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Kinesiology

Relationships between Balance and Functional Performance in Football Players

by
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The aim of the present study was to examine the relationships between balance performance as measured by the Balance Error Scoring System and functional performance in football players. Twenty-two football players from University League Final Group in Turkey (age 23.05 ± 1.65 years, height 176.58 ± 6.99 cm, weight 68.80 ± 7.00 kg) volunteered to participate in the study. Postural performance was measured by the Balance Error Scoring System (BESS). For functional performance, standing broad jump, triple-hop, vertical jump, four-line sprint and three-corner run test were used. There was not a statistically significant relationship among the all BESS scores and triple-hop in non-dominant leg, power, four-line sprint, and three-corner run performances ($p<0.05$). Triple-hop in dominant leg performance correlated with foam surface, tandem leg and total BESS score ($r = 0.755$, $p < 0.01$; $r = 0.664$, $p < 0.05$; $r = 0.713$, $p< 0.01$, respectively). Standing broad jump performance correlated with foam surface, tandem leg and total BESS score ($r = 0.737$, $p < 0.01$; $r = 0.692$, $p < 0.05$; $r = 0.617$, $p< 0.05$, respectively). There was a statistically significant relationship among the single leg BESS score and vertical jumping performance ($r = -0.596$, $p<0.05$). In conclusion, the activities requiring explosive power may reflect the ability of managing a balanced posture but the activities in which time period is longer may not.

Key words: postural control, jumping, acceleration, anaerobic endurance, footbal

Introduction

The ability to minimize postural sway can be defined as the postural performance (Paillard et al., 2006). Balance performance has a fundamental role in many athletic activities, and skill in postural control may designate successful performance (Adlerton et al., 2003).

In evaluation of athlete's postural sway, there are many methods such as Balance Error Scoring System (BESS) (Wilkins et al., 2004; Rieman and Guskiewicz 2000; Valovich et al., 2003), Star Excursion Balance Test (Gribble et al., 2004; Kinzey and Armstrong 1998), Kinesthetic Ability Trainer (Hansen et al., 2000; Surenkok et al., 2006), Romberg Test (Guskiewicz and Perin, 1996), Chattecx Balance System (Levine et al., 1996), Equi Test System (Wrisley et al., 2007) and Biodex Balance System (Arnold and Schmitz, 1998; Gioftsidou et al., 2006). The BESS is a valid and reliable measure method of postural stability (Riemann et al., 1999). The test is cheaper than force platforms, requires less practice for effective administration, and can be used for immediate sideline assessment (Riemann et al., 1999). The BESS scores were similar to the EquiTest long forceplate (Rieman et al., 1999) and the Sensory Organization Test composite scores (Riemann and Guskievicz, 2000). Many authors used the BESS to assess balance

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performance in athletes (Wilkins et al., 2004; Valovich et al., 2003; Onate et al., 2004; Hamilton et al., 2008; Fox et al., 2008; Bressel et al., 2007) and recreationally active subjects (Susco et al., 2004).

The maintenance of posture can be evaluated in a stable state or following a specific perturbation such as a jump or sudden stop (Gerbino et al., 2007). Athletes usually had superior balance ability than non-athletes (Davlin, 2004) and athletes with the higher the level of competition had the more stable the posture than the lower the level of competition (Paillard and Noe, 2006). The experienced athletes generally use specific sensorial knowledge in organizing posture in relation with the requirements of each discipline (Perin et al., 1998, Vuillerme et al., 2001). In a sport like football, players must compulsorily achieve motor skills and control their posture during the match, while using visual information about other team members and the opponents (Paillard and Noe, 2006).

Paillard et al. (2006) declared that postural talents might be considered as an indicator of performance in the playing of football. During a match, football players frequently perform lower extremity passing, shooting, and dribbling skills with football cleats on grass field (Orchard, 2002). They must maintain a position of balance as they run at high speed, change direction rapidly and powerfully kick the ball to pass or shoot. Furthermore, players must conserve balance as they are prevented by opposing players and try to steal the ball (Gerbino et al., 2007).

The playing of football requires a unipedal balance to perform different technical movements such as shooting, dribbling, and passing (Paillard et al., 2006). The balance in the supporting foot is essential to shoot as accurately as possible (Paillard et al., 2006). On the other hand, football training brings out to a strong visual dependence in relation to the ball, opposing players and other team members. The requirement to control the ball with the feet exacts the players to bring their gaze down, which is in contradiction with the requirement to watch the shifting of the other players (Paillard and Noe, 2006).

Postural proficiency can be deliberated as one criterion of performance or ability in conditions specific to the playing of football (Paillar et al., 2006). Authors declared that the ability to efficiently maintain balance rely on physical fitness factors such as muscle strength and anaerobic capacity (Era and Heikkinen, 1985; Nguyen et al., 1993). Football contains forceful and explosive activities (e.g. tackling, jumping, kicking, turning and changing pace). The generated power during football-specific activities depends on the strength of muscles carrying out movements (Relly et al., 2000). Pant et al. (2006) reported that students with high muscle strength have ability to better balance. Balance performance can be developed through resistance, flexibility, aerobic and anaerobic training (Judge et al., 1993; Messier et al., 2000; Shintaku et al., 2005). Football players use their one leg as support leg when kicking a ball and in possession of the ball (Adlerton et al., 2003; Kellis et al., 2001) and have better one-legged stance stability (Matsuda et al., 2008). Hence, we expect that sprint, acceleration, anaerobic run, vertical or horizontal jump may be related with balance performance in football players. The aim of the present study was to examine the relationships between balance performance as measured by the BESS and functional performance in football players.

Materials and methods

Subjects

Twenty-two football players from University League Final Group in Turkey (age 23.05 ± 1.65 years, height 176.58 ± 6.99 cm, weight 68.80 ± 7.00 kg, years of football experience 8.6±4.1 years) volunteered to participate in the study. Participants were excluded if they had a lower extremity injury, vestibular problems, visual problems, or a concussion in the 6 months before the study. Before testing began, the aim and procedures of the study were explained to the participants and informed consent was obtained. The study was approved by the Ethics Committee in Selçuk University. The study was performed during competitive season. Subjects were restrained from fatiguing exercise before test days. Functional performance tests in football field and balance test in University laboratory were conducted. Balance performance as measured by BESS was used to represent balance ability. Assessments of functional performance included four-line sprint test, three-corner run test in addition to three jumping tests. Jumping tests are standing broad jump test, triple-hop test, and vertical jump test. Although these are mainly known as tests used for evaluating of jumping performance, they have features different from each other. The vertical jump demands lower limb power in order to reach maximal height and depends on upon power applied vertically (Hamilton et al., 2008). Hop tests include components of strength, power, and balance. Triple-hop test requires the generation of power in single leg to maximize horizontal distance (Hamilton et al., 2008). Standing broad jump test measures maximal distance covered vertically on either leg.

Procedures

Height and weight were measured with subjects in training clothes (shorts and t-shirt) and barefoot. Height was measured to the nearest 0.1 cm. Weight was measured to the nearest 0.1 kg using a scale. Body mass index (BMI) was calculated as weight/height squared (kg/m2). In first test day, balance performance measurement was conducted. In second test day, vertical jump, standing broad jump, triple-hop, four-line sprint and three-corner run tests were consecutively applied. Subjects rested 5 min between functional performance tests.

Balance Error Scoring System. Postural performance of subjects was measured using the BESS. The BESS is a valid and reliable measure of postural stability and comprises 6 stance conditions: double-leg, single leg, and tandem stances on both a firm surface and a foam surface (Riemann and Guskiewicz, 2000). The BESS requires participants to stand unsupported with their eyes closed. The foam surface was done on a 50 x 41 x 6 cm block of medium-density foam (Airex Balance Pad, Alcan Airex AG, CH-5643 Sins/Switzerland). A stopwatch was used to time each of the 20-second trials. One BESS error was scored if the subject engaged in any of the following: (1) lifting the hands off the iliac crests; (2) opening the eyes; (3) stepping, stumbling, or falling; (4) moving the hip into more than 30° of flexion or abduction; (5) lifting the forefoot or heel; or (6) remaining out of the test position for longer than 5 seconds. Error scores were calculated for each of the 6 conditions and summed to obtain the total BESS score. The double-leg stance conditions consisted of the subject standing with feet together. The single-leg stance was performed on the non-dominant leg, as determined by which limb the subject would not preferentially use to kick a ball. The dominant leg was positioned so that the hip was flexed to approximately 30° and the knee flexed to 90°, leaving the foot approximately 6 to 8 inches off the ground. In tandem stance, the non-dominant foot was positioned behind the dominant foot, and the subject was instructed to maintain the stance with the great toe of the non-dominant foot touching the heel of the dominant foot. For all conditions, we instructed the subject to remain still with eyes closed and hands on the hips (Riemann and Guskiewicz, 2000). After the instruction, each subject was given 2 familiarization trials on each condition before the actual data collection. The subject remained as still as possible; if he moved from the test position, he was to return to it as soon as possible. The number of errors for each of the 6 tests was observed and recorded for the subject's BESS score. A higher score on the BESS indicate a poor postural control. All subjects and all trials were scored by one examiner.

Vertical Jump Test (VJT). Vertical Jump test was used to examine the explosive power of the lower extremities. To measure the vertical jump height of the subjects, we used a digital vertical jump meter (Takei, 5105-Jump MD, Tokyo, Japan). The subject was allowed to have 3 attempts to obtain their maximal jump height. Subjects were instructed to stand on the center of a rubber mat with a special digital belt tightly fitted around their waist. The belt was connected to the rubber plate by a cord. Before jumping, any slack was removed from the cord, and subjects were instructed to jump vertically using a countermovement with arm swing. During the jump, an approach step was not permitted. Three trials of each jump were measured with a 0.5- to 1.0- minute rest period between trials. The best trial defined by vertical jump height was recorded (in cm).

Standing Broad Jump Test (SBJT). The test was performed according to Eurofit Test Battery (Council of Europe, 1988). A start line was determined on a non-skid floor and a tape meter was extended from the start line forward. Subjects were requested to stand behind the starting line, their toes were away from behind the start line, their arms were on the front in parallel with the floor and knees were bent. Subjects were instructed to push off vigorously and jump forward as far as possible. The participant had to land with the feet together and to stay upright. The distance was measured from the starting line to the point where the heel struck the ground upon completing the test. The test was repeated twice, and the best score was recorded (in cm).

Triple-Hop Test (THT). Subjects were instructed to stand in a stepping position behind the starting line with their non-dominant leg forward. This test was performed by starting behind the start line with only the leg in use touching the ground. The subject hopped three continuous times on the dominant leg to reach the maximal horizontal distance. The test

Kinesiology

Table 1

Physical characteristics of players (n=22)

	Mean	SD
Age (years)	23.05	1.65
Height (cm)	176.58	6.99
Weight (kg)	68.80	7.00
Body fat (%)	12.39	1.13
BMI (kg/m^2)	22.17	1.66

Table 2

BESS scores according to stance positions and surfaces in the test.

Variables	Mean	SD
Firm surface	1.22	1.26
Foam surface	12.11	2.76
Double leg	0.00	0.00
Single leg	10.22	1.77
Tandem leg	3.11	2.19
Total BESS score	13.33	3.38

Table 3

Means and standard deviations (SD) for performance tests

Variables	Mean	SD
Triple-Hop in dominant leg (m)	6.85	0.50
Triple-Hop in non-dominant leg (m)	7.10	0.48
Standing Broad Jump (m)	2.69	0.16
Vertical jump (cm)	64.75	6.73
Four-Line Sprint (s)	14.16	0.28
Three-Corner Run (s)	31.29	0.96

was repeated with the non-dominant leg. The non-dominant leg was determined by which limb the subject would not preferentially use to kick a ball. Measurement was taken from the starting line to the point where the heel struck the ground upon completing the third hop. The test was repeated three times, and the best score for dominant and non-dominant leg was recorded (in cm) (Bolgla and Keskula, 1997; Hamilton et al., 2008; Rösch et al., 2000).

Four-Line Sprint Test (FLST). The ability of sprinting and acceleration in athletes was assessed by four-line sprint test (Rösch et al., 2000; Taskin, 2009). As shown in figure 1, a starting line (A) was determined on a football field. Line B and C were marked behind and in front of the starting line. There was distance 10 meter from line A to line B and line C. The finishing line (D) was 20 meter away from line C. The subject lay on the ground behind the line A. When the starting command was given, the subject ran to line B and touched the line with foot. Then he turned back and ran from line B to line C. Later, after he touched line C with foot, he turned back again, ran from line C to line A and touched line A. Finally, he turned back again and ran to line the finishing line (D) between 2 flag posts. The time between the starting command and crossing the finish line was measured by a stopwatch and was recorded as the score of the subject in units of 0.1 seconds (Rösch et al., 2000).

Three-Corner Run Test (TCRT). This test was used for the purposes of assessment of Speed and anaerobic endurance in athletes (Rösch et al., 2000; Taskin, 2009). As shown in figure 2, the test field was designed. After the starting command, the subject ran to the flag post (1) away 80 meter from the start. He turned to left hand side and ran the flag post (2), away 20 meter from the flag post (1). Then he ran back to the flag post (3), away 82.4 meters from the start. Finally, he turned to right hand, ran to finish line (4) and crossed the finish line. The time between the starting command and crossing the finish line was measured by a stopwatch and was recorded as the score of the subject in units of 0.1 seconds (Rösch et al., 2000).

Statistical Analysis

All analyses were performed using SPSS 16.0 for Windows (SPSS Inc., Chicago, IL). Values were expressed as mean and standard deviation (SD). A ShapiroWilks test was used to examine whether the variables were normally distributed. In case of normality, the associations between BESS scores and sport performances data were analyzed using Pearson product-moment correlation analysis. If a variable was not normally distributed, then a Spearman correlation analysis was applied. Because of double leg BESS score was "0", it was excluded from analysis. The level of significance chosen was $p < 0.05$.

Results

Descriptive statistics is illustrated in table 1. Data relating to BESS performance of football players are presented test surfaces, stance positions and total BESS score (table 2). Test scores of sport performance are shown in table 3.

There was not a statistically significant relationship among the all BESS scores and triple-hop performance in dominant leg and non-dominant leg ($p>0.05$). Standing broad jump performance did not correlated with firm surface, foam surface, single leg, tandem leg and total BESS score ($p > 0.05$). There was a statistically significant negative relationship among

Table 4

Correlations analysis between balance parameters and tests of sport performance

Variables	*Triple-Hop in dominant leg*	*Triple-Hop in non-dominant leg*	*Standing Broad Jump*	*Vertical jump*	*Four-Line Sprint*	*Three-Corner Run*
Firm Surface						
Correlation Coefficient †	,341	,601	,489	-0.009	0.425	-0.150
p value	,370	,087	,182	0.977	0.193	0.553
Foam Surface						
Pearson Correlation	,513	,548	,603	-0.233	0.310	0.099
p value	,158	,127	,086	0.444	0.353	0.695
Single Leg						
Pearson Correlation	,435	,583	,607	-0.596*	0.371	-0.091
p value	,242	,100	,083	0.031	0.261	0.718
Tandem Leg						
Pearson Correlation	,520	,594	,583	0.073	0.468	0.089
p value	,152	,092	,100	0.812	0.146	0.725
Total BESS						
Pearson Correlation	,520	,636	,641	-0.315	0.572	0.010
p value	,151	,066	,063	0.295	0.066	0.968

** $p < 0.05$, † Non-parametric Spearman correlation analysis.*

the single leg BESS score and the vertical jump heights (r = -0.596, p<0.05). In other word, vertical jump performance and balance performance increased as parallel in football players. Balance performance did not correlated with four-line sprint, and three-corner run performances (p>0.05; table 4).

Discussion

The findings in this study show that total BESS scores were not associated with jumping, the ability of sprinting-acceleration, and speed-anaerobic endurance performances in football players. The present study also revealed that single leg (on non-dominant leg) BESS scores were negatively correlated with vertical jump height.

Jumping and Balance

In this study, jumping performances of football players were measured by standing broad jump test, triple-hop test with dominant and non-dominant leg and vertical jump test. The findings of the present study were that there were not correlations observed between balance performance and triple-hop distance in dominant leg and non-dominant leg. Furthermore, standing broad jumping performance was not significantly related to BESS scores. A significant relationship between vertical jump and single leg BESS score was found. The findings were not in accordance with results of Hamilton et al. (2008), who found no relationship between balance and triple-hop distance in dominant leg and vertical jump in football players.

During a match sprinting, tackling, kicking, jumping, acceleration and deceleration demand muscle strength and explosive power in football (Reilly et al., 2000). Jumping and sprinting performance of athletes may infer muscle strength of the lower limbs (Wisloff et al., 2004). Contrary to our results, Pant et al. (2006) studied the correlation between muscles strength in relation to dorsiflextion, plantarflextion, eversion and inversion strength with body balance in students (19-21 years). They found correlations between body balance and muscles strength on ankle joint, and declared that the person, who had good muscles strength, had better balance performance (Pant et al., 2006). Soyuer and Mirza (2006) investigated the correlation between lower muscle strength and balance in people with multiple sclerosis and healthy subjects. Findings of them showed that there were relationships between lower extremity muscle strength and balance performance in healthy individuals (Soyuer and Mirza, 2006). It could be thought that the result of the present study is in contrast with results of Pant et al. (2006) and Soyuer and Mirza (2006). In parallel with the finding of this study, Lee et al. (2009), the isokinetic muscle strengths of the quadriceps and hamstring muscles were not found to correlate with single-limb dynamic standing balance. Wiksten et al. (1996) noted no significant relationship differences between balance performance and the strength of muscle groups in non-disabled women (18-30 years).

The Ability of Sprinting-Acceleration and Balance

During a football match, movements performed in high speed can be characterized into movements demanding accelerate, maximal speed or agility. The chance rate in speed to reach the highest velocity within the shortest possible time was defined as acceleration (Little and Williams, 2005). In the present study, it was found that the ability of sprinting and acceleration was not associated with balance performance. This result suggests that sprinting and accelerating performance of football players during game is not a valid indicator of postural control. To our knowledge, no present authors have examined the correlation between the ability of sprinting-acceleration and balance performance in literature.

During the BESS, football players did not wear shoes and socks, and closed their eyes throughout the test stances in a stable position. Balance exacts inputs of derived information from mechanoreceptors (Hamilton et al., 2008). On the other hand, this study used the four-line sprint test to determine the ability of sprint and acceleration in football players. The test requires the chance of direction as fast as possible, as well as high intensity muscular contractions. Therefore, this result may be explained by the different requirements of the BESS and four-line sprint tests.

Speed-Anaerobic Endurance and Balance

Football demands a high level condition of players to achieve the physical requirements during a match (Bangsbo, 2003). During the match, maintaining of power output is essential for activities with repetition (Gacesa et al., 2009). Three-corner run test used in this study assesses the speed endurance and anaerobic endurance in football players (Rösch et al., 2000, Taskin, 2009). The time of completion of this test by football players was 31.29 s. Some authors used Wingate anaerobic power test to measure the anaerobic performance in football (Gacesa et al., 2009; Magal et al., 2009; Meckel et al., 2009). The Wingate test consists of pedaling for 30 seconds at a maximum effort. Times of completion in either test are nearly similar. Therefore, it is thought that three-corner test reflects the anaerobic performance of football players.

To our knowledge, this is the first study to evaluate the relationship speed-anaerobic endurance and balance performance in football player. Hence, this study evaluated the relation between anaerobic endurance and BESS score. No correlations were found between three-corner run test and BESS performance in football players. Anaerobic force was depicted as the highest possible impulse generated by the neuromuscular system within a time limit (Cometti et al., 2001). Whereas, balance performance refers to the ability of postural control system operated as a feedback control circuit between the brain and the musculoskeletal system (Guskiewics, 2004). Therefore, it may be thought that postural control system doesn't have a feature affecting the anaerobic performance in football players.

In conclusion, the findings of this research point out no correlation between BESS performance and jumping performance. Single leg balance performance merely related with vertical jump in football players. No relation was found between the ability of keeping anaerobic power and the ability of maintaining the balance. The activities requiring explosive power like vertical jumping may reflect the ability of managing a balanced posture but horizontal jumping and the activities in which time period (four-line sprint and three-corner run) is longer may not.

The proprioceptive skills of football players may be more developed to maintain a suitable posture (Paillard and Noe, 2006). Providing a disrupted balance again is performed through instant corrections and reflexive reactions. Therefore, the anaerobic activities lasting longer may not reflect the character of balance skill. On the other hand, while BESS includes static postures, functional performance has been determined through the methods requiring dynamic activities. So, using computerized posturography devices, difficulty level of which can be adjusted instead of BESS in determining balance performance may help to get more objective results in future researches. We suggest that relationships between balance performance and field performance tests should be researched by using others balance test. Coaches and trainers should realize that balance performance in football players might not be improved by movements which include activities such as jumping, sprinting, anaerobic endurance in their train.

References

Adlerton AK, Moritz U, Moe-Nilssen R. Force plate and accelerometer measures for evaluating the effect of muscle fatigue on postural control during one-legged stance. Physiotherapy Research International, 2003; 8: 187–199.

Arnold BL, Schmitz RJ. Examination of balance measures produced by the biodex stability system. J Athl Training, 1998; 33(4), 323–327.

Bangsbo J. Physiology of Training: Science and Soccer. Relly, T., Williams, A.M., eds. Roudlegde, New York, 2003.

Bolgla LA, Keskula DR. Reliability of lower extremity functional performance tests. J Orthop Sport Phys, 1997; 26(3):138-142.

Bressel E, Yonker JC, Kras J, Heath EM. Comparison of static and dynamic balance in female collegiate soccer, basketball, and gymnastics athletes. J Athl Training, 2007; 42(1): 42-46.

Cometti G, Maffiuletti NA, Pousson M, Chatard JC, Maffulli N. Isokinetic strength and anaerobic power of elite, subelite and amateur French soccer players. Int J Sports Med, 2001; 22: 45-51.

Council of Europe. Handbook of Euro fit, 1988.

Davlin CD. Dynamic balance in high level athletes. Percept Motor Skill, 2004; 98:1171–1176.

Era P, Heikkinen E. Postural sway during standing and unexpected disturbance of balance in random samples of men of different ages. J Gerontol, 1985; 40: 287–295.

Fox ZG, Mihalik JP, Blackburn JT, Battaglini CL, Guskiewicz KM. Return of postural control to baseline after anaerobic and aerobic exercise protocols. J Athl Training, 2008; 43(5): 456-463.

Gacesa JZP, Barak OF, Grujic NG. Maximal anaerobic power test in athletes of different sport disciplines. J Strength Cond Res, 2009; 23(3): 751-755.

Gerbino GP, Griffin ED, Zurakowski D. Comparison of standing balance between female collegiate dancers and soccer players. Gait Posture, 2007; 26(4): 501-507.

Gioftsidou A, Malliou P, Pafis, G, Beneka A, Godolias G, Maganaris CN. The effects of soccer training and timing of balance training on balance ability. Eur J Appl Physiol, 2006; 96(6):659–64.

Gribble PA, Hertel J, Denegar CR, Buckley WE. The effects of fatigue and chronic ankle instability on dynamic postural control. J Athl Training, 2004; 39(4), 321–329.

Guskiewics KM. Regaining postural stability and balance: Rehabilitation techniques for sports medicine and athletic training. Prentice W.E., ed. McGraw-Hill Companies Inc., New York, 2004.

Guskiewicz KM, Perrin DH. Research and clinical applications of assessing balance. J Sport Rehabil, 1996; 5: 45–63.

Hamilton RT, Shultz SJ, Schmitz, RJ, Perrin DH. Triple-hop distance as a valid predictor of lower limb strength and power. J Athl Training, 2008; 43(2): 144-151.

Hansen MS, Dieckmann B, Jensen K, Jakobsen BW. The reliability of balance tests performed on the kinesthetic ability trainer (KAT 2000). Knee Surg Sports Tr A, 2000; 8, 180–185.

Judge JO, Lindsey C, Underwood M, Winsemius D. Balance improvements in older women: effects of exercise training. Phys Ther, 1993; 73: 254–265.

Kellis S, Gerodimos V, Kellis E, Manou V. Bilateral isokinetic concentric and eccentric strength profiles of the knee extensors and flexors in young soccer players. Isokinet Exerc Sci, 2001; 9, 31–39.

Kinzey SJ, Armstrong CW. The reliability of the star-excursion test in assessing dynamic balance. J Orthop Sport Phys, 1998; 27, 356–360.

Lee HM, Cheng CK, Liau JJ. Correlation between proprioception, muscle strength, knee laxity, and dynamic standing balance in patients with chronic anterior cruciate ligament deficiency. Knee, 2009; 16: 387–391.

Lebsack DA, Perrin DH, Hartman ML, Gieck JH, Weltman A. The relationship between muscle and balance performance as a function of age. Isokinet Exerc Sci, 1996; 6:125-132.

Levine D, Whittle MW, Beach JA, Ollard PG. Test-retest reliability of the chattecx balance system in the patient with hemiplegia. J Rehabil Res Dev, 1996; 33(1), 36–44.

Little T, Williams AG. Specificity of acceleration, maximum speed, and agility in professional soccer players. J Strength Cond Res, 2005; 19(1), 76–78.

Magal M, Smith RT, Dyer JJ, Hoffman JR. Seasonal variation in physical performance related variables in male NCAA Division III soccer players. J Strength Cond Res, 2009; 23(9): 2555-2559.

Matsuda S, Demura S, Uchiyama M. Centre of pressure sway characteristics during static one-legged stance of athletes from different sports. J Sport Sci, 2008; 26(7): 775 – 779.

Meckel Y, Machnai O, Eliakim A. Relationship among repeated sprint tests, aerobic fitness, and anaerobic fitness in elite adolescent soccer players. J Strength Cond Res, 2009; 23(1): 163-169.

Messier SP, Royer TD, Craven TE, O'Toole ML, Burns R, Ettinger WH. Long-term exercise and its effect on balance in older, osteoarthritic adults: results from the fitness, arthritis, and seniors trial (FAST). J Am Geriatr Soc, 2000; 48: 131–138.

Nguyen T, Sambrook P, Kelly P, Jones G, Load S, Freund J, Eisman J. Prediction of osteoporotic fractures by postural instability and bone density. Brit Med J, 1993; 307: 1111–1115.

Onate JA, Beck BC, Van Lunen BL. On-field testing environment and balance error scoring system performance during preseason screening of healthy collegiate baseball players. J Athl Training, 2007; 42(4): 446–451.

Orchard J. Is there a relationship between ground and climatic conditions and injuries in football? Sports Med, 2002; 32: 419-432.

Paillard T, Noe F, Riviere T, Marion V, Montoya R, Dupui P. Postural performance and strategy in the unipedal stance of soccer players at different levels of competition. J Athl Training, 2006; 41(2):172–176.

Paillard T, Noe F. Effect of expertise and visual contribution on postural control in soccer. Scand J Med Sci Spor, 2006; 16(5): 345-348.

Pant H, Sukumar K, Sharma H, Pandey AK, Goel SN, Roorkee IIT. Correlation between muscles strength in relation to dorsiflextion, planterflextion, eversion and inversion strength with body balance. J Biomech, 2006; 39(Supplement 1): 557.

Perrin P, Schneider D, Deviterne D, Perrot C, Constantinescu L. Training improves the adaptation to changing visual conditions in maintaining human posture control in a test of sinusoidal oscillation of the support. Neurosci Lett, 1998; 245: 155-158.

Reilly T, Bangsbo J, Franks A. Anthropometric and physiological predispositions for elite soccer. J Sport Sci, 2000; 18:9, 669-683.

Riemann BL, Guskiewicz KM. Effects of Mild Head Injury on Postural Stability as Measured Through Clinical Balance Testing. J Athl Training, 2000; 35: 19–25.

Riemann BL, Guskiewicz KM, Shields EW. Relationship between clinical and forceplate measures of postural stability. J Sport Rehabil, 1999; 8(2), 71–82.

Rösch D, Hodgson R, Peterson L, Graf-Baumann T, Junge A, Chomiak J, Dvorak J. Assessment and evaluation of football performance. Am J Sport Med, 2000; 28(Suplement 5): 29-39.

Shintaku Y, Ohkuwa T, Yabe K. Effects of physical fitness level on postural sway in young children. Anthropol Sci, 2005; 113, 237–244.

Soyuer F, Mirza M. Relationship between lower extremity muscle strength and balance in multiple sclerosis. J Neurol Sci [Turk], 2006; 23(4): 257-263.

Surenkok O, Isler AK, Aytar A, Gultekin Z, Akman M. Effect of knee muscle fatigue and lactic acid accumulation on balance in healthy subjects. Isokinet Exerc Sci, 2006; 14, 301–306.

Susco TM, McLeod TCV, Gansneder BM, Shultz SJ. Balance recovers within 20 minutes after exertion as measured by the balance error scoring system. J Athl Training, 2004; 39(3): 241–246.

Taskin H. Effect of circuit training on the sprint-agility and anaerobic endurance. J Strength Cond Res, 2009; 23(6): 1803-1810.

Valovich TC, Perrin DH, Gansneder BM. Repeat administration elicits a practice effect with the balance error scoring system but not with the standardized assessment of concussion in high school athletes. J Athl Training, 2003; 38, 51–56.

Vuillerme N, Nougier V, Prieur JM. Can vision compensate for a lower limbs muscular fatigue for controlling posture in humans? Neurosci Lett, 2001; 308:103-106.

Wilkins JC, McLeod TCV, Perin DH, Gansneder BM. Performance on the balance error scoring system decreases after fatigue. J Athl Training, 2004; 39(2), 156–161.

Wisloff U, Castagna C, Helgerud J, Jones R, Hoff J. Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. Brit J Sport Med, 2004; 38: 285-288.

Wrisley DM, Stephens MJ, Mosley S, Wojnowski A, Duffy J, Burkard R. Learning effects of repetitive administrations of the sensory organization test in healthy young adults. Arch Phys Med Rehab, 2007; 88(8), 1049–54.

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