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THE EFFECT OF CONCURRENT ACTIVATION POTENTIATION ON THE KNEE EXTENSOR AND FLEXOR PERFORMANCE OF MEN AND WOMEN

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This study evaluated the effect of remote voluntary contractions (RVC) during isometric and isokinetic knee flexion and extension tests and evaluated gender differences therein. Subject peak torque, rate of torque development, and power were assessed with a dynamometer in RVC and no RVC's conditions. A two way mixed ANOVA with repeated measures for condition was used to evaluate the interaction between conditions and gender, and to assess the main effects. Main effects were evaluated with a paired samples *t*-test. Results revealed a significant interaction between all but one test condition and gender as well as significant main effects for all of the variables assessed ($P \leq 0.05$). Men attained 9.2% to 19.7% greater performances in the RVC condition for all variables whilst women demonstrated no significant differences between test conditions.

KEYWORDS: remote voluntary contractions, ergogenic, strength, power

INTRODUCTION: Maximizing the magnitude and rate of muscular force production is the goal of many athletic training programs. As a result, ergogenic training strategies have been sought. The concept of concurrent activation potentiation (CAP) has been proposed to capitalize on the simultaneous contractions of muscles remote to the prime mover, potentially augmenting the performance of the prime mover via motor overflow (Ebben, 2006). Recent research has yielded some evidence describing potential advantages of CAP (Ebben et al., 2008a; Ebben et al., 2008b). Nonetheless, this phenomenon and potential gender differences in response to CAP have yet to be assessed.

Recent evidence supports the idea that RVC's influence motor performance. Research evaluating the effect of jaw clenching on rate of force development (RFD) demonstrated that clenching the jaw before, as well as before and during a test of grip strength, resulted in 8.5% and 15.8 % greater RFD, respectively, compared to when the jaw was not clenched (Hiroshi, 2003). Others have tested the effects of RVC's such as jaw clenching during an athletic task, demonstrating that athletes manifested 19.5% higher RFD during the counter movement jump with a clenched jaw, compared to without jaw clenching (Ebben et al., 2008a). Thus, jaw clenching increases RFD in both clinical and athletic performance tests. A variety of RVC's in addition to jaw clenching have been proposed to be potentially effective in stimulating CAP (Ebben, 2006) and an aggregate of jaw clenching, hand gripping, and the Valsalva maneuver was found to be more effective than RVC conditions such as jaw clenching or hand gripping alone (Ebben, et al., 2008b).

Research demonstrating an increased RFD during the countermovement jump when jaw clenching was used as a RVC, employed both men and women as subjects, but did not specifically assess gender differences. Other studies assessed the CAP effect using only men as subjects. At present, research examining the effect of CAP is limited to studies assessing RFD during gripping and jumping, and isometric tests of torque development during isometric knee extension with male subjects. Additional research examining the effectiveness of RVC's is warranted and potential gender differences in response to this phenomenon need to be investigated. Therefore, the purpose of this study was to investigate the effect of RVC's on peak torque, rate of torque development, power, and work, in both isometric and dynamic conditions and to assess gender differences therein.

METHODS: Subjects included 11 men (mean \pm SD, age 21.63 ± 1.80 yr; body mass 83.68 ± 10.40 kg) and 10 women (mean \pm SD, age 20.70 ± 1.34 yr; body mass 66.36 ± 5.11 kg) who participated in collegiate athletics, club sports, or intramural sports. Baseline isometric (ISOM) knee extension peak torque and isokinetic (ISOK) knee extension and flexion peak torque in the NO-RVC condition revealed that women in this study had approximately 71.5 to 73.2% of the ability of their male counterparts. The subjects 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.

After general and dynamic warm up, subjects were positioned on and strapped in a dynamometer (System 4, Biodex Inc., Shirley, NY) according to manufacturer specifications. The knee was positioned goniometrically at 90° and calibrated with the system software. During the ISOM condition, the knee joint angle was adjusted until the software indicated the knee was at 60° of flexion. The ISOK condition was performed at $60^\circ \cdot \text{sec}^{-1}$.

Subjects then performed test specific warm up sets of leg extension and flexion exercises in two test conditions. One condition included performing the exercises with an open mouth and pursed lips, thus limiting the likelihood of jaw clenching, and consistent cycling between inspiratory and expiratory flow in order to reduce the Valsalva effect (NO-RVC). In this condition, subjects also held hand dynamometers (Lafayette Hand Dynamometer, model 78010, Lafayette Industries, Lafayette, IN) which were used to confirm the absence of hand gripping. The RVC condition included maximal jaw clenching on a dental vinyl mouth guard, the performance of the Valsalva maneuver, and maximal bilateral hand gripping using hand dynamometers. Subjects performed test specific warm ups in both NO-RVC and RVC conditions at 75%, and at 100% of their self perceived maximum ability.

The test consisted of subjects performing 1 ISOM knee extension for 5 seconds in both the NO-RVC and RVC conditions at 100% of their maximum ability, as well as 1 set of 3 repetitions of ISOK knee extension and flexion in both the NO-RVC and RVC conditions, at 100% of their self perceived maximum ability. All test sets were counterbalanced and randomized with 4 minutes of recovery between tests to reduce order and fatigue effects.

Torque curves for each subject were analyzed using manufacturer's software. Data were sampled for seconds 2-4 of the 5 second ISOM test exercises. Peak torque and rate of torque development were calculated for each 3 second sample in the ISOM condition. Peak torque, rate of torque development, and power, were calculated for knee flexion and extension using the average values obtained from all 3 repetitions in the ISOK condition. Rates of torque development were calculated for the first 300 ms of each test exercise and normalized to a second, for both the ISOM and ISOK conditions.

All data were analyzed using SPSS 16.0. A two way mixed ANOVA with repeated measures for condition was used to evaluate the interaction between NO-RVC and RVC conditions and gender, and to assess the main effects. Significant main effects were further evaluated with a paired samples *t*-test. Additionally, gender differences in strength and ISOM and ISOK torque in the NO-RVC condition were assessed with an independent samples *t*-test. Assumptions for linearity of statistics were tested and met. Statistical power (*d*) and effect size (η^2) are reported and all data are expressed as means \pm SD. The *a priori* alpha level was set at $P \leq 0.05$.

RESULTS: A significant interaction was found between test condition and gender for ISOM peak torque, rate of torque development, ISOK knee flexion peak torque, ISOK knee extension rate of torque development, ISOK knee flexion rate of torque development, ISOK knee extension power, and ISOK knee flexion power ($P \leq 0.05$ for all interactions). Thus, differences exist in the response of men and women to the RVC and NO-RVC test conditions.

Analysis revealed significant main effects for ISOM peak torque for condition ($P = 0.006$, $d = 0.83$, $\eta^2 = 0.33$) and gender ($P = 0.001$, $d = 1.00$, $\eta^2 = 0.95$), and ISOM rate of torque development for gender ($P = 0.009$, $d = 0.79$, $\eta^2 = 0.31$), but not condition ($P = 0.09$, $d = 0.40$, $\eta^2 = 0.14$). The specific responses of men and women in the RVC and NO-RVC

conditions were evaluated with tests of simple effects for all ISOM tests conditions and gender with results described in Table 1.

Table 1. Mean peak torque and rate of torque development (\pm SD) during ISOM knee extension.

	Men (N=11)			Women (N=10)		
	NO-RVC	RVC	%	NO-RVC	RVC	%
PT (N·m)	227.51 (61.88)	253.21 (66.41)	10.16*	164.65 (20.51)	166.09 (30.95)	0.87
RTD (N·sec ⁻¹)	323.00 (95.01)	402.32 (128.57)	19.72 [†]	251.92 (83.62)	239.89 (87.17)	-5.00

PT = peak torque; RTD = rate of torque development; % represents the percentage difference between conditions when the NO-RVC is divided by the RVC condition

* Significant difference between NO-RVC and RVC conditions ($P < 0.01$)

[†] Significant difference between NO-RVC and RVC conditions ($P < 0.05$)

Analysis yielded significant main effects for ISOK knee extension peak torque for condition ($P = 0.001$, $d = 0.96$, $\eta^2 = 0.44$) and gender ($P \leq 0.001$, $d = 1.00$, $\eta^2 = 0.96$), and ISOK knee extension for condition ($P = 0.004$, $d = 0.88$, $\eta^2 = 0.37$), and gender ($P \leq 0.001$, $d = 1.00$, $\eta^2 = 0.98$). Main effects were found for ISOK knee extension rate of torque development with significant main effects for condition ($P = 0.006$, $d = 0.83$, $\eta^2 = 0.34$) and gender ($P = 0.004$, $d = 1.00$, $\eta^2 = 0.93$) as well as for ISOK knee flexion rate of torque development for condition ($P = 0.001$, $d = 0.95$, $\eta^2 = 0.44$), and gender ($P \leq 0.001$, $d = 1.00$, $\eta^2 = 0.96$). The analysis of main effects for ISOK knee extension power, resulted in significant main effects for condition ($P \leq 0.001$, $d = 0.99$, $\eta^2 = 0.52$) and gender ($P \leq 0.001$, $d = 1.00$, $\eta^2 = 0.96$). Similarly, for ISOK knee flexion power, significant main effects were seen for condition ($P \leq 0.001$, $d = 0.98$, $\eta^2 = 0.50$), and gender ($P \leq 0.001$, $d = 1.00$, $\eta^2 = 0.97$). In order to evaluate the main effects and the specific responses of men and women in the NO-RVC and RVC conditions, simple effects for all ISOK test conditions and gender were evaluated with results depicted in Table 2.

Table 2. Three repetition average (\pm SD) peak torque, rate of torque development, power, and work during ISOK knee extension (KE) and knee flexion (KF).

	Men (N=11)			Women (N=10)		
	NO-RVC	RVC	%	NO-RVC	RVC	%
KE PT (N·m)	218.40 (44.39)	251.42 (60.27)	13.13*	159.91 (24.46)	173.80 (38.94)	8.00
KE RTD (N·sec ⁻¹)	419.12 (109.40)	480.39 (143.6)	12.76* [†]	298.53 (68.49)	298.58 (93.39)	0.00
KE Power (W)	158.92 (35.46)	180.84 (42.89)	12.13* [†]	111.99 (16.45)	115.88 (21.48)	3.36
KF PT (N·m)	116.91 (15.14)	136.46 (27.52)	14.33*	83.55 (12.14)	85.82 (15.55)	2.66
KF RTD (N·sec ⁻¹)	225.73 (41.54)	259.69 (35.93)	13.08*	155.79 (39.91)	158.05 (54.28)	1.53
KF Power (W)	90.74 (15.56)	103.11 (19.68)	12.00*	62.75 (8.95)	64.98 (13.29)	3.44

KE = knee extension; KF = knee flexion; PT = peak torque; RTD = rate of torque development; % represents the percentage difference between conditions when the NO-RVC is divided by the RVC condition

* Significant difference between NO-RVC and RVC conditions ($P < 0.01$)

DISCUSSION: This is the first study to investigate gender differences in CAP. Men demonstrated statistically higher performances of 9.2 to 19.7% in the RVC compared to the NO-RVC condition, for all outcome variables assessed. In contrast, women showed no significant differences between conditions for any of the outcome variables. The results of this study confirm the ergogenic effect of CAP for men, for the outcome variables assessed, consistent with previous recommendations (Ebben, 2006) and research examining isometric measures (Ebben et al., 2008b).

For the men in the present study, peak torque was 10.2% greater in the RVC compared to the NO-RVC condition which was similar to past research that revealed isometric mean and peak knee extensor torque was approximately 14.6 and 14.8% greater, respectively, in the RVC compared to NO-RVC condition (Ebben et al., 2008b). In the present study, an aggregate of jaw clenching, handgripping, and the Valsalva maneuver was used since it has

been demonstrated to be the most effective RVC condition (Ebben et al., 2008b). However, unlike previous research (Ebben et al., 2008b) the current study examined and found gender differences.

Past work in this area revealed that compared to the non-jaw clenching condition, jaw clenching increased RFD during the countermovement jump by 19.5% (Ebben, et al., 2008a). This range of RFD augmentation compares similarly to the increased rate of torque development demonstrated by the men in the RVC condition in the present study which was 19.7% during isometric testing, and 12.7 and 13.1% during isokinetic knee flexion and extension testing, respectively.

The women subjects in this study demonstrated no statistically greater performance in the RVC compared to the NO-RVC condition for any of the outcome variables. This finding is without precedent in the limited literature examining CAP. However, in a study designed to assess the effect of using dynamometer handgrips on subject stability during isokinetic testing, gripping the dynamometers handles resulted in a statistically significant difference of 8.4% in knee extensor torque, compared to the condition where subjects crossed their arms over their upper torso (Stumbo et al., 2001). It is interesting to note that in this study, only the performance of men was greater in the handgripping condition (Stumbo et al. 2001). While increased stability may have augmented the performance of the male subjects only, it is also possible that this study demonstrates an unintended CAP effect as a result of motor overflow that is specific to men only (Stumbo et al., 2001), consistent with the results of the present study.

Baseline tests of NO-RVC ISOM and ISOK extension and flexion torques revealed values for women that were 71.5 to 73.2% of their male counterparts. Thus, the women in this study appear to be well trained with respect to the men and larger than typical gender differences in strength are not an explanation for the gender differences found in this study.

A review of other potentiation phenomenon, such as post-activation potentiation demonstrates no significant effect in many studies and performance enhancement ranging from 2.0 to 9.5% for the studies that demonstrated an effect. (Hodgson et al., 2005). In contrast, the men in the present study performed in a range that was 9.2 to 19.7% higher in the RVC compared to the NO-RVC condition.

CONCLUSION: Results from the present study expand the findings of an ergogenic effect of CAP in men for every variable assessed. Remote voluntary contracts have potential to augment the performance of strength training exercises.

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