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# The Relationship between Postural Stability, Performance and Trunk Muscle Endurance in Adult Female Athletes

**Çağatay Müslüm GÖKDOĞAN[1], Nevin A. GÜZEL[1], Nihan KAFA[1], Serdar ELER[2], Yaprak Arzu ÖZDEMİR[2]**
[1]Gazi University, Faculty of Health Sciences, Department of Physical Therapy and Rehabilitation, Ankara, TURKEY
[2] Gazi University, Faculty of Sports Sciences, Ankara, TURKEY
**Email:** cagataygokdogan@gmail.com

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## Abstract

Background: Postural stability is considered as the most important component of athletic performance as it occurs in almost all movement types. This study aims to identify the relationship between the postural stability, performance and trunk muscle endurance of female athletes in different branches of sports.

Materials and Methods: 45 female athletes participated in the study. Trunk muscle endurance of the participants was measured with the McGill core endurance tests and the prone bridge test. Postural stability of the participants was evaluated using Biodex Biosway Balance System, sportive performance was tested with the vertical jump and the hexagonal obstacle test.

Results: A negative relationship was observed between the prone bridge test and right postural stability overall index, between the prone bridge test and right anterior - posterior postural stability index, and also between the prone bridge test and left medial - lateral postural stability index parameters. No relationship was observed between sportive performance tests and postural stability, and between trunk muscle endurance and sportive performance tests.

Discussions: It can be said that in female athletes in order to have a better postural stability, trunk muscle endurance should be increased as postural stability and trunk muscle endurance are related with each other.

**Keywords:** Postural Balance, Performance, Trunk Muscle Endurance

## Introduction

Sport is an activity that involves performing high level activities and maintaining static and dynamic balance simultaneously during training or competition (Hugel, Cadopi, Kohler, & Perrin, 1999; Perrot, Deviterne, & Perrin, 1998). Athletes need to have good physical fitness and some performance factors that need to be improved in order to acquire some sports-related movements (Sayers, 2000). Today, it is argued that both physical and psychological mechanisms affect an athlete's performance capability. For a successful performance, a gymnast needs to touch the ground without losing his or her balance at the end of the movement; a football player needs to take the correct position maintaining his/her balance depending on the ball coming towards him/her while at the same time checking the position of both his/her teammates and the opponent; or a basketball player needs to maintain his/her balance when s/he touches down the ground after the player jumps for a rebound with his/her opponent (Erkmen, Suveren, Göktepe, & Yazıcıoğlu, 2007).

Balance is defined as the ability to maintain the body gravity center within support limits(Shumway-Cook, Anson, & Haller, 1988).Static balance is the skill of sustaining a base of support with minimum movement (Coskun, Unlu, Golshaei, Kocak, & Kirazcı, 2019). Maintenance of postural balance is an important requirement for the efficient performance in undertaking most sporting activities (Sarabon, Hirsch, & Majcen, 2016).

Trunk muscles are composed of 29 pairs of muscle groups that support lumbo-pelvic-hip complex. This muscle group contributes to the stabilization of pelvis, vertebra and kinetic chain (Crisco, Panjabi, Yamamoto, & Oxland, 1992). The core region which is defined as the center of functional kinetic chain resembles a cylinder which is formed by the paravertebrals and gluteals at the back, the abdominals in the front, the diaphragm at the top, and the pelvic flor and hip circumference muscles at the bottom. The contraction of these muscles creates maximum stability proximally and leads to optimal controlled and effective movement in distal regions (Kibler, Press, & Sciascia, 2006; Richardson, Jull, Hodges, & Hides, 1999).

Studies that examine the importance of postural stability, sports performance and trunk muscle endurance parameters separately for athletes and that show the relationship between these parameters are not very common in the literature. To the best our knowledge, no studies have yet examined postural stability, performance and trunk muscle endurance in a single study and explored the relationship among these parameters.

This study aims to investigate the relationship between postural stability, performance and trunk muscle endurance in female athletes and to reveal differences specific to different branches of sport.

## Material and Method

*Participants*

A total of 45 female athletes (15 volleyball, 15 handball, and 15 football players) and 15 healthy sedentary controls volunteered to take part in the study after being informed about the study in written form. The average age of the participants was 22.91 ± 5.86 years; average height was 1.69 ± 0,08 meters, and average weight was 62.08 ± 10.43 kilograms. Inclusion criteria were; 1. not being injured in the last 3 months; 2. being a professional athlete that does training 5 days a week for the last two years.

Each participant voluntarily provided written informed consent before participating and the study was approved by the Ethics Committee of the Gazi University.in the study

*Procedure*

*Vertical Jump Test:* While the athletes were standing upright on the side of the wall, the place where their fingertips touched was marked. Then, the athletes were asked to jump as much as possible in a way that their feet are in the air, and they were also asked to mark the last point they jumped to with the marker they were given. The difference between the marked points was taken in centimeters. The test was repeated three times and at the end, the best value was taken (Mackenzie, 2005). This test is known to have excellent interrater reliability (ICC = 0.97) (Sattler, Sekulic, Hadzic, Uljevic, & Dervisevic, 2012)

*Hexagonal Obstacle Test (HOT):* A hexagonal was formed on the ground in a way that the side length is 66 centimeters. While the participant was standing in the middle of the hexagonal, s/he was asked to jump out of all the sides facing the same side all the time and to return to the center again. When the participant first jumped, a chronometer was started. Participants were asked to repeat this behavior three times. When the third round was over, the chronometer was stopped. After the participant relaxed for 5 minutes, the second test was carried out and the average of the two tests was taken. When the participant jumped to the wrong side or stepped on the side, the test was repeated (Mackenzie, 2005). According to Paoule et al. intraclass correlations (ICC) ranged between 0.86 and 0.95 for the HOT (Pauole, Madole, Garhammer, Lacourse, & Rozenek, 2000).

*Trunk flexion test:* The participant was asked to cross his/her arms on his/her chest. The trunk of the participant was positioned at 60° flexion on the floor and the knees were positioned at 90° flexion. A chronometer was started. When the position of the participant was disrupted, the chronometer was stopped and the test was terminated. The trunk flexion test is known to have excellent interrater reliability (ICC = 0.97-0.98) (Evans, Refshauge, & Adams, 2007).

*Trunk extensor test:* The participants were positioned in prone position and their spina iliaca anterior superiors were at the side of the bed. The participants were asked to move their upper trunk forward and straight over the side of the table. This position was fixed over the knees with a belt. A chronometer was started. When the position of the participant was disrupted, the chronometer was stopped and the test was terminated. This test has been shown to have good reliability (ICC = 0.83) (Latimer, Maher, Refshauge, & Colaco, 1999).

*Side Bridge test:* The participant was asked to lie on his/her dominant side and put one foot over the other. Also, s/he was asked to put his/her non-dominant arm over his/her dominant shoulder by crossing the arm and to stand on the dominant forearm and elbow. A chronometer was started. When the position of the participant was disrupted, the chronometer was stopped and the test was terminated. This test has excellent intra-rater reliability (ICC = 0.97) (McGill, Childs, & Liebenson, 1999).

*Prone bridge test:* The participant was asked to lie down in prone position in which his/her hands and feet were open at shoulder width. Then, the participant was asked to raise his/her body by raising himself/herself on hands, forearms and toes. A chronometer was started. When the position of the participant was disrupted, the chronometer was stopped and the test was terminated. The test has been shown to have excellent reliability (ICC = 0.98) (Tong, Wu, & Nie, 2014).

*Postural stability test:* Postural stability of the participants was evaluated using the Biodex Biosway Portable Balance System (950- 460 USA) device. This device tests participants' ability to maintain the center of balance. The stability index used in this test shows the participant's level of distance from the center. In this test, the participant stood on one leg on the platform for 20 seconds without moving and without joining his legs. This test has been shown to have good reliability (ICC = 0.85) (Arifin, Osman, & Abas, 2014)

*Statistical Analysis*

Statistical analyses were conducted using Statistical Package for the Social Sciences (SPSS) version 22. Whether the data have shown normal distribution or not was examined using the Kolmogorov-Smirnov test. The variables that showed normal distribution were calculated using the Pearson test, while the variables which did not show normal distribution were subjected to the Spearman test in order to calculate the correlation coefficient and statistical significance. For numerical variables, range values (IQR) like average, standard deviation, median, and interquartile range (IQR) were used as complementary statistics. The Kruskal Wallis Test was used in order to determine whether there was any significant difference between the averages pertaining to one dependent variable in the independent group. In numerical variables, the Mann-Whitney U test was used to make a comparison between two independent groups. Type-1 error level was identified as 5% ($p \leq 0.05$) for statistical significance. The power of the work was found to be %99 when the effect size was taken as 0.50.

## Findings

**Table 1**. Demographic characteristics of the participants

| n=60 | Mean ± SD | Median | IQR (25/75) | Min | Max |
|---|---|---|---|---|---|
| Age (year) | 22.91 ± 5.86 | 23.00 | 17.00/ 27.75 | 14.00 | 35.00 |
| Height (m) | 1.69 ± 0.08 | 1.70 | 1.65/ 1.75 | 1.48 | 1.93 |
| Body mass (kg) | 62.08 ± 10.43 | 62.02 | 55.50/ 66.95 | 40.00 | 93.50 |
| Body mass index (kg/m²) | 21.44 ± 2.26 | 21.32 | 20.15/ 22.49 | 16.79 | 29.49 |

**Table 2.** The relationship between parameters in athletes

| n=45 | | Age | Bmi | Vj | Hot | Tf | Te | Pb | Sbd | Rps | Rpsap | Rpsml | Lps | Lpsap | Lpsml |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Age** | r | | 0.39* | 0.23 | -0.13 | 0.10 | 0.30* | 0.34* | 0.06 | -0.35* | -0.37* | -0.24 | -0.19 | -0.12 | -0.28 |
| | p | 1 | **0.007** | **0.141** | **0.39** | **0.49** | **0.04** | **0.01** | **0.67** | **0.01** | **0.01** | **0.10** | **0.19** | **0.41** | **0.05** |
| **Bmi** | r | | | 0.002 | -0.07 | -0.01 | -0.03 | 0.10 | -0.01 | -0.15 | -0.14 | -0.06 | 0.08 | 0.12 | -0.03 |
| | p | | 1 | **0.99** | **0.63** | **0.92** | **0.80** | **0.50** | **0.44** | **0.31** | **0.33** | **0.66** | **0.57** | **0.40** | **0.83** |
| **Vj** | r | | | | -0.29 | 0.24 | 0.21 | 0.06 | 0.18 | -0.10 | -0.02 | -0.05 | 0.20 | 0.18 | 0.06 |
| | p | | | 1 | **0.06** | **0.11** | **0.15** | **0.67** | **0.23** | **0.48** | **0.88** | **0.72** | **0.16** | **0.22** | **0.67** |
| **Hot** | r | | | | | 0.04 | -0.14 | -0.05 | -0.15 | 0.11 | 0.15 | 0.10 | 0.08 | 0.09 | 0.10 |
| | p | | | | 1 | **0.78** | **0.35** | **0.71** | **0.31** | **0.44** | **0.29** | **0.50** | **0.57** | **0.54** | **0.48** |
| **Tf** | r | | | | | | 0.48* | 0.38* | 0.27 | -0.18 | -0.15 | -0.03 | 0.33* | 0.28 | 0.14 |
| | p | | | | | 1 | **0.001** | **0.001** | **0.06** | **0.22** | **0.31** | **0.83** | **0.02** | **0.05** | **0.35** |
| **Te** | r | | | | | | | 0.44* | 0.45* | -0.23 | -0.30* | -0.01 | 0.10 | 0.08 | -0.04 |
| | p | | | | | | 1 | **0.002** | **0.002** | **0.12** | **0.04** | **0.92** | **0.50** | **0.58** | **0.78** |
| **Pb** | r | | | | | | | | 0.65* | -0.38* | -0.44* | -0.04 | -0.17 | -0.11 | -0.30* |
| | p | | | | | | | 1 | **0.001** | **0.009** | **0.002** | **0.78** | **0.24** | **0.44** | **0.04** |
| **Sbd** | r | | | | | | | | | -0.22 | -0.26 | 0.05 | -0.05 | -0.03 | -0.09 |
| | p | | | | | | | | 1 | **0.14** | **0.07** | **0.71** | **0.717** | **0.83** | **0.55** |
| **Rps** | r | | | | | | | | | | 0.87* | 0.67* | 0.11 | -0.01 | 0.31* |
| | p | | | | | | | | | 1 | **0.001** | **0.001** | **0.47** | **0.94** | **0.03** |
| **Rpsap** | r | | | | | | | | | | | 0.29* | 0.13 | -0.003 | 0.35* |
| | p | | | | | | | | | | 1 | **0.04** | **0.36** | **0.98** | **0.01** |
| **Rpsml** | r | | | | | | | | | | | | 0.05 | 0.00 | 0.08 |
| | p | | | | | | | | | | | 1 | **0.72** | **0.99** | **0.59** |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lps** | r | | | | | | | | | | | | | 0.83* | 0.71* |
| | p | | | | | | | | | | | | 1 | **0.001** | **0.001** |
| **Lpsap** | r | | | | | | | | | | | | | | 0.31* |
| | p | | | | | | | | | | | | | 1 | **0.03** |
| **Lpsml** | r | | | | | | | | | | | | | | |
| | p | | | | | | | | | | | | | | 1 |

**Abbreviations**: **Bmi:** Body Mass Index, **Vj:** Vertical Jump, **Hot:** Hexagonal Obstacle Test, **Tf:** Trunk Flexion, **Te:** Trunk Extension, **Pb:** Prone Bridge, **Sbd:** Side Bridge Dominat, **Ps:** Postural Stability, **Rpsap:** Right Postural Stability Anterior Posterior, **Rpsml:** Right Postural Stability Medial Lateral, **Lpsap:** Left Postural Stability Anterior Posterior, **Lpsml:** Left Postural Stability Medial Lateral, ***:** Significance With P < 0.05

**Table 3.** Pairwise comparison of the parameters that were found to be different in different sports branches

| | Trunk flexion | Trunk extension | Prone bridge | Side bridge dominant | Vertical Jump | Hexagonal obstacle |
|---|---|---|---|---|---|---|
| Volleyball - Handball P value | **>0.0083** | **>0.0083** | **>0.0083** | **>0.0083** | **>0.05** | **<0.01**** |
| Volleyball – Football P value | **>0.0083** | **>0.0083** | **>0.0083** | **>0.0083** | **<0.01**** | **<0.01**** |
| Handball – Football P value | **>0.0083** | **>0.0083** | **>0.0083** | **>0.0083** | **<0.01**** | **>0.05** |
| Control-Handball P value | **<0.0083**** | **<0.0083**** | **<0.0083**** | **<0.0083**** | **<0.01**** | **<0.05*** |
| Control – Football P value | **<0.0083**** | **<0.0083*** | **>0.0083** | **<0.0083**** | **>0.05** | **<0.01**** |
| Control – Volleyball P value | **<0.0083**** | **<0.0083**** | **<0.0083**** | **>0.0083** | **<0.01**** | **<0.01**** |

For the parameters that do not show normal distribution, as the new equation is α=α/6=0,0083 with Bonferroni adjustment, p<0,0083 was denoted as significant. According to the table, trunk flexion, trunk extension, prone bridge, and side bridge dominant parameters do not show normal distribution. *: Significance with P < 0.05, **: Significance with P < 0.01

*Results of the analysis pertaining to the athletes*

A negative moderate relationship was found between trunk extension and right anterior posterior postural stability index (r=-0.30, p=0.04) parameters (Table 2).

A negative moderate relationship was found between prone bridge parameter and right postural stability overall index (r=-0.38, p=0.009), between the prone bridge test and right anterior posterior postural stability index (r= -0.44, p=0.002), and also between the prone bridge test and left medial lateral postural stability index (r=-0.30, p=0.04) as seen in Table 2.

No significant relationship was observed between the test parameters that evaluate trunk muscle endurance and those evaluating sports performance (Table 2).

No significant relationship was found between the parameters evaluating postural stability and those that evaluate sports performance (Table 2).

*Differences in Sports Branches*

Differences were observed in football, volleyball and basketball branches in terms of age, the vertical jump test, the hexagonal obstacle test, and all the trunk muscle endurance test parameters (Table 3).

A significant difference was observed between volleyball and handball players in terms of the hexagonal obstacle test variable ($p < 0.01$). It was found that volleyball players completed the hexagonal obstacle test in a shorter time compared to the football players (Table 3).

A significant difference was observed between volleyball players and football players as far as the vertical jump test and the hexagonal obstacle test variables are concerned ($p<0.01$). It is further seen that volleyball players were more successful in both the vertical jump and the hexagonal obstacle test (Table 3).

A significant difference was observed between handball and football players in terms of the vertical jump test variables ($p< 0.01$). It was observed that in the vertical jump test, handball players jumped higher than football players (Table 3).

A significant difference was observed between the control group and handball players in terms of the variables in the whole trunk muscle endurance test, the vertical jump test and the hexagonal obstacle test. It was revealed that better results were obtained from the control group in the tests measuring the performance and trunk muscle endurance of handball players (Table 3).

A significant difference was observed between the control group and football players in terms of the variables in the trunk flexion, trunk extension, side bridge, and hexagonal obstacle tests. Football players were found to be more successful in these tests compared to the control group (Table 3).

A significant difference was found between the control group and the volleyball players in terms of the trunk flexion, trunk extension, prone bridge test, vertical jump test and hexagonal obstacle test variables. It was observed that volleyball players were more successful in all the parameters compared to the football players with significant differences (Table 3).

## Discussion and Conclusion

According to the results of the study, which focuses on the female athletes in football, volleyball and handball branches, there is a significant relationship between trunk muscle endurance and postural stability. Furthermore, when these three sports branches are compared with each other, it was seen that there are significant differences in performance parameters like the vertical jump and hexagonal obstacle test, in all the trunk muscle endurance tests and in risks of fall. Volleyball players are the most successful athletes in sportive performance test. It was also observed that handball players have the best time records in trunk muscle endurance tests.

Kaji et al. examined the acute effects of core stability exercises on postural sway in 17 healthy individuals by observing postural sway before and after core stability exercises. They found that core stability exercises significantly reduce medial lateral sway (Kaji, Sasagawa, Kubo, &

Kanehisa, 2010). Granacher et al. examined the relationship between trunk muscle strength, spinal mobility and balance performances of 34 elderly individuals and found a significant relationship between static and dynamic balance and trunk muscle strength. In another study, Granacher et al. systematically compiled and examined 20 articles and found that trunk muscle strength is significantly related with balance, functional performance and the prevention of falling in the elderly (Granacher, Lacroix, Roettger, Gollhofer, & Muehlbauer, 2014). In present study, a relationship was observed between the prone bridge test showing trunk muscle endurance in the athletes, and trunk extension muscle strength and postural stability. This finding means that as trunk muscle endurance rises, postural stability improves. However, in our study, no significant relationship was found between trunk flexion and lateral bridge tests, and postural stability. As Ekstrom et al. mentioned in their study, this result may be attributed to the fact that different core tests include different muscular activations (Ekstrom, Donatelli, & Carp, 2007).

Furthermore, our study found that compared to the athletes, only right medial lateral postural stability and prone bridge test are related with each other in sedentary controls. This finding may be attributed to weak core muscle endurance and to the fact that core muscles only have an effect on hip knee kinematics on frontal plane while measuring balance standing on one foot.

One of the most significant variables for performance measurements in team sports is condition. Condition is generally measured through some functional measurements targeting lower extremity. One of these measurements is the vertical jump test, which is used to identify lower extremity muscle strength (Özçakar et al., 2003). Sharrock et al. examined the relationship between core stability and athletic performance in 35 athletes, and they revealed no significant relationship between the vertical jump test and trunk muscle endurance (Sharrock, Cropper, Mostad, Johnson, & Malone, 2011). In their study, Parkhouse et al. investigated the effects of core exercises done on static and dynamic ground by 12 adults on performance. They found no significant change in vertical jump values in two groups who did core training on static and dynamic ground at the end of six weeks (Parkhouse & Ball, 2011). In Prieske et al.'s study, 39 football players did core training for nine weeks. The results showed that there was no significant relationship between trunk muscle endurance and vertical jump (Prieske et al., 2016). The results of the study were not compatible with the results of studies in the literature as no relationship was found between the vertical jump test and the McGill core stability test evaluating trunk muscle endurance. The reason behind this finding may be the fact that the vertical jump test evaluates the efficiency of anaerobic energy systems revealed by blasting power rather than evaluating the muscular endurance of lower extremity muscles. Nesser et al. examined the relationship between core stability and performance in 29 adult male football players and found a significant relationship between trunk muscle endurance and vertical jump. However, they did not reveal any significant relationship between other performance parameters and core stability. Thus, they argued that performance tests must be chosen considering the sports branch while evaluating the effect of core stability on performance (Nesser, Huxel, Tincher, & Okada, 2008). This may be one reason for not finding a relationship between core stability and vertical jump in female athletes in the branches of volleyball, handball and football in our study.

Athletes need some performance factors that must be improved and a good physical conformity in order to acquire movements specific to sports. One of these factors is agility. The reason why agility s important in volleyball, handball and football is that athletes need to maneuver without losing control and balance throughout the game. For instance, for volleyball players, spike requires fast reaction or agility in order to rise to block the direction from which the ball is coming (Sayers, 2000). Ozmen et al. investigated the effects of core strength training on balance, agility and core endurance on 20 adolescents. They revealed significant differences between dynamic balance and core endurance of individuals who received core training; however, no significant difference was found in agility (Ozmen & Aydogmus, 2015). Prieske et al. applied a nine-week core training program to 39 football players, and they examined the effect of this training program on agility. They found that core training has no significant effect on agility. Imai et al. conducted a study with 55 football players to examine the relationship between trunk performance and athletic performance. They found no relationship between agility and right and left side bridge tests which are among the trunk muscle endurance parameters (Prieske et al., 2016). Parallel to the findings in the literature, our study also revealed no significant relationship between the tests evaluating trunk muscle endurance and the hexagonal obstacle test which is one of the performance parameters and which shows agility. The reason behind not observing such a relationship may be the fact that there are differences between the three sports branches in the study.

Yaggie et al. investigated the effect of balance training on performance with 36 individuals. After the participants received balance training for four weeks, it was found that balance training had no significant effect on vertical jump height (Yaggie & Campbell, 2006). Zech et al. examined the effect of balance training on performance through a systematic compilation study, and they found that balance training has no significant effect on vertical jump (Zech et al., 2010). The findings of our study support the findings in the literature. In our study, no relationship was observed between the vertical jump test and balance parameters. This finding may be attributed to the fact that the athletes we evaluated had different sports branches and they have not been subjected to such a joint training program before.

In their study conducted in 2015, Engquist et al. compared the performance and balance of students who did sports and who led a sedentary life. 151 females and 119 males participated in the study. The study revealed that females who did sports had significantly better performance and balance compared to the sedentary females. Increased muscle mass and condition in individuals who do sports help them show better performance compared to sedentary individuals (Engquist, Smith, Chimera, & Warren, 2015). Our study further revealed that individuals who do sports have significantly better performance compared to sedentaries as expected. The comparison between the sports branches showed that female handball players are better in terms of trunk stability, while volleyball players are better in terms of performance parameters. This may be attributed to the fact that the football players in our study were younger and psychomotor developmental characteristics. The reason behind volleyball players' success in performance tests may be that volleyball includes movements that require jumping. Handball players, on the other hand, had the best results in the trunk muscle endurance tests, which may be because handball players had more core endurance training in their training programs compared to the other sports branches.

It may be argued that in order to have a better postural stability, trunk muscle endurance must be improved as there is a link between postural stability and trunk muscle endurance in female volleyball, handball, and football players. According to others, volleyball players are better in terms of performance and also handball players are better in terms of trunk stability.

**Conflict of interest**

There is no conflict of interest intellectually or financially.

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