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Research Article / Araştırma Makalesi

Plyometrics or balance training effects on lower body power, balance and reactive agility in collegiate basketball athletes: A randomized control trial

Kolej basketbol oyuncularında pliometrik ve denge antrenmanlarının alt vücut gücü, denge ve reaktif çeviklik üzerine etkileri

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ABSTRACT

Objective: Our purpose was to examine the effects of a 4-week plyometric training or balance training program on lower body power, balance, and reactive agility in collegiate basketball athletes.

Materials and Methods: Twenty-five National Collegiate Athletic Association Division III basketball players (14 women, 11 men; 18±2.2years, 172.5±9.4 cm, 71.9±8.9 kg) participated this study. They were assigned to 3 groups in this Randomized Controlled Trial: (1) Plyometric (n=8), (2) Balance (n=9), (3) Control (n=8). Participants in the plyometric and balance groups performed training for 2 times/week for 4 weeks during pre-season while the control group did not perform any training outside of regular practice. Separate 2 (Within, time: pre, post) x 3 (Between, group: plyometric, balance, control) Repeated-Measures ANOVAs with adjusted-Bonferroni pairwise-comparisons examined participants' Single Leg Triple Hop (SLTH; m) distance, Balance Error Scoring System (BESS; errors) scores, and Reactive Agility (RA; s) times before and after training.

Results: No statistically significant interactions existed across any tests Participants' performance remained similar pre and post training (SLTH: $F_{2,21}=2.1$, $p=0.2$; BESS: $F_{2,21}=.52$, $p=0.6$; RA: $F_{2,21}=2.2$, $p=0.13$). All groups had overall similar SLTH ($F_{2,2}=0.07$, $p=0.8$) and BESS scores ($F_{2,21}=3.8$, $p=0.06$). Although groups had overall different RA times ($F_{2,2}=22.2$, $p<.001$). No statistically significant interactions existed across any tests.

Conclusions: Overall, 4-weeks of plyometric or balance training did not change lower body power, balance, and reactive agility time in collegiate basketball athletes. Potential reasons may include timing of interventions, intervention durations, training program intensity, and that the participants were already trained collegiate athletes. How much duration and intensity of plyometric and balance training is required to influence performance in collegiate basketball players needs further study.

Keywords: *Plyometric exercise, balance training, athletic performance, basketball*

ÖZ

Amaç: Bu çalışma ile kolej basketbol oyuncularında 4 haftalık pliometrik antrenman veya denge antrenmanı programının alt vücut gücü, denge ve reaktif çeviklik üzerindeki etkilerini incelemek amaçlanmıştır.

Gereç ve Yöntem: Bu çalışmaya yirmi beş Ulusal Kolej Spor Birliği 3. Lig basketbol oyuncusu (14 kadın, 11 erkek; 18 ± 2.2 yıl, 172.5 ± 9.4 cm, 71.9 ± 8.9 kg) katılmıştır. Bu randomize kontrollü çalışmada katılımcılar 3 gruba atanmıştır: (1) Pliometrik (n = 8), (2) Denge (n = 9), (3) Kontrol (n = 8). Pliometrik ve denge gruplarındaki katılımcılar sezon öncesi 4 hafta boyunca haftada 2 kez antrenman yaparken, kontrol grubu normal antrenman programını sürdürmüştür. 2 ayrı (zaman bağlı;ilk, son) ve 3 ayrı (gruplar arasında; pliometrik, denge, kontrol) ikili Bonferroni düzeltmeli Tekrarlı Varyans Analizi Ölçümleri ile katılımcıların Tek Bacak Üçlü Sıçrama (SLTH; m) mesafesi, Denge Antrenmanı öncesi ve sonrası Hata Puanlama Sistemi (BESS; hatalar) puanları ve Reaktif Çeviklik (RA; s) süreleri değerlendirilmiştir.

Bulgular: Hiçbir testte istatistiksel olarak anlamlı farklılık bulunmamıştır. Antrenman öncesi ve sonrası katılımcıların performansı benzer kalmıştır (SLTH: $F_{2,21} = 2.1$, $p = 0.2$; BESS: $F_{2,21} = .52$, $p = 0.6$; RA: $F_{2,21} = 2.2$, $p = 0.13$). Tüm grupların SLTH ($F_{2,2} = 0.07$, $p = 0.8$) ve BESS skorları ($F_{2,21} = 3.8$, $p = 0.06$) benzer bulunmuştur. Genel olarak grupların RA süreleri farklı olmasına rağmen ($F_{2,2} = 22.2$, $p <.001$).Hiçbir testte istatistiksel olarak anlamlı farklılık bulunmamıştır.

Sonuç: 4 haftalık pliometrik veya denge antrenmanı, kolej basketbol sporcularında güç, denge ve reaktif çeviklik süresini değiştirmemiştir. Bu sonuç, uygulamaların zamanlaması, süresi, antrenman programının yoğunluğu ve katılımcıların iyi antrene kolej sporcuları olmasından kaynaklanmış olabilir. Kolej basketbol oyuncularının performansını etkileyecek düzeyde gerekli olacak pliometrik ve denge antrenman süresini ve yoğunluğunu belirleyebilmek için daha fazla araştırmaya ihtiyaç vardır.

Anahtar Sözcükler: *Pliometrik egzersiz, denge antrenmanı, sportif performans, basketbol*

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INTRODUCTION

Basketball is one of the most popular team sports worldwide. Basketball requires motor skills of shooting, passing, dribbling and jumping combine with athletic abilities emphasizing speed, power and coordination (1). The nature of basketball requires athletes to react to stimuli and perform quick movements with sudden directional changes in all three planes of motion. For practitioners working with basketball athletes, power, balance, and reactive agility exercises are commonly used to improve on-court performance (1). Accordingly, assessments and training programs should reflect the imposed demands of the sport. Furthermore, it is not surprising that the most common injuries across different levels of basketball are to the lower extremity (2).

The jumping ability of basketball athletes is an important physical ability to be a successful in the sport (3). Jumping assessments measure lower body power, which is a product of force and velocity. The single-leg triple hop (SLTH) test for distance is a valid and reliable test of power for determining readiness to participate in activity (4). The SLTH requires muscular strength, utilization of the stretch-shortening cycle, neuromuscular coordination, and joint stability in the lower limb (4). Previous researchers note that the SLTH as a valid predictor of lower limb strength and power (4). Reactive Agility (RA) is defined as the ability to rapidly change directions in reaction to different stimuli (5). The open environment reactive agility is a key component for basketball players as they often have to react to an opponent with a quick, explosive move (5). Previous research has shown that reactive agility tests can discriminate between semiprofessional and amateur basketball players (6,7). Balance is defined as the ability to maintain or move within a weight-bearing position without falling (8). The Balance Error Scoring System (BESS) test has been used among various sports to assess balance (8,9) and identify balance deficits in those who complete balance training (9).

Plyometrics, also known as 'jump training', are exercises that typically involve eccentric contractions to decelerate the body followed immediately by an explosive concentric contractions of muscles (10). Plyometric training can improve agility by inducing specific neural adaptations, specifically to increased intermuscular coordination (10). Plyometrics operate by utilizing the stretch shortening cycle (10). This cycle allows the muscle to accumulate elastic energy through the deceleration phase and release it during the acceleration phase to enhance the muscle's power output and force (10,11). The stretch shortening cycle is a typical component of muscle activity in sports that include acceleration, changing of directions, and jumps (9). Plyometric exercises commonly used in basketball include depth jumps, box jumps, and vertical jumps. Prior researchers have noted improvements in jumping, sprint performance, and lower body muscle strength after 4-12 weeks of plyometric training (12). Combining plyometrics training with a periodized strength program can improve vertical jumping, strength, power, joint awareness, and overall proprioception after training (11).

As mentioned earlier, high rates of lower body injuries exist in basketball (13). These injuries often occur a result of landing incorrectly or sudden changes in direction (13). Taking part in balance training can improve balance, reaction times and injury risk (13-15). Improved lower body function during activity allows the individual to control the body's center of mass, ultimately reducing injury risk (14). Additionally, combined balance and plyometric training can reportedly improve jump, sprint, and agility in athletes (12,15,17).

Generally, lower body power, balance and reactive agility are important motor abilities for basketball (11,13,18). So, practitioners often implement 2-6-week to improve these specific motor abilities in athletes. However, for how long to implement specific training mesocycles to improve power, balance and reactive agility in collegiate basketball athletes remains unclear.

Therefore, the objective of this study was to examine the effects of a 4-week plyometric or balance training program on lower body horizontal power, balance, and reactive agility in collegiate basketball athletes.

MATERIALS and METHODS

Participants

Twenty-Five National Collegiate Athletic Association Division III men's and women's basketball players volunteered for the study (14 women, 11 men; 18 ± 2.2 years, 172.5 ± 9.4 cm, 71.9 ± 8.9 kg). Participants were allowed to participate if they were (1) on the collegiate basketball team, (2) cleared for participation by the University Sports Medicine staff, and (3) 18 years of age or older. Participants were excluded if they (1) had a lower body injury within the past 3 months or (2) could not perform the tests. The participants basketball experience was 8.4 ± 2.2 years. The team consisted of players across the 4 collegiate years, with an average 2.1± 0.8 years of playing time as a team, together Participants' routine training practice regimen included strength and conditioning training sessions 3 days/week, 2 hours/day. These training sessions included a combination of aerobic, and resistance training. All training sessions were supervised by the same certified strength and conditioning coach.

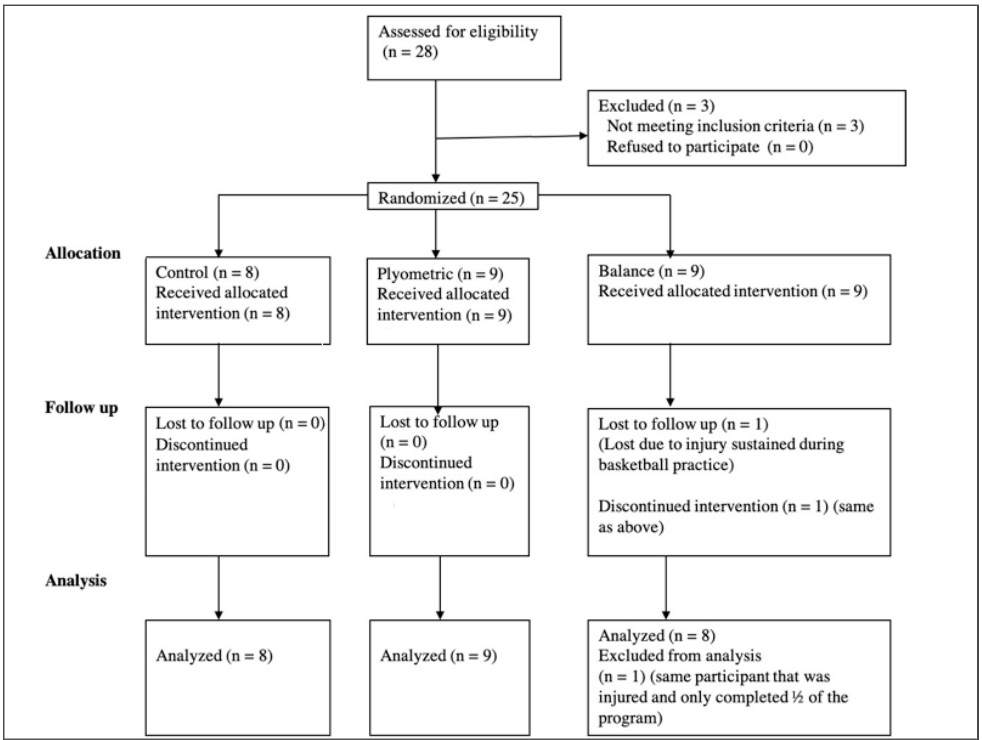

Figure 1. CONSORT Flow Chart for Randomized Controlled Trial examining the Effects of 4 Weeks of Supplemental Plyometrics or Balance Training on Lower Body Power, Balance, or Reaction Time in Collegiate Basketball Athletes

Protocol

We used a randomized controlled trial study design. The local university review board approved all study procedures (George Mason University Approval Number: 1112792-1: September 11, 2017). After providing signed informed consent, all participants completed a questionnaire to determine their level of physical activity to ensure they were able and prepared to workout at the prescribed intensity.

See CONSORT Study Flowchart for this randomized controlled trial (Figure 1). Participants were randomly assigned to 3 different groups: 1) Plyometric (n=8), (2) Balance (n=9), (3) Control (n=8). Participants in the plyometric and balance training groups participated in 4 weeks of supplemental training, twice a week. Participants in the control group did not receive any extra training and only participated in pre and post testing sessions. The participants' SLTH distances (m), BESS test (number of errors), and RA times (s) were tested before (pre) and after (post) training.

Single-Leg Triple Hops

To examine lower body power, participants completed SLTH for distance using previously published guidelines (4). (See Figure 2). Specifically, a standard tape measure was fixed to the ground, perpendicular to a starting line Participants were instructed to stand on the designated testing leg (the right leg was tested first, then left for all participants), with the great toe on the starting line. The distance of the tape measure was 20 meters. Participants performed 3 consecutive hops forward on the same leg, while landing on the same leg (4). The distance hopped from the starting line to the point where the heel struck the ground upon completing the third hop was measured. Participants completed 3 trials on the right and left leg. Hops were considered valid if landing was on 1 leg and if landing was on the initial testing leg, and invalid if the participant lost balance or made additional hops after landing (4). The maximum distance (m) for both legs was used for analyses (4).

Balance Error Scoring System

The BESS test was used to assess balance in this study following prior published procedures (8,9). The BESS is a valid and reliable clinical test that measures stability and requires participants to perform 6 stance conditions: double-leg, single-leg, and tandem on both a firm and foam surface, each for 20 seconds with eyes closed (8,9). BESS test errors included: lifting hands off the iliac crests, opening eyes, stumbling, stepping, falling, moving the hip into 30 degrees or more of flexion or abduction, lifting the forefoot or heel, and remaining out of the testing position for more than 5 seconds (8,9). After all the 6 conditions were tested, the total errors were summed and used for analyses (8,9).

Reactive Agility (RA)

We used a previously published test to examine participants' RA (5). RA is the change of direction in response to a given stimulus mid-test (4). To examine RA, participants participated in a 'Y' shaped agility test with timing gates (Brower Timing Systems, Manufacturer, RI, USA). All testing was performed on a standard collegiate basketball court. A white tape to outline the start line using a tape measure, which was 0.9 m wide, was used. The long, straight line of the 'Y' was 0.9 m wide and 5 m long, outlined with cones on the outside. A cue line for the test investigator was outlined horizontally by red tape halfway through the long, straight path at 2.5m. The cue line allowed the investigator to know when to point in a predetermined direction when the athlete approached (5).

A halfway point line was outlined with white tape at the top of the straight path. Using a goniometer, two 45-degree angles were measured to make up the outside lines that connected the 'Y' angle. Both upper part 'Y' lanes were 0.9 m wide and 5.0 m long, and were outlined by cones as well. To determine where the inside lines of the 2 angled 'Y' connecting lines were placed, 2 tape measures were laid down, being sure to maintain a 0.9 m lane width, and the investigators lengthened the tape measure until they both met in the middle completing the 'Y' shaped test (5). The lines were then outlined with cones. The investigator stood on the floor at the top of the inside 'Y' angle to cue the participants on which direction to turn. Each session began with a 10-minute dynamic warm up. Participants were instructed to stand at the start line, but to make sure no body parts were leaning through the timing gates, to avoid tripping the timing gates and resulting in a false start (5).

Timing gates were placed at: (1) the start line, (2) halfway point of the 'Y', and (3) the finish line. The timing system began collecting data once the athlete ran through the first timing gate. The timers calculated the time between the start and halfway point, halfway point to finish line, and start to finish line (5). The test began with a sound signal ("Go") from the investigator and the athlete sprinted past the first timing gate. Timing gates beeped when they detected movement to collect times. When the investigator saw the participant reach the red cue line, he/she pointed left or right to show the participant which direction to turn on the 'Y' course (5).

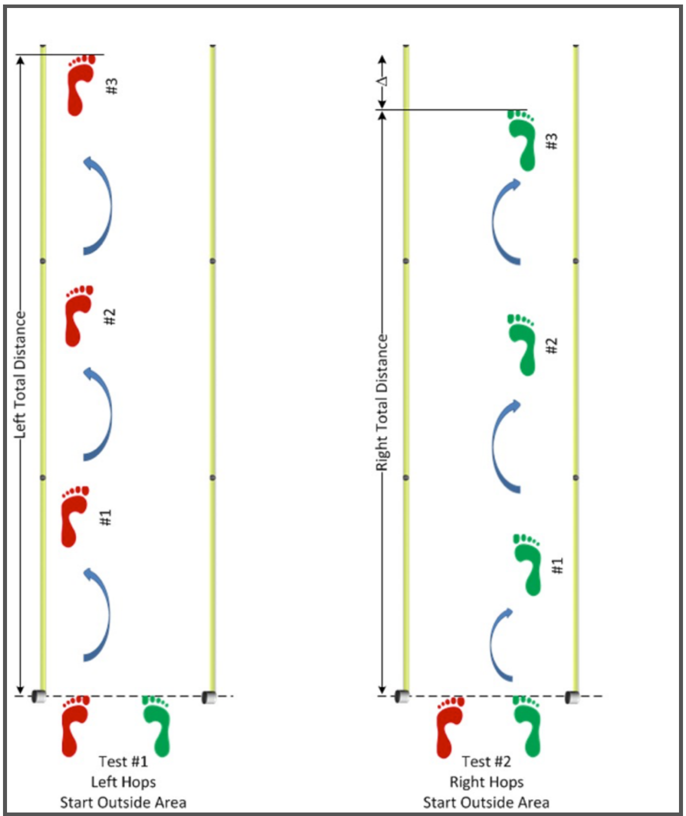

Figure 2. Set up for the Single Leg Triple Hop Test for Distance assessing Lower Body Power in Collegiate Basketball Athletes

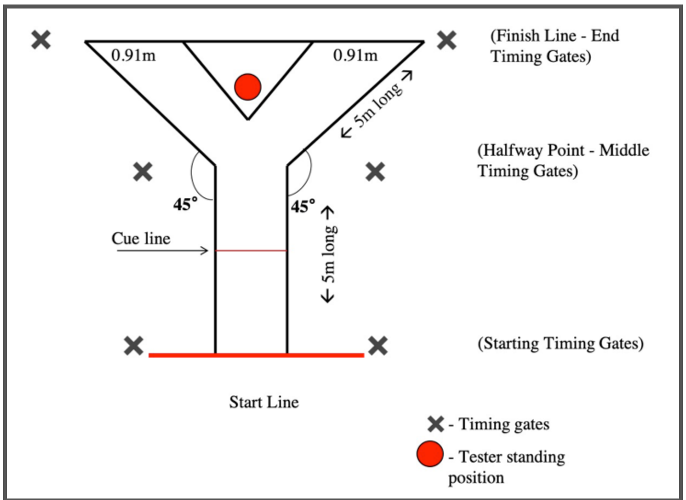

Figure 3. Set up for the Reactive Agility Test assessing Lower Body Reaction Time in Collegiate Basketball Athletes

All directions were previously determined randomly by the investigator, so that the participant would have to react and run in a specified direction and not pre-plan. Practice trials were not allowed, so as to not allow the participant to get accustomed to the course. The participant completed 1 trial on the left and 1 trial on the right side. The test was invalid if the participant went outside the lanes, stopped in the middle of the course or before exiting timing gates, or go in the opposite direction of investigator's visual cue (Figure 3).

Supplemental Training Program Protocols

The training plyometric and balance programs were adapted from a previously published study (19). The training programs below were modified to fit a 4-week program, as opposed to 8 weeks in the abovementioned study due to the limited time during pre-season for this study. The plyometric training program began with a 10-minute dynamic warm up session. The program started with 40 ground contacts during the 1st week and gradually increased every other week, reaching up to 180 by week 5. Participants received 90 seconds' rest between each set of exercises (19). See (Table 1) for program details.

Table 1. Exercise Protocol for the 4 week Plyometric Training Program in Collegiate Basketball Athletes

Plyometric Exercises	Week 1	Week 2	Week 3	Week 4
Countermovement Jump	1x8	2x10	1x10	
Drop Jump + 1 Step	1x8	2x10	1x10	
Horizontal Line Jump	1x8	2x10	1x10	
Lateral Hops	1x8	2x10	1x10	
Ankle Jumps	1x8	2x10	1x10	3x12
Single Leg cone jump front to back, side to side				3x12 / leg
Single leg max rebounding hops + 5m acceleration				3x12 / leg
Hurdle Jump				3x12

Note: 1x8 = 1 set of 8 repetitions

Adapted from;

Chaouachi M, Granacher U, Makhlouf I, Hammami R, Behm DG, Chaouachi A. Within Session Sequence of Balance and Plyometric Exercises Does Not Affect Training Adaptations with Youth Soccer Athletes. J Sports Sci Med. 2017 Mar 1;16(1):125–36.

The balance training program began with a 10-minute dynamic warm up session. This program consisted of exercises on stable and unstable surfaces. Participants received 60-90 seconds' rest between each set of exercises (19). The exercises included in this program were: unilateral and bilateral standing on a dyna-disc or Airex® pad progressing to a single leg squat, supine straight leg bridge on a physioball, lunge on Airex® pad or BOSU® ball progressing to lunge with dumbbells, and a bilateral squat with bar placed on shoulders using Airex® progressing to BOSU® ball (19). See (Table 2) for program details.

Statistical Analyses

Three Separate 2 (Within, Time: pre, post) x 3 (Between, Group: plyometric, balance, control) Repeated-Measures ANOVAs examined the effects of the training programs on SLTH, BESS, and RA ($p \leq .05$). For significant main effects, a post-hoc Bonferroni pairwise comparisons with adjustments to the p-values as appropriate was conducted. All analyses were conducted using SPSS 24.0 (IBM Corp. Armonk, NY).

Table 2. Exercise Protocol for the 4 week Balance Training Program in Collegiate Basketball Athletes

Balance Exercises	Week 1	Week 2	Week 3	Week 4
Unilateral & bilateral standing on dyna-disc ® progressing to single leg squat	1x8 / leg	2x10 / leg	2x12 / leg	2x15 / leg
Supine straight leg bridge on physioball®	1x8 / leg	2x10 / leg	2x12 / leg	2x15 / leg
Lunge on Airex ® progressing to BOSU ®ball or dyna-disc ® with dumbbells	1x8 / leg	2x10 / leg	2x12 / leg	2x15 / leg
Bilateral squat with bar placed on shoulders on Airex ® progressing to BOSU® ball or dyna-disc®	1x8	2x10	2x12	2x15

Note: 1x8 = 1 set of 8 repetitions

Adapted from;

Chaouachi M, Granacher U, Makhlouf I, Hammami R, Behm DG, Chaouachi A. Within Session Sequence of Balance and Plyometric Exercises Does Not Affect Training Adaptations with Youth Soccer Athletes. J Sports Sci Med. 2017 Mar 1;16(1):125–36.

RESULTS

Overall, no interactions existed across all analyses. The groups had similar SLTH ($F_{2,2}=0.07$, $p=0.8$) and BESS scores($F_{2,2}=3.8$, $p=0.06$). Although the groups had overall different RA scores ($F_{2,2}=22.2$, $p<.001$), Bonferroni pairwise-comparisons did not reveal pairwise group differences. Participants' performance remained similar before and after training (SLTH: $F_{2,21}=2.1$, $p=0.2$; BESS: $F_{2,21}=.52$, $p=0.6$; RA: $F_{2,21}=2.2$, $p=.13$). (Table 3).

DISCUSSION

Primary Findings

Lower body power, balance, and reactive agility are important motor abilities for performance in collegiate basketball players. The purpose of this study was to examine if a 4-week supplemental plyometric or balance training affects these measures as compared to a control group. Our primary findings were that a 4-week supplemental plyometric training or balance training program did not change lower horizontal body power, balance, or reactive agility time in collegiate basketball athletes. Over a sufficient period of time, an appropriately prescribed training program should lead to corresponding physiological adaptations. The following paragraphs discuss our findings in detail and offer plausible explanations as to why participants performance remained similar before and after the training programs.

Comparions with Prior Work

When comparing the baseline scores of the participants in the current study, the to prior research examining power, balance, and agility. Oxfeldt et al. (5) found that physically active participants RA times were 2.5 + 0.15 which is in agreement with the current participants RA times Scores (pre = 2.25 ± 0.21, post 2.13 ± 0.14).

Table 3. Single Leg Triple Hop (SLTH, distances, M + SD), Balance Error Scoring System (BESS), and Reactive Agility (RA) pre and post 4 Weeks of Plyometrics or Balance Training in Collegiate Basketball Athletes

	SLTH (m)		BESS (errors)		RA (s)	
Group	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Plyometrics	6.1 ± 1.0	6.1 ± 0.81	13.5 ± 5.9	11.6 ± 6.5	2.24 ± 0.17	2.17 ± 0.12
Balance	6.5 ± 0.93	6.5 ± 0.84	10.7 ± 6.5	10.6 ± 3.2	2.17 ± 0.22	2.08 ± 0.12
Control	5.5 ± 1.1	5.6 ± 1.3	12 ± 4.8	8.7 ± 2.1	2.36 ± 0.22	2.25 ± 0.15
Overall	6.1 ± 1.1	6.1 ± 1.0	12 ± 5.7	10.4 ± 4.4	2.25 ± 0.21*	2.13 ± 0.14*

** Significantly different from pre-training, $p < 0.05$*

Likewise, in their systematic review of BESS scores, Bell et al. (9) noted that the baseline scores of normal healthy participants was 11.2 + 3.8, which is in agreement with the current participants BESS Scores (pre = 12 ± 5.7, post 10.4 ± 4.4). Finally, Hamilto et al. (4) found that the baseline SLTH scores of normal healthy collegiate athletes was 5.47 + 0.97, which is close to our partcipants' scores (pre = 6.1 ± 1.1 m, post = 6.1 ± 1.0 m). Combining all these prior observations indicates that the current participants' performances were close to their maximal physical performances in peer athletic healthy groups.

SLTH Performance and Training Programs

We expected that the plyometric training would increase SLTH performance for the plyometric training group. The plyometric training protocol was the same protocol used by Chaouachi et al.,(19) where they found 4-5% improvements in the SLTH after 4 weeks of training (11,19). However, an important difference between our study and Chaouachi et al. (19) was the age of the participants. Specifically, our participants were 18 ± 2.2 years while those in the Chaouachi et al. (19) study were much younger (13-14-year-olds).

Likewise, Makhlouf et al. reported significant changes in the SLTH following 8 weeks of training (17). However, again in this study, participants were between the ages of 10-13 years old. It is possible that given the age and the level (Division III Collegiate) of our participants, they may have been approaching the limits of their potential for functional performance. In other words, the programs we used may have been below a minimum threshold needed for significantly obseravable changes in our our older and collegiate participants' SLTH performance. In a review investigating vertical jump performance in male and female basketball players, the researchers concluded that skill level was important in determining vertical jump performance(3). This observation provides added support to our explanation that if our participants were already performing the SLTH at a high level, they were close to their maximal performance and had lesser ability for further improvements.

Furthermore, while we did choose the SLTH as it can predict lower body power, (4) the SLTH may not be specific enough to to measure changes to the plyometric training protocol. Specifically, several of the plyometric exercises emphasized vertical jumping, but the SLTH is a horizontally based jumping test. Changes in jumping performance are known to be specific to the direction (horizontal vs. vertical) of plyometric training (20). So, how plyometric training that largely included vertical direction motion exercises would influence horizontal motion activities needs study. Taken as a whole, we believe that training age, and participant skill levels may be important factors to consider when examining effects of training programs on functional performance.

Balance Performance and Training Programs

The unchanged balance performance post training that we found in the current study is in contrast with some prior work by McLeod et al. (15) who found balance improvments after a 6-week neuromuscular training program in female high school basketball athletes. Possible reasons for the conflicting findings may be similar to those mentioned above. Explicitly, this means that in the study by McLeod et al. (15) the participants were female high school basketball players. However, the participants in our study were both male and female collegiate basketball players. Thus our participants were older and likely already performing at higher levels. Furthermore, the total training volume in the study by McLeod et al. (15) was 18 hours (2 training sessions/week for 1.5 hours x 6 weeks), while the total training volume in the current study was 2 hours (2 training sessions/week for 15 minutes x 4 weeks). Overall thus, the balance training implemented in the current study may have been insufficient in terms of volume (sessions x time) to influence participants' balance. Interestingly, in a recent systematic review of balance training with athletes in a variety of sports in 50 studies, (21) the authors suggested a practical recommendation for an efficient balance training protocol was for a duration of 8 weeks with 2 x 45 min training sessions per week. Combining our findings with the abovementioned suggestions, it appears that longer durations (both per session training time and overall training duration) may be needed to positively impact balance performance.

Reactive Agility and Training

Regarding RA post training, we found no significant changes in RA for the plyometric or balance training groups. The abovementioned training volume and beginning skill levels may again offer partial explanations of the lack of change in RA performance in our study. Interesingly, some prior researchers note that RA requires a cognitive component (22). Using the same RA protocol prior researchers found that the decision-making time was on average over 5% of the total movement time (18). The training protocols implemented in our study did not include any training in which participants were provided visual or verbal cue and instructed to react to it. This observation may support our finding that participants did not show improvements in a RA test without cognitive reaction and decision-making training. Overall, how cognitive reaction and decision-making training may influence reactive agility needs additional study in the future.

Limitations and Future Recommendations

We acknowledge several limitations of this study including the abovementioned shorter training intervention volume (duration and intensity) and the relatively small sample sizes. Still, given that basketball teams usually have smaller roster sizes, we believe that our numbers per group (n=7 to 8) were reasonable based on our study purpose. We also only had 4 weeks in the pre-season to train the athletes until their basketball in-season began. In a recent systematic review, the authors suggest that plyometrics can improve jumping performance over a 4-12 week period (12). Our study training times were on lower end of that range (4 weeks) may partially explain why we did not observe significant changes in performance. Further, a positive dose-response relationship exists in regarding to plyometric training programs and jumping performance (12). Accordingly, if we provided more than 15 minutes and more than 4 weeks of training, we can speculate that we may have seen performance changes. Previous researchers (23) also suggest that performance improvements after training result from enhanced motor unit recruitment. Neural adaptations occur when athletes respond or react due to improved coordination between the central nervous system signals and proprioceptive feedback (23). However, we did not explicitly examine these factors. Thus, further study is needed to examine specific relationships among motor learning and neural adaptations and how these affect performance (10,23). We also did not control the particpants' activity outside of the study. All 3 groups continued with their daily activities, practice, games, and team training programs. So, if the control group also took part in plyometric or balance exercises outside of our study during regular practice, all group scores may have improved their performance in the pre-season - despite our differing interventions. Controlling this other training may offer cleaner understanding of how a specific training program alters performance and needs to be examined in future investigations.

Practical Implications

Taken as a whole, the practical implications of our findings are that to improve lower body power, balance, and reaction time in collegiate basketball athletes, training programs need to be longer than 4 weeks - and in fact - a minimum of 6 weeks (15,16). Practitioners should also consider the baseline skill levels of participants when designing training programs so that the total training volume and intensity challenges the participants and helps induce performance enhancements.

CONCLUSION

Overall, 4-weeks of supplemental plyometric or balance training programs did not change lower body power, balance, and reactive agility time in collegiate basketball athletes. Potential reasons for may include the timing of interventions, shorter intervention times, training program intensity, and the fact that the participants were already trained collegiate athletes. How much plyometric and balance training duration and intensity is required to influence performance in collegiate basketball players needs further study. Ultimately, practitioners should consider sport-specific movement requirements and the athletic season when devising training programs to improve their athletes' performance.

Conflict of Interest / Çıkar Çatışması

The authors declared no conflicts of interest with respect to authorship and/or publication of the article.

Financial Disclosure / Finansal Destek

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