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Original Research

Analysis of Core Endurance and, Static and Dynamic Balance Relationship in Adolescent Athletes

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Abstract

Objectives: Core muscles are key components for improving sports performance and preventing injury. In addition, balance is known to have a significant effect on sports performance. This study focuses on how the static endurance of core muscles interact with the static and dynamic balance in adolescent athletes.
Materials and Methods: 49 athletes [water polo (n=13), fencing (n=8) and swimming (n=28)] have participated in this study. Mc-Gill core endurance tests were used to evaluate the core muscles endurance. And, HUBER-360 device was used to evaluate the static and dynamic balance skills. Once the measurements were completed, Pearson or Spearman correlation test was used to assess the relationship between the collected data.
Results: The results have revealed a moderately negative correlation between trunk flexion test and double-foot static balance test's eyes open area value (r =-0.427; p=0.002); and a weak negative correlation among the left bridge endurance test and the eyes open test and the left foot static balance test' area values (r=-0.306/-0.347; p<0.05). No relationship was observed between the core muscles endurance and the dynamic balance skills (p>0.05).
Conclusion: Incorporating anterior core muscles endurance exercises into training regimens may be beneficial in improving static balance performance in adolescent athletes. However, it appears that the endurance of lateral and posterior trunk muscles is not associated with static and dynamic balance.

Keywords: *muscle strength, torso, balance.*

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Introduction

Balance is a key factor in the coordination of motor responses in human body with the contribution of visual, vestibular and somatosensory inputs (Egesoy et al., 2018). Balance is crucial for performance in almost all sports branches (Kiers et al, 2013).

Core stabilization is defined as the ability to control the position and movements of the torso against pelvis to generate optimum strength and to control of the extremities during physical activity (Kibler et al., 2006). The core muscles operate similar to a long-armed fixed cylinder within which the muscles can stabilize particularly during rotation (Kibler et al., 2006). The core (lumbopelvic-hip complex) is a three-dimensional structure with its boundaries defined by muscles. It is comprised of the diaphragm superiorly; the pelvic floor and hip girdle muscles inferiorly; the abdominal and oblique muscles antero-laterally; and the paraspinal and gluteal muscles posteriorly (Akuthota and Nadler, 2004).

Gluteal muscles helps to stabilize the torso on the foot and to also generate foot strength during action and are related to lower and upper extremity muscle strength and, improving the endurance of core muscles helps to increase the activity of the gluteus medius muscle (Chan et al., 2013; Kocahan and Akınoğlu, 2018). An athlete with a good core stabilization will be able to sustain more loads and also demonstrate a more efficient and better display of technical movements (Akuthota and Nadler, 2004; Cohen, 2013; Erdem and Akyüz, 2017). Also, the knee and hip kinematics in the frontal plane are more developed in athletes who activate the core region in one-leg stance. Similarly, a decrease in core stabilization negatively affected the one-leg stance (Shirey et al, 2012; Cinar-Medeni et al, 2015; Lacey and Donne 2019).

Good balance skills may help to reduce injury risks in athletes and to provide a better reflection of the sensorimotor control mechanisms required in sports-specific activities on performance (Cinar-Medeni et al, 2015). Therefore, it is important to assess balance skills by determining the factors associated with it (Shirey et al, 2012; Cinar-Medeni et al, 2015; Lacey and Donne 2019). A few other studies have shown that balance skill is associated with active arm swing, core stabilization, and torso muscle endurance (Hu et al., 2012; Eylen et al., 2017; Mandal et al., 2017). Furthermore, the hip muscles also contribute to the balance ability by helping the posture on the lower extremities (Filipa et al., 2010). Knowing that the core muscles also include the hip muscles, the gluteus medius muscle is active in the one-leg stance phase. Thus, the strength training of the gluteus medius muscle increases balance and postural control. Kim et al. and Leavey et al. were of the opinion that there should be a positive relationship between the endurance of the core muscles and improving balance skills (Kim et al., 2009; Leavey et al, 2010).

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While many studies suggested that there is a relationship between the endurance of the core muscles and the static balance skill, there are limited studies that investigated the relationship between dynamic balance and core muscles in athletes. In one of these limited studies, Gordon et al. had a contrasting view, stating that the relationship between core muscle strength and balance was not clear and more research was needed to reach a conclusion (Gordon et al., 2013). In our study, it was hypothesized that there would be a relationship between the endurance of anterior, posterior and lateral core muscles and static and dynamic balance skills in adolescent athletes. Our study focuses on the relationship between the endurance of the anterior, posterior and lateral core muscles and, the static and dynamic balance skills in adolescent athletes.

Material and Method

The data of this study were obtained from the athletes who applied to the athlete education and health research center between August 2019 and December 2019 for health and performance measurements and volunteered to participate in the study. 49 athletes [water polo (n=13), fencing (n=8) and swimming (n=28)] were selected for our study. Following the interviews related to the history of illness and injury of these athletes, a sports medicine specialist has conducted physical examinations on each participant. The inclusion criteria was set as the following; being a licensed athlete in the field, being member of a national team and volunteering to participate in our study. On the other hand, the exclusion criteria was; having had low back pain, having undergone spine or knee surgery, having suffered an ankle sprain within the last 6 months, having suffered a lower back and/or lower extremity injury, having a biomechanical malalignment in the observational postural analysis, and being an amateur athlete. In the beginning, 33 of the 82 applicants were excluded from the study as they were not able to meet the criteria. Among the qualified 49 athletes, 11 are female and 38 are male.

Prior to the study, each athlete was informed about the details and asked to sign a consent form (parental consent was obtained for the ones younger than 18) confirming their agreement to participate. Authorization from the University’s Social and Humanities Ethics Committee (19.04.2019-42/186) was also obtained., The study was conducted in accordance with the 2008 Principles of the Declaration of Helsinki.

Study Protocol

Human Body Equilibrium 360 (HUBER 360®) device was used to measure the balance skills, whereas, the endurance of the core muscles was evaluated by the Mc-Gill core endurance tests. Measurements were made followed by a questionnaire on the athletes' injury history and

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with a physical examination conducted by a sports physician. The selected athletes as part of the inclusion criteria were initially evaluated using the HUBER-360 device to prevent possible fatigue as a result of the core endurance test. Following the balance skill measurements, Mc-Gill core endurance tests were performed, which included torso flexion, torso extension and, right and left lateral bridge tests, respectively. The same order was followed to apply these tests to all athletes. The athletes were asked not to perform any training the day before the tests.

Balance Ability Measurement

The following parameters were used to perform the balance ability measurements: stability on two legs, stability on one leg, and stability limits of the HUBER 360® device. These tests had to be performed barefoot without socks. For the stability assessment tests, the eyes were open then closed for 50 second intervals while in an upright position. For this test, the evaluations included the extent to which the athlete can maintain her/his position, her/his distance from the center, the length and area extended during the center change and the speed parameters in these changes. For the balance on one foot; the measurements were performed by placing the left and then the right foot at a predetermined point, and using the suspended position with one free leg's knee and hip flexed. The athlete was asked to stand on one leg for 30 seconds without support in order to evaluate the length of the center of gravity projection during the center change and the area covered by this length. An increase in the extended length and the covered area values in the two-leg and single-leg stability tests indicates a poor static balance skill. For the dynamic balance test, the measurements were related to the distance the athlete could reach and the total area covered within this distance as a result of the athlete's maximum stretches to the front, front-left, left, left-back, back, back-right, right and right-front sides. The dynamic balance test and the functional reach test are similar (Duncan et al., 1990). For the dynamic balance test, the increase in the total covered area indicates a better dynamic balance skill (Akınoğlu et al., 2018).

Static Endurance Measurement of Core Muscles

The static endurance of core muscles which included trunk flexion test, trunk extension test and, right and left lateral bridge tests, were measured using the McGill Core Endurance Test, which has been shown to be reliable in measuring normal endurance ratios between torso flexion, extension, and lateral bending exercises especially in young subjects (McGill et al., 1999). The measurements were performed by using a stopwatch. Results were recorded in seconds. The increase in the duration of these tests positively affected the endurance of the core muscles. The tests were stopped when the test position was disturbed or the participant was not able to continue the test. The balance of strength between the core muscles enables the core

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muscles to take a better role in stabilization. In this context, if the right and left core muscles are of similar strength, approaching 100%; Similarly, the fact that the strengths of the anterior and posterior core muscles are similar, close to 79%, suggest that core stabilization is good (McGill and Childs, 1999; McGill, 2005; Plisky et al., 2009; Leavey et al., 2010).

Trunk Flexion Test

The torso flexion test was performed to assess the static endurance of the anterior group core muscles. For this test, the athletes were positioned with the hips and knees in 90 degree flexion, the torso in 60 degrees flexion and the arms crossed on the torso. The attending physiotherapist in charge of the evaluation supported the athlete's feet and fixed them on the ground. The athlete was asked to stay still without disturbing her/his torso position. The tests were stopped when the torso position deteriorated or the athlete was not able to continue the test (McGill and Childs, 1999; Leavey et al., 2010).

Torso Extension Test

Static endurance of the posterior core muscles was evaluated by the Torso Extension Test. This test was performed with the athletes laying in the prone position with their pelvis, hips and knees on the bed and the torso extending outside of the bed from the anterior superior spina iliaca level. The attending physiotherapist helped to stabilize the lower extremities of the athletes, while they maintain the horizontal position of their torso parallel to the floor with the arms crossed on the torso. The test was stopped when the torso position deteriorated or the athlete was not able to continue the test (McGill and Childs, 1999; Leavey et al., 2010).

Lateral Bridge Test

Static endurance of the right side core muscles was evaluated by the Right Lateral Bridge Test and, Static endurance of the left side core muscles was evaluated by the Left Lateral Bridge Test. To prepare for these tests, the athletes were asked to lay down on their side with the arm on the tested side perpendicular to the floor, the elbow flexed 90 degrees while the forearm on the bed, the upper extremity crossed on the torso, the lower extremities in extension, and the upper foot in front of the lower foot. Athletes were asked to lift their bodies on their forearms and toes while maintaining the position. The test was stopped when the body was not able to maintain a straight position and the hip fell towards the bed, or when the participant was not able to continue the test (McGill and Childs, 1999; Leavey et al., 2010).

Statistical Analysis

G*Power 3.1.9.7 program was used to calculate the smallest sample size required for analysis in groups. Since the relationship between the variables will be analyzed, the correlation (correlation: point biserial model) part of the G*Power program was used. When the power of

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the test was 80%, the margin of error was 5%, and the effect size was 0.40, the total sample size was 44. For this reason, it was decided to make the necessary sample size with 10% more athletes in the study and to reach a total of 49 athletes.

SPSS 20.0 software was used to perform the statistical anaylsis of the collected data from the tests. Analytical methods (Kolomogrov-Smirnov) were used to check if the variables fell within normal distribution or not. The balance analysis results showed that the parameters related to eyes open area, eyes open speed, eyes closed distance, eyes closed area, eyes closed speed and right foot area were outside the normal distribution, while other balance and core endurance parameters were within normal distribution. For the comparison of the variables; Pearson correlation analysis was used for normally distributed numerical variables while Spearman correlation analysis for at least one of the non-normally distributed ones. Statistical error was defined as $p<0.05$.

Results

The details of the participating 49 athletes comprised of 11 female (22.4%) and 38 male (77.6%) are shown in Table 1 below.

Table 1: Demographic Information of Athletes

	X±SD	**Median (%25-75)**
Age (years)	16±1	16 (15-17)
Length (m)	1.74±0.09	1.73 (1.69-1.78)
Body weight (kg)	67±11	65 (60-74)
Body mass index (kg/m^2)	21.96±1.96	21.76 (20.63-23.41)
Gender	Female n=11 (22.4%); Male n=38 (77.6%)	
Sports branch	Water polo n=13 (26.5%) Fencing n=8 (16.3%) Swimming n=28 (57.1%)	

X±SD: Mean ± Standard Deviation

Table 2 shows the average and standard deviation of parameters related to the static endurance of the core muscles on athletes including the ratio between the core muscles, as well as the parameters of their static and dynamic balance skills.

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Table 2: Athletes' Core Endurance and Static and Dynamic Balance Skills Data

		X±SD	**Median (25-75 IQR)**
Core Endurance	Trunk Flexion (sec)	60±15	63 (52-71)
	Trunk Extension (sec)	83±19	81 (71-96)
	Right Lateral Bridge (sec)	60±22	59 (47-73)
	Left Lateral Bridge (sec)	59±19	58 (47-74)
	Trunk Flexion/Trunk Extension Ratio (%)	74.93±20.32	74.23 (61.36-86.30)
	Right Lateral Bridge/Left Lateral Bridge Ratio (%)	101.57±20.1	100.00 (90.91-107.55)
Stability on two leg	Eyes Open Distance (mm)	680.96±116.99	658.99 (598.00-747.00)
	Eyes Open Area (mm²)	342.78±166.61	317.77 (215.73-415.34)
	Eyes Open Speed (mm/s)	13.72±2.42	13.00 (12.00-15.00)
	Eyes Closed Distance (mm)	1067.61±349.056	994.00 (81600-1173.00)
	Eyes Closed Area (mm²)	670.85±437.0213	535.00 (393.00-749.71)
	Eyes Closed Speed (mm/s)	21.34±6.96	20.00 (16.00-23.07)
Stability on one leg	Left Foot Distance (mm)	1607.04±358.74	1635.00 (1333.00-1820.00)
	Right Foot Distance (mm)	1551.46±331.97	1472.92 (1337.00-1821.00)
	Left Foot Area (mm²)	866.72±343.96	864.00 (652.00-1081.00)
	Right Foot Area (mm²)	921.15±551.0364	100.00 (90.91-107.55)
Dynamic Balance	Stability Area (mm²)	66302.29±14442.43	69684.00 (56124.00-76880.00)

X±SD: Mean ± Standard Deviation

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The analysis of the relationship between the static endurance of the core muscles and, the static balance skills of two leg and single leg showed that trunk flexion test and bipedal static balance test were moderately negatively correlated with eyes open area value (r=-0.427; p=0.002), and as the endurance of anterior group core muscles increased bipedal static balance skills have improved. Moreover, the left lateral bridge and the two leg static balance tests were negatively correlated with the eyes open area value and the area value of the left foot static balance test (respectively r=-0.306/-0.347; p<0.05). No correlation was found in other parameters of static balance. And, as the endurance of the left lateral group core muscles increased, the static balance skills of two leg and left leg have improved (Table 3).

No relationship was found between the static endurance of the core muscles of the participants and their dynamic balance skills (Table 3).

Table 3

The Relationship Between Athletes' Core Endurance and, Static and Dynamic Balance Skills

			Trunk Flexion (sec)	**Trunk Extension (sec)**	**Right Lateral Bridge (sec)**	**Left Lateral Bridge (sec)**
Stability on two leg	Eyes Open Distance (mm)	r	0.163	-0.084	0.069	0.032
		p	0.263	0.564	0.635	0.828
	Eyes Open Area (mm²)	r	**-0.427****	-0.181	-0.267	**-0.306***
		p	**0.002¥**	0.212¥	0.064¥	**0.032¥**
	Eyes Open Speed (mm/s)	r	0.126	-0.181	-0.089	-0.07
		p	0.389¥	0.214¥	0.543¥	0.633¥
	Eyes Closed Distance (mm)	r	0.065	-0.067	0.012	0.036
		p	0.657¥	0.645¥	0.934¥	0.808¥
	Eyes Closed Area (mm²)	r	-0.22	-0.134	-0.161	-0.135
		p	0.129¥	0.360¥	0.268¥	0.356¥
	Eyes Closed Speed (mm/s)	r	0,055	-0.068	-0.001	0.026
		p	0.705¥	0.643¥	0.996¥	0.859¥
Stability on one leg	Left Foot Distance (mm)	r	0.133	0.037	-0.013	-0.029
		p	0.361	0.8	0.928	0.844
	Right Foot Distance (mm)	r	0.078	0.05	0.105	0.168
		p	0.592	0.733	0.472	0.247
	Left Foot Area (mm²)	r	-0.1	-0.133	-0.267	**-0.347***
		p	0.495	0.361	0.064	**0.015**
	Right Foot Area (mm²)	r	-0.103	-0.006	-0.125	-0.058
		p	0.482¥	0.968¥	0.392	0.69¥
Dynamic Balance	Stability Area (mm²)	r	-0.229	-0.191	-0.065	-0.138
		p	0.114	0.188	0.655	0.345

¥:Spearman correlation analysis, Others: Pearson correlation analysis

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Discussion and Conclusion

This study focuses on how the static endurance of core muscles interact with the static and dynamic balance in adolescent athletes. As a result it was determined that as the static endurance of the anterior core muscles increased, the two leg static balance skill have also increased in parallel. In addition, as the static endurance of the left side core muscles increased, the static balance skills of two leg and left leg have also increased. But it was determined that there is not any relationship between the static endurance of the core muscles and the dynamic balance ability.

The level of physical activity is known to affect balance (Ambegaonkar et al., 2014; Bednarczuk et al., 2019). Studies proved that balance skills are different in people with sedentary or active lifestyle, and that balance skills of athletes are better than those of non-athletes (Gökdemir et al., 2012; Thompson et al., 2017). Consequently, balance skills of non-athletes were observed to have increased in parallel to their increased level of physical activity (Gonçalves et al., 2019). Studies show that as the intensity of sports increase in athletes, the better their balance skills become. And, this has indirectly helped to minimize the risk of sports injuries (Jadczak et al., 2019). Muscle strength is another physical fitness parameter that is affected by physical activity level. Studies show that the muscle strength is directly proportional with the level of physical activity. As the physical activity level increases, muscle strength is also expected to increase (Kuh et al., 2005; Trans et al., 2009). At the same time, it was noted that muscle strength and balance skills varies among individuals who do sports and those who do not, and that doing active sports increases muscle strength and balance skills (Sadeghi et al., 2013; Jadczak et al., 2019). Because of this amateur athletes were not included in our study after taking into account the above findings.

Sports activities increase muscle strength and balance skills and vice versa, increase in muscle strength and balance improves sports performance (Sadeghi et al., 2013; Watson et al., 2017; Jadczak et al., 2019). Core muscles are one of the most crucial elements that affect sports performance and are directly related to sports injuries. Studies have shown that core training in addition to normal training programs increases balance skills (Ozmen and Aydogmus, 2016; Erdem and Akyüz, 2017; Watson et al., 2017). It was also suggested that lumbar spine control increases with core stability training, and in turn increases the balance ability (Eylen et al., 2017). The core muscles are expected to be related to each other as they allow the distribution of strength from the center to the periphery including the muscles involved in balance (Akuthota and Nadler 2004; Kibler, 2006; Hibbs et al., 2008; Rivera, 2016). Studies have shown that there is relationship between muscle strength and balance: showing the static balance skill increases

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as the endurance of the core muscles increases (Mandal et al., 2017). Barati et al., in their study to examine the relationship between trunk muscle endurance and static balance on 50 male students determined that there was a positive relationship between the endurance of trunk flexor, extensor and lateral muscles and, static balance parameters (Barati et al., 2013). In our study, static balance skills of the athletes increased as some of the static endurance of their core muscles increased.

Ambegaonkar et al., shows that athletes with good hip muscle strength had better star balance test skills (Ambegaonkar et al., 2014). Moreover, it was observed that there was a positive correlation between the endurance of the left side core muscles and the right side posteromedial values of the star balance test. This proved that lateral core muscle training programs could improve the posteromedial balance (Ambegaonkar et al., 2014). The results of our study showed that static balance skills of both feet and left foot static balance increased as the static endurance of the left side core muscles increased. This may be related to the fact that the athletes we included in the study did water polo, fencing and swimming and were professional athletes at the national team level.

The gluteus medius muscle is the most important muscle in maintaining balance (Jeong et al., 2014). The fact that the core muscles also included the gluteus medius muscle and that it takes an active role during single leg stance from standing, stepping and walking phases, forms the basis of its relationship with static and dynamic balance (Kim et al., 2009; Jeong et al., 2014). One study found that dancers who received 9-week core stabilization training gained an increase in their static and dynamic balance skills at the end of the training, and this result was interpreted based on the relationship between core muscles and balance (Watson et al., 2017). The results of our study are partially in parallel with the current literature, showing that there is a relationship between the static endurance of the core muscles of the athletes and their static balance skills. However, we did not find any relationship between the static endurance of the core muscles and their dynamic balance ability. When we think about our athletes core stability strength ratio was close to the normal values, this could be due to the fact that we evaluated the dynamic balance with the functional reach test by using HUBER divice in our study, which may not have been ideal for evaluating dynamic balance tests.

Our study came to a conclusion that as the static endurance of the anterior and left side core muscles increased, the static balance skill also increased. However, no relationship was established between the static endurance of the posterior and right side core muscles and the static balance ability, and between the static endurance of all core muscles and the dynamic balance ability. We think that incoporating anterior core muscles endurance exercises into

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training regimens in adolescent athletes may have positive effect, improving static balance performace. However, it seems to indicate that endurance of posterior and right lateral trunk muscles does not correspond with static and dynamic balance.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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