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Effect of a 6-week core stability training program on active trunk repositioning: a randomised controlled trial

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Abstract

Introduction. Core stability training has recently attracted attention for improving muscle performance. This study aimed to examine the effect of core stability training on active trunk repositioning error.
Methods. Forty healthy males, randomly assigned into two equal groups – experimental and control groups – participated in the study. Their age, weight, height, and BMI ranged between 18–22.5 years, 64–85 kg, 1.63–1.83 m, and 19.4–25 kg/m^2, respectively. The Biodex Isokinetic dynamometer was used to assess the absolute error (AE) at both 30° and 60° trunk flexion, measured at a 60°/s angular velocity. Data were recorded twice; before (pre-test) and after (post-test) a 6-week period during which the experimental group was trained.
Results. Mixed 3-way ANOVA revealed that the AE was significantly lower at 60° trunk flexion in both groups at pre-test, and in the control group at post-test compared with 30° flexion ($p < 0.05$). In addition, the AE decreased significantly in the post-test in the experimental group only at both trunk flexion angles compared with pre-test ($p < 0.05$).
Conclusions. The decreased active trunk repositioning error with core stability training indicates improvement in trunk proprioception. Thus, core stability training could be beneficial if added to rehabilitation programs that aim to improve trunk proprioception.
Key words: core, isokinetic, repositioning error, proprioception

Introduction

The 'core', also known as the 'lumbo-pelvic-hip complex', refers to that space bounded by the diaphragm superiorly, pelvic floor and hip girdle inferiorly, abdominal and oblique muscles anterolaterally and the paraspinal and gluteal muscles posteriorly [1]. These muscular structures impart corset-like stability for the spine [2]. Spinal stability is further improved with increased intra-abdominal pressure. Stability increases by about 1.8 times with doubling of the pressure [3].

Core stability depends on simultaneous integration among the active (muscles), passive (bones and ligaments), and neural control subsystems. Good stability aims at maintaining neutral spinal alignment and transferring loads properly to and from the extremities, with much emphasis on preventing injury [4]. Core stability is considered as essential a factor in the basic patterns of movements as joint stability, mobility, strength, neuromuscular control, balance, and proprioception [5].

Proprioception, in part, refers to one's awareness of their limb positioning, usually measured through active and passive joint position sense [6]. In the spine, the proprioceptors (mechanoreceptors) are found in the facet joints, intervertebral discs, spinal ligaments, and paraspinal muscles [7]. Muscle spindles, present in the paraspinal muscles, are responsible for monitoring the trunk position and motion, especially the mid-range of trunk motion [8]. Since monitoring trunk motion is crucial for producing motion patterns, it is anticipated that any deficit in proprioception would negatively affect the quality of motion [9].

It has been shown that proprioceptive deficits cause delayed reflexive responses with consequent delays in muscle contraction, which is necessary to protect the joint against excessive motion [10]. In addition, reduced trunk motion control is associated with and caused by back muscle fatigue [11]. Although, core training has been extensively studied with much emphasis on its effect on pain [12], trunk muscles' cross-sectional area [13], trunk muscles' strength and endurance [14] and the body's overall balance [15], there is a lack of knowledge on the effect of core stability exercises on trunk proprioception.

Therefore, this study was carried out to explore the effect of a 6-week beginners' core stability exercise program on trunk proprioception assessed through measuring the active repositioning error; the difference between reposition angle and target angle. Assessing active trunk repositioning has clinical relevance, as its affection is related to lower extremity injury. It was found that for every degree increase in the average active trunk repositioning error, the odds ratio of knee injury increases 2.9 times, and the odds ratio of ligament/meniscal injury increases 3.3 times [16]. Thus, if core stability exercises are proven to reduce active trunk repositioning error, it is anticipated that the risk of knee injury could be reduced. We hypothesised that our core stability program would decrease active trunk repositioning error.

Subjects and methods

Participants

Forty healthy male college students participated in the study. Their age, weight, height, and BMI ranged between 18–22.5 years, 64–85 kg, 1.63–1.83 m, and 19.4–25 kg/m^2, respectively. The BMI was specified for the participants as it affects postural stability and thus may affect proprioception [17]. Participants were randomly assigned into two equal groups; the experimental or control group. All participants had their back and abdominal muscle strengths assessed as grade four by a manual muscle test and normal flexibility

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of the trunk extensors, lateral flexors and rotators as well as hip flexors. The manual muscle and flexibility tests were conducted by the same examiner. Volunteers were excluded if they had a history of any previous back and/or abdominal surgeries and/or diseases, any previously perceived episodes of low back pain within one year of being involved in the study, any previous core stability training program experience, any previously diagnosed trunk deformity, any previous or concurrent neuromuscular or neurological problems that may affect proprioception (e.g. spinal cord tumour, or epilepsy), any previously diagnosed vestibular system affection, any current systemic illness (e.g. diabetes mellitus), any current medications, or if having a history of drug abuse. Each included participant then signed an informed consent. The study was approved by the Institutional Ethical Approval Review Board of the Faculty of Physical Therapy, Cairo University.

Procedures

This study involved a pre-test post-test control group design. A Biodex System 3 Pro multijoint testing and rehabilitation system (Biodex Medical Systems, Shirley, NY, USA) was used for measuring the active trunk repositioning error after stabilising the participant's sacral base to minimise hip and pelvic involvement, and to ensure that the trunk movement is consistent with the isokinetic system dynamometer. Before starting the test, a familiarisation session was conducted to acquaint the participant with both the device and the test to be performed. Three trials, with a pre-adjusted rest period of 10 seconds in between each two successive trials, were performed by each participant for averaging, where the mean absolute error (AE) value (the difference between the reposition angle and target angle) was recorded and used for statistical analysis. The AE is used to assess the proprioceptive performance; it determines the individual's accuracy in reproducing the position and is measured in degrees [18].

The sense of joint position was assessed starting from a neutral spine position, with the participant being blindfolded to limit visual cueing. Each participant actively flexed the trunk up to 30° and 60°, which were identified to be the target positions. Starting the testing procedure with either the 30° or 60° angle was randomly selected by asking the participant to select one of two folded pieces of paper placed in a container. After exercising in the randomly chosen position, the participant was allowed to rest for as long as it took the examiner to change the back support inclination angle of the isokinetic chair in preparation for the next test. The participant's trunk moved at an angular velocity of 60°/s. The target position, whether 30° or 60°, was identified when the back support of the chair automatically stopped there. The participant was instructed to remember each target position while it was held for five seconds. The participant returned to the neutral position, then was instructed to flex the trunk to the target position and mark the position by pressing a 'hold' button (Figures 1, 2). This procedure was repeated three times for calculating the mean values of the AE, which were used for the data analysis. Lower values of the AE indicate that the sense of position is more accurate.

The AE was measured twice for each participant of both groups; before and after the 6-week study period. During this 6-week period, experimental group participants performed a pre-determined core stability program, while those in the control group did not. This pre-determined core stability program included a warm-up period followed by three main core stability exercises; 'Curl-Up', 'Side-Bridge', and 'Bird-Dog', which are components of the Saal and Saal [19] dynamic

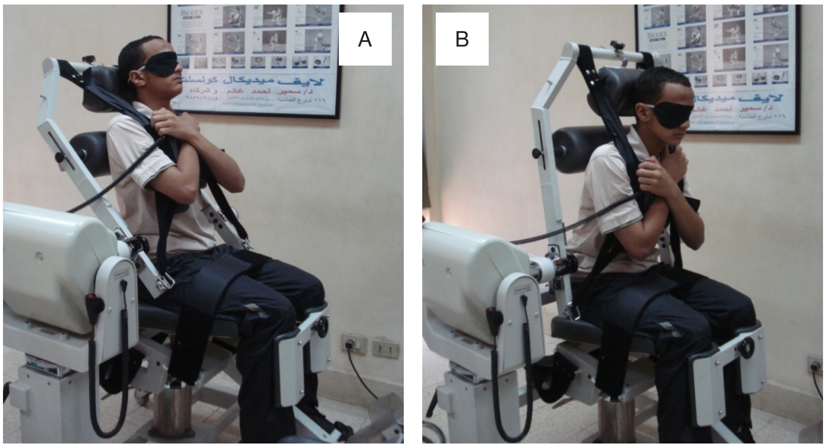

Figure 1. Repositioning test at 30-degree trunk flexion; start (A) and end (B) positions

Figure 2. Repositioning test at 60-degree trunk flexion; start (A) and end (B) positions

lumbar stabilisation efficacy program. The pre-determined program consisted of three phases, each lasting for two consecutive weeks. A set of 15 repetitions for each exercise was performed once each training day in the first phase, twice each training day in the second phase, and three times each training day in the third phase. Each participant trained three days per week [20].

The warm-up period involved a 'Cat-Camel' motion of the spine (5–8 spine flexion-extension cycles). This warm-up exercise was carried out to reduce spinal viscosity and neural tension. In the 'Curl-Up' exercise, the participant was asked to raise the head and upper shoulders off the therapeutic mat and hold the final position for 7–8 seconds [21].

In the 'Side-Bridge' exercise, the participant was instructed to bridge the torso between the elbows and knees. Once he mastered and tolerated this exercise, the challenge was increased by bridging using the elbows and feet. The participant raised the pelvis from the therapeutic mat and held it in a straight line 'plank' position for 7–8 seconds. This exercise was performed on both sides, right and left.

In the 'Bird-Dog' exercise, the participant adopted a quadruped position, then he raised opposite upper and lower limbs (right arm and left leg, then left arm and right leg) to be in line with the trunk. He was asked to hold the posture for 7–8 seconds. Abdominal bracing was to be maintained throughout all the conducted exercises without holding his breath [21].

Statistical analysis

Three independent variables were tested in this study, each with two levels. They were the trunk flexion range of motion factor (30° and 60° trunk flexion positions), the time factor (pre-test and post-test conditions) and the tested group factor (experimental and control groups). The dependent variable was the active repositioning error.

SPSS version 17 for Windows was used for the statistical analysis. First, data screening for normality assumption, testing for the presence of extreme scores, as well as the presence of significant skewness and kurtosis was carried out using the Kolmogorov-Smirnov and Shapiro-Wilk normality tests. Screening for the homogeneity of variance assumption was also conducted. Once it was determined that the normality and homogeneity assumptions were not violated, a parametric analysis was carried out. Mixed 3-Way Analysis of Variance (ANOVA) was conducted to compare between the 30° and 60° trunk flexion positions, the experimental and the control groups, and the pre- and post-test conditions. Finally, the ANOVA was conducted to test the interactions among the three independent variables (range of motion, tested group & time) with the alpha level set at 0.05. Subsequent multiple pairwise comparison tests were conducted with Bonferroni adjustment of the alpha level.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Research Ethical Committee of the Faculty of Physical Therapy, Cairo University (approval No.: P.T.REC/012/002580).

Informed consent

The detailed treatment procedure has been explained to the participants, along with the risks and benefits, and written informed consent was taken.

Results

Forty healthy individuals, randomly assigned to two groups; experimental and control, participated in the study. As indicated by the unpaired *t*-tests, there were no significant differences ($p > 0.05$) for the mean values of the weight, height and BMI between both groups. However, there was a significant difference ($p < 0.05$) for the mean value of the age between both groups (Table 1).

Table 1. Descriptive statistics and unpaired *t*-tests for the mean demographic and anthropometric data of the experimental and control groups

	Experimental group (*n* = 20) (mean ± *SD*)	Control group (*n* = 20) (mean ± *SD*)	*t*-value	*p*-value
Age (years)	19.35 ± 1.11	20.45 ± 1.64	2.488	0.018*
Weight (kg)	70.15 ± 6.44	72.45 ± 6.91	1.089	2.300
Height (cm)	174.7 ± 7.02	176.3 ± 7.24	0.760	0.452

* significant at α < 0.05

The Mixed 3-Way ANOVA and the pairwise tests revealed that the AE was significantly lower at the 60° trunk flexion position compared with the 30° position in the pre-test condition for the experimental group, the pre-test condition for the control group and the post-test condition for the control group. However, there was no significant difference between the trunk flexion positions in the post-test condition for the experimental group. In addition, the AE decreased significantly in the post-test condition compared with the pre-test condition for the experimental group at both trunk flexion positions. However, there was no significant difference in the AE between the pre- and post-test conditions for the control group at both trunk flexion positions.

Finally, there were no significant differences in the AE between both groups in the pre-test at the 30° trunk flexion position, nor at the 60° trunk flexion position. However, there were significant decreases in the AE of the experimental group compared with the control group in the post-test conditions at both 30° and 60° trunk flexion positions. Tables 2 and 3 present the mean values of the active repositioning error at the 30° and 60° trunk flexion positions in the pre- and post-test conditions for both groups together with the pairwise comparison tests.

Table 2. Descriptive statistics for the mean values of the Absolute error

	Experimental group (mean ± *SD*)		Control group (mean ± *SD*)	
	pre-test	post-test	pre-test	post-test
At 30° trunk flexion	5.7 ± 2.26	3.2 ± 1.66	5.27 ± 1.93	6.09 ± 2.83
At 60° trunk flexion	4.4 ± 1.68	3.17 ± 1.76	4.33 ± 1.43	4.8 ± 1.81

Table 3. Multiple pairwise comparisons for Absolute error at 30° and 60° trunk flexion in the pre- and post-tests in the experimental and control groups

			p-value
Within-subject effect	Multiple pairwise comparison tests for the absolute error at both trunk ranges of motion		
	pre-test	30° vs. 60° (experimental group)	0.006*
		30° vs. 60° (control group)	0.045*
	post-test	30° vs. 60° (experimental group)	0.95
		30° vs. 60° (control group)	0.047*
	Multiple pairwise comparison tests for the absolute error for both ‘pre’ and ‘post’ tests		
	30°	pre-test vs. post-test (control group)	0.13
		pre-test vs. post-test (experimental group)	0.001*
	60°	pre-test vs. post-test (control group)	0.23
		pre-test vs. post-test (experimental group)	0.003*
Between-subjects effect	Multiple pairwise comparison tests for the absolute error between the tested groups		
	30°	experimental vs. control group (pre-test)	0.52
		experimental vs. control group (post-test)	0.001*
	60°	experimental vs. control group (pre-test)	0.90
		experimental vs. control group (post-test)	0.006*

* significant at $\alpha < 0.05$

Discussion

Spinal stability is the pillar upon which normal function of the spine and the active generation of forces in the trunk depend. It is also essential for the transfer of forces between the upper and lower limbs [22]. Injuries to the core muscles may lead to spinal instability which, if sustained during movements, is associated with insufficient strength and endurance of the trunk-stabilising muscles, leading to inappropriate recruitment of the trunk muscles, mainly the abdominal ones. Accordingly, any trunk-stabilising muscle weakness must be identified and corrected, as this weakness may be a predisposing factor for muscle and joint injury [23].

As revealed by the findings of the current study, the mean values of the active repositioning error increased significantly at 30° trunk flexion compared with 60° trunk flexion in the pre-test condition for the experimental group, the pre-test condition for the control group, and the post-test condition for the control group. However, there was no significant difference in the active repositioning error between both tested trunk flexion positions in the post-test condition for the experimental group.

The cause of the significant increases in the mean values of the active repositioning error at 30° flexion compared with 60° flexion may be attributed to the fact that activation of conscious proprioceptors located in the joint capsule is related to the joint angle. At the mid-range of joint motion, these proprioceptors are not stimulated enough to contribute to proprioception. Whereas, at the end ranges of motion, they are thought to signal proprioceptive information. Cutaneous receptors respond in the same way as joint receptors at the extremes of ranges of motion [24].

In addition to that, the role of ligamentous receptors in serving proprioceptive information can be neglected [25]. So, the muscle proprioceptors are, to a great extent, the only joint position sensors in the midranges of motion. Since the 60° trunk flexion angle is closer to the end range than the 30° angle and the muscle spindles can respond across the entire physiologic range of motion, unlike the joint and cutaneous mechanoreceptors [26], at 60° trunk flexion, the cutaneous and joint receptors share proprioceptive information with the muscle receptors that arises in the brain, helping and supporting the muscle receptors. On the other hand, 30° trunk flexion is a midrange angle in which the muscle receptors are almost the only contributors to proprioceptive information, which may result in lower proprioception acuity than that at the end ranges. These findings are in agreement with those reported by Willems et al. [27].

Another finding in the current study was a decrease in the mean value of the active repositioning error at 30° in the post-test of the experimental group that is more than that at 60°, which may have caused the insignificant difference between both angles as the mean values of the active repositioning error at both degrees in the post-test are close to each other.

On another note, the statistical analysis revealed that there were no significant differences in the active repositioning error between the pre- and post-test conditions in the control group for either the 30° or the 60° trunk flexion positions as they did not conduct any training program. However, there were significant decreases in the active repositioning error in the post-test conditions at both 30° and 60° trunk flexion compared with the pre-test conditions in the experimental group. This may be attributed to improvement in trunk proprioception resulting from the 6-week core stability training. The core training might have caused neural adaptations involving more efficient neural recruitment patterns, faster nervous system activation, improved synchronisation of motor units and lowered neural inhibitory reflexes [28].

The improvement in trunk proprioception found in the current study after performing the core program is indirectly supported by other studies that investigated the effect of core stability training on dynamic balance and postural control. The findings of the study conducted by Samson [29] to assess the effect of a 5-week core stabilisation training program on dynamic balance in tennis players revealed that the Star Excursion Balance Test (SEBT) scores were increased in both groups, indicating improvement of dynamic balance, which was suggested to result from the test-retest effect. However, the post-test results were not significantly different between both groups. Regardless of the non-significant outcome, Samson suggested that the increased SEBT scores are a sign of improvement in dynamic balance in the core stability training group.

In the same context, Aggarwal et al. [30] conducted a study to determine the effect of core stability training on dynamic balance and muscle performance in non-professional outdoor sports players. Three groups (core stability training, balance training and control) were evaluated for dynamic balance using the SEBT and for core stability using the pressure bio-feedback Sahrmann core stability test. The statistical analysis revealed that the core stability training group was improved in both dynamic balance and core stability.

The findings by Piegaro [31], who examined the effect of core stability training on balance, tested via the Biodex balance system and SEBT in healthy individuals, disagreed with those of Samson [29] and Aggarwal et al. [30], which revealed improvements in dynamic balance after core stability training. Piegaro's statistical analysis revealed that there was no significant difference between the pre- and post-test conditions, which was thought to be attributed to the short duration of the core program, which lasted for four weeks.

The last finding of the current study was the lack of significance in the active repositioning error between both groups for either the 30° or 60° trunk flexion positions in the pre-test condition. This insignificance may be attributed to the homogeneity of the sample. Yet, there were significant differences at each of the 30° and 60° trunk flexion positions in the post-test condition, with lower mean values recorded in the experimental group. This indicates improvement in trunk proprioception in the experimental group after conducting the 6-week core stability program. The improvement in trunk proprioception may be attributed to the therapeutic effects of the exercises.

Limitations

Our study has several limitations. Using the back attachment seat provided the participant with sensory feedback because it was intimately attached to his body. The findings cannot be generalised to the female population, as the study was limited to healthy male individuals. The fact that the isokinetic dynamometer does not measure trunk repositioning errors in the frontal or transverse planes also did not allow the researchers to evaluate trunk proprioception from all three planes of motion. Finally, the isokinetic system used in this study does not evaluate sense of movement (threshold to detect passive movement and direction of movement). So, the researchers could not evaluate all aspects of proprioception. Based on the abovementioned findings of the current study, the alternative hypothesis is accepted.

Conclusions

The decreased active trunk repositioning error with core stability training indicates improvement in trunk proprioception. Thus, core stability training would be beneficial if added to rehabilitation programs that aim to improve trunk proprioception.

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Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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