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A COMPARISON OF ABDOMINAL AND HIP FLEXOR MUSCLE ACTIVATION BETWEEN TWO SELECTORIZED STRENGTH TRAINING MACHINES

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ABSTRACT

Given the recent focus on core training in athletic and rehabilitative circles, a variety of abdominal strengthening exercises, utilizing both body weight and machines, are commonly performed to train this musculature. Often these exercises will involve motion of the lower extremities to some degree, in addition to different starting configurations of hip and knee angles. Given this variety of training possibilities, it is beneficial to quantify differences in muscular recruitment between the modalities. In order to test the hypothesis that starting hip position and leg motion will influence abdominal and hip flexor muscle activation, twelve healthy subjects performed abdominal crunches on two different machines at a normalized workload and angular velocity while electromyographic signals were collected. One machine imposed a neutral hip position, a flexed knee, and stationary leg-anchor points (Cybex Eagle NX Abdominal, CY), while the second started with a greater degree of hip flexion, similar degree of knee flexion, and mobile leg-anchor points (crunch-style, CR). Muscle activation was comparable on both machines for the upper ($P = 0.21$) and lower rectus abdominis ($P = 0.672$), and the external obliques ($P = 0.338$), while rectus femoris activity was greater ($P = 0.011$) on CR relative to CY. If minimizing hip flexor activation is a concern during abdominal resistance training, as has been suggested for individuals suffering from low back pain, these data suggest that CY may be a better alternative.

INTRODUCTION

In addition to body weight and free weight exercises (e.g., crunches, planks), a variety of selectorized strength training machines have been developed to target the abdominal musculature. As a result, one may question which machine design is optimal for training this muscle group, which includes the rectus abdominis and external obliques. This is especially critical given the recent focus on strength training protocols for the 'core.' Given the variety in training tools, it is advantageous to quantify differences in abdominal muscle activation amongst exercises designed to target this muscle group.

Often, abdominal-focused resistance machines employ different design features, most of which have gone predominantly untested. Amongst these features include: mobile vs. stationary leg anchor points, which in turn impose different ranges of motion, and starting configurations at the hip and knee. Recent research seems to suggest that starting hip angle may influence abdominal muscle activation during resistance exercise (Sundstrup, et al. 2012). However, these findings have not been extrapolated to test inter-machine effectiveness at targeting the trunk flexors.

Researchers have suggested that increased hip flexor activity during abdominal-focused resistance training may be undesirable for those suffering from low back pain (Escamilla 2010). This is due to the fact that high levels of psoas major activity, a deep hip flexor, have been demonstrated to result in high anterior shear and compressive forces at the lumbar spine, namely at the L5-S1 intervertebral joint (Santaguida and McGill 1995). This is of particular concern for those with weak abdominal musculature, as the abdominals create a posterior pelvic tilt torque at the lumbar spine that serves to stabilize against the antagonistic anterior pelvic tilt torque exerted by the hip flexors. Given these concerns, it may be advantageous to perform exercises that are challenging to the abdominals and obliques, while concurrently minimizing hip flexor activation.

Therefore, the objective of the present study was to quantify, via surface electromyography (EMG), the activation of the hip and trunk flexors during the use of two different abdominal-focused resistance training machines. It was hypothesized that a crunch-style machine will result in an increase in rectus femoris activation, while starting the hip in a neutral position with a stationary base would result in greater abdominal activation levels.

METHODS

Subjects

Twelve healthy subjects (age: 34±13 yrs, weight: 75.2±10.1 kg, height: 177.1±10.4 cm), free from any current musculoskeletal injury were made aware of the study's objectives and volunteered to participate in the following experiment. All subjects were familiar with, and had performed some form of resistance training in the past.

Abdominal resistance machines

The abdominal resistance machines under investigation (Figure 1) were a prototype Cybex Eagle NX abdominal machine (CY; Cybex International Inc, Medway, MA) and a crunch-style abdominal machine (CR). The major defining characteristics for CY include a stationary base (i.e., the anchor points for the legs do not move), a flexed knee, and neutral hip position. The major defining characteristics for CR include a mobile base (i.e., the anchor points that move upward toward the torso throughout the range of motion), a flexed knee, and a flexed hip. An alternate lower extremity position on CY was also investigated consisting of a more flexed hip and more extended knee (Figure 2).

Figure 1. The two abdominal resistance machines (CY on left, CR on right), with arrows indicating the resistance arm's approximate point of contact with the user

Figure 2. Alternate lower extremity configuration on CY

Experimental protocol

Each subject attended two testing sessions. During the first session, the 10 repetition maximum (RM) workloads for both CY and CR machines were determined based on ACSM guidelines. The second testing session was performed between 1-7 days following the first to allow for adequate muscular recovery following the RM testing.

The aim of the second session was to quantify muscle activation levels when working at the aforementioned 10RM workloads using electromyography (EMG). The electrode sites on each subject's skin were prepared by shaving, abrading, and treating with alcohol. Bipolar silver-silver chloride surface electrodes (Noraxon Dual Electrode #272, Scottsdale, AZ, USA) were placed according to recommended guidelines (Cram et al. 2012) for the upper rectus abdominis (URA), lower rectus abdominis (LRA), external oblique (EO), and rectus femoris (RF). All electrodes were placed unilaterally, on the subject's right side.

After successful placement of the electrodes, subjects were instructed to perform four repetitions on each device. Workloads were normalized based on the 10RM, while angular velocities were normalized with a metronome. On CY, subjects were given a target to push toward during repetitions to ensure a consistent range of motion, and as a result, angular velocity at the lumbar spine. On CR, the end of the repetition was demonstrated to all subjects visually as a location marked off on the weight stack that corresponded to the same range of motion on CY. Ranges of motion at the lumbar spine were approximated by analysis of a sagittal plane view of the subjects using Dartfish software (Dartfish ProSuite 6.0.712.0, Dartfish USA, Alpharetta, GA, USA).

The order of experimental conditions, i.e. the two different machines, was counterbalanced between the participants. All repetitions on both machines were performed to a metronome set at 0.89 beats/sec (68 beats/min). Given that both machines were performed through approximately 40 degrees of lumbar flexion, the metronome ensured that a consistent angular velocity of 45 degrees/sec was maintained across trials. Each subject performed 4 repetitions at their 10RM workload, followed by a rest period of 3-5 minutes, and finally 4 additional repetitions on the second device.

Data analysis

All raw EMGs were sampled at 1000Hz using a four channel data acquisition system (Noraxon MyoSystem 1400L, Scottsdale, AZ, USA). To create a linear envelope, raw data were full wave rectified and filtered using a bi-directional low-pass Butterworth filter with a cutoff frequency of 10Hz utilizing default software (MyoResearch XP Master Edition 1.08.17). The mean area under the curve, representative of the mean muscle activation during the repetition, was quantified across all five repetitions for each subject and condition. Grand means were then calculated from these values.

Statistical analysis

Paired T-tests were performed comparing the two machines for 10RM, and each of the four muscle groups under investigation (Excel 2007, Microsoft Corporation, Redmond, WA, USA). Differences were considered significant at $P < 0.05$.

RESULTS

There was no statistically significant difference between 10RM workload on CY (163±37.9 lbs) or CR (168.5±33.2 lbs, P = 0.21) abdominal machines. At these workloads, there was no statistically significant difference in mean muscle activation (Figure 2) between CY and CR for the URA (65.77±39.37 vs. 62.38±43.72 µV, P = 0.672), LRA (46.67±25.08 vs. 39.22±28.79 µV, P = 0.112), or EO (69.88±26.63 vs. 63.88±29.29 µV, P = 0.338). There was, however, a significant decrease in RF activation for CY compared to TG (34.13±17.33 vs. 61.30±38.10, P = 0.011). For a point of reference, RF activation was also measured during the alternate configuration on CY, which was also significantly lower than CR (41.28±23.00, P = 0.010).

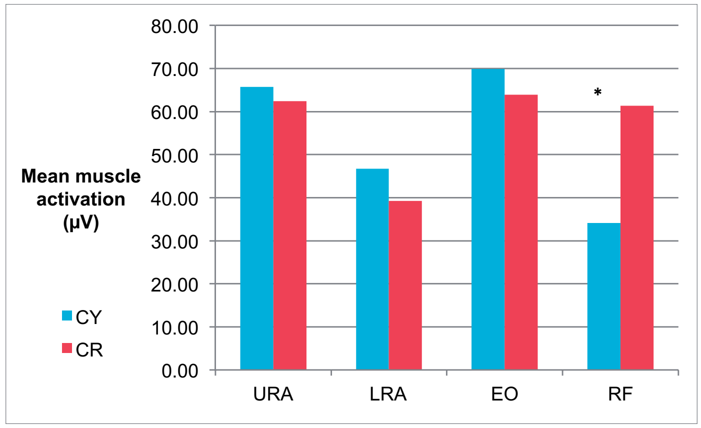

Figure 3. Mean activation for the four muscles under investigation for both the Cybex (CY) and crunch-style (CR) abdominal strength training machines. * Indicates statistically significant difference (P<0.05).

DISCUSSION

Contrary to our hypothesis, there were similar levels of abdominal and oblique activation on the two resistance machines tested. This suggests that, when working at a similar intensity, the abdominal muscle activation is not different between these two modalities. Although there was no difference between mean workloads for the two devices, there were workload differences intra-individual. This was by design, to ensure that effort was equivalent between the devices, and any differences that would therefore result are a reflection of the user's interaction (either imposed or afforded to the user) with the device.

Although the muscle activity of the deeper hip flexors such as the illiacus and psoas major cannot be measured via surface electrodes, studies have shown comparable activation levels between these muscles and rectus femoris during abdominal resistance training (approximately ±10%, Juker et al. 1998). Taking this into consideration, the statistically significant reduction in RF activation for the CY condition likely is indicative of similar reductions in the activation of illiacus and psoas major.

In support of our hypothesis, the CR machine with a mobile leg support elicited greater rectus femoris activity relative to the machine with a stable base. The illiacus and psoas major muscles both contribute to hip flexion, but do not cross the knee joint, as does rectus femoris.

Thus, increasing both hip and knee flexion angle likely creates a high level of passive tension on the biarticular rectus femoris. This likely will in turn create a passive (i.e., due to increased elastic tension in the muscle opposed to active tension due to muscular contraction) anterior pelvic tilt torque, against which the abdominals must contract. Therefore, it can be argued that by increasing the length of RF, one can passively increase anterior pelvic tilt torque, thereby increasing the necessary activation of the abdominals which insert on the pubis of the pelvis and contribute to posterior pelvic tilt during lumbar spinal flexion. Thus, if the aim would be to minimize the activation of the hip flexors during this exercise, these data suggest that the CY machine would be preferred. Our data also suggest that this minimization of hip flexor activation would not be at the expense of changes in abdominal or oblique activation.

The findings of the present study are consistent with those of Sundstrup et al. (2012) in which a comparison was made between an abdominal machine and crunches on a swiss ball with elastic resistance. This study found that abdominal activation was greater when performing swiss ball crunches compared to the crunch-style abdominal machine. It is interesting to note that the starting hip angle during the swiss ball condition is fairly close to neutral (i.e., 0 degrees of hip flexion), which is closely mimicked in the CY condition in the present study. Our data support these findings and suggest that starting hip angle likely has an influence on the activation of both the abdominals and the hip flexors during abdominal resistance training.

In conclusion, muscle activation levels between the two abdominal-focused resistance machines under investigation were comparable, with the notable exception of hip flexor activation. Those suffering from, or at a high risk for developing lower back pain may wish to avoid the high hip flexor activation that occurs during exercise on a crunch-style abdominal machine.

[SUMMARY]

Both machines demonstrated similar levels of abdominal and oblique muscle activation when working at the same relative intensity and speed, while the crunch-style machine elicited 79.6% greater hip flexor activation.

Increased hip flexor activity during abdominal exercise may be a concern to those at risk for low back pain, as this may result in excessively high levels of compression and shear at the lumbar spine.

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