Original Article

Effect of balance and proprioceptive training on balancing and technical skills in 13-14-year-old youth basketball players

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Abstract

Introduction Balance and proprioceptive training programs improve balance and positively affect technical skills in different sports. However, there is lack of research on the effect of balance training in basketball specifically for 13-14 year old youth athletes. The purpose of this study was to identify the effect of a balance and proprioceptive training program on dynamic and static balance and on technical skills in youth basketball players. **Materials and Methods** After the initial test assessments (e.g. Dynamic and static balance, fast shooting, passing accuracy, defensive sliding, lay up, maneuver running), a total of 30 young male and 25 female 13-14 – year- old basketball players (males ± 0.52 , females: ± 0.48) were randomly allocated into the experimental group for boys (EB) and girls (EG), and into the control group for boys (CB) and girls (CG). Only two experimental groups underwent the balance and proprioceptive training program for 8 weeks. At the end of the training intervention, the initial test assessments were repeated. **Results** A significant difference was observed between pre- and post-test scores in the EB group's dynamic balance, static balance, fast shooting, and passing accuracy tests; specifically, a 13.2, 33.1, 8.6, and 10.2% improvement was observed for the post-test conditions, respectively. In addition, there was a significant difference between pre- and post-test scores in the EG group's dynamic balance, passing accuracy, defensive sliding, and lay-up tests; specifically, a 34.9, 18.8, 3.1, and 12.6% improvement was observed for the post-test conditions, respectively. The percent difference (post-pre intervention program) in static balance, fast shooting, and passing accuracy was significantly different between EB and CB groups. In addition, a significant difference between EG and CG groups was observed in dynamic balance and passing accuracy scores. **Discussion** Although sport trainers and coaches fail to consider the effect of specific balance and proprioceptive programs on the improvement of balance and technical skills young age, it is believed that inexpensive training intervention may be beneficial for balance control and execution of some complex technical skills (e.g. passing accuracy), and, thus, should be implemented by basketball coaches. **Conclusions** It was determined that an 8-week balance and proprioceptive training program improved passing accuracy scores of 13–14-year-old basketball players regardless of sex. In addition, this program improved static balance and fast shooting in boys and dynamic balance in girls.

Keywords: Intervention, young, post training, effect, fitness

Introduction

Basketball is one of the most popular sports [Masin, 2003] and demands a combination of various technical, tactical, psychological and physiological characteristics [Refoyo et al, 2009]. The technical skills are important factors in distinguishing players and could determine their level [Refoyo et al, 2009]. Nevertheless, basketball requires the players with or without ball to execute movements such as passing and receiving the ball while balancing on one leg, while looking in the same or the opposite direction, to have constant visual contact with their teammates and opponents, while during physical contact are required to shoot. As such, balance as a basic neuromuscular ability [Winter, 1995] proves to be an aptitude of great importance for the performance of basketball players [Kostopoulos et al, 2012].

The balance and proprioceptive training programs contribute significantly not only on reducing musculoskeletal injuries but also on their rehabilitation [Caraffa et al, 1996], moreover seem to be essential to achieve higher basketball performance [Hrysomallis, 2011]. Basketball players have high levels of balance, equivalent to the athletes in soccer, gymnastics, dance, while they are outperforming non-trained ones [Bressel et al, 2007; Gerbino et al, 2007; Bieć & Kuczyński, 2010]. It is also possible that the relationship of balance-movement and technical skills to be reflected in different way according to different technical level of basketball

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players [Pavlidou et al, 2006; Bressel et al, 2007; Kioumourtzoglou et al, 1998; Matsuda et al, 2008]. Moreover, it has been observed that a 12-week proprioceptive and balance routine improves passing skills in adult basketball players [Kostopoulos et al, 2012]. Yet, the trainability of proprioceptive and balance training, and the relationship between balance and basic technical skills in young basketball players has not been fully confirmed.

In addition, the possible variation on balance ability among sports and adults [Hrysomallis, 2011] could also be a factor between males and females, since girls seem to have a better balance ability at younger ages. On the other side, males in younger ages show lower levels of balance ability than girls [Dorneles et al, 2013] since females demonstrate an advanced function of their vestibular system at the age of 7-8 years old comparative to boys [Hirabayashi & Iwasaki, 1994]. Moreover, uninjured female adolescent athletes demonstrate better postural stability on video-force plate analysis than their uninjured male counterparts [Howell et al, 2017].

Despite the lack of research about the effectiveness of balance training on basketball, specifically for youth athletes aged 13-14 years old, it is assumed that balance and proprioceptive training programmes could be supportive and improve not only the balance ability but also the technical abilities of female and male basketball players. Therefore, the main aim of this research was to study the effectiveness of an eight week balance and proprioceptive training program on balance and basic technical skills of basketball athletes 13-14 years old and secondary to detect any possible difference between boys and girls.

Method

In the present study (**Figure 1**), 30 youth male and 25 youth female basketball players aged 13-14 years old (± 0.52 for boys and ± 0.48 for girls) voluntarily participated. The study was approved by the Ethics Committee of the National and Kapodistrian University of Athens. All the participants and their parents were fully informed; for the purpose and the procedures of the study and they gave their written consent. All subjects had previous training experience more than three years and participated in 4x90 min training sessions per week.

In the initial measurement the anthropometric characteristics of all subjects were measured (**Table 1**). Two measurements were taken for each anthropometric variable (Balance Salus, Milano) and were averaged. If three measures were taken, the median value was used. Height and sitting height were measured to the nearest mm, body mass to the nearest 0.1 kg [Bailey, 1997; Mirwald, 1978]. A third measurement was required if there was a difference in the first two by more than 4 mm for height or sitting height and 0.4 g for weight [Mirwald, 1978]. The leg length was measured by tape with millimeter precision. The maturity offset from Peak High Velocity (PHV) via gender-specific predictive equations was calculated from the measurements of height, weight, sitting height and the length of the tibia. Specifically, the maturity offset was derived from = $9.236 + 0.0002708 \cdot \text{Leg Length and Sitting Height interaction} + 0.001663 \cdot \text{Age and Leg Length interaction} + 0.007216 \cdot \text{Age and Sitting Height interaction} + 0.02292 \cdot \text{Weight by Height ratio for the boys}$ and = $9.376 + 0.0001882 \cdot \text{Leg Length and Sitting Height interaction} + 0.0022 \cdot \text{Age and Leg Length interaction} + 0.005841 \cdot \text{Age and Sitting Height interaction} + 0.002658 \cdot \text{Age and Weight interaction} + 0.07693 \cdot \text{Weight by Height ratio for girls}$ as suggested from Mirwald and colleagues [2002].

The percentage of body fat was estimated by measuring triceps and suprascapular skinfolds (Harpenden Skinfold Caliber, UK) using the formula as described on page 719 of Slaughter and colleagues (1988). The estimation of body fatness was based on the sum of these two skinfold thicknesses, with the intercepts and regression coefficients varying by sex and skinfold sum and among boys by stage of maturation and race (see Appendix I). All subjects were considered as white and boys' pubescent, similar to other studies [Freedman et al, 2013; Laurson et al, 2011].

The dynamic and static balance of the right and left foot were measured. Additionally, some of the basic technical basketball skills [Riches, 2013; Stewart, 2018] such as the ability to pass, maneuver with the ball, defensive slide, drive (lay-up) and shoot were also evaluated. The subjects were divided randomly into the experimental and control group building four teams. The boys (EB) and girls (EG) experimental group, and the boys (CB) and girls (CG) control group. The two experimental groups undertook an 8-week balance and proprioceptive training program additional to their basketball training program. The program took place one month after the pre-competition period. Post-test assessments took place at the end of the training intervention.

Figure 1. Experimental protocol. 30 youth male and 25 youth female basketball players after the initial assessments were divided randomly into the experimental and control group building as such four groups. The boys (EB) and girls (EG) experimental group and the boys (CB) and girls (CG) control group. After the initial

assessment, an 8-week balance and proprioceptive training program took place only for the boys' and girls' experimental group. Post-test assessments took place at the end of the training intervention.

Dynamic and Static balance assessment.

The dynamic balance was evaluated using a balance platform (**Figure 2**), (Stability platform-Lafayette, USA). At the beginning of the assessment the examiner hold the platform (dimension 106.68 x 64.77cm) in a sloping position, whereas the platform was touching the ground from the side of the dominant leg and was firm. As such the athletes stepped on the platform with their dominant leg, precisely on the position for the dominant leg. The examiner helped the subjects to place the other leg on the platform. When the subjects placed both legs on the platform, the examiner gave a signal to set free the platform and the timing for each effort begun. At the same time the electronic timer, which was connected to the platform, recorded the time of staying or crossing the balance position in milliseconds. The balance position was set in the range of 5°.

The subjects executed three efforts of 30sec each, with a rest of 30sec between successive trials. The average of the three attempts was registered. All subjects wore sport clothes and shoes. Before the beginning of the assessment, the examiner demonstrated the test, while the subjects executed one trial-attempt of 3 sec.

Evaluating the static balance requires vertical support, on a thin wooden surface (2.5cm width, 2.5cm height and 28cm length), in the first 1/3 of the sole of one foot. At the beginning of each assessment, the subjects placed 1/3 of the sole of one foot on the platform.

They then flexed the other leg at the knee joint and attempted to balance the platform without coming into contact with the ground throughout the balancing attempt. The hands were free to help balancing the body. Three (3) attempts were made for each foot without a break. If the subjects lost their balance in the first 3 sec the attempt was repeated. The final performance was the total time of the six (6) efforts. Before the beginning of each assessment, the examiner demonstrated the test, while the subjects executed one trial-attempt for each leg.

Figure 2. Stability platform-Lafayette.

Technical skills assessment.

1st Speed and accurate shooting test [Hopkins et al, 1984].

All subjects executed three trials of 60sec each. The first was a trial-attempt, while the other two were recorded. Between the two attempts there was a three minute break. All subjects were standing behind the shooting line, with a horizontal distance of 3.66m from the board (**Figure 3**). With the command “ready-go”, the subject was shooting the ball; then catching the ball and shooting again from another area. During shooting at least one leg should have been behind the 3.66m line, while maximum four drives were allowed for each effort, but not in a row. All subjects were required to shoot from different area every time. A mistake (steps, double dribbling etc.) was translated into no points and a zero score.

If two consecutive drives took place and the second one was successful, no points were given and the score was zero. If more than four drives took place and there were all successful, no points were given and the score was zero. If the subject couldn't shoot from all five predetermined areas, then the test was repeated. The examiner noted the areas from where shooting took place, as well as the number of drives.

The score was as follow: Two (2) points for every successful basket, and one (1) point for every unsuccessful basket, that hit the ring of the basket. The points that gathered from the two efforts during the 60sec were added together and the sum of them was the final score for the subjects.

Figure 3. Speed and accurate shooting test from 3.66m horizontal basket distance for 60sec.

2nd Passing accuracy test [Hopkins et al, 1984].

All subjects executed three efforts of passing and receiving the ball on targets while moving (**Figure 4**). The targets were square with radio 61cm on a flat wall, the underside of the first (A), third (C) and fifth (E) square abtained from the ground 162cm, while the second (B), fourth (D) and sixth (F) abtained 91cm. The distance between the squares was 61cm and the subject moved parallel to the wall having a 244cm distance. The first attempt was a trial one, while the other two were assessed. Between the two attempts there was a three-minute break. With the command “ready-go”, the subject started from the left side passing the ball with two hands from chest on target A. The subject then received the ball and moved on to the second (B) target, where also passing and receiving was required, then to the third (C) target and so on. The same procedure was followed till the target F, after the subject executed two passes, then continued to target A and moved on successively to targets E, D, C and B. At the target A had to pass twice before continuing. Every pass that met the target or the line around the target gained two (2) points. Every pass that hit in between the targets gained one (1) point. The points that sum up till 30sec represented the score for each attempt. The final score for each subject was the sum of the two attempts. If the subject during passing stepped onto the dividing line of 244cm or the pass was not executed with both arms, the pass gained no points. If the subject hit twice the targets B, C, D and E, no point was given on the second pass.

Figure 4. Passing accuracy test. The subject started the attempt from the left side, passing with two hands from chest on target A.

Then received the ball and moved on to the second (B) target, where also passing and receiving was required, then to the third (C) and so on. On target F, two passes were required to continue to target A.

3rd Obstacle dribbling test, (right/left hand) [Hopkins et al, 1984].

The subject had three attempts to execute dribbling in a distance with six (6) obstacles (cones) (**Figure 5**) within the three seconds rule restricted area. The first was a trial-attempt, while the other two were assessed. Between the two attempts there was a three minute break. With the command “ready-go”, the subject started the attempt from point A by dribbling with the weak hand (for example the left hand). When the subject reached cone B, changed direction and went to cone C by altering hand, dribbling with the right hand. The subject continued to cone D with the right hand, to cone B with the left hand and then cone E with the right hand, while continued with the same hand to cone F.

The second attempt started with the other hand, the right one, and the same procedure was followed. The time that the subject spent to complete the predetermined distance, was the performance time and the final time was the sum of the two performances.

Figure 5. Obstacle dribbling test, i) right and ii left hand. The subject had three seconds to complete dribbling in a distance with six (6) obstacles as soon as possible.

4th Defensive sliding test [Hopkins et al, 1984; Apostolidis et al, 2004].

The subject executed three attempts. The first was a trial-attempt, while the other two were assessed. Between the two attempts there was a three-minute break. With the command “ready-go”, the subject started from point A while always facing the basketball center court, executed defensive sliding to the right without crossing the legs. When point B was reached, touched outside of the line the ground with the right hand, changed direction and executed defensive gliding to point C, touched outside of the line the ground with the left hand, and then similarly to point D and so on. The subject continued to move based on the predetermined route (**Figure 6**). The assessment was finished when both legs crossed the starting - finishing line. It was not allowed to cross the legs nor change direction before touching the ground outside of the line. If the predetermined rules were not followed the penalty was to repeat the test from the beginning, by taking into account the time consumed up to the time of the violation. The time consumed till completion of the route, was the performance for each attempt. The final performance was calculated by the sum of the two (2) attempts.

Figure 6. Defensive sliding test.

5th Lay-up test [Bos, 1988].

For the execution of this assessment two cones were placed to the three seconds rule restricted area extension at 6.25m. The subject took place behind the cone and could start from whichever side of the basket she/he wanted. With the command of the examiner, the subject started and executed as many drives and lay-ups within two minutes as possible (**Figure 7**). After every effort, claimed the ball and moved to the opposite cone

with the ball, to execute the next lay-up. The total sum of the attempts and the sum of the successful attempts was recorded. Between the two attempts there was a three minute break.

Figure 7. Lay-up test. The subject executed as many drives and lay-ups within two minutes as possible.

6th No ball maneuver running [Getchell, 1979].

The test required a rectangular surface 10 meter long and 5 meter wide (10x5m), with 4 cones 3.33m apart (**Figure 8**). The subject started running from the first cone till the last as fast as possible. As such the subject turned 180° and run to the first cone. Namely, the subject maneuvered between the cones and upon reaching the last one the subject made a turn, maneuvered back between the cones, and returned to the first one. Then the subject maneuvered to the last cone and made a turn of 180° and maneuvered back to the first cone where the finishing point was. The assessment was repeated twice and vice versa and as a result the sum of the two attempts was calculated. Between the two attempts there was a three-minute break.

Figure 8. No ball maneuver running test. The subject begun from the starting point and running as fast as possible between the cones, according to the plan.

Intervention Plan

The 8 weeks intervention training (see Appendix II) consisted of balance and proprioceptive exercises [Lesinski et al, 2015], executed 3 times per week, and was applied immediate after their regular basketball training programme on the same basketball court. A total of 24 training interventions (sessions) were applied. Every session consisted of 6 exercises of balance and proprioception, which lasted between 14 -26min, while the subjects executed it in the form of circuit training. To avoid the adaptation of the subjects the training program was adjusted every two weeks, by increasing the duration and the level of difficulty of the exercises. Instruments such as bosu balls®, mini trampolines, wobble boards, balance beams, agility ladders, hoops and obstacles were used [Kasbparast et al, 2014; Verhagen et al, 2005; Kraemer & Knobloch, 2009].

Statistical analysis

To analyze the data, descriptive statistics including means, standard deviations, Pearson's correlation, *t*-tests for dependence or independence groups were applied. All statistical analyses were performed using SPSS for windows (v23, Armonk, NY: IBM Corp.). The statistical significance was set at the level of $p \leq 0.05$.

Results

Somatometric characteristics are shown in **Table 1**. There were no differences between the experimental and the control group, both in boys' and girls' groups in the pre and post the intervention program. Pearsons' correlation coefficient, pre- and post- intervention program regarding somatometric characteristics and balance are presented in **Table 2**, while technical skills and balance in

Table 3.

Although there was a significant difference among pre and post test scores in the EB groups' dynamic balance, static balance, fast shooting and passing accuracy tests indicated a 13.2, 33.1, 8.6 and 10.2 % improvement in post condition, respectively (**Table 4**). On the other hand there was a significant difference among pre and post test scores in the EG group's dynamic balance, passing accuracy, defensive sliding and lay up tests indicated a 34.9, 18.8, 3.1 and 12.6 % improvement respectively in post condition (**Table 4**). Quite similar, percentage deference (post-pre intervention program) in static balance, fast shooting and passing accuracy differed significant among EB and CB group's but not in dynamic balance ($p=0.17$) due to the fact that data points were spread out over a wider range of values (**Figure 9**). Significant difference among EG and CG group's in percentage deference (post-pre intervention program) was also found in dynamic balance and passing accuracy scores (**Figure 10**).

Table 1. Somatometric characteristics (mean $\pm$ SE) for the experimental boys (EB) and girls (EG), and the control boys (CB) and girls (CG) group, respectively, in the Pre- and Post- intervention program

	EB (n=15)	Pre	EB (n=15)	Post	CB (n=15)	Pre	CB (n=15)	Post
Age (yr)	13.0 $\pm$ 0.2		13.2 $\pm$ 0.2		13.0 $\pm$ 0.1		13.3 $\pm$ 0.1	
Weight (kg)	59.9 $\pm$ 2.4		61.5 $\pm$ 2.5		58.0 $\pm$ 2.8		59.3 $\pm$ 2.7	
Height (cm)	169.7 $\pm$ 1.7		170.7 $\pm$ 1.8		162.5 $\pm$ 2.1		164.2 $\pm$ 2.3	
Tricep skinfold (mm)	15.6 $\pm$ 1.8		15.9 $\pm$ 1.7		16.5 $\pm$ 2.0		18.7 $\pm$ 1.9	
Suprascapular skinfold (mm)	10.3 $\pm$ 1.0		10.4 $\pm$ 1.0		12.1 $\pm$ 1.6		11.9 $\pm$ 1.6	
Body Fat (%)	26.6 $\pm$ 2.1		27.2 $\pm$ 2.1		27.5 $\pm$ 3.6		30.2 $\pm$ 3.3	
Seated height (cm)	156.5 $\pm$ 1.0		156.9 $\pm$ 1.0		153.7 $\pm$ 1.0		154.0 $\pm$ 1.1	
Tibia length (cm)	45.0 $\pm$ 0.7		45.3 $\pm$ 0.7		41.2 $\pm$ 0.6		41.4 $\pm$ 0.8	
Maturity offset (yr)	-0.1 $\pm$ 0.2		0.0 $\pm$ 0.2		-0.4 $\pm$ 0.2		-0.3 $\pm$ 0.2	
	EG (n=13)	Pre	EG (n=13)	Post	CG (n=12)	Pre	CG (n=12)	Post
Age (yr)	13.0 $\pm$ 0.2		13.2 $\pm$ 0.2		13.0 $\pm$ 0.2		13.2 $\pm$ 0.2	
Weight (kg)	56.5 $\pm$ 1.4		58.9 $\pm$ 1.3		54.8 $\pm$ 2.0		55.2 $\pm$ 2.0	
Height (cm)	164.5 $\pm$ 1.2		165.6 $\pm$ 1.1		158.3 $\pm$ 1.1		159.9 $\pm$ 1.0	
Tricep skinfold (mm)	19.1 $\pm$ 1.1		20.6 $\pm$ 1.0		17.1 $\pm$ 0.9		16.6 $\pm$ 1.1	
Suprascapular skinfold (mm)	13.1 $\pm$ 1.2		12.1 $\pm$ 1.2		10.3 $\pm$ 1.2		11.0 $\pm$ 1.5	
Body Fat (%)	26.0 $\pm$ 1.8		26.8 $\pm$ 1.8		21.3 $\pm$ 1.7		20.8 $\pm$ 2.2	
Seated height (cm)	156.5 $\pm$ 0.9		156.6 $\pm$ 1.0		151.8 $\pm$ 0.8		153.0 $\pm$ 0.8	
Tibia length (cm)	42.8 $\pm$ 0.6		43.0 $\pm$ 0.5		39.5 $\pm$ 0.4		40.4 $\pm$ 0.4	
Maturity offset (yr)	1.4 $\pm$ 0.1		1.6 $\pm$ 0.1		1.0 $\pm$ 0.1		1.2 $\pm$ 0.1	

Table 2. Pearson's r correlation coefficient of the somatometric characteristics and balance, for the experimental boys (EB) and girls (EG), and the control boys (CB) and girls (CG) group, respectively, in the Pre- and Post- intervention program.

	Dynamic balance								Static balance							
	EB	Pre	EB	Post	CB	Pre	CB	Post	EB	Pre	EB	Post	CB	Pre	CB	Post
	(n=15)		(n=15)		(n=15)		(n=15)		(n=15)		(n=15)		(n=15)		(n=15)	
Age	0.04 (0.87)		0.45 (0.09)		-0.30 (0.27)		-0.23 (0.41)		0.38 (0.16)		0.516* (0.05)		-0.02 (0.95)		-0.18 (0.52)	
Weight	0.09 (0.74)		0.06 (0.83)		-0.32 (0.24)		-0.17 (0.55)		-0.561* (0.03)		-0.19 (0.49)		0.26 (0.35)		0.16 (0.57)	
Height	0.13 (0.65)		0.13 (0.64)		-0.14 (0.63)		0.20 (0.47)		-0.34 (0.21)		-0.05 (0.87)		0.40 (0.14)		0.08 (0.77)	
BF	-0.09 (0.76)		-0.27 (0.34)		-0.13 (0.66)		-0.23 (0.40)		-0.29 (0.29)		-0.50 (0.06)		-0.08 (0.78)		-0.04 (0.90)	
Maturity offset	0.10 (0.72)		0.31 (0.26)		-0.24 (0.39)		0.04 (0.88)		0.04 (0.89)		0.29 (0.29)		0.30 (0.28)		-0.02 (0.95)	
	EG	Pre	EG	Post	CG	Pre	CG	Post	EG	Pre	EG	Post	CG	Pre	CG	Post
	(n=13)		(n=13)		(n=12)		(n=12)		(n=13)		(n=13)		(n=12)		(n=12)	
Age	0.21 (0.48)		0.15 (0.62)		-0.06 (0.86)		0.33 (0.29)		0.17 (0.58)		0.34 (0.25)		-0.49 (0.11)		-0.42 (0.17)	
Weight	-0.35 (0.24)		-0.44 (0.13)		-0.55 (0.07)		-0.45 (0.14)		0.24 (0.42)		0.01 (0.98)		0.28 (0.37)		0.34 (0.28)	
Height	-0.22 (0.47)		-0.29 (0.34)		-0.39 (0.20)		-0.27 (0.40)		0.20 (0.51)		0.05 (0.86)		0.24 (0.46)		0.18 (0.57)	
BF	-0.19 (0.73)		-0.53 (0.06)		-0.49 (0.11)		-0.618* (0.03)		0.26 (0.40)		0.37 (0.21)		0.04 (0.91)		0.38 (0.23)	
Maturity offset	-0.09 (0.78)		-0.06 (0.85)		-0.30 (0.35)		0.14 (0.67)		0.05 (0.87)		0.06 (0.85)		-0.20 (0.54)		-0.15 (0.65)	

* significant correlation ($p \leq 0.05$).

Table 3. Pearson's r correlation coefficient of technical skills and balance for the experimental boys (EB) and girls (EG), and the control boys (CB) and girls (CG) group, respectively, in the Pre- and Post- intervention program.

	Dynamic balance				Static balance			
	EB Pre (n=15)	EB Post (n=15)	CB Pre (n=15)	CB Post (n=15)	EB Pre (n=15)	EB Post (n=15)	CB Pre (n=15)	CB Post (n=15)
Fast shooting	-0.01	0.17	-0.41	-0.41	0.33	0.38	-0.32	-0.53*
Passing accuracy	0.99	0.54	0.13	0.13	0.23	0.16	0.25	0.04
	-0.31	0.27	-0.57*	-0.10	0.18	0.07	-0.12	-0.39
Maneuver dribbling	0.27	0.34	0.03	0.72	0.51	0.81	0.67	0.15
	-0.19	-0.37	0.18	-0.05	-0.26	-0.23	-0.02	0.45
Defensive sliding	0.48	0.17	0.53	0.86	0.36	0.42	0.96	0.09
	-0.09	-0.40	0.13	0.12	0.00	0.04	-0.22	0.18
Lay-up	0.76	0.15	0.64	0.68	0.99	0.89	0.43	0.51
	0.26	0.28	-0.21	0.36	0.18	0.24	-0.36	-0.09
Maneuver running	0.35	0.32	0.45	0.19	0.52	0.40	0.18	0.74
	-0.06	-0.46	0.09	0.20	-0.26	-0.29	-0.28	0.08
	0.84	0.08	0.76	0.47	0.35	0.29	0.31	0.77
	EG Pre (n=13)	EG Post (n=13)	CG Pre (n=12)	CG Post (n=12)	EG Pre (n=13)	EG Post (n=13)	CG Pre (n=12)	CG Post (n=12)
Fast shooting	0.13	-0.23	0.11	0.07	0.31	-0.32	0.29	0.06
Passing accuracy	0.66	0.45	0.73	0.83	0.30	0.29	0.35	0.85
	-0.28	-0.12	0.17	0.48	0.20	0.14	0.38	0.32
Maneuver dribbling	0.36	0.69	0.60	0.11	0.51	0.66	0.23	0.32
	-0.04	-0.01	0.78**	-0.08	0.26	0.59*	0.88**	0.01
Defensive sliding	0.896	0.98	0.00	0.79	0.40	0.04	0.00	0.77
	-0.15	0.29	0.21	-0.04	0.12	0.17	-0.15	0.02
Lay-up	0.64	0.34	0.51	0.91	0.69	0.58	0.63	0.96
	0.18	-0.28	-0.04	-0.01	0.05	0.49	0.09	0.43
Maneuver running	0.55	0.36	0.92	0.99	0.88	0.09	0.78	0.17
	-0.02	-0.44	-0.29	-0.39	0.08	0.44	-0.14	-0.15
	0.95	0.14	0.37	0.21	0.80	0.13	0.66	0.63

* significant correlation ($p \leq 0.05$).

** significant correlation at the 0.01 level.

Table 4. Technical skills and balance (mean $\pm$ SE) for the experimental boys (EB) and girls (EG), and the control boys (CB) and girls (CG) group, respectively, in the Pre- and Post- intervention program.

	EB (n=15)	Pre	EB (n=15)	Post	CB (n=15)	Pre	CB (n=15)	Post
Dynamic balance (sec)	8.6$\pm$0.5*		9.9$\pm$0.5*		8.0 $\pm$ 0.5		8.4 $\pm$ 0.5	
Static balance (sec)	37.9$\pm$3.2*		66.5$\pm$9.4*		27.0 $\pm$ 0.6		27.6 $\pm$ 0.9	
Fast shooting (pts)	40.5$\pm$1.1*		44.5$\pm$1.1*		34.6 $\pm$ 1.4		34.9 $\pm$ 1.4	
Passing accuracy (pts)	185.4$\pm$5.4*		206.9$\pm$5.2*		175.5 $\pm$ 3.9		179.8 $\pm$ 3.5	
Maneuver dribbling (sec)	17.3 $\pm$ 0.3		17.1 $\pm$ 0.3		19.0 $\pm$ 0.3		18.6 $\pm$ 0.4	
Defensive sliding (sec)	23.3 $\pm$ 0.5		23.1 $\pm$ 0.5		24.9 $\pm$ 0.6		24.4 $\pm$ 0.6	
Lay-up (pts)	10.9 $\pm$ 0.2		11.5 $\pm$ 0.3		9.3 $\pm$ 0.4		9.4 $\pm$ 0.4	
Maneuver running (sec)	34.5 $\pm$ 0.6		34.8 $\pm$ 0.6		37.9 $\pm$ 0.5		37.4 $\pm$ 0.5	
	EG (n=13)	Pre	EG (n=13)	Post	CG (n=12)	Pre	CG (n=12)	Post
Dynamic balance (sec)	7.7$\pm$0.7*		11.8$\pm$0.7*		10.1 $\pm$ 0.7		10.3 $\pm$ 0.8	
Static balance (sec)	61.2 $\pm$ 6.7		65.3 $\pm$ 6.2		63.7 $\pm$ 11.9		68.1 $\pm$ 11.8	
Fast shooting (pts)	38.4 $\pm$ 1.0		37.8 $\pm$ 1.0		35.5 $\pm$ 1.0		35.6 $\pm$ 1.2	
Passing accuracy (pts)	181.4$\pm$6.2*		225.0$\pm$7.9*		189.7 $\pm$ 3.9		190.0 $\pm$ 3.5	
Maneuver dribbling (sec)	18.8 $\pm$ 0.3		18.9 $\pm$ 0.3		19.5 $\pm$ 0.6		18.7 $\pm$ 0.6	
Defensive sliding (sec)	24.6$\pm$0.4*		23.8$\pm$0.4*		24.4 $\pm$ 0.3		23.5 $\pm$ 0.4	
Lay-up (pts)	9.2$\pm$0.3*		10.6$\pm$0.4*		9.8 $\pm$ 0.5		10.0 $\pm$ 0.3	
Maneuver running (sec)	35.9 $\pm$ 0.5		36.0 $\pm$ 0.6		36.9 $\pm$ 0.6		36.3 $\pm$ 0.5	

* significant difference ($p \leq 0.05$) between Pre- and Post- intervention program, for each experimental group.

Figure 9. Percentage difference (mean $\pm$ SE), in the Post- and Pre- intervention program regarding technical skills and balance of the experimental (EB) and control (CB) group of boys. The * mark shows significant difference ($p \leq 0.05$).

Figure 10. Percentage difference (mean $\pm$ SE), in the Post- and Pre- intervention program for the technical skills and balance of the experimental (EG) and control (CG) group of girls. The * mark shows significant difference ($p \leq 0.05$).

Discussion

The balance-proprioceptive training programs could be beneficial to balance, and have a supportive effect on the technical skills of various sports [Hrysomallis, 2011]. In this research, the aim was to examine the effect of a balance and proprioceptive training program on the dynamic and static balance as well as on various technical skills on youth basketball players aged 13-14 years old. It was initially hypothesized that an eight-week balance and proprioceptive training program will improve not only dynamic and static balance but also basic technical skills [Riches, 2013; Stewart, 2018] such as fast shooting, passing accuracy, defensive sliding, lay-up, maneuver dribbling and maneuver running. It was found that an eight-week balance and proprioception training program improves passing accuracy scores in 13-14 years old basketball players regardless sex, fast shooting, static balance in boys and dynamic balance in girls.

Balance, static or dynamic, is one of the most substantial neuromotor abilities of humans for common everyday activities, as well as in basketball where various and complex sport technics are required [Gambetta & Gray, 1995]. The balance control is a complex motor ability that results from the interaction of multiple kinesthetic processes [Horak & Macpherson, 1996] and is essential for basketball players [Hrysomallis, 2011].

To maintain body balance, central stimuli transmitted from the periphery to the Central Nervous System (CNS) are processed and given appropriate balancing commands.

However, a number of studies appraised training programs and/or proprioceptive programs with different duration, applied on different age groups in different sports, revealed different conclusions [Hrysomallis, 2011]. The application of a combined eight- week balance training program in athletes aged 12-15 years old [Chaouachi et al, 2014], or in adults [Huang & Yamamoto, 2013; Kachanathu et al, 2014] has proven to improve dynamic balance. Although a four-week balance intervention program in children aged 6-7 years old did not improve balance, a four-week balance intervention program seemed to have a positive effect on adolescents. Verhagen and colleagues [2005] documented no improvement in balance, after a five and a half week intervention program, training two times per week. Eight-week static and dynamic balance programs in basketball players revealed a significant improvement on the static and dynamic balance [Panwar et al, 2014]. Nonetheless, currently there is a lack of information regarding the effectiveness of balance-proprioceptive training programs on the performance of young basketball players and especially on their balance ability. Given the importance of speed and power on the performance of basketball players, another factor that is also essential is the proprioceptive control, which is expressed as the effect of stabilizing reflexes in controlling balance [Riva et al, 2016]. Initially prior to training intervention the EB group displayed a lower ability in static balance while the EG group displayed a lower ability in dynamic balance, respectively. However, Butz and colleagues [2015] demonstrated no significant differences on dynamic balance between boys and girls aged 5-12 years old. Nevertheless, our findings originally indicated that, the balance-proprioceptive intervention program, consisting of high-frequency instability exercises, improved the static balance for adolescent boys and the dynamic balance for girls. Moreover, anthropometric characteristics such as height and center of gravity may interfere in balance performance. In the present study boys had higher average height than girls, suggesting that the higher the height, the more is the distance that the center of gravity has from the ground, thus the boys could demonstrate a greater instability [Nolan et al, 2005; Caron et al, 1997]. One reason for similar age adolescent girls and boys who presented distinctive anthropometric characteristics could be the maturation offset [Rivas & Andries Junior, 2007]. However, maturity offset average of the EG group was significantly greater than the EB indicating earlier maturation development. Consequently, the different anthropometric characteristics between groups may partially explained by different balance-proprioceptive training adaptations in balance.

Similarly, a greater level of balance improvement corresponds with a better basketball technic especially on passing accuracy [Kostopoulos et al, 2012]. Nevertheless there was no significant balance-proprioceptive training effect on the most of the basketball technics that were tested or any strong correlation within the subjects (

Table 3, Table 4, Figure 9, Figure 10).

This may particularly be the case in the exercises that were executed during the intervention training program, which had no practical link to the basketball technical skills. Similarly, Hobbs [2008] did not find any statistically significant correlation between balance and basketball playing ability in different adult level basketball players. However, our findings presented a significance effect of balance-proprioceptive training on passing accuracy in EB and EG groups and on fast shooting only in EB group. Such findings may partially be due to the fact that the subjects were passing to the wall during lateral movements, as such balance may be a prerequisite to stop and pass. Likewise, during the assessment fast shooting and during sliding and shooting, where standing and jumping with one leg was required, balance seemed to be an important characteristic for boys. The exercises of the intervention training program had a gradually progression on the level of difficulty and were also connected with passing, which challenged athlete's balance ability and even more when performed on stable/unstable surfaces. This appears to improve gravity center awareness and contribute to increased ankle strength in the closed kinetic chain (Kostopoulos et al, 2012; Bekris et al, 2012) resulting improvement on passing accuracy and fast shooting. Based on previous studies the interaction between balance - proprioceptive training programs and team sport technical skills or sport performance was evident [Ricotti, 2011; Salaj et al, 2007; Boccolini et al, 2013]. Mahmoud [2011] pointed out the importance of balance in implementing technical skills, such as passing, dribbling and shooting while changing direction, stopping, jumping and faking in young basketball players. Similar evidence is seen from another study from Kostopoulos and colleagues [2012], which likewise, pointed the importance of a 12 - week proprioception and balance training protocol on passing skills improvement in amateur adult basketball players. To the authors' knowledge, no study has documented improvement on fast shooting in young male basketball players.

Quick direction-change during a maneuver dribbling or maneuver running while maintaining absolute control of the ball and body movement challenged the athlete's balance system. However, there are no available evidence to suggest that dynamic and static balance control is strongly associated with basketball maneuver dribbling, defensive sliding, lay-up and maneuver running ability. In contrary, a football study demonstrated no improvement in dribbling after ten-week proprioception and balance training intervention program in amateur players [Bekris et al, 2012]. In the current study speed and agility were likely to have contributed more on maneuver dribbling, defensive sliding, lay-up and maneuver running than balance, due to the fact that evaluation was based on time for the performing predefined routes. Nevertheless, it is assumed that the aforementioned

technical skills are not directly related to the balance. For that reason, it would appear pertinent future studies to concentrate on the qualitative performance technical skill tests instead of speed and agility based technical skill tests. Thus may eventually illustrate the importance of balance on the basic basketball technical skills.

Though, physiological profile of EB and EG groups seems to be representative of their age [Mahmoud, 2011], subjects were recruited in a nonrandomized order and that could be argued that the generalizability of the data is limited. The subjects were trained in separated sessions and boys were trained separately from girls, which may be considered a limitation in the present study. It could be reasoned that different training experiences may lead to a different neuromuscular coordination, joint strength, range of movements that will fluctuate balance improvement [Balter et al, 2004; Lephart et al, 1996]. Additionally, the post intervention adaptations may be, in part, affected by other factors, such as the unique sensorimotor challenges imposed by players' basketball positions.

Conclusion

It is important to note that sport trainers and coaches fail to consider the effect of specific balance and proprioceptive programs on the improvement of the balance and technical skills in the young ages [Ricotti, 2011]. Collectively, the results of this study showed that an 8-week proprioception and balance training program improves adolescent basketball players' passing accuracy in both sexes, fast shooting, static balance in boys and dynamic balance in girls. In view of the results it is believed that such inexpensive training intervention could be beneficial for balance control and execution of some complex technical skills such as passing accuracy, and hence should be account by the basketball coaches.

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APPENDICES

Appendix I

The recommended Slaughter skinfold thickness equations* for predicting percent body fat from a child's sex, maturation, and thicknesses of the triceps and subscapular skinfolds. [from p 719 of Slaughter MH, Lohman TG, Boileau RA, Horswill CA, Stillman RJ, Van Loan MD, Bemben DA. Skinfold equations for estimation of body fatness in children and youth. <i>Hum Biol.</i> 1988; 60 (5):709-723]. For accuracy and validity of the Slaughter skinfold thickness equations please see Freedman et al. 2013.						
SF sum (mm) [†]	Sex	Race	Maturation	Intercept	Coefficients for SF sum	
					Linear	Squared
≤ 35	Boys	White	Prepubertal	-1.7	1.21	-0.008
≤ 35 [‡]	Boys	White	Pubertal	-3.4	1.21	-0.008
≤ 35	Boys	White	Postpubertal	-5.5	1.21	-0.008
≤ 35	Boys	Black	Prepubertal	-3.2	1.21	-0.008
≤ 35	Boys	Black	Pubertal	-5.2	1.21	-0.008
≤ 35	Boys	Blacks	Postpubertal	-6.8	1.21	-0.008
≤ 35 [‡]	Girls	All	All	-2.5	1.33	-0.013
> 35 [‡]	Boys	All	All	1.6	0.783	0
> 35 [‡]	Girls	All	All	9.7	0.546	0

* The formula for the Slaughter-calculated percent body fat is intercept + linear coefficient • (SF sum) + squared coefficient • (SF sum²). Nevertheless, the intercepts and coefficients vary by (i) the thickness of the SF sum, (ii) sex, (iii) race (white vs. black) and (iv) maturation. For example, if a Postpubertal white boy had a SF sum of 34 mm [second row], his PBF_{Slaughter} would be calculated as -5.5 + 1.21•(34) - 0.008•(900) = 28.44%.

[†] SF sum is the sum of the subscapular and triceps skinfolds.

[‡] Used equations for estimation of body fatness according child's sex, maturation, and thicknesses of the triceps and subscapular skinfolds, in this study.

Appendix II

Intervention Program

The intervention program was for young basketball players, implemented right after the regular training program, lasted eight weeks and took place on a basketball court 3 times per week. Each training unit consists of 6 balance-proprioceptive exercises, whereas subjects performed in the form of a 14 to 26-minute circuit-training. The program changed every two weeks, with the duration and the level of difficulty to increase, in order to avoid any adaptation to the test process. A total of 24 intervention exercises were performed.

1st – 2nd week:

Training: 30sec, Break: 30sec, 2 sets, Break set: 2min, Total: 14min.

1st Exercise: The subjects balanced on one leg and moved their free leg as far as they could by crossing forward- backward and right-left, without touching the ground.

2nd Exercise: The subjects balanced on one leg while placing the other leg on the interior side of the knee of the fixed leg. They then lifted the toe of their foot and tried to maintain their balance in this position (flamingo).

3rd Exercise: The subjects balanced with two feet on a balance platform with hands on the waist.

4th Exercise: The subjects applied skipping on the Bosu.

5th Exercise: The subjects performed a lateral bounce over a low hurdle with one foot and attempted to maintain their balance during landing. The subjects performed with the right and the left leg, alternatively.

6th Exercise: The subjects carried out jump ropes with their right and left leg, alternatively.

3rd-4th week:

Training: 45sec, Break: 45sec, 2 sets, Break set: 2min, Total: 20min.

1st Exercise: The subjects balanced on one leg and moved the other leg as far as they could by crossing forward- backward and right-left, without touching the ground.

2nd Exercise: The subjects balanced on one leg while placing the other leg on the interior side of the knee of the fixed leg. They then lifted the toe of their foot and tried to maintain their balance in this position (flamingo).

3rd Exercise: The subjects balanced with two feet on a balance platform with hands on the waist.

4th Exercise: The subjects applied skipping on Bosu.

5th Exercise: The subjects performed a lateral bounce over a low hurdle with one foot and attempted to maintain their balance during landing. The subjects performed with the right and the left leg, alternatively.

6th Exercise: The subjects carried out jump ropes with their right and left leg, alternatively.

5th-6th Week

Training: 45sec, Break: 45sec, 2 sets, Break set: 2min, Total: 20min.

1st Exercise: The subjects with their eyes closed balanced on one leg and moved the other leg as far as they could by crossing forward- backward and right-left, without touching the ground.

2nd Exercise: The subjects balanced with one foot on a thin surface (platform) and subsequently imitated the passing and shooting movement.

3rd Exercise: The subjects balanced with one leg on a balanced platform with hands on the waist.

4th Exercise: The subjects stood on the ground, jumped with two legs on the Bosu, then jumped with one leg on the ground and tried to maintain their balance.

5th Exercise: The subjects applied jumps with one leg on a coordination ladder, namely: right-stabilisation-centre-stabilisation-left-stabilisation.

6th Exercise: The subjects applied jumps rope with the right leg followed by the left leg.

7th-8th week:

Training: 60sec, Break: 60sec, 2 sets, Break set: 2min, Total: 26min.

1st Exercise: The subjects with eyes closed balanced on one leg on a thin platform.

2nd Exercise: The subjects balanced on one leg on a thin platform and imitated specific movements such as, chest- passing and passing over the head, alternatively.

3rd Exercise: The subjects with eyes closed balanced on one leg on a balance platform with hands on the waist

4th Exercise: The subjects jumped with one leg on the Bosu, stabilised and then jumped and landed on the ground with the other leg.

5th Exercise: The subjects jumped on one leg on a small trampoline imitating the execution of specific technical skills, such as: jump - stabilisation on one leg - imitating passing – jump – stabilisation - imitating shooting.

6th Exercise: The subjects executed jump ropes with the right and left leg being at a right angle, alternatively.