Shoulder Flexion Torque Is Augmented by a Volitional Abdominal Isometric Contraction

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Abstract

Cacolice, PA, Carcia, CR, and Scibek, JS. Shoulder flexion torque is augmented by a volitional abdominal isometric contraction. *J Strength Cond Res* 35(4): 920–923, 2021—A stable core provides a solid base to facilitate effective extremity function. It is unclear whether an individual is able to produce a greater amount of upper extremity torque while performing a volitional core contraction when compared with the independent contraction that occurs subconsciously. Therefore, the purpose of this study was to determine whether peak shoulder flexion torque values were different with and without a concurrent volitional core isometric contraction. Thirty healthy, recreationally active college-aged students participated. Surface electromyography from the rectus abdominis (RA) was captured using a telemetry system interfaced with a software acquisition system and personal computer. In a counterbalanced alternating order, subjects completed 3 trials of maximal isometric shoulder flexion at 90° with and without a volitional abdominal contraction. Percent activation of the RA was greater when subjects volitionally contracted their core (15.8 ± 12.7%) compared with the subconscious contracted condition (6.3 ± 4.8%) ($p \leq 0.001$). Isometric shoulder flexion peak torque was greater when the core was actively contracted (44.6 ± 18.9 N × m) compared with when the core was recruited subconsciously (30.7 ± 15.7 N × m) ($p \leq 0.001$). These findings suggest the clinician should encourage the individual to activate their core musculature when performing upper extremity strength activities.

Key Words: core, electromyography, EMG, stabilization, stiffness

Introduction

The core musculature has been operationally defined as those muscles associated with the lumbopelvic–hip complex (7). Subjects who engage in core training programs display decreased lower extremity injury (12), increased lower extremity strength (4), and improved lower extremity functional performance (4). While few studies have examined the effect of core stability programs on the upper extremity, the evidence suggests core stability training also promotes increased upper extremity strength (11,19) and performance (16). Hence, the importance of core stability training cannot be overstated.

One theory to explain how core stability training results in improvements in extremity strength and performance may be related to increased stiffness of the core region. Stiffness can be defined as the quantity of force necessary to cause a displacement (15,17). Increased stiffness of the core region after a training program would be evidenced as observed morphologic and neuromuscular changes occurring from the respective core training program. When compared with a more compliant structure, a stiffer structure requires greater force before it can be displaced. As a result, stiffer structures are more effective with transferring force from 1 region to another. Force generated in the lower extremity for example may be more efficiently transferred across a strong and stable core to the respective upper extremity when throwing a ball compared with a more compliant core. The by-product of this greater stiffness and improved efficiency theoretically would be greater force output when throwing the ball.

The stiffness of a joint is influenced by both active (e.g. muscle) and passive (e.g. capsuloligamentous) restraints. Joint stiffness can be immediately altered by a local muscular contraction (14). In the context of a series of joints such as in the spine, an acute local muscle contraction is theorized to promote a greater amount of active stiffness of the trunk region. In this case, the increased stiffness is believed to provide a stable base from which the extremities may more effectively function. In fact, to promote stability and improve function, it is commonplace for practitioners in a rehabilitation setting to instruct their patients or clients to first actively engage their core musculature before performing a particular exercise or activity.

If core stiffness is in fact partly responsible for the documented improvements in extremity function and strength, it would seem logical that any means of increasing core stiffness, whether it be by external bracing or even an acute muscle contraction, should provide an environment in which measureable changes in extremity strength would be evident during a task. It is unknown, however, if an acute core muscle contraction provides sufficient stability such that extremity performance is augmented.

Given this scenario, the purpose of this study was to determine whether acutely altering trunk stiffness through an isometric contraction of the core musculature influenced one's ability to produce upper extremity torque. We chose to examine upper rather than lower extremity torque production, given the paucity of literature associated with core stability and upper extremity strength. We hypothesized subjects would be able to generate a greater amount of upper extremity torque

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when performing a volitional isometric core contraction compared with when the core musculature was recruited in an automatic, subconscious fashion.

Methods

Experimental Approach to the Problem

All data acquisition took place in the University Exercise Physiology laboratory, and each subject followed identical procedures. This Observational Descriptive study used a repeated-measures, counterbalanced laboratory design. Contracted state of the abdominals at 2 levels (volitional abdominal isometric contraction [VAIC]; subconsciously recruited only) was the independent variable while isometric shoulder flexion peak torque (ISFPT) was the dependent variable. Upper extremity dominance was operationally defined as the upper extremity with which the subject chose to write.

Subjects

This investigation was approved by the Duquesne University Institutional Review Board (Protocol #12-23). A convenience sample of 30 healthy, recreationally active, college-aged students (mean ± *SD*: 14 female, 16 male; age = 21.9 ± 1.2 years [age range: 20–25 years]; mass = 75.2 ± 16.3 kg; height = 174.7 ± 9.4 cm, 5 left- and 25 right-handed dominance) was recruited. Upon subject arrival to the laboratory, inclusion and exclusion criteria were reviewed to ensure eligibility. Subjects had no shoulder or abdominal injuries in the last 12 months requiring either visitation with a physician or the utilization of an upper extremity sling. In addition, subjects also had no shoulder or abdominal injuries that required rehabilitation in the last 12 months. Those that met the inclusion criteria were provided with and signed a University Institutional Review Board approved written consent form to participate.

Procedures

After each subject provided written consent to participate, a brief bilateral shoulder screen was performed. This brief screen ensured the shoulders of all subjects exhibited normal range of motion. No eligible subject demonstrated marked range of motion limitation. Following the shoulder screen, subjects completed a Penn Shoulder Scoring (PSS) form. The PSS is a reliable and valid instrument to quantify shoulder pain, satisfaction, and function (13). The purpose of gathering the PSS was to verify the functional health of each subject's shoulders. Each subjects' height and mass were then determined using a scientific grade medical beam balance scale (Jarden Corporation, Rye, NY).

Each subject then performed a 5-minute warm-up on an upper extremity ergometer (Monark, Vansbro, Sweden) at a self-selected pace. After the warm-up, each subject's skin lateral to the umbilicus was cleaned with an isopropyl alcohol wipe to reduce electrical impedance. In addition, the skin over each subject's patella was also cleaned in a similar manner. Surface silver–silver chloride (Ag–AgCl), disposable, snap-fit circular electrodes with a fixed 2-cm interelectrode distance (Model #272; Noraxon, Scottsdale, AZ) were applied in a bilateral fashion 3 cm horizontally from the umbilicus. The location for placement of the electrodes was consistent with previous recommendations (3), and work (6). Electrodes were oriented vertically, parallel to the muscle fiber direction. A single 1-cm disposable, snap-fit, circular dispersal electrode (Model #270; Noraxon) was placed over the anterior surface of the patella of each subject to provide a differential signal. Each corresponding lead from the portable surface electromyography (sEMG) telemetry unit (Telemyo 900; Noraxon) was then attached to the respective sEMG electrode. Each subject donned the telemetry unit around their waist through a belt-type apparatus. Unit specifications of the sEMG system included an amplifier gain of 1 $mV \cdot V^{-1}$, bandwidth range of 10–500 Hz, CMRR 114 dB, input resistance from 20 MΩ to 1 GΩ, and a sampling rate of 2000 Hz. The sEMG receiver and amplifier were connected to an analog/digital board and a desktop computer (Dell, Austin, TX). The sEMG telemetry unit was then interfaced with a software acquisition and analysis system (DATAPAC; Run Technologies, Laguna Hills, CA).

Before proceeding, muscle activity was verified by observing the EMG activity on the computer when each subject performed an isometric contraction of the rectus abdominis (RA). Upon signal confirmation, the RA electrodes and leads were further secured using 7-cm-wide under wrap (Cramer Products, Inc., Gardner, KS) circumferentially around the torso of each subject (Figure 1). The patellar electrode was secured in a similar fashion around the knee.

Subjects then assumed a supine position on a padded floor with their hips and knees flexed, so that their feet were flat against the floor (Figure 2). Subjects crossed their arms over their chest and were instructed to perform an "abdominal crunch" only high enough such that their scapulae came off the floor. Subjects were asked to hold the end position of the crunch for 5 seconds. Subjects were then given 30-second recovery before the next trial. The crunch was repeated until a total of 3 acceptable trials were recorded. The first 3 trials that met the inclusion criteria were used for data analysis. Inclusion criteria included (a) visible response from each muscle, (b) acceptable signal-to-noise ratio, and (c) quiet baseline of sEMG data before each repetition. In this study, all sEMG trials met inclusion criteria for acceptance. The mean of the 3 trial peaks was determined and reported as the maximal volitional isometric contraction (MVIC).

Each subject then sat on an adjustable height stool that was adjacent to an isokinetic unit (Biodex, Shirley, NY). The stool height was adjusted such that each subject's hips and knees were flexed to 90° with feet flat on the ground. The height of the dynamometer head was then adjusted to the same height as the greater tuberosity of the humerus for each subject. In addition, the lever arm of the dynamometer was adjusted, so that each subject's dominant hand could comfortably grasp the dynamometer lever arm hand grip (Figure 3). Once properly positioned, the lever arm of the isokinetic unit was locked parallel to the floor. This position was confirmed with a bubble level on the dynamometer lever arm. The subject was then asked to complete 6 trials of maximal isometric shoulder flexion against the locked isokinetic lever arm.

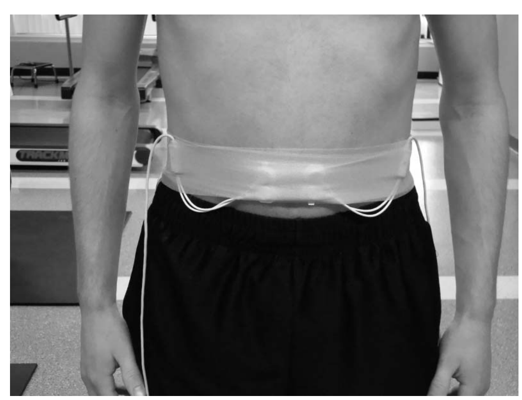

Figure 1. Rectus abdominis surface electromyography electrode placement and security.

Figure 2. Maximal volitional isometric contraction assessment with surface electromyography.

Each trial lasted 6 seconds with a 30-second rest period between trials. The work-to-rest ratio was purposely selected to facilitate a maximal contraction and minimize fatigue (9). All subjects completed the ISFPT trials with the dominant upper extremity under 2 conditions: (a) with abdominals subconsciously activated only (3 trials) and (b) with a VAIC (3 trials) for a total of 6 trials. Subjects were instructed to perform the ISFPT trials either "with the abdominals contracted," or "with the abdominals not contracted." The condition testing order between subjects was completed in an alternating order. Before data collection, the isokinetic device was calibrated through the accompanying software to ensure accuracy of the dependent measure.

Statistical Analyses

An a priori power analysis (G*Power, v3.1.3) determined that a minimum sample size of 27 subjects was required for a power of 0.80 and medium effect size (Cohen's $d = 0.50$) (18). Isometric shoulder flexion peak torque values were identified by the isokinetic software, stored on, and then later retrieved from the computer connected to the isokinetic unit. Rectus abdominis sEMG was reduced using a commercially available software data analysis program (DATAPAC; Run Technologies). Rectus abdominis sEMG data were high- and low-pass filtered using cutoff frequencies of 30 and 200 Hz, respectively. These frequencies were selected to minimize the effect of extraneous noise—specifically cardiac interference (5). These data were then processed with a Root Mean Square method using a time constant of 10 ms. Percent RA activation for right and left sides were averaged to obtain a representative value for both the contracted and relaxed conditions. Normalization was achieved by dividing the trial RA sEMG by the sEMG from the MVIC. Data were exported and arranged as variables into IBM SPSS Data Collection Software v20 (IBM, Armonk, NY). Descriptive statistics for height, body mass, age, and sex of the overall group were generated. Two paired *t*-tests were performed to (a) compare RA test conditions and (b) compare the ISFPT output under the different RA conditions. Statistical significance for all analyses was set a priori at $p \leq 0.05$.

Results

The subject's Penn Shoulder Scores indicated a high level of self-reported functional health (97.43 $\pm$ 4.42). During ISFPT, percent activation of the RA was greater when subjects volitionally contracted their abdominals (15.8 $\pm$ 12.7%) compared with the independent contraction condition (6.3 $\pm$ 4.8%) ($t = 5.34$, $p < 0.001$). Isometric shoulder flexion peak torque was greater when the abdominals were actively contracted (44.6 $\pm$ 18.9 N $\times$ m) compared with ISFPT when the abdominals were recruited subconsciously (30.7 $\pm$ 15.7 N $\times$ m) ($t = 8.69$, $p < 0.001$).

Discussion

The purpose of this investigation was to determine whether ISFPT values were different with and without a VAIC. The statistical analysis of the sEMG from the RA with and without a VAIC illustrates test conditions were significantly different. The results of this study indicate undercontrolled conditions; young healthy subjects are able to generate a greater amount of ISFPT with an augmented VAIC thereby supporting our hypothesis.

Previous biomechanical research has established the importance of the trunk to extremity function (1,2,20) and injury (12). Specifically, Abt et al. (1) identified fatigue of the core musculature altered lower extremity kinematics in cyclists. Likewise, Leetun et al. (12) identified core muscle weakness was associated with a higher likelihood of lower extremity injury. Collectively, these studies highlight the importance of the core musculature in an athletic environment.

Evidence for a volitionally rigid or stiff trunk in assisting an upper extremity strength measure is limited. In 2010, Keogh et al. (11) identified healthy subjects were able to shoulder press a greater amount of weight in a supported sitting position when compared with an unsupported sitting position. Although abdominal musculature involvement was not quantified by the investigators, the results suggest a greater amount of trunk stabilization, in this case derived from an external source, enhanced the ability of subjects to lift a greater amount of weight. In yet another study, investigators examined the effect of a VAIC on activation of select scapulothoracic musculature during several shoulder exercises (19). Their results indicated subjects displayed greater levels of serratus anterior EMG when a VAIC was performed during the shoulder exercises compared with when the abdominals were recruited in a subconscious fashion. While the investigators did not quantify the level of abdominal musculature activation, their results parallel ours suggesting a greater amount of proximal stability augments extremity muscle activation and performance. Other research has examined pre-training and post-training improvements of related trunk musculature and upper extremity performance changes (8,16). In these studies similar to that performed by Vega Toro et al. (19), however, investigators did not quantify the degree of trunk musculature activation during the shoulder performance tests.

To the best of our knowledge, this is the first study to demonstrate an objective and significant improvement in ISFPT with a VAIC.

Figure 3. Isometric shoulder flexion peak torque assessment with surface electromyography and isokinetic dynamometer.

Indeed, ISFPT was more than 45% higher when the abdominals were actively recruited. Although the 9.5% difference in RA activation between test conditions was statistically significant, we are unable to determine whether this level of activation difference was solely responsible for the observed change. One might contend that more of a difference in core muscle activation greater than found in the current investigation would be required to provide the stabilization necessary to explain the observed in ISFPT results. It is entirely possible other factors or mechanisms (e.g., heightened excitation of the alpha motor pool) as a result of the VAIC were in part responsible for the observed increased torque of the shoulder flexors (10).

For the current study, we chose to ask the subjects to perform a VAIC vs. a contraction of other core musculature (i.e., trunk extensors) to stiffen the trunk. From a kinematic perspective, any extension of the spine had the potential if not performed in an isometric fashion to result in a net increased shoulder flexion moment by extending the trunk thereby facilitating shoulder elevation. With activating a core stabilizer that flexes the thoracolumbar spine, any thoracolumbar motion generated would in theory produce a reduced net shoulder flexion moment. This rationale then suggests that some unobserved thoracolumbar movement associated with the RA VAIC was not the cause for the increased ISFPT.

Our findings denote when performing activities that require an isometric shoulder flexion contraction, the individual should consider performing a concurrent isometric contraction of the abdominals if an increase in shoulder flexion torque is desired. The benefits for such a contraction may serve to be both protective and have the potential to improve performance. As such, it would be indicated to incorporate this paired behavior in both preparticipation activities and in rehabilitation activities for shoulder injuries.

Our study has several limitations. First, the results should not be generalized to conditions beyond those used in this study nor to other populations. Second, there is the possibility that subjects contracted other muscles or muscle groups when asked to perform the VAIC as we solely quantified activity of the RA. Furthermore, there is a possibility that the abdominal contraction was not solely responsible for the differences in the dependent measure. As previously noted, other mechanisms may be responsible for the observed difference. Additional research with other populations and additional measures of upper extremity function (e.g., concentric and eccentric contractions and/or other shoulder muscle groups) as well as examining other potential causes for the differences are warranted.

Practical Applications

The results suggest that clinicians should consider augmenting glenohumeral exercise programs with synchronized volitional abdominal isometric activation as upper extremity torque production may be significantly enhanced. Similarly, active and healthy individuals engaged in upper extremity strengthening programs may benefit from volitional augmented abdominal contraction during exercise.

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