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Core muscle activity during suspension exercises

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ABSTRACT

Objectives: Suspension exercise has been advocated as an effective means to improve core stability among healthy individuals and those with musculoskeletal complaints. However, the activity of core muscles during suspension exercises has not been reported. In this study, we investigated the level of activation of core muscles during suspension exercises within young and healthy adults.
Design: The study was conducted in a controlled laboratory setting.
Methods: Surface electromyographic (sEMG) activity of core muscles (rectus abdominis, external oblique, internal oblique/transversus abdominis, and superficial lumbar multifidus) during four suspension workouts (hip abduction in plank, hamstring curl, chest press, and 45° row) was investigated. Muscle activity during a 5-s hold period of the workouts was measured by sEMG and normalized to the individual's maximal voluntary isometric contraction (MVIC).
Results: Different levels of muscle activation were observed during the hip abduction in plank, hamstring curl, and chest press. Hip abduction in plank generated the highest activation of most abdominal muscles. The 45° row exercise generated the lowest muscle activation.
Conclusions: Among the four workouts investigated, the hip abduction in plank with suspension was found to have the strongest potential strengthening effect on core muscles. Also, suspension training was found to generate relatively high levels of core muscle activation when compared with that among previous studies of core exercises on stable and unstable support surfaces.

1. Introduction

A growing body of research is focused on core stability training (CST). Core stability refers to an effective recruitment of core muscles (including the abdominal, back, pelvic, and hip muscles) leading to an optimal production of force and precise control of lumbopelvic-hip movement, as well as appropriate load transfer from the spine to the pelvis and distal segments.[1] As such, it is thought to be a determinant factor for effective motor performance.[2] In support of this notion, weak or fatigued core muscles are associated with suboptimal tennis strokes,[1] altered cycling mechanics,[3] and increased incidence of non-contact anterior cruciate ligamentous[4] and hamstring injuries.[5] Furthermore, preliminary evidence shows that CST reduces injury rate[6] and enhances performance[7] in elite athletes and improves short-term rehabilitation outcome in individuals with musculoskeletal problems.[8]

Due to evidence of positive effects of CST in sports training and musculoskeletal rehabilitation, it has gained popularity as a component of training programs.[9] However, a recent meta-analysis[8] and systematic review[10] conclude that CST studies show mixed results in terms of the effectiveness of CST in improving outcomes of athletic training[10] and producing long-term reductions in chronic low back pain.[8] These conflicting results might be explained by several methodological issues. First, CST is often one component of a more extensive training program, making it challenging to evaluate the effect of CST in isolation. Second, forms of CST vary widely from specific muscle strengthening exercises to functional training such Tai Chi or Pilates. Such inconsistencies in training progression and the lack of specificity in functional training are likely to produce mixed results. Third, not all studies report changes in core muscle performance following training, raising doubt as to whether study outcomes can be attributed to CST.[8,10] Thus, the evaluation of core muscle activity during various exercises is fundamental for evidence-based practice of CST.

Core stabilization exercises can be performed on stable (e.g., traditional plank exercises) or unstable (e.g., Swiss ball exercises) surfaces. Compared with exercises performed on a stable base, exercises performed on an unstable base present a greater challenge to the maintenance of core stability, evidenced by an increase in core muscle activity.[11–13] Exercise performed using a suspension device is one form of CST with an unstable base.

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This type of training consists of multi-planar and multi-joint movements against gravity with body weight as resistance. During the exercise, one or both limbs are supported on handle straps (or cradles) at the ends of a suspension cable with a single above-head (i.e., ceiling or wall) anchor point. The level of workout difficulty is adjusted by altering the "working angle" (i.e., inclination of the body from upright position) and/or adding balancing equipment. Suspension exercise has become a popular type of CST due to its versatility, with a simple set-up, low space occupancy, and large variety of workouts. Understanding core muscle activity during various workouts can aid rehabilitation specialists in selecting appropriate therapeutic exercise for clients with different conditions or at different stages of rehabilitation. Therefore, the main objective of this study was to investigate core muscle activity during four different suspension exercise workouts.

2. Methods

Eighteen healthy participants (8 men and 10 women; age: 21.9 ± 1.7 years; height 165.9 ± 0.9 cm, weight 54.7 ± 6.6 kg) participated in this study. Individuals were excluded if they participated in elite sports training, had a history of musculoskeletal complaints in the past 6 months, or had any contraindications to exercise. Informed written consent was received from participants before any study procedures. All procedures were approved by the Human Subjects Research Ethical Committee of the Department of Rehabilitation Sciences, Hong Kong Polytechnic University and conducted in accordance with the Declaration of Helsinki.[14]

The suspension device (TRX® PRO Suspension Trainer, Fitness Anywhere LLC, San Francisco, USA) consisted of a 12-foot adjustable nylon cable with handle straps at both ends that was anchored to the ceiling (3 m above the ground) via a carabiner.

The activity of four core muscle groups – the rectus abdominis (RA), external oblique (EO), internal oblique/tranversus abdominis (IO/TrA), and superficial lumbar multifidus (LMF) on the left side of the body was evaluated using surface electromyography (sEMG) during four suspension workouts. Bagnoli DE-3.1™ reusable surface double differential detection sEMG sensors (Delsys, Boston, USA) were used to detect sEMG signals. Three 99.9% Ag parallel bars (contact: 10 mm × 1 mm each) spaced 1 cm apart were housed in a rectangular case (41 mm × 20 mm × 5 mm) with a common mode rejection ratio of 92 dB and an input impedance of 10^{15} Ω. Data were collected with a sampling rate of 1000 Hz and bandpass filtered from 20 to 450 Hz. Raw sEMG signals were acquired with a Bagnoli-8™ Desktop EMG system (Delsys, Boston, USA) and amplified with a gain factor of 1 k. The root-mean-square (RMS) value of sEMG signals was then calculated using LabVIEW software (National Instruments, TX, USA). Prior to electrode attachment, the skin at the placement site was cleaned with abrasion and alcohol to enhance surface contact. sEMG electrodes were placed at standard points according to existing guidelines with their orientation parallel to muscle fibers to ensure optimal signal recording. Briefly, positions of the electrodes were as follows: 2 cm lateral to the umbilicus for the RA[15]; at the intersection of the vertical line along the anterior superior iliac spine (ASIS) and the straight line from the lowest rib to the opposite pubic bone for the EO[15]; 2 cm inferior and medial to the ASIS within the inguinal ligament for the IO/TrA[15]; at the intersection of the line joining the posterior superior iliac spine, the center of L1/L2 vertebrae, and the horizontal line along the L5 vertebra for the LMF.[15] The ground electrode was placed over the left lateral malleolus.

All participants underwent a familiarization session one week prior to the data collection session, during which they were accustomed to the experimental set-up during trials of the proper exercise technique. Before data collection, each participant warmed up with 5 min of cycling[16] and static stretching of the suspension exercise prime moving muscles (including upper trapezius, pectoralis, biceps, triceps, abdominals, back extensors, hip flexors and extensors, quadriceps, and hamstring muscles).[17] sEMG data were collected during two 5-s maximal voluntary isometric contraction (MVIC) trials against manual resistance for each muscle of interest with a 2-min between-trial rest period.[11,18] The average RMS value during a middle 3-s window of each trial was chosen as the representative MVIC value for data normalization and further analysis.[19] For the RA, participants laid with their hips and knees flexed to 90° and their trunk maximally flexed (i.e., curl-up) against bilateral shoulder resistance manually provided by the experimenter pushing the trunk into extension.[15] For the EO and IO/TrA, participants exerted additional resisted trunk rotation to the right and left, respectively.[15] For the LMF, participants laid prone with their lower limbs supported and restrained on a plinth and their hands clasped behind their heads. They then performed maximal trunk extension to maintain the unsupported upper body in a horizontal position against manual resistance applied at the posterior shoulders bilaterally.[15]

Four different workouts were tested: hip abduction in plank (HAP), chest press (CP), 45° row (ROW), and hamstring curl (HC). The starting position for HAP was prone on elbows (body aligned horizontally with shoulders and elbows at 90° flexion) with forefeet anchored in the cradles of the suspension system, which were adjusted to hang 10 inches from the ground (Fig. 1A). The action involved hip abduction to end range while maintaining the trunk as a horizontal plank. The CP was conducted with feet under the anchor, hands holding the cradles, body inclined forward 70°, shoulders flexed to 90°, and elbows extended (Fig. 1B). The body was then lowered by performing shoulder horizontal abduction to 90° and elbow flexion to 90° while maintaining plank position. The ROW was conducted in standing position with feet under the anchor, body inclined 45° backward, shoulders flexed to 90°, and elbows in extension while holding onto the handle straps. The body was then pulled up toward the anchor by adduction of the scapulae, extension of the shoulders, and flexion of the elbows to 90° while keeping the body in plank position (Fig. 1C). The starting position for HC was supine with ankles anchored at the cradles, which were set 7 inches above the ground, and upper limbs supported on the ground (Fig. 1D). The action involved pulling the heels toward the buttocks and flexion of the knees to 90° while maintaining the trunk and hips in plank position. Joint position and movements were visually monitored. For each exercise, five repetitions were conducted in a 3-5-3-s (up-hold-down) tempo, with a minimum 2-min rest between each repetition. Tempo was monitored with an electronic metronome at 60 beats per min. Participants were instructed to maintain the hold position and breathe naturally without head movements or talking. sEMG data were collected during the holding period. Correct positioning and execution of the exercises were visually monitored by a separate experimenter. The RMS of sEMG activity was computed during a middle 3-s period of the hold position. The average RMS of five repetitions of each exercise was normalized against the RMS of the MVIC for each respective muscle and expressed as percentage of MVIC (%MVIC).

Data were analyzed using SPSS 20.0 software (SPSS Inc, Chicago, IL, USA). One-way repeated-measured analysis of variance (ANOVA) was used to test for differences between muscle activations within the same exercise and differences between muscle activations across exercises for the same muscle group. Pairwise comparisons were conducted using contrast analysis with post hoc Bonferonni adjustment. Statistical significance was set at $\alpha = 0.05$. Data are expressed as mean and standard deviation (SD).

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