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The efficacy of Air Alert plyometric training program on enhancing biomotor skills in adolescent basketball players

Onur Yalçın, PhD[a], Mahmut Açak, PhD[a], Ahmet Kurtoğlu, PhD[b], Özgür Eken, PhD[c], Ramazan Bayer, PhD[d], Monira I. Aldhahi, PhD[e,*]

Abstract

Background: Basketball is an important sport that utilizes a variety of biomotor skills. Diverse training programs are employed to enhance the biomotor attributes and elevate the performance levels of basketball players. Plyometric training (PT) is frequently used to improve athlete performance. However, different models of PT can yield varying effects on athletic performance.

Methods: This study aimed to determine the impact of a PT program named "Air Alert" on athletes' biomotor skills. Twenty-four basketball players aged 15 to 16 years voluntarily participated in the study. The participants were randomly assigned to 2 groups: the Air Alert plyometric training group (AIR) (n = 12) and the plyometric training group (n = 12). The AIR was trained 3 days a week, while the plyometric training group was trained 2 days a week for 15 weeks. Pre- and posttest measurements of height (cm), body weight (kg), vertical jump, line agility, 20 m sprint, Illinois agility, repeated sprint, and flamingo balance tests were performed for all participants.

Results: There were no significant differences in height (cm) (F = 1.035, $P = .320$, $\eta p^2 = .045$), weight (F = 1.735, $P = .201$, $\eta p^2 = .073$), and BMI measurements (F = 1.376, $P = .253$, $\eta p^2 = .059$) within and between groups. However, significant differences were observed between the groups in vertical jump (F = 14.343, $P = .001$, $\eta p^2 = .395$), line agility (F = 75.366, $P = .000$, $\eta p^2 = .774$), 20 m sprint (F = 93.001, $P = .000$, $\eta p^2 = .809$), balance (F = 59.513, $P = .000$, $\eta p^2 = .730$), Illinois agility test (F = 143.243, $P = .000$, $\eta p^2 = .867$), and repeated sprint test (F = 140.986, $P = .000$, $\eta p^2 = .865$).

Conclusion: The results of this study indicate that the AIR program is more effective in enhancing the biomotor skills of basketball players than other plyometric training programs. Based on these results, it is recommended that coaches who aim to develop training strategies to enhance athletic performance should consider incorporating an Air Alert program.

Abbreviations: AIR = Air Alert plyometric training group, PT = plyometric training, PTG = plyometric training group, RST = repeated sprint test.

Keywords: adolescent athletes, Air Alert program, basketball performance, biomotor skills, plyometric training

1. Introduction

Basketball is one of the most popular team sports globally and requires the execution of various physical and technical tasks during gameplay. Successful performance of these tasks relies on a broad range of biomotor skills. The literature emphasizes the importance of factors such as strength, speed, agility, endurance, and flexibility among these skill.[1–3] Various training methods and programs have been employed to enhance basketball players' performance and reduce their risk of injury. Plyometric training (PT) is commonly used to enhance jumping and change-of-direction skills.[4,5] It involves exercises that utilize the stretch-shortening cycle, which allows muscles to quickly transition to concentric action.[6] The widespread use of jumping exercises in basketball stems from the various in-game situations. For example, players exhibit strong reliance on vertical power performance when defending, shooting, and rebounding.[7–9] According to the principle of training specificity,

Informed consent was obtained from all study participants prior to their participation.

The authors have no funding and conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

The study was conducted in accordance with the Declaration of Helsinki and reviewed and approved by the Inönü University Clinical Research Ethics Committee (decision number: 2024/6146).

[a] Faculty of Sport Science, Çanakkale Onsekiz Mart University, Çanakkale, Türkiye, [b] Faculty of Sport Science, Bandirma Onyedi Eylul University, Balikesir, Türkiye, [c] Faculty of Sport Science, Inonu University, Malatya, Türkiye, [d] Faculty of Health Science, Malatya Turgut Özal University, Malatya, Türkiye, [e] Department of Rehabilitation Sciences, College of Health and Rehabilitation Sciences, Princess Nourah bint Abdulrahman University, Riyadh, Saudi Arabia.

** Correspondence: Monira I. Aldhahi, Department of Rehabilitation Sciences, College of Health and Rehabilitation Sciences, Princess Nourah bint Abdulrahman University, P.O. Box 84428, Riyadh 11671, Saudi Arabia (e-mail: mialdhahi@pnu.edu.sa).*

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basketball players should regularly participate in jumping programs. Studies have shown that athletes engaging in PT exhibit improvements in muscle strength,[10–12] sprint performance,[13–15] change in direction speed,[16–18] and balance.[6,19] Basketball is a complex and dynamic sport in which athletes simultaneously utilize their physical and mental skills to deliver impressive performance.

The fundamental components of this sport are jumps, accelerations, sprints, decelerations, and rapid changes in direction. Notably, a study by Abdelkrim et al (2010) highlighted that elite men's basketball players is characterized by high physical attributes differ according to age and specific individual positional roles. On average, a basketball player performs approximately 1050 movements during a game, with a change in speed or direction every 2 seconds, underscoring the highly dynamic and intermittent nature of basketball.[20] Elite basketball players demonstrate exceptional performance metrics. Abdelkrim et al (2007) reported an average of 40 to 60 maximum jumps, 50 to 60 changes in speed and direction, and a distance of 991 m through high-intensity actions.[21] Basketball competitive nature necessitates frequent movement changes. Conte et al (2015) found 52% of medium-to-high-intensity sprints involve quick direction changes,[22] highlighting the importance of repeated sprint ability and rapid direction changes.[23] In addition, balance is critical for basketball players to deliver effective performance. Studies by DiFiori et al (2018) and Ramirez et al (2022) have emphasized that a strong balance is necessary for basketball players to execute high-speed movements such as frequent direction changes and unilateral actions.[24,25]

Optimal basketball performance requires players to surpass their opponents in terms of their speed, acceleration, strength, and power. Despite the recognized benefits of plyometric training in enhancing these attributes in various team sports, a performance gap remains in basketball-specific programs. PT has become a significant component of training programs for various team sports including soccer,[26] handball,[27] volleyball,[28] and basketball. While plyometric training has been established as an effective means of enhancing strength and power in team sports, a deficit exists in research on basketball-specific programs.[5] The Air Alert program, which was designed to enhance leg strength, may address this knowledge gap. In this context, although the effects of plyometric exercises on many branches have been examined in the literature, the number of studies examining specific training programs such as air alerts is limited. It is important to analyze the effects of specific training programs such as air alerts on physical and athletic performance levels in sports branches where jumping and related motoric characteristics are important, such as basketball branches. Therefore, this study aimed to analyze the effect of Air Alert plyometric training on the biomotor characteristics of basketball players. In this context, the hypothesis of our research was that Air Alert plyometric exercises would have a positive effect on the biomotor characteristics of basketball players.

2. Materials and methods

2.1. Study design and participants

A quasi-experimental design was conducted. The sample size was estimated using the G*Power software (version 3.1.9.3, Germany) The power analysis (confidence interval = .95, alpha = .05, beta = .85, effect size = .50) indicated that a study with 24 participants would have an actual power of 86.3% for the current analysis. Consequently, 24 basketball players aged 15 to 16 years volunteered to participate in this study. Figure 1 presents the flowchart of the study. The participants were assigned to either the Air Alert plyometric training group (AIR) (n = 12) or the plyometric training group (PTG) (n = 12). The inclusion criteria were as follows: (a) aged 15 to 16 years, (b) holding a sports license for at least 2 years, (c) having no injury history in the past 6 months, and (d) voluntary participation. Exclusion criteria were: (a) being aged 15 to 16 years but not holding a sports license for at least 2 years, and (b) holding a sports license for at least 2 years but having an injury history in the past 6 months. Additionally, termination criteria for the study included observing symptoms such as dizziness, confusion, ataxia, cold, and clammy skin during the study, or verbal requests from the athlete to withdraw from the study. Prior to commencement, necessary permissions and approvals were obtained from the Inönü University Clinical Research Ethics Committee (decision number: 2024/6146), and the study was conducted in accordance with the Declaration of Helsinki.

Before conducting the tests, a structured warm-up protocol was implemented to optimize muscle activation. This protocol consisted of 2 phases. The first phase involved 15 minutes of low-intensity running, maintaining an intensity below 40% of HRmax. The second phase included mobility and flexibility exercises. Dynamic mobility drills, such as walking lunges, leg swings, hip circles, and deep squat-to-stand movements, were performed. Flexibility exercises specifically targeted the quadriceps, hamstrings, hip flexors, and gastrocnemius-soleus muscle groups. The AIR group completed the training 3 days per week, while the PTG group was trained 2 days per week over a period of 15 weeks. Pre- and posttest measurements were taken for all participants, including height (cm), body weight (kg), vertical jump, line agility, 20 m sprint, Illinois agility, repeated sprint, and flamingo balance test values.

2.2. Study procedure

2.2.1. Body weight and height measurements. Tanita SC-330S electronic scale with 0.1 kg precision was used to determine the participants' body weight. A precise stadiometer (SECA-Mod.220; Seca GmbH & Co. KG, Germany) with a reading resolution of 0.01 meters was used to measure the volunteers' height.[29]

2.2.2. Line agility test. Players started at the top-left corner of the key at the free-throw line and ran 5.8 m to the baseline. Players then side shuffled 4.9 m to the right across the baseline before running backward to the top-right corner of the free-throw line. Players then side shuffled 4.9 m to the left, where they touched the floor with their foot at a designated point, and then immediately completed the same circuit in the opposite direction. Timing ceased when players reached the starting position again.[30]

2.2.3. Illinois test. The course consisted of 3 cones arranged in a straight line, with a total length of 10 m and width of 5 m, with each cone spaced 3.3 m apart in the middle section. The test involved a slalom run, which included a 180° turn every 10 m, comprising 40 m of straight running and 20 m of slalom between cones. The fastest of the 3 attempts was recorded as the final agility time. A 5-minute rest period was allowed between each attempt.[31]

2.2.4. Vertical jump test. Athletes were asked to stand with their feet shoulder-width apart. The athletes were asked to reach the highest point that they could reach. In Vertec, this was considered as the zero-starting point. The athletes were asked the following action: jumping and touching by bending their knees, hips and ankles without taking a step, the highest point they can reach on the Vertec of the jump will be recoded. Jumping distance heights were determined by subtracting the highest distance that the athletes reached from Vertec calculated from arm arm-length distance.[32]

2.2.5. Flamingo static balance test. It was used to measure static body balance. A specially prepared balance bar and

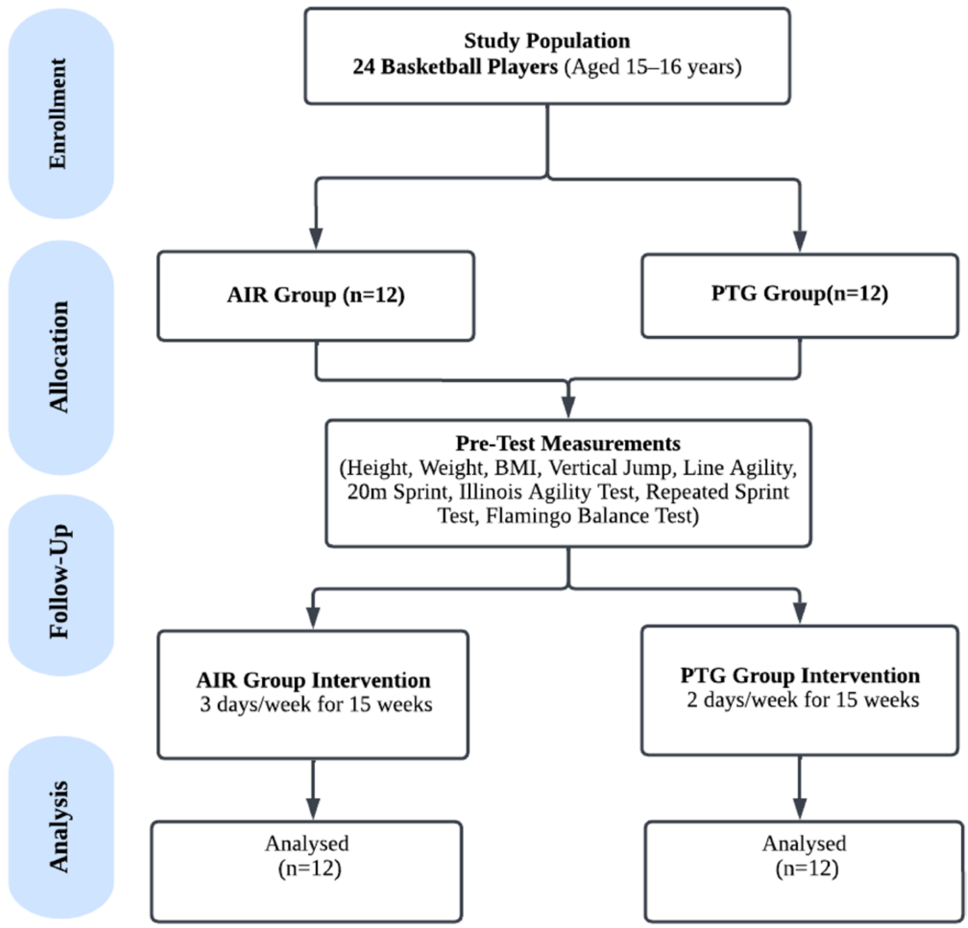

Figure 1. Flow diagram of the study.

stopwatch were used in the test. The balance bar was a wooden balance instrument 50 cm long, 4 cm high, and 3 cm wide. Two supports with a length of 15 cm and width of 2 cm were used to balance the tool. The participant stepped on the table longitudinally with the foot of her preference, bent the free foot towards the hip, and held it with the hand on the same side. The other arm was left free to ensure balance. After the participant took the correct position, the test administrator was asked to hold on until the participant regained his/her balance, and the time was started as soon as the participant regained his/her balance and released support. In case of loss of balance (release of the held foot or fall), the test was stopped, and the participant took the old position again and continued from where he/she left off. The one-minute period was completed, and time interruption was recorded.[33]

2.2.6. 20 m sprint test. A 20 m sprint test was performed to measure the speed of the athletes. The 20 m sprint test was performed using a stopwatch. For the test, 2 funnels were placed at the start and end points at 20 m. Before the test, information about the test protocol was provided and the athletes were given a trial. Athletes performed the test 3 times with 2-minute intervals. The mean performance values were calculated and recorded. If the athletes slowed down before 20 m, another training funnel of a different color was placed at 25 m, and they were asked to run to the funnel. The athletes started in a stationary manner immediately next to the starting line as the starting point. The sprint test was repeated 3 times and the average were recorded in seconds.[34]

2.2.7. Repeated sprint ability test. The test was performed by the athlete sprinting a distance of 20 m 6 times. The athlete was given 25 seconds (s) to jog in between and return to the starting line. The mean values of the 6 sprint performance parameters of the athletes were calculated and recorded.[35]

Applied training programs: each group performed a plyometric training regimen for 2 days a week for 15 weeks. Detailed descriptions of each group's training program are provided below.

2.2.8. Exercises performed by the PTG. The exercise list has been designed and published previously.[36]The program encompassed the following: (1) jumping rope; (2) double-foot leap without using the arms; (3) double-foot leap using the arms; (4) single-foot hop (right and left); (5) double forward jump; (6) double-foot jump with the knees pulled to the abdomen; (7) double-foot hop left and right on the rope; (8) double-foot jumps over the funnel; (9) jump into the hoop by changing the arms; (10) single-foot fall from the hoop (by changing feet); (11) jump from the hoop to the floor; and (12) jump from hoop to floor, from floor to hoop; (13) jumping from the hoop to the floor, and (14) jumping with a 360° rotation; (15) serial jumps over the hoops; (16) sit-ups with a medicine ball; (17) jumping from the hoop to the floor and from the floor to the hoop with a medicine ball; (18) low post drill; (19) one-foot landing on a hoop with a medicine ball; (20) catch and jump; (21) two feet jumping from the floor to the hoop; (22) jumping with a 180° rotation, and (23) serial jumping from the hoop[37]. The exercise (Air Alert Group) list showed in Table 1 (Fig. 2).

2.2.9. Exercises practiced by the Air Alert Group.

2.2.9.1. Leap ups (with/without rope). This exercise can be performed without a rope, if desired, but the arms should be

Table 1

Training program applied to plyometric training group.

Week	Exercise type	Number of repetitions	Number of sets	Rest time between sets
1–2	1-4-6-2-10-7-3-5-8	* 10-10-10-10-10-10-10-10	2	1–2 minutes.
3–4	1-4-6-2-10-7-3-5-8	* 10-10-15-15-10-15-10-10	2	1–2 minutes.
5–6	1-3-11-5-7-8-2-12	* 15-10-10-15-10-10-10	2	1–2 minutes.
7–8	1-15-13-20-8-19-20	* 15-15-15-10-10-10	2	1–2 minutes.
9–10	1-16-12-9-19-21	* 10-20-15-10-10	2	1–2 minutes.
11–12	1-20-21-16-17-19-22	* 10-10-10-10-15-10	2	1–2 minutes.
13–14	1-19-18b-22-23-15-18a	* 15-10-15-10-15-10	2	1–2 minutes.
15	1-23-17-18a-19-18b-15	* 20-10-20-15-20-20	2	1–2 minutes.

Each sit-up in the workout is considered a single jump. Each number in the exercise-type column refers to the number of exercises used in the training. Refer to the exercises in the Exercise type column by number in the "PTG" section in Section 2.

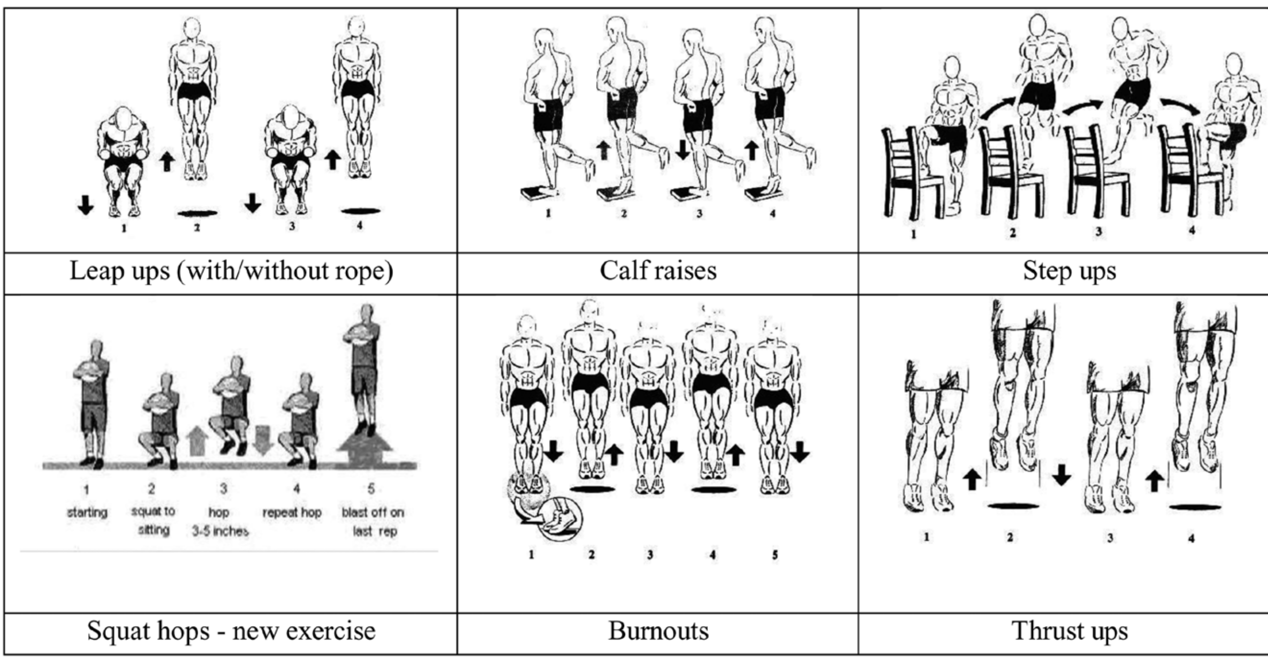

Figure 2. Illustration of Air Alert training.

held at the side while jumping. Initially, the athlete takes a ¼ squat position with legs shoulder-width apart, jumps in an upright posture without leaning forward, and jumps at least 8 to 10 inches high at the moment of jumping. The heels were not in contact with the ground.

2.2.9.2. Calf raises. Stand on 1 leg on a high object. Support should be provided from something on the side of balance. The athlete goes up on the tiptoe, pushes as far as possible, and then returns to the starting position. Movement should be slow.

2.2.9.3. Set ups. The athlete puts 1 foot on the frame, jumps up as high as possible and rises, changes feet in the fall and returns to the starting position with the feet changed and does the same movement in series. The athlete's knee on the frame should be at an angle of 90°. The movement should be done slowly.

2.2.9.4. Thrust ups. The athlete jumps to the highest height with arms flexed at the side, legs shoulder-width apart, toes pointing inward, and legs tensing without bending. Heels should not touch the ground.

2.2.9.5. Burnouts. The athlete's feet are side-by-side at a distance of 1 inch from each other. The athlete jumps to a height of 2 to 3 cm on the tiptoe with tense legs. The arms were fixed at the side, and movement was performed as fast as possible.

2.2.9.6. Squat jump. The athlete holds the basketball at chest level and jumps 3 to 5 inches up on the tiptoe in a full squat position. The athlete finished the set by standing up and making the last jump to the highest height. The exercise list performed showed in Figure 2.

2.2.10. Training program applied to Air Alert Group. During the exercise plan period, the 15 weeks were divided into single and double weeks, in consecutive order (Table 2). In odd weeks, training is performed on Monday–Wednesday–Friday, while in even weeks, training is performed on Tuesday–Wednesday–Thursday.

2.3. Statistical analysis

All statistical analyses were conducted using SPSS 25.0 (SPSS, Inc., Chicago, IL) and GraphPad Prism (Version 9.5.0). The data obtained are expressed as the mean ± standard deviation. The normality of the data was assessed using the Shapiro–Wilk test, which indicated that all variables were normally distributed ($P > .05$). Mauchly test of sphericity was performed, and the assumption of sphericity was confirmed. Additionally, a

Table 2

Training program applied to Air Alert group.

Week	Exercise type	Number of repetitions	Number of sets	Rest time between sets
1	1-2-3-4-5-6	20-10-10-15-100-15	2-2-2-2-1-4	2 min-25 sec-2 min-1 min-1 min-1 min-2 min
2	1-2-3-4-5-6	20-15-15-20-200-20	3-2-2-2-1-4	2 min-25 sec-2 min-1 min-1 min-1 min-2 min
3	1-2-3-4-5-6	25-20-15-25-300-20	3-2-2-2-1-4	2 min-25 sec-2 min-1 min-1 min-1 min-2 min
4	1-2-3-4-5-6	30-25-20-30-200-30	3-2-2-2-2-4	2 min-25 sec-2 min-1 min-1 min-1 min-2 min
5	1-2-3-4-5-6	25-30-20-35-250-25	4-2-2-2-2-4	2 min-25 sec-2 min-1 min-1 min-1 min-2 min
6	1-2-3-4-5-6	50-35-25-40-300-30	2-2-2-2-2-4	2 min-25 sec-2 min-1 min-1 min-1 min-2 min
7	1-2-3-4-5-6	30-40-25-50-350-25	4-2-2-2-2-5	2 min-25 sec-2 min-1 min-1 min-1 min-2 min
8	1-2-3-4-5-6	50-45-30-60-200-25	3-2-2-2-3-5	2 min-25 sec-2 min-1 min-1 min-1 min-2 min
9	1-2-3-4-5-6	50-50-30-70-300-30	4-2-2-2-3-5	2 min-25 sec-2 min-1 min-1 min-1 min-2 min
10	1-2-3-4-5-6	40-50-35-80-250-30	5-2-2-2-4-5	2 min-25 sec-2 min-1 min-1 min-1 min-2 min
11	1-2-3-4-5-6	50-30-35-90-275-30	6-4-2-2-4-5	2 min-25 sec-2 min-1 min-1 min-1 min-2 min
12	1-2-3-4-5-6	75-35-40-100-300-30	4-4-2-2-4-6	2 min-25 sec-2 min-1 min-1 min-1 min-2 min
13	–	–	–	–
14	1-2-3-4-5-6	30-30-20-30-250-20	3-2-2-2-1-4	2 min-25 sec-2 min-1 min-1 min-1 min-2 min
15	1-2-3-4-5-6	100-50-20-100-500–503-2	4-4-2-2-4-5	2 min-25 sec-2 min-1 min-1 min-1 min-2 min

Each number in the exercise-type column refers to the number of exercises used in training. The exercises in the Exercise type column are referred to by number in Section 2 as "Exercises practiced by the Air Alert group."

2 × 2 repeated measures ANOVA was used to compare the pre- and posttest variables between the different groups. Cohen d effect size was calculated to define the magnitude of pairwise comparisons for the pre- and posttests, Cohen d effect size with a 95% confidence interval was calculated. Effect size magnitude was classified as follows: <0.2 = trivial, 0.2 to 0.6 = small effect, >0.6 to 1.2 = moderate effect, >1.2 to 2.0 = large effect, and > 2.0 = very large effect.[37] Statistical significance for all analyses was set at $P < .05$.

3. Results

Table 3 compares the pre- and posttest values of participants' height (cm), weight (kg), and BMI (kg/m²) across the exercise groups. According to the table, there were no significant differences within groups for height (cm) before (F = 0.003, $P = .956$) and after exercise (F = 0.181, $P = .080$), weight (kg) before (F = 0.717, $P = .406$) and after exercise (F = 1.033, $P = .321$), and BMI (kg/m²) before (F = 0.037, $P = .849$), and after exercise (F = 2.152, $P = .157$). Additionally, when examining the values between groups, there were no significant differences in height (cm) (F = 1.035, $P = .320$, ηp^2=0.045 [$P > .05$]) (Fig. 3A), weight (kg) (F = 1.735, $P = .201$, ηp^2=0.073 [$P > .05$]) (Fig. 3B), and BMI (kg/m²) (F = 1.376, $P = .253$, ηp^2=0.059 [$P > .05$]) (Fig. 3C).

Table 4 compares the pretest and posttest values of the participants' vertical jump, line agility, 20 m sprint, balance, Illinois, and repeated sprint test (RST) scores across the exercise groups. According to the table, there were significant differences within groups for vertical jump values before (F = 221.825, $P = .000$) and after exercise (F = 90.971, $P = .000$), line agility values before (F = 46.953, $P = .000$) and after exercise (F = 29.431, $P = .000$), 20 m sprint values before (F = 72.084, $P = .000$) and after exercise (F = 26.503, $P = .000$), balance values before (F = 52.901, $P = .000$) and after exercise (F = 13.225, $P = .001$), Illinois values before (F = 155.987, $P = .000$) and after exercise (F = 19.682, $P = .000$), and RST values before (F = 159.671, $P = .000$), and after exercise (F = 17.272, $P = .000$). Additionally, when examining the values between groups, there were significant differences in vertical jump (F = 14.343, $P = .001$, ηp^2=.395 [$P < .05$]) (Fig. 4A), line agility (F = 75.366, $P = .000$, ηp^2=.774 [$P < .05$]) (Fig. 4B), 20 m sprint (F = 93.001, $P = .000$, ηp^2=.809 [$P < .05$]) (Fig. 4C), balance (F = 59.513, $P = .000$, ηp^2=.730 [$P < .05$]) (Fig. 4D), Illinois (F = 143.243, $P = .000$, ηp^2=.867 [$P < .05$]) (Fig. 4E), and RST (F = 140.986, $P = .000$, ηp^2=.865 [$P < .05$]) (Fig. 4F).

4. Discussion

During sports competitions, especially in power-intensive activities like jumping and directional changes, sports scientists frequently utilize plyometric training to improve athletes' explosive power.[5,26,28] The Air Alert training program includes movements similar to plyometric training methods and is known to be particularly effective in enhancing leg muscle strength in basketball players.[38] Accordingly, this study aimed to determine the effects of an Air Alert training program on athletes' biomotor skills. The results indicated minor changes in the pre- and posttest mean values for height (cm), weight (kg), and BMI (kg/m²) following the training. However, no statistically significant differences were observed within or between the groups for these anthropometric measurements. This finding aligns with existing literature, which similarly reports no significant changes in height, weight, or BMI after 8 weeks of plyometric training when comparing experimental and control

Table 3

Comparison of participants' physical characteristics within and between groups.

	Group	N	M ± SD	Comparison between groups	F	*P*-value
Height (cm)	AIR pretest	12	186.25 ± 9.83	F = 1.035	.003	.956
	PTG pretest	12	180.17 ± 5.49	*P* = .320		
	AIR posttest	12	186.58 ± 9.76	η_p^2 = .045	.181	.080
	PTG posttest	12	188.33 ± 29.01			
Weight (kg)	AIR pretest	12	77.58 ± 13.87	F = 1.735	.717	.406
	PTG pretest	12	72.67 ± 15.24	*P* = .201		
	AIR posttest	12	77.17 ± 13.79	η_p^2 = .073	1.033	.321
	PTG posttest	12	72.17 ± 13.81			
BMI (kg/m²)	AIR pretest	12	22.15 ± 1.87	F = 1.376	.037	.849
	PTG pretest	12	22.32 ± 4.28	*P* = .253		
	AIR posttest	12	21.95 ± 1.78	η_p^2 = .059	2.152	.157
	PTG posttest	12	20.80 ± 4.28			

BMI = body mass index, F = two-way mixed ANOVA test value in repeated measurements, M = mean, *P* = probability (*P* < .05), SD = standard deviation.

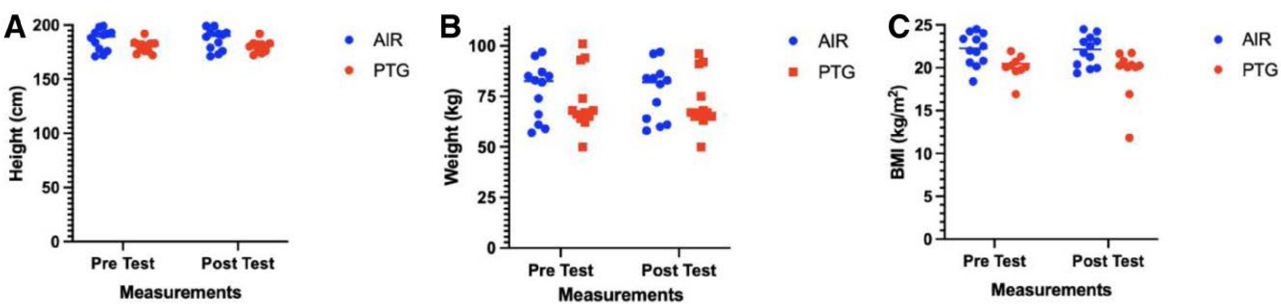

Figure 3. Pretest and posttest comparisons of participants' physical characteristics within and between groups.

Table 4

Comparison of participants' exercise measurements within and between groups.

	Group	N	M ± SD	Comparison between groups	F	*P*-value
Jump test	AIR pretest	12	44.92 ± 3.28	F = 14.343	221.825	<.001
	PTG pretest	12	47.92 ± 5.80	*P* = .001		
	AIR posttest	12	61.83 ± 6.87	η_p^2 = .395	90.971	<.001
	PTG posttest	12	58.75 ± 5.84			
Line agility test	AIR pretest	12	12.91 ± .67	F = 75.366	46.953	<.001
	PTG pretest	12	13.82 ± 1.23	*P* = .000		
	AIR posttest	12	11.49 ± .80	η_p^2 = .774	29.431	<.001
	PTG posttest	12	12.69 ± 1.03			
20 M sprint test	AIR pretest	12	3.25 ± .11	F = 93.001	72.084	<.001
	PTG pretest	12	3.41 ± .18	*P* = .000		
	AIR posttest	12	2.64 ± .29	η_p^2 = .809	26.503	<.001
	PTG posttest	12	3.04 ± .13			
Balance test	AIR pretest	12	9.58 ± 4.69	F = 59.513	52.901	<.001
	PTG pretest	12	9.92 ± 3.14	*P* = .000		
	AIR posttest	12	4.75 ± 2.34	η_p^2 = .730	13.225	.001
	PTG posttest	12	7.50 ± 3.17			
Illinois test	AIR pretest	12	18.15 ± 1.01	F = 143.243	155.987	<.001
	PTG pretest	12	17.95 ± .58	*P* = .000		
	AIR posttest	12	15.16 ± .80	η_p^2 = .867	19.682	<.001
	PTG posttest	12	16.88 ± .65			
RST test	AIR pretest	12	3.63 ± .20	F = 140.986	159.671	<.001
	PTG pretest	12	3.59 ± .32	*P* = .000		
	AIR posttest	12	2.37 ± .20	η_p^2 = .865	17.272	<.001
	PTG posttest	12	3.18 ± .16			

ηp^2 = partial eta square, AIR = Air Alert group, F = two-way mixed ANOVA test value in repeated measurements, M = mean, *P* = probability (*P* < .05), PTG = plyometric training group, RST = repeated sprint ability test, SD = standard deviation.

groups.[5] Similarly, Ramírez-Campillo et al. (2013) reported no significant differences in anthropometric measurements between experimental and control groups following plyometric exercises.[6] Variables such as genetic makeup, nutrition, and sleep patterns can potentially influence the outcomes of anthropometric measurements.

There were statistically significant differences in the pretest and posttest values of vertical jumps within and between groups for basketball players who participated in the AIR and PTG programs. However, the AIR program was more effective than the PT program. Upon reviewing the relevant literature, our findings were consistent with those of previous studies. Hulfian et al. (2018) reported that an Air Alert program improved the jumping ability of 18 soccer players in their study. There are a limited number of studies on Air Alert training programs in the literature. Upon reviewing similar studies, it was noted that plyometric training programs similar to air alerts improve athletes' jumping abilities.[39] Meylan and Malatesta (2009) implemented an 8-week plyometric training program consisting of 90-minute sessions twice a week for 14 adolescent athletes. training, improvements in the jumping ability of participating soccer players have been observed.[40] Latorre Román et al. (2017) reported significant improvements in the jumping ability of preadolescent basketball players who participated in a 10-week contrast training program (isometric + plyometric).[41] Asadi et al. (2017) found a significant increase in the vertical jumping ability of young basketball players after 8 weeks of plyometric training.[42] Additionally, Ramírez-Campillo et al. (2016) demonstrated significant improvements in jumping ability after 6 weeks of plyometric training, suggesting that appropriate jumping exercises can enhance physical attributes such as jumping, sprinting, and changing direction in basketball players.[43] However, Bouteraa et al. (2020) found no significant improvement in the jumping performance of young female basketball players after 8 weeks of combined balance and plyometric training.[44] Similarly, Zemková and Hamar (2010) reported no significant improvements in jumping values in a 6-week study.[45] These differing results could be attributed to variations in the initial conditioning levels of the participants, characteristics of the study groups, or duration of the studies.

In contemporary basketball, the game is played at a rapid and dynamic pace. The study demonstrated statistically significant differences in the pretest and posttest values of line agility, 20 m sprint, balance, Illinois agility, and RST within and between groups of basketball players who participated in the AIR and PTG programs. The AIR program was more effective than the PT program. Therefore, the Air Alert training program had a significant impact on enhancing the physical performance of basketball players. Our findings are consistent with those in the existing literature.[46,47] Additionally, a review of the relevant literature revealed numerous studies reporting that plyometric training exercises enhance athletes' agility, balance, and repeated sprint performance. Miller et al. (2006) observed improvements in agility performance among athletes who participated in a 6-week plyometric training program.[48] Another study involving 24 male basketball players aged 18-36 who participated in plyometric training 3 times a week for 6 weeks observed an increase in their agility performance.[49] In a study involving elite basketball players who underwent an 8-week plyometric training program, significant improvements in agility test scores were observed.[50] Similarly, in a study involving young female basketball players who participated in an 8-week plyometric training program, it was noted that plyometric training is a safe and feasible intervention for enhancing agility. Factors influencing agility performance in athletes include parameters such as age and sex, as well as certain physiological factors. Some researchers have suggested that plyometric training can affect muscle spindles, Golgi tendons, tendons, and body posture control,[51] thereby enhancing agility in participants.[52]

Plyometric training can enhance muscle strength and balance primarily through neural adaptations.[53] The results of our study support those in the existing literature. Significant improvements in balance performance were observed in athletes following an Air Alert training program. Similarly, it has been noted that an 8-week plyometric training program is a safe and feasible intervention for improving balance in young female basketball players.[44] A meta-analysis also demonstrated that plyometric training is an effective exercise for enhancing balance.[54] However, another study found that a 4-week plyometric training program did not alter balance performance in university basketball players.[55] İlbak and Açak (2022) investigated the effects of plyometric training combined with EMS on athletic performance in basketball players and found no statistically significant difference in balance performance between groups.[56]

Plyometric training significantly affects athlete speed and sprint performance. It has been determined that plyometric training enhances speed by affecting muscle length, strength, and flexibility.[57] Further studies have shown that an increase in

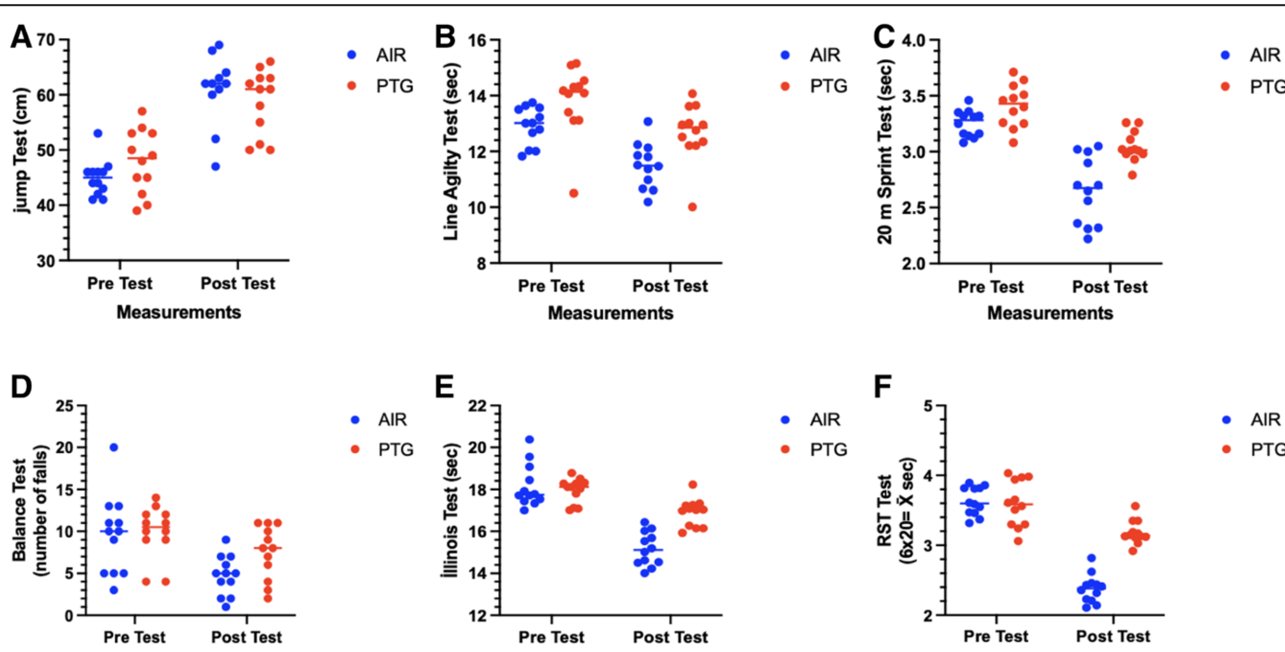

Figure 4. Pretest and posttest comparisons of participants' exercise measurements within and between groups.

muscle mass and muscle fiber hypertrophy induced by plyometric training can lead to improvements in participants' speed.[58] Our study results support these findings. Additionally, previous studies also corroborate our results.[28,59,60] Similarly, Ramirez-Campillo et al. (2022), in their meta-analysis, reported that physical attributes such as sprint and change-of-direction in basketball players can be improved through appropriate plyometric training.[25] Another study involving young basketball players concluded that plyometric training positively affected sprint capabilities in this population.[61] Furthermore, Barrera-Domínguez et al. (2023) indicated in their study that an 8-week plyometric training program improved the sprint performance of basketball players.[62]

This study has several limitations that should be considered. First, the relatively small sample size of 24 participants limits the generalizability of the findings, as larger, more diverse populations may exhibit different responses to the Air Alert training program. Additionally, the study focused solely on adolescent male basketball players, making it difficult to extend the results to female athletes or individuals from other age groups. Lastly, psychological variables such as motivation and training adherence were not assessed, which could provide valuable context for the physical performance improvements observed. Future research should address these limitations to offer a more comprehensive understanding of the effectiveness of plyometric training.

5. Conclusions

A significant difference was observed between the pretest and posttest values for vertical jump, line agility, 20 m sprint, balance, Illinois agility, and RST in basketball players who participated in both the Air Alert jumping program and traditional plyometric training. Notably, the improvements in the Air Alert training group were statistically more significant compared to those in the traditional PTG, suggesting a superior effectiveness of the Air Alert program. The observed enhancements, particularly in agility, sprint performance, and repeated sprint ability, are crucial for optimizing performance in modern basketball. Therefore, it is recommended that basketball coaches and athletes incorporate the Air Alert training program into their regular training regimens. Additionally, the applicability of this program extends to other sports where plyometric performance plays a vital role. Further research is warranted to examine the effects of Air Alert plyometric exercises on physiological parameters. Moreover, studies investigating the acute effects of Air Alert compared to conventional plyometric training would provide valuable insights for optimizing training phases and competition preparation.

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Author contributions

Conceptualization: Mahmut Açak, Ahmet Kurtoğlu, Özgür Eken, Ramazan Bayer, Monira I. Aldhahi.
Data curation: Onur Yalçın, Mahmut Açak, Ahmet Kurtoğlu, Özgür Eken, Ramazan Bayer, Monira I. Aldhahi.
Formal analysis: Onur Yalçın, Özgür Eken.
Investigation: Onur Yalçın, Mahmut Açak, Ahmet Kurtoğlu, Özgür Eken, Ramazan Bayer, Monira I. Aldhahi.
Methodology: Onur Yalçın, Mahmut Açak.
Writing – original draft: Onur Yalçın, Mahmut Açak, Ahmet Kurtoğlu, Özgür Eken, Ramazan Bayer, Monira I. Aldhahi.
Writing – review & editing: Onur Yalçın, Mahmut Açak, Ahmet Kurtoğlu, Özgür Eken, Ramazan Bayer, Monira I. Aldhahi.

References

[1] Boddington BJ, Cripps AJ, Scanlan AT, Spiteri T. The validity and reliability of the basketball jump shooting accuracy test. J Sports Sci. 2019;37:1648–54.
[2] Robertson SJ, Burnett AF, Cochrane J. Tests examining skill outcomes in sport: a systematic review of measurement properties and feasibility. Sports Med. 2014;44:501–18.
[3] Abdelkrim NB, Castagna C, El Fazaa S, El Ati J. The effect of players' standard and tactical strategy on game demands in men's basketball. J Strength Cond Res. 2010;24:2652.
[4] Simenz CJ, Dugan CA, Ebben WP. The effect of players' standard and tactical strategy on game demands in men's basketball. J Strength Cond Res. 2005;19:495–504.
[5] Cherni Y, Jlid MC, Mehrez H, et al. Eight weeks of plyometric training improves ability to change direction and dynamic postural control in female basketball players. Front Physiol. 2019;10:726.
[6] Ramírez-Campillo R, Meylan C, Alvarez C, et al. Effects of in-season low-volume high-intensity plyometric training on explosive actions and endurance of young soccer players. J Strength Cond Res. 2014;28:1335–42.
[7] Scanlan AT, Dascombe BJ, Kidcaff AP, Peucker JL, Dalbo VJ. Gender-specific activity demands experienced during semiprofessional basketball game play. Int J Sports Physiol Perform. 2015;10:618–25.
[8] Taylor JB, Taylor JB, Wright AA, Dischiavi SL, Townsend MA, Marmon AR. Activity demands during multi-directional team sports: a systematic review. Sports Med. 2017;47:2533–51.
[9] Stojanović E, Stojiljković N, Scanlan AT, Dalbo VJ, Berkelmans DM, Milanović Z. The activity demands and physiological responses encountered during basketball match-play: a systematic review. Sports Med. 2018;48:111–35.
[10] Lloyd RS, Oliver JL. The youth physical development model. Strength Cond J. 2012;34:61–72.
[11] Lloyd RS, Oliver JL, Meyers RW, Moody JA, Stone MH. Long-term athletic development and its application to youth weightlifting. Strength Cond J. 2012;34:1.
[12] Lloyd RS, Cronin JB, Faigenbaum AD, et al. National strength and conditioning association position statement on long-term athletic development. J Strength Cond Res. 2016;30:1491–509.
[13] Morin J-B, Bourdin M, Edouard P, Peyrot N, Samozino P, Lacour J-R. Mechanical determinants of 100-m sprint running performance. Eur J Appl Physiol. 2012;112:3921–30.
[14] Bishop DJ, Girard O. Determinants of team-sport performance: implications for altitude training by team-sport athletes. Br J Sports Med. 2013;47:i17–21.
[15] Asadi A, Young WB, de Villarreal ES. The effects of plyometric training on change-of-direction ability: a meta-analysis. 2016;2015:0694.
[16] de Villarreal ES, Requena B, Cronin JB. J Strength Cond Res. 2012;26:575.
[17] Moran RN, Hauth JM, Rabena R. The effect of massage on acceleration and sprint performance in track & field athletes. Complement Ther Clin Pract. 2018;30:1–5.
[18] Hernández S, Ramirez-Campillo R, Álvarez C, et al. Effects of plyometric training on neuromuscular performance in youth basketball players: a pilot study on the influence of drill randomization. J Sports Sci Med. 2018;17:372–8.
[19] Ramírez-Campillo R, Gallardo F, Henriquez-Olguín C, et al. Effect of vertical, horizontal, and combined plyometric training on explosive, balance, and endurance performance of young soccer players. J Strength Cond Res. 2015;29:1784–95.
[20] Abdelkrim NB, Chaouachi A, Chamari K, Chtara M, Castagna C. Positional role and competitive-level differences in elite-level men's basketball players. J Strength Cond Res. 2010;24:1346.
[21] Abdelkrim NB, El Fazaa S, El Ati J. Time–motion analysis and physiological data of elite under-19-year-old basketball players during competition. Br J Sports Med. 2007;41:69.
[22] Conte D, Favero TG, Lupo C, Francioni FM, Capranica L, Tessitore A. Time-motion analysis of Italian elite women's basketball games. J Strength Cond Res. 2015;29:144–50.
[23] te Wierike SC, de Jong MC, Tromp EJ, et al. Development of repeated sprint ability in talented youth basketball players. J Strength Cond Res. 2014;28:928–34.

[24] DiFiori JP, Güllich A, Brenner JS, et al. The NBA and youth basketball: recommendations for promoting a healthy and positive experience. Sports Med. 2018;48:2053–65.
[25] Ramirez-Campillo R, García-Hermoso A, Moran J, Chaabene H, Negra Y, Scanlan AT. The effects of plyometric jump training on physical fitness attributes in basketball players: a meta-analysis. J Sport Health Sci. 2022;11:656–70.
[26] Bianchi M, Coratella G, Dello Iacono A, Beato M. Comparative effects of single vs. double weekly plyometric training sessions on jump, sprint and change of directions abilities of elite youth football players. J Sports Med Phys Fitness. 2019;59:910–5.
[27] Chelly MS, Hermassi S, Aouadi R, Shephard RJ. Effects of 8-week in-season plyometric training on upper and lower limb performance of elite adolescent handball players. J Strength Cond Res. 2014;28:1401–10.
[28] Silva AF, Clemente FM, Lima R, Nikolaidis PT, Rosemann T, Knechtle B. The effect of plyometric training in volleyball players: a systematic review. Int J Environ Res Public Health. 2019;16:2960.
[29] Piercy KL, Troiano RP, Ballard RM, et al. The physical activity guidelines for Americans. JAMA. 2018;320:2020–8.
[30] Stojanović E, Aksović N, Stojiljković N, Stanković R, Scanlan AT, Milanović Z. Reliability, usefulness, and factorial validity of change-of-direction speed tests in adolescent basketball players. J Strength Cond Res. 2019;33:3162–73.
[31] Arazi H, Coetzee B, Asadi A. Comparative effect of land-and aquatic-based plyometric training on jumping ability and agility of young basketball players. South Afr J Res Sport Phys Educ Recreat. 2012;34:1.
[32] Reiman MP, Manske RC, Functional Testing in Human Performance. Human kinetics; 2009.
[33] Rami P, Prabhakar MM. Comparison of static balance in male football and basketball players by using flamingo balance test. Int J Physiother. 2018;5:162.
[34] Young W, Russell A, Burge P, Clarke A, Cormack S, Stewart G. The use of sprint tests for assessment of speed qualities of elite Australian rules footballers. Int J Sports Physiol Perform. 2008;3:199–206.
[35] Fukuda DH, Assessments for Sport and Athletic Performance. Human Kinetics; 2019.
[36] Cicioğlu I, Gökdemir K, Erol E. The effect of plyometric training on vertical jump and some physical and physiological parameters of 14-15 age group basketball players. Spor Bilimleri Dergisi. 1996;7:11–23.
[37] Hopkins WG, Marshall SW, Batterham AM, Hanın J. Progressive statistics for studies in sports medicine and exercise science. Med Sci Sports Exerc. 2009;41:3–13.
[38] Ramirez-Campillo R, Moran J, Oliver JL, Pedley JS, Lloyd RS, Granacher U. Programming plyometric-jump training in soccer: a review. Sports. 2022;10:94.
[39] Hulfian L, Kusuma LSW, Subakti S. Aplikasi air alert training untuk komponen biomotorik dasar pemain sepak bola ekstrakurikuler sman 1 montong gading. Gelora: Jurnal Pendidikan Olahraga dan Kesehatan IKIP Mataram. 2019;5:66.
[40] Meylan C, Malatesta D. Effects of in-season plyometric training within soccer practice on explosive actions of young players. J Strength Cond Res. 2009;23:2605–13.
[41] Latorre Román P, Villar Macias FJ, García Pinillos F. Effects of a contrast training programme on jumping, sprinting and agility performance of prepubertal basketball players. J Sports Sci. 2018;36:802–8.
[42] Asadi A, Ramirez-Campillo R, Meylan C, Nakamura FY, Cañas-Jamett R, Izquierdo M. Effects of volume-based overload plyometric training on maximal-intensity exercise adaptations in young basketball players. J Sports Med Phys Fitness. 2016;57:1557–63.
[43] Ramírez-Campillo R, González-Jurado JA, Martínez C, et al. Effects of plyometric training and creatine supplementation on maximal-intensity exercise and endurance in female soccer players. J Sci Med Sport. 2016;19:682–7.
[44] Bouteraa I, Negra Y, Shephard RJ, Chelly MS. Effects of combined balance and plyometric training on athletic performance in female basketball players. J Strength Cond Res. 2020;34:1967–73.
[45] Zemková E, Hamar D. The effect of 6-week combined agility-balance training on neuromuscular performance in basketball players. J Sports Med Phys Fitness. 2010;50:262–7.
[46] Rustiawan H. Pengaruh Latihan interval training dengan running circuit terhadap peningkatan vo2max. Jurnal Wahana Pendidikan. 2020;7:15.
[47] Hulfian LG. Athletes through interval training and circuit training. Jurnal Pendidikan Olahraga dan Kesehatan IKIP Mataram. 2016;3:466.
[48] Miller MG, Herniman JJ, Ricard MD, Cheatham CC, Michael TJ. The effects of a 6-week plyometric training program on agility. J Sports Sci Med. 2006;5:459–65.
[49] Demir ME, Dağlıoğlu O. The Effect of plyometric training program on physical performance in basketball players. Eur J Phys Educ Sport Sci. 9
[50] Huang H, Huang W-Y, Wu C-E. The effect of plyometric training on the speed, agility, and explosive strength performance in elite athletes. Appl Sci. 2023;13:3605.
[51] Kubo K, Ishigaki T, Ikebukuro T. Effects of plyometric and isometric training on muscle and tendon stiffness in vivo. Physiol Rep. 2017;5:e13374.
[52] Kubo K, Ikebukuro T, Yata H. Effects of plyometric training on muscle–tendon mechanical properties and behavior of fascicles during jumping. Physiol Rep. 2021;9:e15073.
[53] Lee HM, Oh S, Kwon JW. Effect of plyometric versus ankle stability exercises on lower limb biomechanics in taekwondo demonstration athletes with functional ankle instability. Int J Environ Res Public Health. 2020;17:3665.
[54] Ramachandran AK, Singh U, Ramirez-Campillo R, Clemente FM, Afonso J, Granacher U. Effects of plyometric jump training on balance performance in healthy participants: a systematic review with meta-analysis. Front Physiol. 2021;12:730945.
[55] Lee J, Martin J, Wildehain R. Ambegaonkar Plyometrics or balance training effects on lower body power, balance and reactive agility in collegiate basketball athletes: a randomized control trial. Turk J Sports Med. 2021;56:5–12.
[56] İlbak I, Acak M. The effect of plyometric training combined with electrical muscle stimulation on sports performance parameters in basketball players. Spor ve Performans Araştırmaları Dergisi. 2022;13: 189–200.
[57] Manouras N, Papanikolaou Z, Karatrantou K, Kouvarakis P, Gerodimos V. The efficacy of vertical vs. horizontal plyometric training on speed, jumping performance and agility in soccer players. Int J Sports Sci Coaching. 2016;11:702–9.
[58] Michailidis Y, Venegas P, Metaxas T. Effects of combined horizontal plyometric and change of direction training on anaerobic parameters in youth soccer players. Sports. 2023;11:27.
[59] Arslan E, Kilit B, Clemente FM, et al. Effects of small-sided games training versus high-intensity interval training approaches in young basketball players. Int J Environ Res Public Health. 2022;19:2931.
[60] Ferley DD, Scholten S, Vukovich MD. Combined sprint interval, plyometric, and strength training in adolescent soccer players: effects on measures of speed, strength, power, change of direction, and anaerobic capacity. J Strength Cond Res. 2020;34:957–68.
[61] Aksović N, Berić D, Kocić M, Jakovljević S, Milanović F. Plyometric training and sprint abilities of young basketball players. Facta Univ Series Phys Educ Sport. 2020:539.
[62] Barrera-Domínguez FJ, Almagro BJ, Sáez De Villarreal E, Molina-López J. Effect of individualised strength and plyometric training on the physical performance of basketball players. Eur J Sport Sci. 2023;23:2379–88.