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CORE MUSCLE ACTIVATION DURING TRADITIONAL ABDOMINAL EXERCISES: AN ELECTROMYOGRAPHICAL COMPARISON

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ABSTRACT

The purpose of this study was to compare the electromyographic (EMG) activity of global trunk musculature during common training exercises. Twenty apparently healthy men (age 25.9 ± 5.6 years; height 175.22 ± 8.46 cm; weight 81.28 ± 6.86 kg) and women (age 22.8 ± 1.81 years; height 166.06 ± 8.47 cm; weight 63.03 ± 10.38 kg) volunteered to participate in this study. Surface electrodes were placed on the RA, EO, LSES and RF. Subjects then performed five repetitions of four common abdominal movements (crunch (C), pike (PK), V-up (VUP), and towel pike (TP)). Means (± SD) for the percent maximal voluntary contractions (%MVC) were measured for each participant during each exercise.

For the RA, the VUP provided significantly greater activity compared to all other exercises; while PK showed the significantly lowest. In terms of the EO, TP elicited the significantly greatest muscle activation; whereas the C provided the lowest EO values. For the RF, the TP had the greatest activity and C the lowest. Lastly, the C and PK provided significantly lower activity in the LSES compared to the TP and VUP.

Results indicate that EMG activity increased during exercises which involved greater ranges of motion, stability demands, and incorporation of body weight resistance (i.e., TP and V-up). Overall, the TP and VUP exercises provided the greatest activation of the examined musculature compared to the standard C and PK. Determining proper movements for the athlete or client can be made based upon the necessary muscular activation levels of the exercises examined within the current manuscript.

Keywords: training, abdominal, exercise technique, performance

INTRODUCTION

A growing interest of research in the field of strength and conditioning, as well as rehabilitation, is a focus on core musculature training. For the purpose of this study, the core will be referred to as the superficial global musculature involved in trunk stability and balance (i.e., rectus abdominis (RA), external obliques (EO), rectus femoris (RF) and lumbosacral erector spinae (LSES)). Superficial musculature of the trunk is primarily responsible for spinal movements (e.g., flexion, extension, stability, as well as resisting spinal perturbations (e.g., rotation, torsion) (10,15,20). Core stability refers to an effective recruitment of the trunk muscles leading to increased force production and precise control of lumbopelvic-hip movement (16,19). Increases in core strength may also aid in the prevention of injuries, improve coordination, and help to ensure proper spine protection and function (4,11,19).

Long-term core training has demonstrated increases in athletic performance and power development (14). For example, Nikolenko et al, (17) examined the relationship between a dynamic core power test (i.e., front abdominal power throw) and measures of sport performance (i.e., vertical jump, 40-yard sprint, 5-10-5 shuttle run and 1 repetition maximum back squat). Results showed a significant moderate correlation (r = 0.652) between the front power throw, and back squat (r = 0.509). Power dominant sports such as golf, football, tennis, baseball, and track and field where a strong and stable core is important to transfer power though the kinetic chain can be the deciding factor between movement success and failure (11).

The core musculature is responsible for supporting postures, creating motion, coordinating muscle actions, allowing for stability, absorbing force, generating force, and transmitting forces throughout the body (5). Thus, understanding the differences in muscle activation produced by traditional abdominal exercises can be of benefit to strength coaches, therapists, other health care specialists in order to properly progress individuals through rehabilitation or training (9). Therefore, the purpose of this investigation was to compare the electromyographic (EMG) activity of the RA, EO, RF, and ES during traditional core training exercises. It was hypothesized that exercises involving greater ranges of motion and increased bodyweight resistance would elicit greater activation of the examined musculature.

MATERIALS & METHODS

Subjects

Twenty subjects (10 men and 10 women) participated in this investigation. All descriptive statistics for the participants are presented in Table 1. Participants completed health history and medical questionnaires prior to testing to ensure that they were free from cardiorespiratory, musculoskeletal, metabolic, and neurological disorders. Subjects with any prior injuries that would otherwise affect muscular activation were excluded from data collection. Participants provided a medical history and provided written consent. Individuals were also asked to come to the lab having refrained from heavy intensity exercise 24 hours prior to testing. This study was approved by the University's Institutional Review Board.

Table 1. *Descriptive statistics of the study participants*

	Men (n = 10)	Women (n = 10)	All (n = 20)
Age (yr)	25.9 ± 5.61	22.8 ± 1.81	24.35 ± 4.35
Height (cm)	175.22 ± 8.46	166.06 ± 8.47	171.43 ± 9.91
Body mass (kg)	81.28 ± 6.86	63.03 ± 10.38	72.16 ± 12.69

Procedures

Electromyography

All EMG values were collected using a BIOPAC MP150 BioNomadix Wireless Physiology Monitoring System with a sampling rate of 1.0 kHz. Data was analyzed using Acqknowledge 4.2 software (BIOPAC System, Inc., Goleta, CA). Signals were converted from analog to digital with a sampling rate of 2 kHz along with a bandpass filter using a 20- to 400-Hz cutoff frequency and a fourth-order Butterworth filter. Prior to electrode placement (Biopac EL504 disposable Ag-AgCl), participant skin sites were prepped for application through shaving, exfoliation, and alcohol cleansing in order to reduce impedance from dead surface tissue and oils. The electrode placement and preparation methods chosen for this investigation were consistent with Cram and Kasman (8). All EMG activity was recorded using root mean square transformation. The mean activity of the last three repetitions of each exercise was averaged; after which these values were calculated and reported as a percentage of the individual's maximal voluntary contraction (%MVC).

Exercise Trials

All subjects were taught proper technique and allowed time to be familiarized with each exercise on a separate day prior to EMG recording. EMG data was collected during one testing session for which each subject performed four abdominal movements along with MVCs. Once all electrodes were placed, MVCs were performed to normalize EMG signals. MVC techniques were consistent with Konrad (13). If any subject was not able to maintain proper form as instructed, then all data was omitted from the analysis process. Each movement was performed at a rate of 4 seconds per repetition (i.e., 2 seconds eccentric, 2 seconds concentric) and repeated for a total of 5 repetitions. During data collection, each subject was allowed a 3-minute rest between each exercise to prevent fatigue of the trunk musculature. The proper technique of each exercise used in this study is as follows.

- Crunch (C): Participants began with feet and shoulders flat on the floor and knees at a 90^{o} angle with arms crossed over on the chest. To begin the movement, subjects flexed at the spine bringing the chest towards the knees with shoulders leaving the ground. Once subjects reached 30^{o}, they were instructed to return to starting position.
- Pike (PK): Participants were instructed to assume a prone plank position on an exercise mat with their arms fully extended and hands on the ground directly beneath the shoulders. The feet were placed together with only the toes in contact with the ground. Subjects were then instructed to "pike" by flexing at the hips slowly and under control until a 90^{o} angle had been formed between the shoulders, hips and legs. The subject was told to maintain a rigid torso, neutral head and spine, and extended legs position throughout each exercise.
- Pike with Towel (TP): Participants performed this variation by placing both feet on a cotton towel and performing the pike as described above (i.e., flexing at the hips to 90^{o}) as well as pulling the feet towards the arms.
- Supine V-up (VUP): Participants began with a supine position with their legs extended and arms outstretched overhead. They were then instructed to bring their arms and legs upward in unison toward the center of their body creating a 'V' position.

Statistical Analysis

Data analysis was performed using SPSS Statistics version 22.0 (Somers, NY). Means and standard deviations were calculated for each variable (RA, EO, ES, and RF). Repeated measures analysis of variance (ANOVA) was used to determine if the normalized (%MVC) values for the RA, EO, ES, and RF were significantly different across the varying exercises. A priori statistical significance was set to a value of $p < 0.05$. A

Bonferroni post hoc was used to determine were the significant differences occurred between the exercises. A Cohen's *d* statistic (7) was calculated as the effect size of the differences in %MVC values and Hopkin's scale of magnitude (12) was used where an effect size of 0-0.2 was considered trivial, 0.2-0.6 was small, 0.6-1.2 was moderate, 1.2-2.0 was large, >2.0 was very large.

RESULTS

The means (±SD), p values, and effect sizes for the selected muscle groups for each exercise are provided in Table 2.

Rectus Abdominis

Significant differences existed between each of the exercises. The PK provided the significantly lowest value; while the VUP was the significantly highest. The C provided EMG values significantly higher than PK, but significantly lower than TP and VUP. The TP showed values significantly greater than C and PK.

External Obliques

The TP was significantly greater compared to the remaining exercises. The C and PK showed no statistical differences, but were both significantly less than the VUP.

Rectus Femoris

The TP was significantly greater than all other exercises. The C was determined to be significantly lower compared to the PK, TP, and VUP. Additionally, the PK was significantly lower than the VUP.

Erector Spinae

The C and PK showed significantly lower values compared to the VUP and TP. Furthermore, no differences existed between the C and PK or TP and VUP.

DISCUSSION

The purpose of the study was to determine the electromyographical differences between common core exercises. Previous investigations into therapeutic and conditioning movements concluded that minimum %MVC values of 40-60% are needed to provide adequate stimuli to promote muscular strength and hypertrophy adaptations (1,3). The findings are consistent with previous research by Axler and McGill (2) stating that not one single exercise was found to be optimal in training all aspects of the core musculature. The current results of this investigation demonstrated significant differences across the movements within the various muscle groups.

Each of the exercises examined elicited significant differences within the RA. These differences were expected as each exercise requires varying ranges of motion, joint movements, and stabilization demands of the spinal column and trunk. The PK, which demonstrated the significantly lowest RA values, the hands and feet are kept in a stationary position while the subject pushes the hips back in a passive motion. Thus, the active role of the RA is primarily spinal stability resulting in a lower activation compared to the remaining exercises. The VUP, which produced the greatest RA values, uses the RA to both stabilize the trunk and flex the spinal column while lifting both the upper and lower body from the floor. The C and TP are completed while only moving either the upper body (i.e., C) or the lower limbs (i.e., TP). The TP is the only exercise that is completed with the addition of an external apparatus (i.e., towel) and resistance (i.e., frictional force). These results conflict with Schoffstahl et al (18) that showed no differences between various abdominal exercises (i.e., C, VUP, and PK). However, these exercises were performed isometrically which can vary EMG activation in comparison to dynamic movements.

Additionally, significant values were seen within the EO, with no differences between the C and PK. The TP provided the significantly highest EO values and may have been caused by the additional external resistance as well as the demands of the EO to maintain proper hip placement. During the TP, the feet are being pulled inwards towards the body, while the EO must maintain control of both legs simultaneously to avoid lateral deviations from a neutral spinal position. This additional role of the EO may have led to the additional increases in activation. While the EO during VUP must also maintain proper spinal alignment, the subjects' hips are placed on the floor which may assist in the avoidance of lateral deviations while performing the movement; thus EO activity during the VUP was significantly lower than the TP.

Significant differences in the RF were also seen between each exercise examined. The TP provided significantly higher activation compared to the remaining exercises, which was slightly above the %MVC baseline for muscle adaptations (i.e., >40%). The increased resistance of the towel sliding may have contributed to the increased activation of the hip flexors and EO. The low activation level during the C was to be expected due to active insufficiency of the hip musculature. During the C, the hips and knees are placed in a flexed position; this in turn shortens the RF to a resting state in which tension cannot be generated (i.e., below 5% MVC) (8,10). These results are consistent with Schoffstall et al. (18), in which the C provided significantly less activation that various other abdominal exercises (i.e., VUP and PK).

In terms of the ES, the C and PK are consistent with previous literature citing approximate levels of 10 %MVC or below for isolated spinal stabilization exercises (6). However, the TP and VUP elicited ES activity higher than 10%MVC indicating that these movements require increased lower back muscular recruitment to maintain spinal stability. The varying levels of ES activation may be explained by the differences in the movement of the trunk during the exercises themselves. During the C, the lower half of the trunk is supported by the ground, while only the upper end of the torso is raised from the floor. Levels of muscular activity 5 %MVC and below are deemed in resting states (8).

PRACTICAL APPLICATIONS

These results of the current investigation provide an in-depth examination into four common abdominal based movements and can provide a means of progression for athletic conditioning and rehabilitation programming. Movements such as the TP and VUP may be of benefit to individuals by increasing the activation of the RA, EO, and RF; however, due to the increases in ES activation, these movements may be reserved for more advance individuals. As previously stated, not one single exercise examined elicited %MVC values necessary for muscular strength adaptations; therefore, a combination of isolated abdominal movements should be incorporated in the conditioning and rehabilitation programs to achieve optimal results. This information may provide practitioners with practical means of determining appropriate exercise selection based upon the skill level of the athlete or client.

Table 2. Comparison of the normalized (%MVC) EMG of the selected musculature between abdominal exercises

	Mean ± SD	p value, effect size		
	RA	**vs. C**	**vs. PK**	**vs. TP**
C	52.09 ± 19.05*	---	---	---
PK	25.57 ± 13.25†	0.001, 1.62	---	---
TP	71.91 ± 23.09$^{\gamma}$	0.027, 0.94	< 0.001, 2.46	---
VUP	89.81 ± 20.65	< 0.001, 1.9	< 0.001, 3.70	0.28, 0.82
	EO			
C	30.40 ± 27.13*	---	---	---
PK	47.81 ± 23.75*	0.079, 0.68	---	---
TP	142.55 ± 66.74	< 0.001, 2.20	< 0.001, 1.47	---
VUP	112.66 ± 57.62ǂ	< 0.001, 1.83	< 0.001, 1.89	0.024, 0.48
	RF			
C	2.05 ± 1.90‖	---	---	---
PK	16.49 ± 9.55*	< 0.001, 2.09	---	---
TP	43.81 ± 23.20	< 0.001, 2.54	< 0.001, 0.86	---
VUP	26.67 ± 13.74ǂ	< 0.001, 2.51	0.002, 1.54	0.004, 0.90
	LSES			
C	5.10 ± 2.31*	---	---	---
PK	6.65 ± 4.47*	0.749, 0.44	---	---
TP	13.97 ± 6.53	< 0.001, 1.81	0.001, 1.31	---
VUP	14.41 ± 10.44	0.008, 1.23	0.002, 0.97	1.00, 0.05

PK = Pike, BOSU = BOSU ball pike, ST = Suspension trainer pike, SB = Swiss ball pike, CC = Core Coaster Pike, RA = Rectus abdominis, EO = External obliques, RF = Rectus femoris, LSES = Erector Spinae

*Significantly lower than TP, VUP ($p < 0.001$)

†Significantly lower than C, TP, VUP ($p < 0.05$)

$^{\gamma}$Significantly less than VUP ($p < 0.05$)

ǂSignificantly less than TP ($p < 0.05$)

‖Significantly less than PK, TP, VUP ($p < 0.001$)

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