women’s muscle activation of the same RVC muscles, in the RVC compared to the NO-RVC condition, during dynamic exercise (3). It is interesting to note that the kinetic performance enhancement achieved during the present study coincide with a non-significant 4.1% and 4.2% greater prime mover muscle activation in the RVC compared to NO-RVC condition, for women and men, respectively. Although the previously mentioned study demonstrated a significant 10.6% and 6.2% increase in PT and RTD, respectively, with a concomitantly significant 14.4% and 25.7% greater prime mover muscle activation, for women and men, respectively (3). The EMG findings of the present study neither confirm nor dismiss the theory (2) that RVC potentially function via the increased descending neural drive as a result of motor overflow.

Gender Differences
Women participants in this study demonstrated no significant changes in PT or RTD between RVC and NO-RVC conditions, which is in contrast to a previous report demonstrating gender differences in response to CAP (3). In that similar study, women demonstrated only significant RVC mediated performance increases in PT; whereas, their male counterparts demonstrated significant RVC mediated increases in all variables assessed (3).

Participants of the present study demonstrated significant gender differences in the degree of activation of the R-FDS and the L-FDS between the RVC and the NO-RVC condition, potentially explaining the gender differences in kinetic performance. Women exhibited 66.4% to 88.6% higher activation of the muscles in the RVC compared to the NO-RVC condition, while men exhibited 96.4% to 96.5% higher activation of the muscles in the RVC compared to the NO-RVC condition. The significantly lower ability of women to activate muscles involved in hand gripping may restrict the magnitude of the RVC driven CAP response of the prime mover for women, considering motor overflow increases with contraction intensity (12) and, therefore, potentially explaining the findings of the present study.

Gender differences were also present in overall levels of muscle activation. Men demonstrated a significantly higher activation of the R-RF. Women demonstrated a non-significantly higher activation of the R-H (antagonist), thus potentially inhibiting the kinetic performance of the R-RF (agonist) that may explain their non-response to CAP. These findings add to the existing literature indicating the ergogenic benefits of CAP for men.

CONCLUSIONS
Results from the present study indicate that RVC such as jaw clenching, hand gripping, and the Valsalva maneuver enhanced men’s isometric knee extensor PT and RTD by 6.1% and 13.9%, respectively. These findings add to the evidence that CAP is an effective ergogenic aid for men and that RVC demonstrate a potential strategy for augmenting strength.
Address for correspondence: Garceau LR, MA, Department of Physical Therapy, Program in Exercise Science, Marquette University, P.O. Box 1881, Milwaukee, WI, 53201. Phone (414-288-5993); FAX: (414-288-6079); Email. lukegarceau@gmail.com.

REFERENCES


Disclaimer
The opinions expressed in JEPonline are those of the authors and are not attributable to JEPonline, the editorial staff or the ASEP organization.