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Original research

The effect of abdominal strength or endurance exercises on abdominal peak torque and endurance field tests of healthy participants: A randomized controlled trial

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ABSTRACT

Objective: To compare the effects of muscular endurance and resisted strengthening protocols on abdominal strength and endurance in a sample of young subjects.
Design: Randomized Clinical Trial.
Setting: University fitness laboratory.
Participants: 79 healthy subjects, (45 males and 34 females) aged 23.5 ± 5.8 years.
Main outcome measures: Measurements were taken at baseline and 12 weeks. Abdominal strength and endurance were evaluated using an isokinetic dynamometer (IKD) and four floor tests including the timed front plank (FP), angle sit (AS), sit-up (SU), and handheld dynamometer (HD).
Results: Multivariate analysis revealed no between group differences for the outcomes or group × time interaction ($P = 0.52$ and $P = 0.31$ respectively). The univariate within group analysis was significant for SU $P = .001$, HD rectus $P = .007$, HD oblique $P = .005$, and for the IKD peak eccentric torque $P = .025$.
Conclusions: A 12-week intervention program addressing endurance or strength did not produce between-group differences over a control group of routine activity maintenance.

1. Introduction

Abdominal strength and endurance have been speculated upon as a predictor of musculoskeletal pathology of the lower back and lower extremity injuries. Leetun, Ireland, Willson, Ballantyne, and Davis (2004) found that individuals experiencing low back and lower extremity injuries over a two year period of time had lower testing values for a double leg lowering test, side plank, and angle sit test. While these differences did not achieve statistical significance, injured athletes' testing values were approximately 10% lower than their non-injured counterparts. Schellenberg, Lang, Chan, and Burnham (2007) reported that individuals with chronic low back pain had lower prone plank test scores than uninjured control subjects and the subjects' prone plank test scores significantly correlate with pain and disability scores. Lower trunk muscle endurance, measured by the number of sit-ups performed in 1 min, was associated with recurrent low back pain in adolescents (Jones, Stratton, Reilly, & Unnithan, 2005). A more recent 10-year prospective study concluded that absolute core strength, measured as isometric flexion and extension values, was predictive of subsequent ACL injuries in competitive ski racers (Raschner, Platzer, Patterson, Werner, Huber, & Hilderbrandt, 2012). These studies suggest that abdominal strength and endurance are components of core stability related to impairments and injury.

Abdominal strength has not only been linked to injury but also to sports performance. Abdominal muscle strength, as measured by hand held dynamometry, strongly correlated to soccer sports performance (Wagner, 2010). Numerous studies have examined the effects of comprehensive training programs that incorporate direct abdominal training and have reported enhanced sports performance (Hibbs, Thompson, French, Wrigley, & Spears, 2008).

Core stabilization exercises have been recommended in rehabilitation programs for low back and lower extremity pathology (Liddle, Baxter, & Gracey, 2004). Routinely, exercises that emphasize abdominal strength and endurance are incorporated in these core stabilization programs as a necessary element. Nonetheless, the best method of increasing strength and endurance is not known, yet a variety of methods have been reported. One study found that bodyweight exercises have minimal effect on isokinetic abdominal strength (Pintar, Learman, & Rogers, 2009) contradicting previous work (Liggett, 1999). A recent study suggested that the use of planks and side-supports are as effective as traditional

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crunches and sit-ups in preparing military recruits for fitness testing (Childs et al., 2009).

Currently, best evidence to support a particular training strategy has not been established since a multitude of different dosages with different exercises has not been systematically compared for clinical effectiveness. Numerous studies have looked at muscle activation levels but do not report the outcome from a treatment program designed to improve trunk performance (Beim, Giraldo, Pincivero, Borror, & Fu, 1997; Hubley-Kozey & Vezina, 2002; Vezina & Hubley-Kozey, 2000). Commonly used exercises have been assessed for changes in muscle thickness demonstrating level of activity achieved during their performance (Teyhen, Rieger, Westrick, Miller, Molloy, & Childs, 2008) without examining effectiveness of a given intervention. Another study found that a core stabilization program, incorporating trunk strengthening exercise in multiple positions did not alter trunk force output or core muscle activation patterns; however, the study examined a very small sample of subjects (Arokoski, Valta, Kankaanpaa, & Airaksinen, 2004). Alternatively, physioball strengthening exercises performed for five weeks, enhanced EMG activation patterns but did not alter strength as measured by Cybex isokinetic strength assessment (Cosio-Lima, Reynolds, Winter, Paolone, & Jones, 2003).

The results of these studies demonstrate inconsistent findings and recommendations concerning the use of abdominal strengthening programs in various rehabilitative programs and a lack of consensus on the best strategies to increase strength or endurance of the abdominal musculature.

The purpose of this study was to compare the effects of a muscular endurance protocol, a resisted strengthening protocol and a control group on abdominal strength and endurance in a sample of healthy young subjects. We hypothesized that the strengthening group would experience the greatest strength gains, the endurance group would experience the greatest increase in endurance field tests and that both the strength and endurance groups would experience greater strength and endurance gains than the control group.

2. Methods

2.1. Subjects

Subjects were recruited from the university community by a flyer distributed throughout the university and sent to professors to announce in class. A sample of 95 subjects volunteered to participate in the twelve-week study. Each participant was informed of the benefits and risks of the investigation and subsequently signed an informed consent form in accordance with the guidelines of the university's Institutional Review Board and approved for use of human subjects. Subjects also completed the Physical Activity Readiness Questionnaire (PAR-Q) to establish medical clearance. Subjects were excluded if they were pregnant, had previous abdominal surgery, a history of acute or chronic low back pain, heart disease, or any contraindication to exercise. Body mass index (BMI) was calculated from weight and height measured using a Detecto Physicians Scale and attached anthropometer. Percent body fat was determined using bioelectrical impedance analysis (BIA; Valhalla Scientific Industries, San Diego, CA). Pre-test instructions concerning the BIA were provided to each subject.

2.2. Baseline procedures

2.2.1. Abdominal strength and endurance

Abdominal (m. rectus abdominis and m. obliquus externus and internus) strength and endurance measures were taken using an isokinetic dynamometer (KinCom, Chattanooga, TN), the front plank, angle sit, and sit-ups. All tests were performed on the same day in a random order determined by rolling a die. One roll of the die was performed to determine if the subjects would perform the floor tests (front plank, angle sit, sit-ups, handheld dynamometer) or the isokinetic dynamometer test first. Subsequent rolls determined the order in which the subject would perform each of the floor tests. The established randomized testing order was followed during the follow-up session.

2.2.1.1. Isokinetic dynamometer (IKD). Isokinetic dynamometry was our primary outcome of interest. The isokinetic dynamometer measured maximal concentric and eccentric trunk flexion torque values through a predetermined range of motion. The KinCom was calibrated for both torque and angular displacement. Methods followed were previously described (Hall, Hetzler, Perrin, & Weltman, 1992; Pintar et al., 2009) and were as follows. Each subject was seated on the KinCom back attachment with the knees flexed to 90° adjusted so that the feet were kept off the ground to minimize hip flexor leverage. The subject's greater trochanter served as the point of reference to which the dynamometer axis was aligned. An adjustable T-bar force application pad was aligned with the chest wall just below the sternal notch. The subject's arms were crossed anteriorly over the T-bar pad. To ensure safety of the subjects, the dynamometer would not allow movement until a 50-Newton (N) force was applied on the T-bar pad. This preload prevented impulse loading and was a means of protecting the subject during eccentric exercise. The KinCom was set on the concentric/eccentric evaluation mode, which allowed the subject to perform forward flexion at a constant velocity of 60° sec^{-1}, through a 60° range of motion (−10°−50°, vertical = 0°). In the concentric mode, the subject was asked to push against the chest pad with maximum force from −10° to 50° of flexion. At the end of each concentric contraction, the subject was asked to continue flexing against the chest pad at maximum force to activate the eccentric phase of the contraction and resist the lever arm from 50° of flexion back to −10°. Each subject performed a submaximal practice trial of six repetitions prior to the actual measurement of peak force to ensure that they could apply the minimum 50N of force in a smooth manner through both phases of the trial. A 1-min rest was provided between the practice trial and the maximum effort trial to ensure that fatigue did not alter their performance. After the practice trial, each subject performed a testing trial of three concentric and eccentric abdominal contractions. The 3 maximum torque curves were visually inspected to determine if they closely replicated each other in form. If they were not consistent, after a 1-min rest, the 3 repetition maximum effort trial was repeated. Maximal torque was determined during the three concentric and eccentric repetitions throughout the range of motion. The same examiner provided verbal encouragement to each subject to promote maximal performance. Flexion torque data were collected at 100 Hz and were imported to a PC to calculate average and peak values using Microsoft Excel (Redmond, WA).

2.2.2. Floor tests

2.2.2.1. Timed front plank (FP) test. Performance of this test was in accordance with the methods outlined by McGill, Belore, Crosby, and Russell (2010). Participants were instructed to lay face down on the ground. To start the test, the subjects placed their elbows and forearms under their chest, and propped themselves up into a plank position using their toes and forearms for support. Their necks were kept straight throughout the duration of the test. When a flat back or proper neck alignment could not be maintained despite verbal cueing from the investigator, the test was terminated. Participants were instructed to hold the plank position for as long as possible. The FP test has been demonstrated to