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Effect of Core Stability Exercises on Trunk Muscle Balance in Healthy Adult Individuals

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Abstract**—Background:** Core stability training has recently attracted attention for improving muscle balance and optimizing performance in healthy and unhealthy individuals. **Purpose:** This study investigated the effect of beginner's core stability exercises on trunk flexors'/extensors' peak torque ratio and trunk flexors' and extensors' peak torques. **Methods:** Thirty five healthy individuals participated in the study. They were randomly assigned to two groups; experimental "group I, n=20" and control "group II, n=15". Their mean age, weight and height were 20.7±2.4 vs. 20.3±0.61 years, 66.5±12.1 vs. 68.57±12.2 kg and 166.7±7.8 vs. 164.28 ±7.59 cm. for group I vs. group II. Data were collected using the Biodex Isokinetic system. The participants were tested twice; before and after a 6-week period during which group I performed a core stability training program. **Results:** The 2x2 Mixed Design ANOVA revealed that there were no significant differences (p>0.025) in the trunk flexors'/extensors' peak torque ratio between the pre-test and post-test conditions for either group. Moreover, there were no significant differences (p>0.025) in the trunk flexion/extension ratios between both groups at either condition. However, the 2x2 Mixed Design MANOVA revealed significant increases (p<0.025) in the trunk flexors' and extensors' peak torques in the post-test condition compared with the pre-test in group I with no significant differences (p>0.025) in group II. Moreover, there was a significant increase (p<0.025) in the trunk flexors' peak torque only in group I compared with group II in the post-test condition with no significant differences in the other conditions. **Interpretation/Conclusion:** The improvement in muscle performance indicated by the increase in the trunk flexors' and extensors' peak torques in the experimental group recommends including core stability training in the exercise programs that aim to improve muscle performance.

Keywords**—**Core Stability, Isokinetic, Trunk Muscles.

I. Introduction

THE spine is an inherently unstable structure as the osteoligamentus lumber spine buckles under small compressive loading. A critical role of the spine musculature is to stiffen the spine in all potential modes of instability. Active control of spinal stability is achieved through the regulation of force in the surrounding muscles. Trunk extensors, flexors, and lateral flexors provide spinal stability during every dynamic movement. So, there is an important need to have balanced muscular capacity by co-activation of agonistic and antagonistic muscles to maintain this spinal stability [1].

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Stability should be started only after achieving good mobility, because adequate muscle length and extensibility are crucial for proper joint function. Also required is a proper relationship between the prime movers, synergists, and stabilizers. Prime movers are the muscles that provide most of the force during a desired body movement. Stabilizers and synergists are muscles that assist in motion by means of controlling or neutralizing forces. Proper timing and coordinated effort of these muscles are important for spinal stability. Muscles that are used frequently can shorten and become dominant in a motor pattern. If a muscle predominates in a motor pattern, its antagonist may become inhibited and cause muscle imbalance [2].

Core stability describes the ability to control the position and movement of the central portion of the body to allow optimum production, transfer and control of force and motion to the terminal segments in the integrated activities. Core stability training targets the muscles deep within the trunk which are connected to the spine, pelvis and shoulders. This training assists in maintaining good posture and provides the foundation for all arm and leg movements [3].

Reference [4] first classified the muscles acting on the lumbosacral spine as either "local" or "global". Scientific modifications have been made to these initial classifications. The "local" musculature includes the transversus abdominis (TA), multifidi, internal obliques and quadratus lumborum muscles. These muscles have short muscle lengths, attach directly to the vertebrae, and are primarily responsible for generating sufficient force for segmental stability of the spine [5]. Recent research has advocated the TA and multifidi muscles as the primary stabilizers of the spine [6]. The "global" musculature is the rectus abdominis, lateral fibers of the external obliques, psoas major and erector spinae muscles [7]. These muscles are ideal for creating movement of the trunk and producing torque, because of their large moment arms and long levers as they are attached from the thorax to the pelvis [8].

"Exercising core musculature", in its essence, is more than "trunk strengthening". In fact, motor relearning of the inhibited muscles may be more important than strengthening. Progressive strengthening of the core muscles, particularly the lumbar extensors, may be unsafe to the back. In fact, many traditional back strengthening exercises may also be unsafe. For example, roman chair exercises or back extensor strengthening machines require at least torso mass as resistance, which is a load, often injurious to the lumbar spine [9]. Traditional sit-ups are also unsafe because they cause increased compressive loads on the lumbar spine [10]. In addition, all these traditional exercises are nonfunctional. Exercise must progress from training isolated muscles to training integrated systems of muscles to facilitate functional activity [11].

A considered contributing factor to chronic low back pain (CLBP) is poor control of trunk muscles during daily living activities. Core stability exercises are designed to address inter-segmental stability by facilitating neuromuscular control in the lumbar spine [12]. Previous EMG studies have reported changes in spinal muscle recruitment patterns after short and long-term specific core stability interventions in patients with CLBP. Studies on core stability programs have advocated efficient neuromuscular control for trunk stability and accurate trunk muscle recruitment [13].

Previously conducted randomized controlled trials have comprehensively reported the effects of core stability exercises versus conventional physiotherapy treatment regimes on pain characteristics, recurrence and disability scores in patients with CLBP [14]. Despite its clinical popularity, there is limited research work that shows the efficacy of specific spinal stabilization exercises on trunk muscle performance and balance. These types of exercises have strong theoretical appeal, yet more studies are still needed. Assessing trunk muscle balance may help with injury prevention, improving efficiency and performance [2] and augmenting lumbar stability prior to sudden loading [1]. So, the main purpose of this study was to investigate the effect of a beginner's core stability exercise program on trunk muscle balance which is indicated by the peak torque ratio between the trunk flexors and extensors. And consequently, the secondary purpose was to measure the individual trunk flexors' and extensors' peak torques.

II. Methods

A. Participants

Thirty five healthy college students from the Faculty of Physical Therapy, Cairo University participated in the study. They were randomly assigned into two groups; experimental (group I) and control (group II). Group I involved 20 participants (10 males & 10 females). Their age, height and weight ranged from 17 to 24 years, 170 to 185cm and 65 to 85 kg respectively. Group II involved 15 participants (6 males & 9 females). Their age, height and weight ranged from 17 to 24 years, 170 to 185cm and 65 to 85kg respectively.

To be included in the study, the participant should have had good abdominal muscle strength of grade four as assessed by manual muscle test. This was determined as having the ability to raise the head and trunk with abdominal muscles' contraction against manually applied moderate resistance. This is in addition to having normal flexibility of the lower back muscles as adequate muscle length and flexibility are important for proper joint function and movement efficiency [2]. Modified Schober test was used to assess the flexibility of the lumbar region. In this test, a mark was made at the level of the posterior iliac spine on the vertebral column i.e. approximately at the level of L5. The examiner then placed one finger 5cm below this mark and another finger at about 10cm above this mark. The participant was then instructed to touch his/her toes. If the increase in distance between both fingers on the participant's spine was more than 5cm, this indicated normal flexibility and hence the participant was included in the study. However, if the increase in the distance between both fingers was less than 5cm, then this indicated limitation in lumbar flexion [15] and the participant was excluded from the study. The exclusion criteria involved having history of previous back or abdominal surgery/injury or any previous episodes of low back pain one year prior to participating in the study [16]. Finally, the participants shouldn't have been involved in any previous strengthening or weight training programs.

B. Instrumentation

The Biodex System 3 Multijoint Testing and Rehabilitation isokinetic dynamometer (Biodex Medical System, Shirley, NY, USA) was used for assessing the isokinteic parameters. The system is being widely used in research, clinical testing and rehabilitation to objectively assess factors of muscle performance that would otherwise be difficult to obtain using manual testing techniques. It measures the internal torque produced by a group of muscles while the body segment is maintaining a constant angular velocity throughout a determined range of motion (ROM). In the current study, it was used for assessing the trunk flexors' and extensors' peak torques and the ratio between them. All variables were recorded in the concentric mode of muscle contraction at an angular velocity of 60º/sec throughout a 70-degree ROM. This velocity was used for evaluating the peak torque which is an indicator of the maximum muscle strength [17]-[19]. Trial-to-trial and day-to-day reliability and validity torque measurement of the Biodex system 3 were all previously established [20].

C. Procedures

Initially and prior to data collection, a brief orientation session about the nature of the study, its aims and the tests to be accomplished was provided to each participant. Then, informed consents were obtained from all participants. The participants were tested while sitting on the adjustable Biodex Isokinetic Dynamometer system seat. The sitting position was tested as it was reported to be the optimal resting position being more tolerated than the standing one. It allows greater ROM both in flexion and extension and hence is the preferred testing position [18], [21], [22].

To assure stability, a pelvic strap was applied and positioned as far as possible to press firmly, yet comfortably, against the superior aspect of the proximal thighs. Two curved anterior leg pads were secured to adjust the knee block position. In addition, a lumbar support pad was located against the lower lumbar spine. Hence, the pelvis was stabilized to minimize any contribution from the hip muscles [21]. Both thighs were then stabilized by two straps and the feet were held in place without being in contact with the floor. The participant sat erect with the head being stabilized neutrally against an adjustable head seat. Two anterior force application straps were aligned vertically and then connected to another horizontal strap which was aligned with the second inter-costal cartilage on the anterior chest wall when measuring the flexion torque. A posterior force application padded roller bar was placed on the posterior trunk just distal to the spine of the scapula when measuring the extension torque. To prevent any jerky movement from the arms, the participant was instructed to rest his/her crossed forearms on the anterior chest wall. In addition, the participant was asked to maintain a neutral head position throughout the testing procedure to avoid any contribution from the neck muscles [22].

The tested trunk range of motion was pre-set by asking the tested participant to flex his/her trunk 50° from the vertical position. The position was confirmed with a protractor situated at the side of the testing chair. The set limit button was then pressed to lock the ROM for this direction. The participant was then asked to extend his/her trunk 20° from the vertical position and the set limit button was pressed again to lock the ROM for this direction. Thus, the isokinetic testing procedures were conducted at a ROM of 70°.

Prior to the actual isokinetic testing procedures, each participant performed one practice series of three sub-maximal trunk extension and flexion repetitions to get accommodated with the specificity of the Biodex speed of movement and trunk ROM. This was done to minimize any practice effect during the actual testing procedure.

Three practice sessions were performed. Each practice session involved performing five consecutive trunk flexion-extension repetitions at the available trunk ROM (70°). The participant was instructed to push and pull as hard and as fast as possible. Verbal encouragement was given during the testing procedure to maximize the participant's voluntary effort. The mean trunk flexors' and extensors' peak torques and the mean trunk flexors/extensors ratio for the three practice sessions were recorded. Each participant of both groups was tested for the isokinetic parameters twice with a six-week period inbetween. Participants of group I performed the beginners' core stability program during this period, while those of group II didn't.

The participants started the training with a warm-up exercise followed by three main core stability exercises; curl-up, side-bridge, and bird dog. This is the most accepted program that includes components from the Saal and Saal [23] seminal dynamic lumbar stabilization efficacy study. The purpose of these fundamental core stability exercises is to gain stability, muscle balance and timing of the deep abdominal wall muscles.

The warm-up exercise involved a "Cat-Camel" motion of the spine (spine flexion-extension cycles). This exercise was done to reduce spine viscosity (internal resistance and friction) and floss the nerve roots as they exit at their respective lumbar levels. The "Cat-Camel" motion was intended as a motion exercise – not a stretch, so the emphasis was on motion rather than pushing at the end ranges of extension and flexion. Five to eight cycles were reported to be sufficient for reducing most viscous-frictional stresses [24].

After performing the warm-up exercise, each participant began to perform the beginner's core stability program. These basic exercises emphasize maintaining the lumbar spine in a neutral position which is the mid-range position between lumbar extension and flexion. All of these exercises are best done with light loads and high repetitions [25].

In the curl-up exercise, the participant's hands were placed under the lumbar spine to preserve a neutral spinal posture. The participant was instructed not to flatten the lumbar spine. He/she was asked to flex one knee with the other kept straight to lock the pelvis-lumbar spine and minimize the loss of the neutral lumbar posture. The curl-up exercise was performed by raising the head and upper shoulders off the floor. The motion took place in the thoracic region - not the lumbar or cervical ones. The exercise was made more challenging by raising the elbows off the floor. The participant was asked to perform abdominal bracing (activating the abdominal muscles), and then curling up against the brace. He/she was asked to hold the posture for 7-8 seconds while breathing deeply and not holding the breath. The isometric holds are recommended to be held not longer than 7-8 seconds because there is rapid loss of the available oxygen in the torso muscles contracting after these limits. Short relaxation of the muscles restores oxygen [24].

In the side-bridge exercise, the participant laid on his/her right side with the right shoulder abducted such that the upper arm was aligned vertical on the ground and the forearm rested on the floor. He/she was asked to raise the pelvis from the floor and hold it in a straight line "plank" position. The participant was asked to hold this posture on one side for 7-8 seconds. Attention was directed towards locking the pelvis to the rib cage via an abdominal brace while breathing deeply and not holding the breath [26]. Advanced variation from the side bridge exercise involved placing the upper leg-foot in front of the lower one to facilitate longitudinal rolling on the torso to challenge both the anterior and posterior portions of the abdominal wall. The participant supported himself/herself with his/her forearms rested on the floor, elbows bent 90° and toes rested on the floor. The participant maintained the spine in a neutral position, recruited the gluteal muscles and kept the head leveled with the floor. He/she was asked to hold this posture for 7-8 seconds, breathe normally throughout the exercise while maintaining the abdominal brace. No compensatory motions such as increased lumbar lordosis or sag were permitted. The side-bridge exercise targets the lateral and abdominal muscles (quadrates lumborum, and abdominal obliques) which are important for optimal stability. The beginner's level of exercise involved bridging the torso between the elbows and knees. Once this was mastered and tolerated, the challenge was increased by bridging using the elbows and feet [24].

In the bird-dog exercise, the participant positioned himself/herself on the hands and knees and braced the abdominal wall. While maintaining a mid-range/neutral curve of the lumbar spine, the participant raised the right arm and left leg (opposite upper and lower limbs) in line with the trunk. He/she was instructed to prevent any rocking of the pelvis or spine (excessive transverse or coronal plane motion). Again, he/she was asked to hold the posture for 7-8 seconds while breathing deeply and not holding the breath. The bird dog exercise challenges the back extensors of both the lumbar and thoracic regions. Only one half of these muscles are challenged at a time by lifting the alternate arm and leg. This reduces the spine load to about a half of that produced during traditional spine extension exercises such as roman chair extensions [24].

The beginner's core stability program used in this study was conducted thrice per week for 6 weeks. The program consisted of three phases, with each phase lasting for two consecutive weeks. The program was performed once, twice and thrice per day in the first, second and third phases respectively. The participant was asked to perform 15 repetitions for each exercise at each session [9]. The participant was instructed not to do the core stability exercises in the first hour of awakening because of the increased hydrostatic pressure in the discs during this time [27]. He/She was also instructed to maintain the bracing techniques throughout all the conducted exercises. Bracing the spine activates all the abdominal and back muscles at once. Cues like "squeeze your tummy, back, sides and front" and "tighten a large belt or corset around your abdomen" were used to help participants to perform this technique [25].

D. Data and Statistical Analysis

All statistical measures were performed through the statistical package for social sciences (SPSS) version 17 for windows. It was intended to compare between both groups "between-subject effect" for the trunk flexors/extensors peak torque ratio and the trunk flexors and extensors peak torques in each of the "pre-test" and "post-test" conditions. In addition, it was intended to compare between the "pre-test" and "post-test" conditions "within-subject effect" for these variables in each of the tested groups. Finally, it was intended to examine the interaction effect. In this study, three dependent variables and two independent variables with two levels each were tested. The dependent variables were the trunk flexors/extensors peak torque ratio, and the trunk flexors and extensors peak torques. The independent variables were the "tested group" with its two levels (group I and group II) and the "time factor" with its two levels (pre-test and post-test conditions).

Initially and as a pre-requisite for parametric analysis, data were screened for normality assumption through using Kolmogorov-Smirnov and Shapiro-Wilks normality tests, and testing for the presence of extreme scores and significant skewness and kurtosis. In addition, data were screened for homogeneity of variance assumption. Once data were found not to violate the normality and homogeneity of variance assumptions, parametric analysis was conducted. 2x2 Mixed Design ANOVA was conducted to compare the trunk flexors/extensors peak torque ratio between group I and II in each of the "pre-test" and "post-test" conditions and to compare between the "pre-test" and "post-test" conditions for the tested peak torque ratio in each of the tested groups. Also, 2x2 Mixed Design MANOVA was conducted to compare the isokinetic trunk flexors and extensors peak torques between group I and II in each of the "pre-test" and "post-test" conditions and to compare between the "pre-test" and 'post-test" conditions for the tested torques in each of the tested groups. As two statistical analysis tests (2X2 Mixed Design ANOVA and 2X2 Mixed Design MANOVA) were performed on the examined sample, the alpha level of significance was adjusted to 0.025 (0.05/2) for each of the two conducted statistical tests. Adjustment was performed to avoid alpha inflation and committing type I error [28], [29]. Two separate statistical tests were conducted as the first dependent variable (trunk flexors/extensors peak torque ratio) depends on the other two dependent variables (trunk flexors and extensors peak torques) in its calculation. This might violate the assumption of independence [30].

III. Results

Descriptive statistics indicated that the mean±SD age, weight, and height were 20.7±2.4 years, 66.5±12.1kg and 166.7±7.8cm respectively for group I and 20.3±0.61 years, 68.57±12.2kg and 164.28 ±7.59cm respectively for group II. As indicated by the unpaired t-tests, there were no significant differences ($p>0.05$) in the mean values of the age, weight, and height between both groups.

The 2x2 Mixed design ANOVA with the subsequent multiple pairwise comparison tests revealed that there were no significant differences ($p>0.025$) between both groups for the trunk flexors/extensors peak torque ratio in the "pre-test" and "post-test" conditions. Also, there were no significant differences ($p>0.025$) between the "pre-test" and "post-test" conditions in either group I or group II. Similarly, the 2x2 Mixed design MANOVA with the subsequent multiple pairwise comparison tests revealed that there were no significant differences ($p>0.025$) between both groups for the trunk flexors and extensors peak torques in the "pre-test" condition. However, there was a significant ($p=0.01$) increase in the trunk flexors peak torque in group I compared with group II in the "post-test" condition with no significant difference ($p>0.025$) for the trunk extensors peak torque.

TABLE I
DESCRIPTIVE STATISTICS FOR THE TRUNK FLEXORS/EXTENSORS PEAK TORQUE RATIO AND FLEXORS & EXTENSORS PEAK TORQUES IN THE EXPERIMENTAL AND CONTROL GROUPS IN THE PRE-TEST AND POST-TEST CONDITIONS

Dependent variables	Tested group	Time of testing	Mean ± SD	Tested group	Time of testing	Mean ± SD
Trunk flexors/extensors peak torque ratio	**Group I**	Pre-test	66.18 ±11.6	**Group II**	Pre-test	63.12 ±13.84
		Post-test	66.88 ±12.89		Post-test	66.85 ±15.43
Trunk flexors peak torque (Nm)		Pre-test	91.71± 24.85		Pre-test	95.01 ± 16.96
		Post-test	140.34 ± 36.95		Post-test	102.91 ± 7.1
Trunk extensors peak torque (Nm)		Pre-test	141.25 ± 36.53		Pre-test	153.54 ± 44.91
		Post-test	209.76 ± 59.16		Post-test	163.96 ± 50.07

Finally, there were significant increases in the trunk flexors (p=0.000) and extensors (p=0.08) peak torques in the "post-test" compared with the "pre-test" condition in group I with no significant differences (p>0.025) in group II. It is pointed out that all the subsequent multiple pairwise comparison tests were conducted with Bonferroni adjustment of the alpha level. Table I presents the mean±SD scores of the trunk flexors/extensors peak torque ratio and trunk flexors and extensors peak torques in group I and II in the “pre-test” and “post-test” conditions..

IV. DISCUSSION

Concerning the trunk flexors/extensors peak torque ratio which is an indicator of trunk muscle balance, the statistical analysis revealed that there was no significant difference in it between group I and II in either the “pre-test” or "post-test" conditions. The homogeneity of the tested sample, indicated by the insignificant homogeneity of variance test, might be the cause of insignificance in the "pre-test" condition. Whereas, the learning effect on the testing procedures might be the cause of insignificance in the "post-test" condition.

Comparing the trunk flexors/extensors peak torque ratio between the “pre-test” and “post-test” conditions in each of the tested groups, the statistical analysis revealed that there were no significant differences in it between both conditions in either group. Our finding is opposed by the significant difference reported by [31]. They conducted a study to investigate the effect of a 6-week specific lumbar stabilization training program on muscle performance in healthy individuals. The training program involved bridging, ball bridging, unilateral bridging, and bird-dog exercises. Surface electromyographic (EMG) data of the abdominal and back muscles were obtained both before and after training. Analysis of the abdominal/back relative muscle activity ratios revealed higher ratios after training. However, it should be pointed out that they used EMG in their study and they measured separated ratios between most of the local and global muscles in the trunk; rectus abominus/erector spinae, internal oblique/iliocostalis lumborum pars thoracis, and transversus abdominis/multifidus. Using EMG enabled them to pick up any trivial activity in the muscles as it is more sensitive than other measures.

The insignificant difference reported in our study might further be attributed to the fact that the studied sample involved healthy individuals. The trunk flexors/extensors peak torque ratio might have been misleading, as if both trunk flexors and extensors had approximate amount of improvement after performing the beginners’ core stability program, the ratio in the “post-test” condition would remain the same as in the “pre-test” condition. With the concept of the ratio being believed to be misleading in some cases, our interest was further extended to examining the variables that are used to calculate the ratio separately (trunk flexors and extensors peak torques in the current study). Hence, this dilemma might be resolved.

The statistical analysis revealed that there were significant increases in both the trunk flexors and extensors peak torques in the "post-test" condition compared with the “pre-test” one in group I, but not in group II. These findings indicate that there was a significant effect of the beginner’s core stability exercises on both trunk flexors and extensors peak torques. Furthermore, this proves that the trunk flexors/extensors peak torque ratio was misleading, as examining each of the trunk flexors and extensors peak torques separately showed significant improvement in group I that was absent in group II.

The significant increase in the trunk flexors and extensors in the "post-test" condition compared with the "pre-test" one is supported by that reported by [32]. He described a conditioning program (for the trunk and upper limbs) that aimed to prevent injury and improve force and power generation for golf players. He declared that the performed trunk exercises (curl up, bird dog, side bridge) had the ability to adequately strengthen all trunk muscles responsible for maintaining a strong and stable spine without exceeding cautious injury thresholds for compressive and shear loading.

Through using computerized tomography (CT), [33] also approved the effect of different training schedules on the cross-sectional area of the paravertebral muscles. They found that the cross-sectional area of the paravertebral muscles increased significantly after performing either a 10-week stabilization training combined with dynamic resistance training or a 10-week stabilization training combined with dynamic-static resistance training with no systematic differences in hypertrophy between the dynamic and dynamic-static strengthening training modes.

In the same context, the significant improvement in the trunk flexors and extensors peak torques with core stability exercises in group I is in accordance with that reported by [34]. They found that dynamic lumbar stabilization exercises performed for eight weeks significantly improved spinal mobility, trunk muscles' strength and endurance. The evaluating procedures involved assessing the fingertip-floor distance, lumbar Schober and modified lumbar Schober for spinal mobility, progressive isoinertial lifting for weight lifting capacity, and trunk muscle endurance tests.

Controversially, our finding of significant difference in the trunk flexors and extensors peak torques between the ‘pre-test” and “post-test” conditions in group I is opposed by the non-significance reported by [35]. They reported that there were no significant changes in the myoelectric activities of the trunk flexors and extensors between both the experimental and control groups using the Cybex strength measurements (isokinetic testing). It should be noted that they used only two types of core exercises (curl up and back extensions), and the program was performed for five weeks. But in our study, we used McGill program that consisted of four main exercises (curl up, side bridge, prone bridge and bird dog exercises), and this program was performed for six weeks.

Similar to the trunk flexors/extensors peak torque ratio, there were no significant differences in both the trunk flexors and extensors peak torques between group I and II in the "pre-test" condition. Again, this may be attributed to the homogeneity of the tested sample. However, there was a significant difference in both torques between both groups in the “post-test” condition. This might be attributed to the number of exercises that addressed the abdominal muscles at the expense of the back ones. In the beginners’ core stability program that was tested in the current study, the researchers used four exercises; curl-up, side-bridge, prone-bridge, and bird-dog exercises. Three of which (curl-up, side-bridge and prone-bridge exercises) were acting mainly on the abdominal muscles, while the bird-dog exercise only was acting mainly on the back muscles.

This finding is supported by the findings reported by [31]. In their study, they examined the effect of a specific lumbar stabilization training program on muscle performance in healthy individuals. Analysis of the relative muscle activity levels tested by EMG showed high activity of the local (segmental-stabilizing) abdominal muscles that was not reported for the local back muscles. Minimal changes in global (torque-producing) muscle activity also occurred. Despite that they studied the local and global muscle systems of the trunk muscles separately, they revealed that the abdominal muscles (local and global) showed higher activities than the back muscles (local and global). This difference might also be attributed to the high torque producing capabilities of the abdominals (greater lever arm and cross-section).

V. Conclusion

The conducted core stability exercise program was capable of improving the trunk flexors’ strength much more than that of the trunk extensors without affecting trunk flexors/extensors muscle balance.

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References

[1] J. Cholewicki, A. P. D. Simons, and A. Radebold, "Effects of external trunk loads on lumbar spine stability," *J. Biomech*, vol. 33, no. 11, pp. 1377-1385, Nov. 2000.

[2] M. Fredericson, and T. Moore, "Muscular balance, core stability, and injury prevention for middle- and long-distance runners," *Phys. Med. Rehabil. Clin. N. Am*, vol. 16, no. 3, pp. 669-689, Aug. 2005.

[3] A. E. Hibbs, K. G. Thompson, D. French, A. Wrigley, and I. Spears, "Optimizing performance by improving core stability and core strength," *Sport Med*, vol. 38, no. 12, pp. 995-1008, 2008.

[4] A. Bergmark, "Stability of the lumbar spine. A study in mechanical engineering," *Acta Orthop. Scand. Suppl*, vol. 230, no. 60, pp. 20-29, 1989.

[5] M. E. Stanford, "Effectiveness of specific lumbar stabilization exercises: A single case study," *J. Manual Manip. Ther*, vol. 10, no. 1, pp. 40-46, Jan. 2002.

[6] P. B. O’Sullivan, G. D. Phyty, L. T. Twomey, and G. T. Allison, "Evaluation of specific stabilizing exercise in the treatment of chronic low back pain with radiologic diagnosis of spondylolysis or spondylolisthesis," *Spine*, vol. 22, no. 24, pp. 2959-2967, Dec. 1997.

[7] C. M. Norris, "Functional load abdominal training: part 1," *Phys. Ther. Sport*, vol. 2, no. 1, pp. 29-39, 2001.

[8] P. Hodges, A. Kaigle Holm, S. Holm, L. Ekstrom, A. Cresswell, T. Hansson, and A. Thorstensson, "Intervertebral stiffness of the spine is increased by evoked contraction of transversus abdominus and the diaphragm: in vivo porcine studies," *Spine*, vol. 28, no. 23, pp. 2594-2601, Dec. 2003.

[9] S. M. McGill, *Low Back Disorders: Evidence based prevention and rehabilitation*, 2nd ed. Champaign, Illinois, USA: Human Kinetics, 2002, pp. 216-222.

[10] D. Juker, S. McGill, P. Kropf, and T. Steffen, "Quantitative intramuscular myoelectric activity of lumbar portions of psoas and the abdominal wall during a wide variety of tasks," *Med. Sci. Sport Exerc*, vol. 30, no. 2, pp. 301- 310, Feb. 1998.

[11] H. F. Farfan, J. W. Cossette, and G. H. Robertson, "The effects of torsion on the lumbar intervertebral joints: the role of torsion in the production of disc degeneration," *J. Bone Joint Surg. Am*, vol. 52, no. 3, pp. 468-497, Apr. 1970.

[12] R. Muthukrishnan, S. D. Shenoy, S. S. Jaspal, S. Nellikunja, and S. Fernandes, "The differential effects of core stabilization exercise regime and conventional physiotherapy regime on postural control parameters during perturbation in patients with movement and control impairment chronic low back pain," *Sports Med. Arthrosc. Rehabil. Ther. Tech*nol, vol. 2, pp. 13, May 2010.

[13] B. Zazulak, J. Cholewicki, and N. P. Reeves, "Neuromuscular control of trunk stability: clinical implications for sports injury prevention," *J. Am. Acad. Orthop. Surg*, vol. 16, no. 9, pp. 497-505, Sep. 2008.

[14] K. P. Barr, M. Griggs, and T. Cadby, "Lumbar Stabilization: a review of core concepts and current literature, part 2," *Am. J. Phys. Med. Rehabil*, vol. 86, no. 1, pp. 72-80, Jan. 2007.

[15] I. F. Macrae, and V. Wright, "Measurement of back movement," *Ann. Rheum. Dis*, vol. 28, no. 6, pp. 584-589, Nov. 1969.

[16] J. D. Mills, J. E. Taunton, and W. A. Mills, "The effect of a 10-week training regimen on lumbo-pelvic stability and athletic performance in female athletes: A randomized-controlled trial," *Phys. Ther. Sport*, vol. 6, pp. 60-66, Feb. 2005.

[17] M. Cale-Benzoor, M. S. Albert, A. Grodin, and L. D. Woodruff, "Isokinetic trunk muscle performance characteristics of classical ballet dancers," *J. Orthop. Sports Phys. Ther*, vol. 15, no. 2, pp. 99-106, 1992.

[18] Z. Dvir, *Isokinetics: Muscle testing, interpretation and clinical applications*, 2nd ed. New York, USA: Churchill Livingstone, 1995, pp. 25-48 145-169.

[19] C. A. Williams, and M. Singh, "Dynamic trunk strength of Canadian football players, soccer players and middle to long distance runners," *J. Orthop. Sports Phys. Ther*, vol. 25, no. 4, pp. 271-276, Apr. 1997.

[20] J. M. Drouin, T. C. Valovich-mcLeod, S. J. Shultz, B. M. Gansneder, and D. H. Perrin, "Reliability and validity of the Biodex system 3 pro isokinetic dynamometer velocity, torque and position measurements," *Eur. J. Appl. Physiol*, vol. 91, no. 1, pp. 22–29, Jan. 2004.

[21] Z. Dvir, and J. Keating, "Reproducibility and validity of a new test protocol for measuring isokinetic trunk extension strength," *Clin. Biomech*. vol. 16, no. 7, pp. 627-630, Aug. 2001.

[22] O. Shirado, T. Ito, K. Kaneda, and T. E. Strax, "Flexion-relaxation phenomenon in the back muscles. A comparative study between healthy

subjects and patients with chronic low back pain," *Am. J. Phys. Med. Rehabil*, vol. 74, no. 2, pp. 139- 44, Mar-Apr. 1995.

[23] J. A. Saal, and J. S. Saal, "Non-operative treatment of herniated lumbar intervertebral disc with radiculopathy. An outcome study," *Spine*, vol. 14, no. 4, pp. 431-437, Apr. 1989.

[24] S. M. McGill, *Low back disorders: evidence-based prevention and rehabilitation*, 2nd ed. Champaign, IL, USA: Human Kinetics, 2007, pp. 221-229.

[25] S. M. McGill, *Ultimate back fitness and performance*, 3rd ed. Waterloo, Canada: Wabuno Publishers, 2004.

[26] S. M. McGill, "Low back stability: from formal description to issues for performance and rehabilitation," *Exerc. Sport Sci. Rev*, vol. 29, no. 1, pp. 26-31, 2001.

[27] M. A. Adams, P. Dolan, and W. C. Hutton, "Diurnal variations in the stresses on the lumbar spine," *Spine*, vol. 12, no. 2, pp. 130-137, Mar. 1987.

[28] B. S. Holland, and M. D. Copenhaver, "Improved bonferroni-type multiple testing procedures," *Psychol.Bull*, vol. 104, no. 1, pp. 145-149, 1988.

[29] M. A. Seaman, K. R. Levin, and R. C. Serlin, "New developments in pairwise multiple comparisons: Some powerful and practicable procedures," *Psychol. Bull*, vol. 110, pp. 577-586, 1991.

[30] A. Field, Discovering statistics using SPSS, 2nd ed.London: SAGE Publications, 2005.

[31] V. K. Stevens, K. G. Bouche, N. N. Mahieu, P. L. Coorevits, G. G. Vanderstraeten, and L. A. Danneels, "Trunk muscle activity in healthy subjects during bridging stabilization exercises," *BMC Musculoskelet. Disord*, vol. 7, pp. 75, Sep. 2006.

[32] G. J. Lehman, "Resistance training for performance and injury prevention in golf," *J. Can. Chiropr. Assoc*, vol. 50, no. 1, pp. 27-42, Mar. 2006.

[33] L. A. Danneels, A. M. Cools, G. G. Vanderstraeten, D. C. Cambier, E. E. Witvrouw , J. Bourgois, and H. J. de Cuyper, "The effects of three different training modalities on the cross-sectional area of the para-vertebral muscles," *Scand. J. Med. Sci. Sports*, vol. 11, no. 6, pp. 335-341, Dec. 2001.

[34] F. Yilmaz, A. Yilmaz, F. Merdol, D. Parlar, F. Sahin, and B. Kuran, "Efficacy of dynamic lumbar stabilization exercises in lumbar microdiscectomy," *J. Rehabil. Med*, vol. 35, no. 4, pp. 163-167, Jul. 2003.

[35] L. M. Cosio-Lima, K. L. Reynolds, C. Winter, V. Paolone, and M. T. Jones, "Effects of physioball and conventional floor exercises on early phase adaptations in back and abdominal core stability and balance in women," *J. Strength Cond. Res*, vol. 17, no. 4, pp. 721-725, Nov. 2003.