Original article

Effects of training on postural stability in young basketball players

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Summary

Background: **in basketball, balance ability is important to reduce non-contact injuries. The purpose of the present study was to investigate the effect of training on balance.**
Methods: **thirty-two healthy male volunteers were recruited from amateur basketball teams. They were asked to perform the Balance Error Scoring System BESS test in order to measure the number of stability errors in six conditions. The test was performed at the beginning of the season (T0) and after 12 weeks (T1). In both cases the test was carried out before (pre-session) and after a training session (post-session).**
Results: **the comparison of the total BESS scores both pre- and post-session showed a statistically significant increase of stability errors at both T0 and T1 (T0: pre-session 8.6±6.1 errors, post-session 10.7±6.3 errors; t=-4.03; p=0.002) (T1: pre-session 7.2±3.8 errors, post-session 9.1±5.4 errors; t=-1.93; p=0.03). Between T0 and T1 we noticed a reduction of errors which reached a statistical significance during the pre-session time (t=2.75; p=0.0049).**
Conclusion: **stability improved after 12 weeks of training, even for those conditions for which no specific training was done to improve, such as on the soft surface and feet aligned in a tandem stance.**

KEY WORDS: balance, exercise, instability, sport.

Introduction

Balance or postural stability is a necessary component in both daily activities and sport[1,2]. While "balance" is a commonly used term to describe the ability to maintain an upright position, "postural stability" is a more specific description of human balance[3]. Postural stability can be defined as the ability of an individual to maintain their center of gravity within the base of support[4]. It involves feedback from the sensorial systems which determine continual neuro-muscular changes[4]. This allows better sport performance and reduces the risk of injury[5,6]. Because of this, sports training, as well as focusing on improving sporting skills, also develops balance. However, the athlete must take into account the fact that fatigue can compromise stability[5,6].
From the literature, an evidence-based relationship between balance ability and the risk of injury is clear[7,8]. In fact, studies have demonstrated that exercise training is effective in reducing the risk of injuries[7,8]. The training improves proprioception and protect athletes from forthcoming injuries. Proprioceptive information from lower limbs is important in the maintenance of equilibrium in basketball due to the nature of the game[9]. Proprioception is even more significant for basketball because the basketball skills are composed by complex movements demanding high balance ability[9]. It was observed that when balance training was implemented during competitive season, the occurrence of injury rate was reduced by 38%[10]. However, the link between balance ability and athletic performance is not fully clear and required further evidence[11,12]. There are, in fact, very few studies that specifically investigated balance training as approach to improving performance[11,12].
Basketball is a high-demand sport activity with a high prevalence of lower limb injuries, namely knee and ankle sprains[13]. It is a sport which involves mainly jumping and landing[14]. Disequilibrium can be found in every specific movement of basketball, such as in the twisting movement of feet, jump shots as well as offensive and defensive rebounds[9]. Besides which, basketball requires the players to habitually address physical contact and various situations involving balance instability, such as basketball-specific accelerations and decelerations, changes in direction, penetrations into the defensive perimeter, boxing out, dribbling and defense position recovery[15]. These actions are often performed in a very limited space and require very fast move-

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ment, high coordination ability and appropriate strength. It is very important to have good balance while executing these skills.
Until now, no study has ever been carried out looking at the effects of training on balance in basketball. Thus, the aim of this study is to verify balance improvement in basketball players. At the same time we also monitored whether fatigue after a training session has compromised balance.

Materials and methods

We set up a clinical longitudinal observational study designed to recruit 32 volunteer healthy male basketball players from amateur teams. The parents of all subjects read and signed the informed consent form approved by the local Ethics Committee, which also approved the study procedures[16]. The observation period lasted for 12 weeks, from September (pre-season) to December 2013 (mid-season). Participants were selected on the following criteria: young male basketball players of different Under Fifteen Basketball, currently participating in basketball at least 1 year before, no lower extremity musculoskeletal injuries, no history of head injury or of pre-existing visual, vestibular, or balance disorders. Anthropometric data was recorded (age=13.6±0.5 years; weight= 55.4±5.8 kg; height=166.5±5.2 cm; previous basketball practice=2.8±1.2 years). Eighty percent of players were right-handed.

Training intervention

All subjects followed the same athletic training programme, three times a week. Each training session consisted of 30 minutes warm-up, isotonic training and proprioceptive exercises and of 90 minutes technical-tactical training. The warm-up was composed of three phases: 5 min of jogging at a comfortable speed; 2 min of static stretching for the lower limb muscles; and 5 min of shooting, from both sides of the court. The isotonic training used the leg press and leg extension isotonic machines. Each subject performed the following: 5 sets of 12 leg press repetitions at 70% 1 RM (Repetition Maximum) with 3 min of recovery and 4 sets of 10 leg extension repetitions at 70% 1 RM with 3 min of recovery. Following, the balance training was performed. First, subjects performed 8 sets of 20 s of Swiss ball kneeling hold balancing with 30 s of recovery; subjects were told to maintain balance on the Swiss ball while keeping their knee at an approximate angle of 90°. Then, they performed 6 sets of 20 repetitions of the two-handed chest pass balance exercise with 30 s of recovery; subjects were instructed to maintain balance on the trial half-sphere while performing 20 chest passes to a teammate in front of them at a distance of approximately 10 m. After these exercises, subjects completed 90 min technical-tactical training session with their head coach.

Balance Error Scoring System

Postural stability was evaluated using BESS. The test was carried out four times: at the beginning of competitive preparation before training (T0 pre-session); at the beginning of preparation after training (T0 post-session); after 12 weeks before training (T1 pre-session); after 12 weeks after training (T1 post-session).
Postural stability was measured using BESS (Balance Error Scoring System) error scores[17-20]. The BESS consisted of 6 separate 20-second balance tests that the subject performed in different stances and on different surfaces. The test consisted of 3 stance conditions (double-leg, single-leg, and tandem stance) and 2 surfaces (firm and foam). The firm surface was the floor of a gym. The foam surface consisted of a 46 x 46 x 13-cm block of medium-density foam on a 10-cm-thick. A stopwatch was used to time each of the 20-second trials. Subjects were instructed to assume the required stance by placing their hands on their iliac crests and were informed that when they closed their eyes, the test would begin. Errors were recorded as the quantitative measurement of postural stability under different testing conditions. Before the test, subjects were allowed to familiarize themselves with the different conditions. They were first allowed to try standing on the firm surface. Once they were comfortable standing on each surface, we instructed them in the correct positioning for each of the 6 conditions. 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 25 cm off the ground. We instructed the subjects not to lean the dominant leg on the non-dominant leg. The non-dominant foot was positioned behind the dominant foot in the tandem stance, and the subject was instructed to maintain the stance with the big toe of the non-dominant foot touching the heel of the dominant foot. For each condition, we instructed the subject to remain still with their eyes closed and hands on their hips. After instruction, each subject was given 2 familiarization trials on each condition before the actual data collection. During the familiarization and testing sessions, each condition lasted 20 seconds, and at no point was the clock stopped. We instructed the subject to remain as still as possible; if he moved from the test position, he was to return to it as soon as possible. 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; (6) remaining out of the test position for longer than 5 seconds. Performance was scored by adding 1 error point for each error committed. Error scores were calculated for each of the 6 conditions and summed to obtain the total BESS score[17-20]. During the testing, the examiner was positioned 3 m away

from the subject, so the subject's eyes, hands, and feet could all be observed.

Power analysis and statistical analysis

Given the previous data in literature related to mean and standard deviation of the number of BESS errors at recruitment and follow-ups[17-20], we established alfa=0,05 and power=0,90 and yielded a minimum number of 24 subjects.

Recruitment and data collection

For each subject recruited we filled in a form showing personal data, weight, height, dominant limb, years of taking part in sport activity and the scores performed at each time. Leg dominance was determined by methods used in previous studies[21,22]. The completed forms were inserted into a database created using FileMaker pro and analysed using STATA MP11 software. To evaluate the differences between the average values of the results at T0 pre- and post-session and at T1 pre- and post-session we used the t-student test for paired samples (T0 pre- *vs* T0 post- session; T1 pre- *vs* T1 post-session; T0 pre- *vs* T1 pre-session; T0 post- *vs* T1 post-session). To evaluate the results of the tests at T1 pre-session we built multiple regression models which investigate age, gender, weight, height, dominant limb, values at T0 both pre-and post-session. To evaluate results at T1 post-session we built multiple regression models which investigate age, gender, weight, height, dominant limb, values at T0 both pre- and post-session and at T1 pre-session. For each test a value of $p<0.05$ was considered statistically significant.

Results

The results of each test, expressed as number of errors, and the statistical evaluations are shown in the Tables 1 and 2.

FIRM SURFACE-total score

The number of errors increased significantly from pre- to post-session at both T0 and T1. In comparing T0 and T1 we found a statistically significant reduction only in the pre-session scores.

FOAM SURFACE-total score

We found a trend to increase the number of errors from pre- to post-session at T0 and T1. A statistically significant reduction was recorded in the pre-session from T0 to T1.

BESS total score

At T0 and T1 we recorded a statistically significant increase of errors from pre- to post-session. At T1 pre-session the number of errors has been reduced significantly respect to T0 pre-session.

Multiple regression analysis

The total score of the firm surface at T1 pre-session was influenced by the total score of the firm surface at T0 post-session (coef 0.25; t=4.71; $p<0.0001$). The total score of the firm surface at T1 post-session was influenced by age expressed in years (coef 2.75; t=2.61; p=0.015). The total score of the foam surface at T1 pre-session was influenced by the total score of the foam at T0 pre-session (coef 0.51; t=4.66; $p<0.0001$) and post-session (coef 0.35, t=2.89; p=0.008). The total BESS score at T1 pre-session was influenced by age (coef -2.34; t=-2.27; p=0.032) and by the total BESS score at T0 pre-session (coef 0.78; t=5.51; $p<0.0001$). The total foam score at T1 post-session was influenced by age (coef 5.7; t=4.15; $p<0.0001$), height (coef -0.35; t=-2.99; p=0.006), dominant right limb (coef 4.1; t=2.69; p=0.013), total foam score at T0 pre-session (coef 0.51; t=2.11; p=0.045). The total BESS score at T1 post-session

Table 1. Values expressed as averages (± standard deviation) of the various BESS tests, at both times in the study pre-and post-session.

	T0 pre-session	T0 post-session	T1 pre-session	T1 post-session
FIRM surface				
Double leg stance	0	0	0	0
Single leg stance	2.5±2.2	3.5±3.2	1.9±0.7	2.8±2.1
Tandem stance	0.8±0.8	1.0±0.9	0.6±0.7	0.9±0.8
Total Firm surface	3.3±2.7	4.5±3.8	2.6±1.2	3.8±2.5
FOAM surface				
Double leg stance	0	0	0	0
Single leg stance	4.0±3.0	4.6±3.2	3.4±2.6	4.1±3.0
Tandem stance	1.3±0.9	1.6±0.9	1.2±0.74	1.2±0.9
Total Foam surface	5.3±3.6	6.2±3.8	4.6±3.0	5.3±3.6
BESS total	8.6±6.1	10.7±6.3	7.2±3.8	9.1±5.4

Table 2. Statistical comparison of each BESS test showing the comparisons between the pre-and post-session score at each time and between each pre- and post-session score respectively at both times in the study.

Firm surface	Statistical comparison value	Foam surface	Statistical comparison value
Double leg stance		**Double leg stance**	
T0 pre-session *vs* T0 post-session	-	T0 pre-session *vs* T0 post-session	-
T1 pre-session *vs* T1 post-session	-	T1 pre-session *vs* T1 post-session	-
T0 pre-session *vs* T1 pre-session	-	T0 pre-session *vs* T1 pre-session	-
T0 post-session *vs* T1 post-session	-	T0 post-session *vs* T1 post-session	-
Single leg stance		**Single leg stance**	
T0 pre-session *vs* T0 post-session	t-2.59, p=0.0073	T0 pre-session *vs* T0 post-session	t=-1.12; p=0.13
T1 pre-session *vs* T1 post-session	t=-2.51; p<0.0085	T1 pre-session *vs* T1 post-session	t=-1.16; p=0.13
T0 pre-session *vs* T1 pre-session	t=4.44; p=0.0001	T0 pre-session *vs* T1 pre-session	t=2.1; p=0.02
T0 post-session *vs* T1 post-session	t=1.31; p=0.01	T0 post-session *vs* T1 post-session	t=0.61; p=0.27
Tandem		**Tandem**	
T0 pre-session *vs* T0 post-session	t=-1.85; p=0.0365	T0 pre-session *vs* T0 post-session	t=-2.3; p=0.15
T1 pre-session *vs* T1 post-session	t=-1.77; p=0.04	T1 pre-session *vs* T1 post-session	t=0; p=0.5
T0 pre-session *vs* T1 pre-session	t=1.43; p=0.08	T0 pre-session *vs* T1 pre-session	t=0.89; p=0.19
T0 post-session *vs* T1 post-session	t=0.39; p=0.35	T0 post-session *vs* T1 post-session	t=2.44; p=0.01
Total		**Total**	
T0 pre-session *vs* T0 post-session	t=-3.56; p=0.0006	T0 pre-session *vs* T0 post-session	t=-149; p=0.07
T1 pre-session *vs* T1 post-session	t=-2.88; p=0.0036	T1 pre-session *vs* T1 post-session	t=-0.99; p=0.16
T0 pre-session *vs* T1 pre-session	t=2.13; p=0.02	T0 pre-session *vs* T1 pre-session	t=2.05; p=0.02
T0 post-session *vs* T1 post-session	t=1.2; p=0.11	T0 post-session *vs* T1 post-session	t=1.04; p=0.15
		BESS	
		T0 pre-session *vs* T0 post-session	t=-4.03; p=0.002
		T1 pre-session *vs* T1 post-session	t=-1.93; p=0.03
		T0 pre-session *vs* T1 pre-session	t=2.75; p=0.0049
		T0 post-session *vs* T1 post-session	t=1.39; p=0.09

was influenced by age (coef 7.6; t=3.11; p=0.005), by height (coef -0.53; t=-3.08; p=0.005), by dominant right limb (coef 5.33; t=3.11; p=0.005), by the total BESS score at T1 pre-session (coef -1.7; t=3.91; p=0.001).

Discussion

The BESS total scores demonstrate that after 12 weeks (at T1) there was an improvement in balance, with a statistically significant difference in the pre-session test. At both times in the study (recruitment and revaluation at 12 weeks, T0 and T1) the postural stability of the post-session was statistically worse compared to the pre-session.
BESS is a standardized, rapid, inexpensive screening test of postural stability that can be helpful for documenting stability[17-20]. It has been used in many studies with healthy athletes, and as an outcome measure relating to low limb instability or those completing neuromuscular training[17-20, 23, 24]. At the beginning this test was used to study balance stability[23]. The average number of BESS errors depends on the stance and surface[23]. Very few errors are associated with the double-limb stance on either the firm or foam surfaces[9]. The single-leg stance is the most responsible for adding errors to the total BESS score on the firm and on the foam surface[18]. Less number of errors are added to the total BESS score during the tandem stance on the two surfaces[18]. The errors of stability linked to position and surface were the same that we found in literature[17-20].
We found that training improved balance stability. In basketball, athletic training focuses on functional strengthening, agility training, and balance training[25]. This specific physical training supports the improvement of balance control[25]. Postural control is obtained by the interaction of three principal systems: the musculoskeletal system, the sensorial system and the central nervous system[6]. The musculoskeletal system is represented mainly by the triceps surae muscle, particularly trained in basketball[13]. In fact, repeated vertical jumping reinforces the ankle muscles and allows a better and more stable joint[12]. As far as the sensorial system is concerned, basketball players have a particularly developled visual system, which compensates for the decreased stress mechanoreceptors and vestibular receptors[26]. The central nervous system reacts by regulating the muscular activity neccessary to maintain good posture and to restore balance when thrown off, based on information received from the sensorial systems[27].
A recent review underlined that there are no significant differences in postural stability between athletes of different specializations and physically active individuals[27]. Various sport disciplines differ for different postural strategies employed: for example, there is a

greater stimulation of mechanoreceptors in gymnastics[28], a more specific development of proprioceptive and vestibular receptors in swimming[29], peculiar development of muscular fibres of the trunk in volleyball[30], a decrease in the centre of gravity in martial arts[31], a reduction in the center of pressure frequency in football[32,33], and stability of the support base with the use of hard boots in skiing[34].
The second result of the study is that balance decreases due to fatigue. Sport particularly tired fast muscular fibres, that have an anaerobic metabolism, that come into play not only during speed and power activities, but also during sudden postural changes[35]. Moreover, muscle fatigue may alter the proprioceptive afferents, causing further instability[36,37].
It has also been discovered in other sports that motory overload reduces stability. In elite gymnasts, the fatigue due to exercises performed in training leads to a reduction of trunk stability[38]. In soccer, high-level players experience fatigue in the last 15 minutes of each half time of a match[39,40] and players may also experience deficits in postural balance during these 15 minutes, as it has been suggested that soccer-specific fatigue can influence the functional stability of players in match play[5]. In volleyball, the fatigue induced by a match has a marked effect on knee joint position sense in elite female volleyball players. Knee joint position sense was less accurate and less consistent after the volleyball match[6]. However in tennis no loss of stability was recorded at the end of the game, consistent with a lower level of muscle fatigue[41].
Due to further study of the results in each test carried out in our case, we found a pattern which was similar to the BESS total, except in some conditions. The first variation is that of the tandem feet test on a firm surface for which we found no statistically significant improvement between T0 and T1. This could be due to the lack of training for this specific position. Training is specific for conditions of bi-podalic support with feet side by side. The second exception is the data found on the foam surface (at T0 and T1, both on one leg or feet in tandem). In the post-session we discovered a decrease in stability even though the values did not reach a significant difference. We hypothesize that this is due to a fatigue-related failure in the neuro-muscular system involved in this particular position. As a matter of fact, training has always taken place on the firm surface of a gym floor. The third variable is that found on the foam surface, when the test was carried out with feet in a tandem position, for which from T0 to T1 balance improved in the post-session. We suppose that this improvement was determined by athletic preparation, even if it was not specific to the stand evaluated in the test, and this justified the lower level of fatigue at the end of the training session.
The analysis of the multiple regression model showed that right dominance could be a confounding factor and it increases the number of errors. This can be explained by the notion that humans are generally right-footed for mobilization tasks, but left-footed for tasks requiring postural stabilization[42-44]. Other confounding factors are height and age. Indeed, in taller subjects, the centre of gravity is higher and this increases the risk of instability[45]. Furthermore, younger subjects have a less mature postural system which accounts for this greater instability[46]. As for the pre-session values at T1, we also found that they were influenced by the values at T0 which can be justified considering that balance is an innate skill for each individual which can be worked on and improved[46].
There are some weak points in our study which need to be pointed out. In our study we analysed the link between training and postural stability. It would also be interesting to analyse the effects of a match, considering that in a match pyscho-physical fatigue conditions can take over which can alter the player's performance. The use of a stabilometry could allow us to quantify the direction (medial-lateral or anterior-posterior) of the deviations. A control group using sedentary subjects could give us a reference to quantify the effects of taking part in sport. It would be interesting to be able to compare the effects of training in other sports.
Despite limitations, the study has deepened our knowledge of the effects made by training and fatigue on balance. We also discovered that predominantly in basketball, even when a pose was not specifically worked and the work surface were not specifally trained on, balance improved. On the other hand, the loss of stability is specifically connected to fatigue in sport.

Conclusions

The findings of this study could have important implications for basketball players and their coaches. It could be useful to ration training loads, allowing for any neccessary recovery time. Furthermore, it could be appropriate to differentiate programmes administered, varying work and support surfaces and in order to train balance in different conditions. Further studies could look at the effects if these different training programmes.

Competing interests

The Authors declare that they have no competing interests.

References

1. Goldie PA, Bach TM, Evans OM. Force platform measures for evaluating postural control: reliability and validity. Arch Phys Med Rehabil. 1989;70(7):510-517.
2. Guskiewicz KM, Ross SE, Marshall SW. Postural Stability and Neuropsychological Deficits After Concussion in Collegiate Athletes. J Athl Train. 2001;36(3):263-273.
3. Rogers ME, Page P, Takeshima N. Balance Training for the Older Athlete. International Journal of Sports Physical Therapy. 2013;8(4): 517-530.
4. Huang MH, Brown SH. Age differences in the control of postural stability during reaching tasks. Gait Posture. 2013; 38(4):837-842.

5. Greig M, Walker-Johnson C. The influence of soccer-specific fatigue on functional stability. Physical Therapy in Sport. 2007;8(4):185-190.
6. Ribeiro F, Santos F, Gonçalves P, Oliveira J. Effects of volleyball match-induced fatigue on knee joint position sense. European Journal of Sport Science. 2008;8(6): 397-402.
7. Hubscher M, Zech A, Pfeifer K, Hansel F, Vogt L, Banzer W. Neuromuscular training for sports injury prevention: a systematic review. Med Sci Sports Exerc. 2010;42:413-421.
8. Zech A, Hubscher M, Vogt L, Banzer W, Hansel F, Pfeifer K. Neuromuscular training for rehabilitation of sports injuries: a systematic review. Med Sci Sports Exerc. 2009;41:1831-1841.
9. Scanlan A, Dascombe B, Reaburn P. A comparison of the activity demands of elite and sub-elite Australian men's basketball competition. J Sports Sci. 2011;29(11):1153-1160.
10. McGuine TA, Keene JS. The effect of a balance training program on the risk of ankle sprains in high school athletes. Am J Sports Med. 2006;34:1103-1111.
11. Hrysomallis C. Balance ability and athletic performance. Sports Med (Auckland, NZ). 2011;41:221-232.
12. Zech A, Hubscher M, Vogt L, Banzer W, Hansel F, Pfeifer K. Balance training for neuromuscular control and performance enhancement: a systematic review. J Athl Train. 2010;45:392-403.
13. Boccolini G, Brazzit A, Bonfanti L, Alberti G. Using balance training to improve the performance of youth basketball players. Sport Sci Health. 2013;9(2):37-42.
14. Ziv G, Lidor R. Vertical jump in female and male volleyball players: a review of observational and experimental studies. Scand J Med Sci Sports. 2010;20(4):556-567.
15. Ben Abdelkrim N, El Fazaa S, El Ati J. Time-motion analysis and physiological data of elite under-19-year-old basketball players during competition. Br J Sports Med. 2007;41(2):69-75.
16. Padulo J, Oliva F, Frizziero A, Maffulli N. Muscles, Ligaments and Tendons Journal. Basic principles and recommendations in clinical and field science research. MLTJ 2013;4:250-252.
17. Wilkins JC, Valovich McLeod TC, Perrin DH, Gansneder BM. Performance on the Balance Error Scoring System Decreases After Fatigue. J Athl Train. 2004;39(2):156-161.
18. Riemann BL, Guskiewicz KM. Effects of mild head injury on postural stability as measured through clinical balance testing. J Athl Train. 2000;35:19-25.
19. Guskiewicz KM. Postural stability assessment following concussion: one piece of the puzzle. Clin J Sport Med. 2001; 11:182-189.
20. Valovich TC. The Use of the Standardized Assessment of Concussion and Balance Error Scoring System and Learning Effects in Youth Sports Participants [dissertation]. Charlottesville, VA: University of Virginia. 2002.
21. Tallon C, Maffulli N, Ewen SWB. Ruptured Achilles tendons are significantly more degenerated than tendinopathic tendons. Medicine and Science in Sports and Exercise. 2001; 33:1983-1990.
22. Pang BSF, Ying M. Sonographic measurement of Achilles tendons in asymptomatic subjects – variation with age, body height, and dominance of ankle. Journal of Ultrasound in Medicine. 2006;25:1291-1296.
23. Bell DR, Guskiewicz KM, Clark MA, Padua DA. Systematic review of the balance error scoring system. Sports Health. 2011;3(3):287-295.
24. Ambegaonkar JP, Caswell SV, Winchester JB, Shimokochi Y, Cortes N, Caswell AM. Balance comparisons between female dancers and active nondancers. Res Q Exerc Sport. 2013;84(1):24-29.
25. McLeod TC, Armstrong T, Miller M, Sauers JL. Balance improvements in female high school basketball players after a 6-week neuromuscular-training program. J Sport Rehabil. 2009;18(4):465-481.
26. Aglioti SM, Cesari P, Romani M, Urgesi C. Action anticipation and motor resonance in elite basketball players. Nat Neurosci. 2008;11(9):1109-1116.
27. Zemková E. Sport-Specific Balance. Sports Med. 2014; 44(5):579-590.
28. Vuillerme N, Teasdale N, Nougier V. The effect of expertise in gymnastics on proprioceptive sensory integration in human subjects. Neurosci Lett. 2001;311(2):73-76.
29. Itamar N, Schwartz D, Melzer I. Postural control: differences between youth judokas and swimmers. J Sports Med Phys Fitness. 2013;53(5):483-489.
30. Sharma A, Geovinson SG, Singh Sandhu J. Effects of a nine-week core strengthening exercise program on vertical jump performances and static balance in volleyball players with trunk instability. J Sports Med Phys Fitness. 2012;52(6):606-615.
31. Gorgy O, Vercher JL, Coyle T. How does practice of internal Chinese martial arts influence postural reaction control? J Sports Sci. 2008;26(6):629-642.
32. Bieć E, Kuczyński M. Postural control in 13-year-old soccer players. Eur J Appl Physiol. 2010;110(4):703-708.
33. Impellizzeri FM, Bizzini M, Dvorak J, Pellegrini B, Schena F, Junge A. Physiological and performance responses to the FIFA 11+ (part 2): a randomised controlled trial on the training effects. J Sports Sci. 2013;31(13):1491-1502.
34. Noe F, Amarantini D, Paillard T. How experienced alpine–skiers cope with restrictions of ankle degrees–of–freedom when wearing ski–boots in postural exercises. J Electromyogr Kines. 2009;19(2):341-346.
35. Ijkema-Paassen J, Gramsbergen A. Development of postural muscles and their innervation. Neural Plast. 2005;12(2-3):141-151.
36. Voight ML, Hardin JA, Blackburn TA, Tippett S, Canner GC. The effect of muscle fatigue and the relationship of arm dominance to shoulder proprioception. J Orthop Sports Phys Ther. 1996;23(6):348-352.
37. Carpenter JE, Blasier RB, Pellizzon GG. The effect of fatigue on shoulder position sense. Am J Sports Med. 1998,2:262-265.
38. van Dieën JH, Luger T, van der Eb J. Effects of fatigue on trunk stability in elite gymnasts. Eur J Appl Physiol. 2012; 112(4):1307-1313.
39. Krustrup P, Mohr M, Ellingsgaard H, Bangsbo J. Physical demands during an elite female soccer game: importance of training status. Med Sci Sports Exerc. 2005;37(7):1242-1248.
40. Mohr M, Krustrup P, Bangsbo J. Fatigue in soccer: a brief review. J Sports Sci. 2005;23(6):593-599.
41. Malliou VJ, Beneka AG, Gioftsidou AF, et al. Young tennis players and balance performance. J Strength Cond Res. 2010;24(2):389-393.
42. Whittington JE, Richards PN. The stability of children's laterality prevalences and their relationship to measures of performance. British Journal Educational Psychology. 1987;57:45-55.
43. Spry S, Zebas C, Visser M. What is leg dominance? In: Hamil J. Proceedings of the XI Symposium of the International Society of Biomechanics in Sports. MA (Ed). 1993. Biomechanics in Sport XI. Amherst Gentry V, Gabbard C. Foot preference behavior: a developmental perspective. Journal of General Psychology. 1995;22:37-45.
44. Alonso AC, Luna NM, Mochizuki L, Barbieri F, Santos S, Greve JM. The influence of anthropometric factors on postural balance: the relationship between body composition and posturographic measurements in young adults. Clinics (Sao Paulo). 2012;67(12):1433-1441.
45. Vieira TMM, Oliveira LF, Nadal J. An overview of age-related changes in postural control during quiet standing tasks using classical and modern stabilometric descriptors. J Electromyogr Kinesiol. 2009;19(6):e513-519.
46. Howe MJA, Davidson JW, Sloboda JA. Innate talents: Reality or myth? Behavioral and Brain Sciences. 1998;21:399-407.