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Original Research

Effects of six weeks of stable versus unstable multi-dimensional surfaces balance training on passing skills and balance performance in young male basketball players

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Abstract

Background and objective: Adolescence is a period when balance and coordination decrease as a result of rapid musculoskeletal growth. These changes may affect various sports-specific skills, including balance. This study aimed to examine the changes in balance performance and basketball passing speed in male youth basketball players following six weeks of balance training performed on unstable versus stable surfaces.

Methods: Twenty-five male basketball players, mean age 15.53 $\pm$ 0.57 years, participated in balance training on different surfaces (unstable surface (US, n = 13); stable surface (SS, n = 12)) for six weeks (2 days/week; 35 to 50 min/day, incrementally). Their physical characteristics, passing skills (passing accuracy and speed test) and balance performance (Y-Balance Test and The Closed Kinetic Chain Upper Extremity Stability Test) were measured.

Results: The improvement rates for passing accuracy (effect size (ES) = 0.86, moderate, $P < 0.001$), lower extremity (ES right = 0.94, moderate, $P < 0.001$; ES left = 0.88, moderate, $P < 0.001$) and upper extremity (ES right = 1.01, moderate, $P < 0.001$; ES left = 0.94, moderate, $P < 0.001$) balance scores, upper extremity stability test power (ES = 0.89, $P \leq 0.001$) and the normalized scores (ES = 1.20, moderate, $P < 0.001$) of the US group were higher than those of the SS group. Passing speed significantly increased only in the US group ($P < 0.028$).

Conclusion: A multi-dimensional surface training model improved balance performance and passing accuracy skills compared to a stable surface training model for male basketball players. US balance training may be used as a complementary training model to increase dynamic balance and passing accuracy skills for male basketball players.

Keywords

Upper limb stability; Lower limb stability; Y-Balance Test; Passing skills; Basketball

1. Introduction

Basketball is a contact team sport requiring the use of multi-dimensional technical skills. Therefore, in addition to endurance, strength, speed, and agility [1], balance which is the skill of combining visual, vestibular, and somatosensory systems under static and dynamic conditions is a significant component in basketball [2]. Maintaining good balance in such a complex game can ensure that players control their bodies, minimize mistakes [3], rapidly change direction in a limited area [1, 3] and prevent falls from a loss of balance [3]. Improving dynamic balance skills is important for basketball players to avoid physical contact, effectively display technical skills with appropriate moves in narrow areas, and to be able to suddenly change position [4].

Success in all sports requires strategies and training methods to increase postural control [5] to improve athletic performance [1]. Strength and conditioning professionals are constantly looking for more effective training models. Multi-station or multi-intervention proprioception programs [6], including balance, strength, plyometrics, and running and stretching exercises, are used to decrease lower extremity injuries [7] in basketball players [8]. McLeod *et al.* [9] found that a 6-week neuromuscular training program (2 days/week; 90 min/day) increased the balance and proprioceptive capacities of female basketball players at the high school level. In addition to these positive effects of balance training on muscular performance, different unstable surfaces (US), such as tilt boards, wobble boards, Bosu balls, stability trainers, ankle discs and elastic bands are frequently used as training models. US of training models have been employed to improve changes in the position of the center of gravity [5], and dynamic balance performances [10]. Balance training using unstable boards has also been found to be an effective training method for male basketball players to improve balance and vertical jump, which frequently occurs in this sport [4].

Few studies have examined the effects of different training models on the technical skills in different sports [1, 11]. Evangelos *et al.* [11] found that balance and proprioception training improved the technical skills of amateur footballers, such as passing the ball over a long (30%), or short distance (27.56%), and ball control (10.40%). In another study, Kostopoulos *et al.* [1] determined that balance training improved the passing skills of amateur male basketball players by 14.92%. It has been recommended that these descriptive proprioception and balance exercises should be performed in basketball training in view of their positive effects [1]. Despite these recommendations [1], there is no complex training model performed on different surfaces to improve performance [4] and passing skills in young basketball players [1, 12].

Adolescence is a period when balance and coordination decrease as a result of rapid musculoskeletal growth. As a part of this change, various physical fitness abilities and sports-specific skills may be also affected. During middle adolescence (14–16 years), skills such as agility, motor coordination, power and speed continue to improve. Since adolescents constantly gain muscle mass, strength and cardiopulmonary endurance, they continue to develop their gross motor skills as well. Therefore, participating in sports specific exercises results in improvement of strength and skills [13]. Studies have found that performing neuromuscular training in adolescence may further enhance these skills [9]. Studies involving basketball players have been conducted to determine the effect of selective plyometric exercises on muscular performance (such as lower extremity strength, balance, agility, jumping) [14], and on the functional movement screen performance [15] by using unstable surfaces. Therefore, it is necessary to perform detailed evaluations on how different training modalities such as stable and unstable multi-dimensional surfaces can affect dynamic balance performance and basketball technical abilities of adolescent males. There have been no studies comparing balance training models for young male basketball players on stable and unstable surfaces.

The purpose of this study was to compare the effectiveness of two different balance training programs performed on stable and unstable surfaces for six weeks (12 training units) on dynamic balance performance, passing speed and accuracy rate in 15 to 16-year-old male basketball players. We also sought to determine the possible effects of the two different balance training models on balance improvement and passing technique by increasing postural control, body stabilization and intermuscular coordination. We hypothesized that the unstable balance training model—along with technical, tactical and strength training—will contribute to the coordination skills of young basketball players more than the balance training model on stable surfaces.

2. Methods

2.1 Participants

The participants were 25 male basketball players (age = 15.57 $\pm$ 0.52 years, height = 178.61 $\pm$ 7.03 cm, mass = 71.69 $\pm$ 9.38 kg) with similar training levels (4 days/week; 2 hours/day) and training history (at least three years and maximum five years, average = 4.2 $\pm$ 1.1 years). They participated in regular technical and tactical basketball and conditioning training and competitions at regional levels for at least three years. They are athletes from the same team competing in a U-15 and U-16 youth league based on age. All players who participated in this study, practiced the same technical and tactical training 3 days a week and played in a match once a week for the entire competition season.

Power analysis was performed using the G*Power (3.1.9.2) program to determine the sample size. The calculation was performed to obtain 95% power at α = 0.05 from the passing test in a study by Kostopoulos *et al.* [1]. Accordingly, evidence indicated that groups should have at least seven subjects. All subjects in the study were randomly divided into two homogeneous groups; the unstable surface group (US; n = 13) and the stable surface group (SS; n = 12), according to the pre-test results.

At the beginning of the study, participants were tested on performance in all tests to be used in this study. Based on the pre-test results (physical characteristics, passing accuracy, passing speed balance, Y-Balance and The Closed Kinetic Chain Upper Extremity Stability Test), the participants in both groups were found to be at the same technical level, and were determined to be homogeneous. Participants were randomly assigned to one of two intervention groups in a 1 : 1 ratio, the unstable surface group (US; n = 13) and the stable surface group (SS; n = 12) using the method of randomly permuted blocks (stratified randomization) on a publicly accessible website (see http://www.randomization.com).

TABLE 1. Participants' characteristics by groups*.

Variables	Unstable surface group (n = 13)	Stable surface group (n = 12)	^{a}P value
Age in years	15.57 ± 0.52	15.63 ± 0.51	0.624
Height, cm	178.61 ± 7.03	177.41 ± 8.11	0.682
Mass, kg	71.69 ± 9.38	67.75 ± 7.92	0.300
BMI, kg/m^2	22.39 ± 1.76	21.45 ± 0.96	0.077
Average arm length, cm	90.66 ± 4.26	88.95 ± 1.03	0.355
Average leg length, cm	94.29 ± 5.07	93.85 ± 3.69	0.849

Note: SD, Standard Deviation; BMI, Body Mass Index ; ^{a}Mann Whitney U Test; $P < 0.05$. * No difference was seen between groups for baseline measurements of physical characteristics.

The subjects' characteristics are presented in Table 1.

Similar to other published training studies [16–18], a true control group could not be incorporated as the two experimental groups were athletes and there were no comparable athletes available that would provide similar baseline values from different basketball teams.

This study was initiated after the necessary permissions (Protocol number: 09.2019-208) had been obtained from the Research Ethics Committee of the School of Medicine, Marmara University. In addition, as subjects were younger than 18, their families were informed about the content of the study, and the families' written permissions were obtained. Volunteer athletes who passed the necessary medical checks before the start of the season were included in the study. Participants were asked about their dominant leg used to kick a ball, and their dominant hand used to throw a ball during their sporting performances.

2.2 Procedure

A pre- and post-test experimental design was employed in this study. The study was conducted in a macrocycle of 6 weeks between April and May during the competition season. The pre- and post-tests of all athletes were performed in a closed basketball court on the same day (Saturday, Sunday) and at the same time (from 6:00 to 8:00 PM) over six-week intervals, and under the same experimental conditions, at least 48 hours after the last training session or match. All tests were completed in two days. Athletes were asked not to perform any other activities on the day the tests were conducted. All athletes participated in tests wearing a basketball jersey, shorts and shoes.

After the anthropometric measurements (height, weight, arms, and leg length) of all participants were recorded on the first day during the pre-test session, the Upper Quarter Y-Balance Test (YBT-UQ) [19], passing accuracy and speed tests were done to assess their passing technique. On the second day, Lower Quarter Y-Balance Test (YBT-LQ) [20, 21] and Closed Kinetic Chain Upper Extremity Stability (CKCUES) [22, 23] tests were performed. Before the tests started, all athletes followed the same warm-up program, which lasted 15 minutes Athletes were permitted to rest for five minutes between the tests. After the completion of the balance training program lasting six weeks (12 training units), post-tests were repeated, using the same procedure.

2.3 Anthropometric measurements

The subjects' body weights and heights were measured, and their body mass index values were calculated (The body mass index BMI = body weight/body height^2 (kg/m^2)). Their heights were measured to a precision of 0.1 cm against a wall (F10-02DM, Muratec-KDS Corp., Kyoto, Japan), and their weights were measured by a digital weighing scale to a precision of 0.1 kg (WB-110A, Tanita, Tokyo, Japan). The lengths of subjects' arms and legs were measured using a non-stretchable tape measure (F10-02DM, Muratec-KDS Corp., Kyoto, Japan) and recorded to a precision of 0.1 cm.

2.4 Y-Balance Test upper quarter

To evaluate participants' upper extremity dynamic balance performance, the Y-Balance Test Upper Quarter (YBT-UQ) protocol in the Y-Balance Test kit (Move2Perform, Evansville, IN, USA) was used. YBT-UQ is a functional test to evaluate the upper extremity stability and mobility in a closed kinetic chain [19]. Reliability was found to be high for the dominant (ICC = 0.91) and non-dominant sides (ICC = 0.92) [24].

To calculate YBT-UQ scores, athletes' arm lengths were measured using a tape measure (F10-02DM, Muratec-KDS Corp., Kyoto, Japan) between anatomical points in accordance with the protocol [19]. The mean lengths of both arms were measured. The arm lengths were recorded to a precision of 0.1 cm.

Athletes performed the YBT-UQ test in three different directions, medial, inferolateral and superiorlateral, for each arm. Subjects were asked to maintain a three-point plank position in a way to keep their test point in a vertical position with respect to their shoulders and open their feet as wide as their shoulders. They placed the thumbs of their hands on the stance platform behind the red line. Afterwards, they pushed their free arm and reached toward the indicator in the medial, inferolateral and superiorlateral directions as fast as possible, returning to the start position under full control of their body and without losing the three-point (tested hand and both feet) plank position. After two trials, the test was repeated three times for each side, and there was a 30-second break between each trial [19]. If the athletes failed to maintain the three points, or if they performed the move by pushing the indicator (i.e., kicking it away) or gained support from the ground or the plate, the test was repeated [5].

The mean values for the distances achieved in three practices were evaluated in cm for each reach direction. In addition, the mean calculated distance was normalized for the length of the upper extremity. The combined score, which was the mean regular and normalized distance in three directions of reach, was also analyzed [19].

2.5 Y-Balance Test lower quarter

The Y-Balance Test Lower Quarter (YBT-LQ) protocol in Y Balance Test kit (Move2Perform, Evansville, IN, USA) was used to evaluate athletes' lower extremity dynamic balance. The YBT-LQ test was found to be highly reliable (ICC intra-rater reliability ranges from 0.85 to 0.91, and its inter-rater reliability ranged from 0.99 to 1.00) [25].

The athletes' leg lengths were measured to calculate pre-test YBT-LQ scores in accordance with the protocol [26]. The mean length of both legs was used in the evaluations.

YBT-LQ measurements were performed in three directions (anterior, posteromedial, and posterolateral, respectively) with each foot as stated in previous studies [21, 25]. Before the start of the test, participants were told to push the indicator as far as possible while maintaining their balance, and to avoid using momentum and stepping on the indicator while pushing [21].

The trials and tests were performed in bare feet. Six practice trials were done before the test for familiarization, and the practice was performed three times in a row in each direction to increase consistency [21]. The test was performed using both legs separately. The test order was organized as right anterior, left anterior, right posteromedial, left posteromedial, right posterolateral and left posterolateral [21]. The breaks between the tests were approximately 20 seconds, which was sufficient for the researchers to record the data and return the indicator to the beginning position [21].

The reach distance in each trial was recorded at a precision of 0.5 cm, and the longest reach distance in three test results obtained for each direction was used for analysis [21, 27]. The combined reach distance score was determined after the greatest reach distances for each direction were normalized by using the limb lengths in order to analyze the general performance in the test [27].

2.6 Determination of the Y-Balance Test measurement score

Measurements scores regarding the Y-Balance Tests were performed using the following formulas [26, 27]:

$$\text{Absolute Reach Distance (cm)} = \frac{\text{practice 1} + \text{practice 2} + \text{practice 3}}{3}$$

Relative Reach Distance [(cm) (Lower Extremity)]: Absolute Reach Distance (cm)/Leg Length (cm) $\times$ 100

Relative Reach Distance [(cm) (Upper Extremity)]: Absolute Reach Distance (cm)/Arm Length (cm) $\times$ 100

Combined Reach Distance score [(cm) (Lower Extremity)] :

$$\frac{\text{Total of 3 direction (cm)}}{3 \times \text{ Leg Length (cm)}} \times 100$$

Combined Reach Distance score [(cm)(Upper Extremity)] :

$$\frac{\text{Total of 3 direction (cm)}}{3 \times \text{ Arm Length (cm)}} \times 100$$

2.7 Passing skills tests

This study evaluated passing skills, which is one of the fundamental techniques in basketball [12]. A particular passing test was used to evaluate athletes' skills in receiving the ball or passing while on the move [28]. The validity and reliability of this passing test ranged between 0.84 and 0.97 [29].

The passing test was performed against a 9.14 m straight wall. Six square targets, each 61 cm, were formed on the wall using tape. Three of these targets (Target 1, 3 and 5) were arranged to be 152 cm above the ground, while the other three (Target 2, 4 and 6) were 91 cm above the ground. There were 61 cm gaps between each square. In addition, a straight line was formed 244 cm away from the wall using tape on the ground in parallel with it. Athletes were asked to move behind this line during the test [29]. All athletes performed the test three times. The first attempt was a trial. The number of passes thrown in 30 seconds was recorded using a video camera (GoPro HERO7-Black, San Mateo, CA, USA). A GoPro camera was mounted on a bicycle helmet worn by the researcher, and athletes were recorded at a distance of 1.5 meters. The scores achieved in two practices were evaluated. Spalding TF1000 basketballs, which meet the standards of the International Basketball Federation (FIBA) [30] were used. Athletes threw the ball to the first target on the wall using the chest passing technique and quickly ran to the next target 61 cm away, after receiving the ball rebounding from the wall. The goal was to complete the passing test by consecutively throwing the ball at the six targets on the wall and continuing for 30 seconds. If all targets were hit in less than 30 seconds, the athletes started to hit the targets in reverse order (Target 6, 5, 4 and so on). Every pass hitting the targets or targets' border lines earned two points, while each pass hitting an empty area earned one point. The total of the scores obtained from two practices determined the final score [1].

2.8 Passing speed test

A passing speed (km/s) test was performed using a velocity speed gun (Bushnell Velocity Speed Gun Model# 101911, Overland Park, KS, USA) which was highly reliable (Gun intraclass correlation coefficient (ICC) = 0.95)) [31]. While performing the passing accuracy test, a second GoPro camera attached to the chest was pointed towards the target wall, and the balls thrown, and athletes were recorded at a distance of 1.5 meters. The first of three measurement was a trial, and the mean passing speeds achieved in the other two practices were recorded (km/s) and evaluated later.

2.9 Closed kinetic chain upper extremity stability test

The Closed Kinetic Chain Upper Extremity Stability Test (CKCUES) protocol was used to evaluate athletes' upper extremity function and stability. The intraclass correlation coefficient for the test–retest reliability of CKCUES was found to be 0.922, while the stability coefficient was 0.859 [22]. The results indicated moderate to excellent reliability regarding CKCUES for adolescents [32].

Two tapes were applied to the ground 91 cm apart to determine the locations where athletes were to put their hands before starting the CKCUES test. Athletes had to position themselves by putting their hands on the two tape lines on the ground with their legs closed and shoulders in parallel with their hands [15, 22]. The athletes lifted one of their hands and touched the other hand, and then returned it to its start position with both their hands for 15 seconds, and the total number of touches was recorded. Each athlete repeated the test three times. A 45-second break was given between each attempt [15]. They were asked to keep their backs in a straight position and maintain this position for the duration of the movement. Three score calculation methods were proposed for evaluating the CKCUES test [32]. These methods included: (1) Total number of touches performed in 15 seconds; (2) Normalized score found by dividing the total number of touches into the athletes' height (cm); (3) Power score found by multiplying the number of touches by 68% of the athletes' weight and dividing the result by 15.

2.10 Training protocols

All balance training programs were applied over one and a half months during the competitive period (April to May). Both groups played a basketball match once a week (Thursday or Sunday). The athletes did strength and conditioning training once (Tuesday) a week (60 min/day) and they continued their regular technical and tactical training three days (120 min/day) a week (Monday, Saturday and Thursday or Sunday) under the supervision of the same coach for six weeks during the study. A regular training program typically focused on technical skills (basketball specific skills like passing, shooting, drippling, etc.), tactical skills of the individuals and the team (offensive and defensive schemes, training match). The athletes did strength and conditioning training at least once a week before the study. The strength and conditioning trainings included techniques some for optimizing basketball performance by combining free weight (disks, dumbbells etc.) and body weight trainings. Based on the recommendation in a meta-analysis on youth resistance training, the average resistance training program consisted of 2–3 sets of 8–15 repetitions with loads between 60% and 80% of the 1 RM on 6–8 exercises [33].

Two different short-term balance training models were used by the adolescent male basketball players based on previous studies [5, 34, 35]. Both training groups performed the same balance training program on unstable or stable surfaces between 18.00 and 19.00 for two days a week (Monday and Thursday) before the athletes' regular training. The first author (TF) organized the annual training plan and also attended and monitored each training session. The subjects of this study had no previous experience in the exercises performed on unstable surfaces.

The balance training program was planned to be stage 1 (first and second weeks), stage 2 (third and fourth weeks), and stage 3 (fifth and sixth weeks) according to the athletes' adaptation to use of unstable surface equipment in order to balance discs, balls and the trampoline. The athletes who were successful in all movements then passed to the next stage. As the training levels of all athletes were similar, they were found to be successful in the same sections of all exercises, and no issues were experienced in passing to the next stage. Each training unit lasted 35 minutes at the beginning and 50 minutes at the end of the six-week (12 training units in total) study. A training unit was completed in three stages, namely, standardized warm-up protocol (5 to 10 minutes), main phase (20 to 35 minutes) and closing practices (5 to 10 minutes).

The training program was based on the basic concepts emphasized for different balance training models by using guidelines for young athletes [1, 5, 16, 17, 34, 35]. The published literature shows different 11 to 12-week (16 to 19 training units; 3 to 6 days/week; 11 to 15 min/day) training models [34] and different balance models (11 to 12 weeks; 2 days/week; 31 to 60 min/week) recommending adolescent athletes to increase the duration of balance training but decrease the frequency. Studies have reported that balance training that lasts for four [36] or six weeks [35] minimum is sufficient to boost dynamic and static balance. This period should be at least six weeks to ensure the athletes' sensory-motor adaptation and improve their balance [35]. Studies have shown that unstable surfaces should be used to improve balance performance [5], and that such practices are effective in boosting static [37] and dynamic balance [10] development. These practices were found to improve athletes' static and dynamic balance skills on unstable surfaces [5]. Normally in a periodized training format, major changes in the training sessions are made every 2 to 4 weeks [38]. Any monotonous routines were removed from the balance training programs. Every two weeks, different exercises were performed, and a total 14 different exercises were planned and diversified from simple to difficult and applied to the participants.

There is no gold standard for the duration of balance training, and it was heterogeneous. Therefore, it is difficult to make a global conclusion about the effectiveness of various types of balance training. In most cases, it was approximately 40–50 minutes however, in some studies, this time was rather short, i.e., only 10–20 minutes a full training session [39]. Athletes performed balance training for 35 to 50 minutes, including a warm-up practice at the beginning of their technical–tactical training for two days (Monday and Saturday) a week along with their technical–tactical and strength training over the six weeks.

The balance training protocols were based on common clinical practice and coaching experience. The exercise forms were created to improve athletes' static and dynamic balance characteristics. In addition, these exercises were standardized with the movements requiring the activation of the basic muscle groups (knee extension and flexion, leg abduction and adduction, abdominal and back muscles, rotation, upper back, arm, and shoulder group muscles) that are used in basketball games and that will activate the lower and upper extremities. The training program load was revised by the number and duration of repeats (Appendix Table 5).

The training volume can be dosed by setting a certain period to complete the exercise. The exercise program was formed based on the number of repetitions and duration according to the type of movements applied. Accordingly, the exercises were performed in different training intensities of 3 sets of 5–21 repetitions, 7–14 exercises, and with a variety of lower-body, upper-body, and whole-body balance exercises including specific balance exercises. Each movement was applied for 3 sets (20–30 seconds loading based on duration; 5–21 repetitions based on the number of repetitions;) and 10–60 seconds of rest interval between each exercise. Rest intervals are set to be 1 : 2 ratio (1 : 2 work/rest ratio).

Athletes in the US group performed 7 to 14 exercises determined for each training unit using a Bosu balance disc (diameter: 33 cm, weight: 1/10 pieces), Delta balance ball (diameter: 52 cm, height when fully inflated: 24 cm/4 pieces) and Delta trampoline (diameter: 102 cm/2 pieces).

Athletes in the SS group did the same number of repetitions and had the same rest intervals between exercises 7 and 14 for each training unit exactly the same way as US group but the only difference was that the SS group practiced all exercises (Busso Balance Disc Exercises, Delta Balance Ball Exercises and Trampoline Exercises) on the ground (Appendix Table 5). No injuries occurred during the six weeks, and subjects were permitted to take part in other physical activities during the study.

2.11 Statistical analysis

Descriptive statistical methods were described using mean, SDs and minimum and maximum scores. The fit to a normal distribution was examined using the Shapiro-Wilk Test. Intra-group pre- and post-test evaluation was performed using the Wilcoxon Signed Ranks Test, while the Mann-Whitney U Test was used for inter-group pre-and post-test evaluations which could not be determined using the Shapiro-Wilk Test. Spearman correlation analysis was used for the relationship between the parameters. In addition, effect size (ES) estimates were calculated using the standardized mean difference to determine the magnitude of the intervention effects (ES = (Mean Post - Mean Pre)/SD of the pre-value) proposed by Rhea for recreationally trained subjects, where <0.35, 0.35–0.80, 0.80–1.50, and >1.50 represented trivial, small, moderate, and large effects, respectively [40]. The level of significance was set at $P < 0.05$. The SPSS version 19.0 was used for all analyses (SPSS, Inc., Chicago, IL, USA).

3. Results

3.1 Results of physical characteristics of the subjects

The physical characteristics of the subjects are presented in Table 1. The ES, P-values, and percentage (%) changes for each group are presented in Tables (Tables 2,3,4). No difference was found in the pre-tests regarding the physical characteristics (Table 1) and performance tests (Tables 2,3,4) between the groups. Physical characteristics and motoric features of the participants in both groups were found to be similar. Accordingly, the pre-test results found the groups to be homogeneous.

3.2 Results of dynamic balance and passing skills test

The Wilcoxon statistical analysis results for pre- and post-test differences regarding the groups indicated that significant increases ($P < 0.05$) were seen in the following: both groups' right leg dynamic balance composite scores (Table 2), both groups' left leg dynamic balance composite scores (Table 2), both groups' right arm dynamic balance composite scores (Table 2), both groups' left arm dynamic balance composite scores (Table 2), both groups' upper extremity closed chain stability, strength and normalized test scores (Table 3) and both groups' passing accuracy test scores (Table 4). Moreover, ball speed significantly decreased in the US group ($P < 0.05$), and no statistically significant difference was found in the SS group ($P < 0.05$).

Except for the passing speed ($P > 0.05$; Table 4), there were significant differences between the groups ($P < 0.01$) for all variables (Tables 1,2,3,4). The results indicated that the improvements in the US group were better, and the greatest improvement in both groups was the increase in passing accuracy test scores (US group: +13.8%; SS group: +6.4%) (Table 4).

The improvement in the US group in the dynamic balance composite tests (Table 2), the CKCUES strength and normalized tests (Table 3) and the passing accuracy tests (Table 4) was classified by a moderate ES. However, in the ball speed, a low ES was seen. Improvements in ball speed (Table 4) were trivial for the SS group, and this groups' development in other test parameters (Tables 2,3,4) had a small ES.

4. Discussion

This study aimed to examine the changes in basketball passing accuracy rate, passing speed, upper extremity stability, lower and upper extremity dynamic balance performances for male youth basketball players following six weeks of balance training performed (12 training units; 2 days/week; 35 to 50 min/day in total) on unstable versus stable surfaces. We found that training on unstable surfaces (Delta balance ball, Bosu balance disc, Delta trampoline) contributed more

TABLE 2. Statistical analysis of upper and lower extremities dynamic balance composite scores.

Dynamic balance composite scores	Unstable surface group (n = 13)				Stable surface group (n = 12)				Baseline differences between groups	Pre-post test differences between groups
	Pre	Post	^{b}P	Effect size¶	Pre	Post	^{b}P	Effect size¶	^{a}P	^{a}P
DBCS—Right Leg, cm	96.66 ± 9.43	105.50 ± 10.67	<0.001**	0.94#	98.96 ± 7.19	102.26 ± 8.03	<0.002*	0.46◇	0.744	<0.001**
DBCS—Right Leg, Differences (%)	9.15 ± 3.78				3.33 ± 1.61					
DBCS—Left Leg, cm	95.79 ± 10.79	105.24 ± 11.51	<0.001**	0.88#	97.91 ± 7.53	101.50 ± 8.37	<0.002*	0.48◇	0.514	<0.001**
DBCS—Left Leg, Differences (%)	9.87 ± 3.72				3.67 ± 1.45					
DBCS—Right Arm, cm	98.16 ± 9.84	108.06 ± 11.26	<0.001**	1.01#	99.93 ± 8.91	102.26 ± 8.03	<0.003*	0.26	0.624	<0.001**
DBCS—Right Arm, Differences (%)	10.08 ± 3.33				2.33 ± 2.09					
DBCS—Left Arm, cm	96.66 ± 9.43	105.50 ± 10.67	<0.001**	0.94#	98.96 ± 7.19	102.26 ± 8.03	<0.003*	0.46◇	0.550	<0.001**
DBCS—Left Arm, Differences (%)	9.15 ± 3.81				3.33 ± 2.10					

Note: SD, Standard Deviation; DBCS, Dynamic Balance Composite Score; ^{a}Mann Whitney U Test; ^{b}Wilcoxon Signed Ranks Test;
* Indicates statistical significance *$P < 0.01$, **$P < 0.001$; ¶Effect size, #Moderate, ◇Small.

TABLE 3. Statistical analysis of the closed kinetic chain upper extremity stability test power scores and normalized scores.

The closed kinetic chain upper extremity stability test scores	Unstable surface group (n = 13)				Stable surface group (n = 12)				Baseline differences between groups	Pre-post test differences between groups
	Pre	Post	^{b}P	Effect size¶	Pre	Post	^{b}P	Effect size¶	^{a}P	^{a}P
CKCUEST—Power Scores	77.75 ± 12.67	89.00 ± 13.87	<0.001*	0.89#	73.45 ± 17.58	76.25 ± 18.55	0.026*	0.16†	0.135	<0.001*
CKCUEST—Power Scores Differences (%)	14.83 ± 6.72				3.70 ± 5.19					
CKCUEST—Normalized Score	0.40 ± 0.05	0.46 ± 0.05	<0.001*	1.20#	0.40 ± 0.05	0.41 ± 0.06	0.034*	0.20†	0.935	<0.001*
CKCUEST—Normalized Score Differences (%)	14.89 ± 6.39				3.62 ± 5.05					

Note: Abbreviations: SD, Standard Deviation; CKCUEST, The Closed Kinetic Chain Upper Extremity Stability Test,
^{a}Mann Whitney U Test; ^{b}Wilcoxon Signed Ranks Test; *Indicates statistical significance *$P < 0.05$ **$P < 0.001$.
¶Effect size, #Moderate, ◇Small, †Trivial.

TABLE 4. Statistical analysis of pass accuracy point and pass speed.

Pass Accuracy Point & Pass Speed	Unstable Surface Group (n = 13)				Stable Surface Group (n = 12)				Baseline differences between groups	Pre-post test differences between groups
	Pre	Post	^{b}P	Effect size¶	Pre	Post	^{b}P	Effect size¶	^{a}P	^{a}P
PAP, count	86.31 ± 13.15	97.62 ± 11.15	<0.001**	0.86#	87.25 ± 10.52	92.50 ± 8.03	<0.004**	0.50◇	0.50◇	<0.001**
PAP, differences (%)	13.80 ± 6.23				6.40 ± 4.65					
PS, km/s	23.30 ± .87	23.95 ± .90	<0.028*	0.75◇	23.55 ± 1.70	23.68 ± 1.69	0.784	0.08†	0.724	0.142
PS, differences (%)	2.90 ± 4.06				0.61 ± 3.91					

Note: SD, Standard Deviation; PAP, Pass Accuracy Point; PS, Pass Speed; ^{a}Mann Whitney U Test; ^{b}Wilcoxon Signed Ranks Test; *Indicates statistical significance.
*$P < 0.01$ **$P < 0.001$; ¶Effect size, #Moderate, ◇Small, †Trivial.

to the improvement of lower and upper extremity dynamic balance and technical basketball performance compared to training on stable surfaces. Moreover, balance training on both surfaces were found to contribute to improvements in the passing accuracy rate, the right and left leg composite balance score, the right and left arm composite balance score and the CKCUES strength performances of young male basketball players. The two different training models found no difference in the increase in passing speed for the two groups. It is recommended that a six-week training model performed by young male basketball players on unstable surfaces be used as an alternative program to improve basketball-specific techniques such as passing accuracy rate, and to increase dynamic balance.

Studies indicate that musculoskeletal development continues rapidly in adolescence and, balance and bodily coordination may decrease or get worse [9]. Therefore, strength and conditioning professionals are constantly looking for effective and different training regimens to improve coordination and balance performance as well as sport specific skills.

Studies have showed that using different training models which change basketball-specific loading elements (loading intensity, frequency, volume, and duration) improve balance performance [5]. Gebel *et al.* [41] reported certain characteristics similar to those of the training model of Lesinski *et al.* [34] for improving balance performance and indicated that loading frequency and duration was not appropriate for adolescent athletes. Accordingly, Gebel *et al.* [41] found that the training model (11 to 12 weeks; 2 days/week; 31 to 60 min/week), in which they increased the duration of weekly balance training while decreasing the frequency, was more effective for increasing adolescent athletes' balance performance. Although this study did not examine the effect of different training durations, the dynamic balance improvement of the basketball players in both the SS and US groups indicated that the balance training for adolescents can be developed in six weeks. Therefore, the results of this study support the opinion of Zech *et al.* [35] that six weeks is sufficient for balance improvement.

Training level is an important factor for efficient balance training [34]. Involvement in sports at an early age, and repeating the moves frequently, has a positive impact on the neurophysiological development of athletes [42], and it can be regarded as one of the factors that improve performance. Previous studies have shown that balance training was more effective for athletes performing regular training [34]. The training model performed on SS provided an insignificant and low development (d = 0.03 to 0.48) in lower and upper extremity dynamic balance composite scores, and the ES of the balance training on US was moderate (d = 0.88 to 1.01). Although the loading duration and frequency of the two different training models we used on various surfaces were the same (Appendix Table 5), results indicated that exercises performed on US contributed more to the dynamic balance performance improvement in lower and upper extremities compared to SS, and that these exercises were effective training models. The results of this study support the outcome of the study by Gioftsidou *et al.* [10] that balance training performed on US were effective in the development of dynamic balance. Moreover, despite employing different study methods, this study is in accordance with the results of the study by Filipa *et al.* [43] that neuromuscular training performed on US for eight weeks is effective in obtaining improvements in the balance test scores and dynamic balance performance of young female football players.

Another significant result was that exercises on US increased the dynamic balance of right (9.2%) and left legs (9.9%), respectively, and right (10.1%) and left arms (9.2%) at similar rates. In addition, balance training on SS improved the dynamic balance composite scores regarding the right (3.3%) and left legs (3.7%) and right (2.3%) and left arms (3.3%). Although the improvement rates and effects were different in both training models, the exercises bilaterally contributed to the dynamic balance improvements in upper and lower extremities. The result of present study shows that there is a positive relationship between the lower and upper extremity dynamic balance composite scores, which stresses the idea that the two different balance training models in this study might have bilaterally increased the dynamic balance performances in lower and upper extremities by increasing the muscular activation and inter-muscular coordination [44]. Moreover, the result that the balance training in this study increased the Y-Balance Test scores more on US than on SS may be explained with the idea that USs ensure active joint stabilization by supporting the neuromuscular system that is responsible for agonistic and antagonistic muscular contractions [36].

We believe that the improvement in dynamic balance performance and statistical differences between the groups results from the balance ball we used as a multi-dimensional surface [36], and from the exercises performed with unstable equipment such as a balance disc. These studies suggested that balance training performed with various tools such as tilt boards, wobble boards, Bosu balls, stability trainers, ankle discs and elastic bands were effective in improving the balance performance and support the results of the present study [5, 36]. Unstable surfaces cause a position that generally creates dorsiflexion in the ankle. This proprioceptive effect on the joint is found to support joints under pressure and provides a more controlled position. The reason dynamic balance performance improved more on US is related to the evidence that proprioceptive sense in soft tissues and joints increased, and activity-specific neural adaptation was ensured [36]. This model is important as it also improves certain other dynamic balance skills that are believed to be necessary for displaying technical skills with appropriate movement combinations in narrow fields, fast-changing positions, tackles, and physical contact [4].

The trampoline, along with the balance ball and cushion used in this study, can be an effective tool for improving dynamic balance performance. Trampoline exercises are for the lower extremities, and they require kinesthetic, visual, vestibular perception, balance, and movements with high degree of muscular coordination. Trampoline exercises are for the lower extremities, and they require kinesthetic, visual, vestibular perception, balance, and movement control. This is associated with more distinctive muscle relaxation and contraction during the exercises performed with the trampoline, and with more coordinated operation of the control at the center of muscles during high muscular coordination [45]. Therefore, the dynamic balance performance on US improvements we achieved on the right and left legs may be explained by the fact that trampoline exercises with a multi-compositional structure can increase proprioceptive senses and augment dynamic balance [45].

The increase in balance performance seen in our research can be also explained by other mechanisms. Six weeks of balance training has been reported to provide neurophysiologic adaptations such as reflex responses and direct muscle responses in youth athletes [46]. Furthermore, improvements in balance training resulted in better spinal and supraspinal adaptation mechanisms for intra- and inter-muscular coordination and changes in reflex transduction [47]. The improvements in balance performance by multi-dimensional surfaces training seen in our study suggests that training models may be more efficient for neurophysiologic adaptations.

The present study also examined the effects of balance training performed on two different surfaces on the accuracy of chest passing and passing speed. Another important result of this study was that the balance training conducted on US (moderate; d = 0.86) was more effective in the increase in the rate of chest passing accuracy, which has been reported to be the one of the fundamental techniques in basketball [12], compared to the training on SS (low; d = 0.50). Different mechanisms might have affected the improvement in passing accuracy rates provided with our training model on US (13.80%) compared to SS (6.40%). The development of static and dynamic skills is related to the development of coordination in both hands [45]. The US training model might have contributed to these improvements by increasing intra- and inter-muscular coordination, decreasing muscular imbalances [48] and ensuring the symmetrical movement of both hands to increase the passing accuracy rate. These hypotheses will be examined in detail in future studies.

Both of our balance training models followed for six weeks positively affected the chest passing accuracy of the athletes. The results of the present study support the concept that balance training, which has been examined in a limited number of studies, [1, 11, 49] are effective training models for improving sport-specific skills. In a study performed on male amateur basketball players, Kostopoulos *et al.* [1] found that 12-weeks of balance training increased the passing accuracy rates by 14.92%. The positive effects that the balance training models examined in this study had on the increase in chest passing accuracy rates support the results of the study by Kostopoulos *et al.* [1]. The results of this study are similar to those of the study by Evangelos *et al.* [11] who found that ten-week balance training performed on unstable surfaces improved certain technical skills in amateur footballers such as long passing (30%), short passing (27.56%) and ball control (48.73%). In addition, the increase in the chest passing accuracy rate of our young basketball players can be explained by the improvement on performance of balance in lower extremities while performing shooting and passing, which provide better body stabilization [49].

Previous studies have found that different balance training models improve balance performance and contribute to the process of acquiring strength, proprioceptive capacity, body stabilization and muscular imbalances in certain sports [4, 9, 11, 36]. One study reported that unstable surfaces cause isometric muscular contractions, insignificant loading, and long-term stretching, and that they improve "core" strength and positively affect sporting performance by increasing body stabilization [50]. The performance improvement in the basketball chest passing technique —a CKCUES method, might have improved the balance training, body stabilization, postural control, and upper extremity stability [50] and increased the accuracy rate. This study did not evaluate core strength and postural control. It is recommended that the effects of different multi-axial surfaces on muscular strength, postural control and body rotation be determined through different balance measurements in future studies.

This study also reviewed the improvements in passing speed performance, an important factor in developing an effective passing technique in basketball. The hypothesis of this study was that passing speed can be improved by performing balance training and, thereby, increasing upper extremity and body stability [50] and boosting intra- and inter-muscular coordination [48]. However, the data from this study indicated that the balance training on US has only a small effect in improving passing speed (2.90%), and that balance training on SS has no effects. This can be explained by the structure and duration of our six-week training model, which was not adequate for ensuring the adaptation necessary for the improvement in an athletes' passing speed. However, it should be noted that certain mechanisms such as the desire to pass in a controlled and accurate way, and ball speed may decrease during the rebound of the ball due to air resistance and gravitational effects [51]. Therefore, another factor in the lack of improvement in this parameter was that the subjects did not throw the ball at maximum power to pass in a more accurate and controlled manner so as to not lose the ball rebounding from the wall during the passing speed measurements. Accordingly, it is recommended that the passing distance be longer in passing speed measurements in future studies.

This study demonstrated a significant improvement (14.8%) in upper extremity stability scores (CKCUES) in the US group following balance training. In contrast, balance training performed on SS provided insignificant improvements in closed kinetics strength performance (low; d = 0.16) while the effect of balance training performed on US was moderate (moderate; d = 0.89). These improvements may be related to the structure of the moves in our training program, the majority of which consist of the implementation of closed kinetics chain exercises where multiple muscles are activated, many joints are used, and the proprioceptive system is activated. Lee and Kim indicated that closed kinetic exercises had a positive effect on proprioceptive senses, joints, and body stabilization and muscular activation [52].

Conventional strength training and basketball practice can influence the results, since learning can also influence some skills, especially in young athletes. The results of previous studies have been shown that practicing specific skills in basketball does not only produce skill efficiency but also increases fitness scores as well [53]. Furthermore, conventional strength training can promote improvement in the pattern of recruitment and coordination of motor units, which helps in inter- and intramuscular coordination, and may have influenced the results of the present study. Another important factor is training frequency which can be effective in gaining strength. The early improvements in muscular strength are attributed to neuromotor factors such as better coordination of motor units and muscle groups [54]. Strength gains in resistance training in children are largely attributed to neurological adaptations. It has been stated that the neural adaptation can occur after the initial weeks of a training program (6–10 weeks) when neural factors prevail, and muscle hypertrophy begins to dominate as training continues past ten weeks [55]. Similar to neural adaptations to strength and power gains, two to three sessions a week improve strength, whereas one session per week maintains strength [33]. In the present study balance training was conducted six weeks (2 days/week) and strength conditioning training was performed only once in a week. For this reason, the increase in balance and pass performances in the group applying the unstable surface training program may not be clearly related to the development of strength. It has been reported that six-week strength training and upper body plyometrics together with basketball training produced no significant changes in upper body strength, grip strength, vertical jump, speed shooting and control dribble in male college students when compared to a control group [56]. For these reasons, in future studies, it may be necessary to include a control group and investigate the performance change in different motor characteristics.

This study has certain limitations. The main limitation is the lack of a control group. We do not know exactly how the balance and passing skills of the participants would have changed over the same period if the training had not been provided. Further studies that include control groups would be useful in validating these findings, considering that endurance, strength, and agility training as well as technical and tactical skills are essential components in youth athletes' regular conditioning programs [18]. We assumed athletes should be allowed to maintain their regular training schedule in order not to cause any disadvantages for the athletes or risk the competitiveness of the team. Our ultimate goal was to investigate changes in the balance performance and basketball passing skills following balance training performed on unstable compared with stable surfaces in youth basketball players. As previous studies have already demonstrated the effectiveness of balance training on the athletic performance in youth athletes [16–18], the objective of the present study was to compare the effect of the order of the training sequence in 2 comparable groups of athletes.

A larger number of subjects should be recruited in future studies. Another limitation was that this study was performed only with young male basketball players. Therefore, no conclusions can be made on the effect of gender.

5. Conclusions

This study demonstrated that a six-week multi-dimensional balance training model (12 training units; 2 days/week; 35 to 50 min/day) in combination with regular basketball training provided a positive change in the lower and upper extremity dynamic balance, passing accuracy, passing speed, and upper extremity stability performance compared to a stable surface training model for male youth basketball players. The results indicated that balance training models performed on both surfaces positively affected improvements in the lower and upper extremity dynamic balance performances of young male basketball players. In addition, these models increased postural control, body stabilization and inter-muscular coordination. The training on US improved basketball-specific passing accuracy compared to SS in the very short period of six weeks. It is recommended that both six-week training models, particularly the one conducted on US, be included by basketball trainers and conditioners, especially during in the competition period of an annual plan. The present study provides an effective and alternative balance training modality for basketball players to enhance the performance of dynamic balance and passing skills. Future studies are necessary to determine the effects of these training models on different age groups and on females. In addition, active mechanisms such as neurophysiological adaptations can be examined by evaluating the effects of US and SS balance training on static and dynamic balance, muscular performance, and sporting methods through bio-mechanic analyses.

Author contributions

TF and AA conceived and designed the experiments; TF provided the materials used and performed the experiments; TF and AA analyzed the data and prepared tables; TF and AA wrote the paper and reviewed drafts of the paper. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

Ethics approval and consent to participate

All subjects gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by Ethics Committee of the School of Medicine, Marmara University (approval number: 09.2019-208).

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Conflict of interest

The authors declare no conflict of interest.

Appendix

See Table 5.

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TABLE 5. Six-week balance training program for both groups.

Busso Balance Disc Exercises*	Set	Repetition-time	Rest
Standing hip abduction with right leg	3	5 rep	10″
Standing hip flexion with left leg	3	5 rep	10″
Standing hip abduction with right leg	3	5 rep	10″
Standing hip flexion with left leg	3	5 rep	10″
Left arm abduction in push-up position	3	5 rep	10″
Right arm abduction in push-up position	3	5 rep	10″
Plank exercise	3	20″	40″
Superman exercise	3	10 rep	20″
Delta Balance Ball Exercises**	Set	Repetition-Time	Rest
Stand on left leg with hands on waist	3	20″	40″
Stand on right leg with hands on the waist	3	20″	40″
PHASE 2 —(3rd week)			
Delta Balance Ball Exercises**	Set	Repetition-Time	Rest
Stand on left leg with hands on waist	3	25″	50″
Stand on right leg with hands on waist	3	25″	50″
Standing hip flexion with right leg	3	5 rep	10″
Standing hip extension with left leg	3	5 rep	10″
Standing hip flexion with right leg	3	5 rep	10″
Standing hip extension with left leg	3	5 rep	10″
Plank exercise	3	25″	50″
Left arm forward extension in push-up position	3	5 rep	10″
Right arm forward extension in push-position	3	5 rep	10″
Left arm reaching opposite waist side in push-up position	3	5 rep	10″
Right arm reaching opposite waist side in push-up position	3	5 rep	10″
Superman exercise	3	15 rep	30″
Busso Balance Disc Exercises*	Set	Repetition-Time	Rest
Pass to wall (Chest pass)	3	12 rep	24″
Pass to fellow player (Chest pass)	3	12 rep	24″
PHASE 2 (4th week)			
Delta Balance Ball Exercises**	Set	Repetition-time	Rest
Stand on left leg with hands on waist	3	25″	50″
Stand on right leg with hands on waist	3	25″	50″
Standing hip abduction, flexion and extension with right leg (3 direction-5 rep)	3	15 rep	30″
Standing hip abduction, flexion, and extension with left leg (3 direction-5 rep)	3	15 rep	30″
Plank exercise	3	25″	50″
Right arm abduction, forward extension and reaching opposite waist side in push-up position (3 direction-7 rep)	3	21 rep	42″
Left arm abduction, forward extension and reaching opposite waist side in push-up position (3 direction-7 rep)	3	21 rep	42″
Superman exercise	3	15 rep	30″
Pass to wall (Chest pass)	3	15 rep	30″
Trampoline Exercises#	Set	Repetition-Time	Rest
Jump on the trampoline with both feet	3	10 rep	20″
Jump on the trampoline with both feet and pass to fellow player (Chest pass)	3	10 rep	20″
PHASE 3 (5th week)			
Delta Balance Ball Exercises**	Set	Repetition-Time	Rest
Stand on left leg with hands on waist	3	30″	60″
Stand on right leg with hands on waist	3	30″	60″
Standing hip abduction, flexion, and extension with right leg (3 direction-7 rep)	3	21 rep	42″
Standing hip abduction, flexion, and extension with left leg (3 direction-7 rep)	3	21 rep	42″
Plank exercise	3	30″	60″
Right arm abduction, forward extension and reaching opposite waist side in push-up position (3 direction-7 rep)	3	21 rep	42″
Left arm abduction, forward extension and reaching opposite waist side in push-up position (3 direction-7 rep)	3	21 rep	42″
Skip hop on balance ball and pass to wall (Chest pass)	3	20 rep	40″
Trampoline Exercises#	Set	Repetition-Time	Rest
Jump on the trampoline	3	12 rep	24″
Jump on the trampoline and pass to wall (Chest pass)	3	12 rep	24″
Jump on the trampoline and pass to fellow player (Chest pass)	3	12 rep	24″

TABLE 5. Continued.

Busso Balance Disc Exercises*	Set	Repetition-time	Rest
PHASE 3 (6th week)			
Delta Balance Ball Exercises**	Set	Repetition-Time	Rest
Stand on left leg with hands on waist	3	30″	60″
Stand on right leg with hands on waist	3	30″	60″
Standing hip abduction, flexion, and extension with right leg (3 direction-7 rep)	3	21 rep	42″
Standing hip abduction, flexion, and extension with left leg (3 direction-7 rep)	3	21 rep	42″
Plank exercise	3	30″	60″
Right arm abduction, forward extension and reaching opposite waist side in push-up position (3 direction-7 rep)	3	21 rep	42″
Left arm abduction, forward extension and reaching opposite waist side in push-up position (3 direction-7 rep)	3	21 rep	42″
Superman exercise	3	20 rep	40″
Skip hop on balance ball and pass to wall (Chest pass)	3	20 rep	40″
Trampoline Exercises#	Set	Repetition-Time	Rest
Jump on the trampoline	3	15 rep	30″
Jump on the trampoline with both feet and pass to wall (Chest pass)	3	15 rep	40″
Jump on the trampoline with both feet and pass to fellow player (Chest pass)	3	15 rep	40″

Note: Each training unit is exactly the same way for both groups, but the only difference is that the stable group practiced all exercises on the ground in a stable surface.

*,**, # Stable surface group performed Busso Balance Disc Exercises*, Delta Balance Ball Exercises** and #Jump Exercises (Trampoline) on the ground.