applied sciences

Article

The Effects of Plyometric Training on the Performance of Three Types of Jumps and Jump Shots in College-Level Male Basketball Athletes

Wei-Yang Huang [1], Cheng-En Wu [2,*] and Hsuan Huang [3]

[1] Physical Education Leader, National Taiwan College of Performing Arts, Taipei 11464, Taiwan; pmp999@tcpa.edu.tw
[2] Office of Physical Education, Tamkang University, No. 151, Ying-Zhuan Rd., Tamshui, New Taipei City 251301, Taiwan
[3] Institute of Physical Education, Health &Leisure Studies of National Cheng Kung University, Tainan 70101, Taiwan; rb7111071@gs.ncku.edu.tw
* Correspondence: charlie255142@gmail.com

Abstract: Recent studies have shown that lower-limb plyometric training can effectively enhance muscle strength and explosiveness, which are particularly important for improving jumping ability. The purpose of this study was to evaluate the effects of plyometric training on vertical, lateral, and horizontal jumping abilities, and their subsequent impact on basketball shooting performance and sports injury prevention. A quasi-experimental design was used, recruiting 30 male college-level basketball players from Taiwan, who were randomly assigned to an experimental group (n = 15) and a control group (n = 15). Both groups participated in 2 h of basketball training daily, while the experimental group additionally engaged in plyometric training twice a week. The results revealed significant improvements in the experimental group in several key areas, including rate of force development (RFD), ground reaction force (GRF), jump height, jump distance, and both horizontal and vertical forces, across vertical, lateral, and horizontal jumps. Specifically, vertical jumps required the highest ground reaction force, followed by lateral jumps, with horizontal (step-back) jumps requiring the least. The optimal angles for the resultant force during take-off were found to be between 66.1° and 66.8° for lateral jumps, and between 56.2° and 57.2° for step-back jumps, while vertical jumps did not show significant variation in take-off angle. In terms of basketball performance, the experimental group demonstrated significantly better post-test results in all three types of jump shots, with the highest accuracy observed in the vertical jump shot, followed by the lateral jump shot, and the lowest in the step-back jump shot. Furthermore, the experimental group experienced a substantial reduction in sports injury rates, with the injury rate decreasing to 6%. These findings indicate that plyometric training not only enhances jumping performance, but also contributes to injury prevention by strengthening lower-limb muscles. This study provides a theoretical basis for coaches to develop comprehensive training programs that improve athletic performance and reduce injury risk.

Keywords: vertical jump; lateral jump; horizontal jump; plyometric training; injury prevention

check for updates

Citation: Huang, W.-Y.; Wu, C.-E.; Huang, H. The Effects of Plyometric Training on the Performance of Three Types of Jumps and Jump Shots in College-Level Male Basketball Athletes. *Appl. Sci.* **2024**, *14*, 12015. https://doi.org/10.3390/app142412015

Academic Editor: Roger Narayan

Received: 25 October 2024
Revised: 19 December 2024
Accepted: 19 December 2024
Published: 22 December 2024

1. Introduction

Jumping is considered an essential movement in basketball skills, because it not only enhances basketball performance, but also helps to strengthen the lower-limb muscles [1]. A successful basketball athlete fundamentally possesses vertical, lateral, and horizontal (backward) jumping abilities, which are crucial for basketball performance. Vertical jumping ability is utilized in rebounding, jump balls, dunking, step-forward jump shots, and leaning jump shots (also known as leaners). Lateral jumping ability is applied in dribbling side-to-side movements and lateral jump shots. Backward jumping ability is used in step-back jump shots.

Basketball jump shots are directly related to basic jumping movements [2], which also indicates that lower-limb strength, flexibility, and coordination can help basketball athletes to quickly jump on the court [3]. Excellent leg strength allows for higher jumps, quick changes in direction, faster sprints, and better jumping and landing, enabling athletes to maintain smooth movement during dynamic actions [4]. However, for basketball athletes to develop excellent jumping ability, they must engage in lower-limb strength training, in order to activate the muscle power of the lower limbs to counteract ground reaction forces [5]. Additionally, the knees and ankles must handle lateral movements and rotations at different angles, allowing the lower limbs to maximize power output and enhance athletic performance [6]. Research shows that lower-limb injuries are the most common injuries among male and female college basketball players [7]. The most common lower-limb injuries are ankle ligament sprains and knee injuries [8]. The cause of these injuries is the stress from constant jumping, landing, and sudden changes in direction during games and practices. Research also indicates that structural knee joint injuries among basketball athletes are significantly associated with playing time, usage rate, and prolonged competition [9]. Therefore, incorporating lower-limb exercises into training programs is indispensable, as it helps to improve basketball athletes' jumping ability and prevent sports injuries [10].

PT is a fast and explosive exercise that can effectively enhance muscle strength and power [11]. Research indicates that jumping ability can be linked to PT [12]. Many studies have shown that PT can significantly improve muscle strength, power, jumping performance, and overall athletic performance [13–17]. Additionally, evidence suggests that incorporating PT into basketball training can enhance the explosive power and vertical jump ability of players' lower limbs [18]. Furthermore, other studies have indicated that strength training following these regimens indeed helps in reducing injury rates [19], as increased muscle strength can enhance skeletal stability and reduce the risk of injuries caused by sports activities.

Thanks to training interventions, it has been possible to identify the performance of vertical and lateral jumps. However, there are currently no studies that explain the differences between vertical, lateral, and horizontal jumps. The kinematic differences among these three types of jumps have not yet been evaluated. Further research is needed to better confirm these differences. Based on an analysis of the existing literature, the purpose of this study was to examine the impact of vertical, lateral, and horizontal jumping abilities on basketball jump shot performance, and to understand how plyometric training aids in injury prevention. The hypothesis of this study was that twelve weeks of PT could significantly enhance three types of jumping abilities, thereby improving jump shot performance and aiding in injury prevention.

2. Materials and Methods

The participants of this study were recruited from a university's college-level male basketball team in Taiwan. The recruits underwent pre-testing. All the participants were required to undergo regular basketball skills training (five times a week, for two hours each session), and were divided into two groups. The experimental group received additional PT twice a week, for 120 min per session. After the experiment, both groups underwent post-testing. A statistical analysis was conducted based on the pre- and post-test data. The research design was quasi-experimental [20].

2.1. Participants

The study population consisted of college-level male basketball athletes from 16 teams from a university in Taiwan, comprising a total of approximately 192 athletes. According to Mills and Gay, the sample size needed to be at least 10% of the population [21]. This study publicly recruited 30 participants, achieving a sample size that represented 10% of the total population. The normality of the sample distribution was examined using a quantile–quantile plot (Q–Q plot), and the 95% confidence interval (CI) was calculated [22].

The results showed that the participants' ages, heights, weights, years of athletic experience (years of participating in basketball training), and sports injury rates over the previous three months (training five days a week, for two hours per day, totaling 120 h) all followed linear normal distributions. These variables were within the 95% confidence interval (CI) ranges, indicating that the sample demonstrated normality. The 30 samples were randomly divided into an experimental group and a control group. *t*-tests of the pre-test mean values for the background factors did not show significant differences, indicating homogeneity between the two groups, as shown in Table 1. The potential risks to participants were not greater than those faced by non-participants, and were considered minimal. The participants' rights were not affected, as participation was voluntary and non-coercive, and informed consent was obtained from the participants in advance, with signatures and dates. This study was approved by the First Human Research Ethics Review Committee of National Cheng Kung University Hospital, with approval number A-ER-113–165.

Table 1. Participant homogeneity analysis.

Variable	EG (n = 15) M ± SD	CG (n = 15) M ± SD	95% Confidence Interval		t-Value	p-Value
			Lower Bound	Upper Bound		
Age (years)	22 ± 1.06	22 ± 1.08	−0.70	0.69	−0.021	0.984
Height (cm)	177.5 ± 3.78	177.6 ± 4.05	−2.65	2.04	−0.281	0.783
Weight (kg)	74.5 ± 8.91	74.5 ± 6.90	−6.38	6.32	−0.009	0.993
Years of athletic experience	9.25 ± 1.15	9.28 ± 1.28	−0.74	0.69	−0.080	0.937
Number of sports injuries (%)	22 ± 12.06	26 ± 14.73	−8.05	15.83	0.698	0.496

EG represents the experimental group, and CG represents the control group. The mean ± standard deviation is expressed as M ± SD. *t*-test values are indicated by *t*-values (*p*-values). $p < 0.05$.

2.2. Intervention

Both the experimental and control groups were required to participate in two hours of basketball training each day from Monday to Friday. This training included technical drills and team practice games directed by two basketball coaches, with personnel management overseen by the research team. Additionally, the experimental group undertook a plyometric training program (PTP) twice a week. The intervention measures were as follows.

In recent years, many studies have employed plyometric training as a method to enhance lower-limb strength across various sports [11,23–26]. Based on the existing literature on plyometric training, this study formulated intervention measures for a plyometric training program (PTP). The intervention spanned 12 weeks, as muscle strength adaptations typically require about 12 weeks [27]. The lower-limb plyometric training program, as shown in Table 2, was conducted twice a week [28], and each session lasted 120 min [29]. The lower-limb plyometric training exercises, as listed in Table 2, were conducted.

The experimental group was to undergo PTP twice a week for a total of 12 weeks. Each session was to follow a circuit training format, with each set followed by a 10–30 s rest, and a 3–5 min rest after completing one circuit. A total of three circuits needed to be completed [30]. Each cycle of PTP required a load intensity based on the individual's maximum strength. Before performing the PTP, each participant in the experimental group was tested for their one-repetition maximum (1RM) for each item, as follows [31]:

First circuit: A light load with high repetitions, with each set repeated 12 to 15 times, at 60% to 70% of the 1RM (one-repetition maximum).

Second circuit: A moderate load with moderate repetitions, with each set repeated 8 to 10 times, at 70% to 80% of the 1RM (one-repetition maximum).

Third circuit: A heavy load with low repetitions, with each set repeated 1 to 5 times, at 80% to 100% of the 1RM (one-repetition maximum).

Table 2. Contents of the plyometric training program.

Content	Reps/Set
Warm-up	Warm-up with 10 min of aerobic exercise.
Dead lift	Barbell (10 kg) + weight plates (20 kg) = 30 kg, 15 reps (Set 1) Barbell (10 kg) + weight plates (30 kg) = 40 kg, 10 reps (Set 2) Barbell (10 kg) + weight plates (40 kg) = 50 kg, 1 to 5 reps (Set 3)
Skater hops	15 reps each on the left and right (Set 1 to Set 3)
Lateral shuffle	15 reps each on the left and right (Set 1 to Set 3)
Jumping lunges with dumbbells	Dumbbell (6 kg) in each hand, 12 reps (Set 1) Dumbbell (8 kg) in each hand, 8 reps (Set 2) Dumbbell (10 kg) in each hand, 1 to 5 reps (Set 3)
Rocket jump	15 reps (Set 1), 10 reps (Set 2), 1 to 5 reps (Set 3)
Lateral box jump	6 inches to your side, 10 reps each side (Set 1 to Set 3)
The modified single-leg squat (MSLS)	Holding a dumbbell in each hand + unilateral (1 leg at a time) training. Dumbbell (6 kg) in each hand, 12 reps (Set 1) Dumbbell (8 kg) in each hand, 8 reps (Set 2) Dumbbell (10 kg) in each hand, 1 to 5 reps (Set 3)
The laterally resisted split squat (LRSS)	Holding a dumbbell in each hand + laterally split squat (one lunge each to the left and right). Dumbbell (6 kg) in each hand, 12 reps (Set 1) Dumbbell (8 kg) in each hand, 8 reps (Set 2) Dumbbell (10 kg) in each hand, 1 to 5 reps (Set 3)
The bilateral back squat (BS)	Barbell (10 kg) + weight plates (30 kg) = 40 kg, 12 reps (Set 1) Barbell (10 kg) + weight plates (40 kg) = 50 kg, 8 reps (Set 2) Barbell (10 kg) + weight plates (50 kg) = 60 kg, 1 to 5 reps (Set 3)
Box jumps	Counter movement jumps Box height: 18 inches, 12 reps (Set 1) Box height: 24 inches, 8 reps (Set 2) Box height: 32 inches, 1 to 5 reps (Set 3)
Cool-down	Muscle relaxation can be performed with roller stretching or static stretching

Based on the PTP measures outlined above, to control the impact of muscle strength enhancement on athletic performance, this study identified the independent and dependent variables.

Independent Variables: 1. PTP: This includes training frequency, intensity, duration, and exercises (as shown in Table 2). 2. Muscle Strength Enhancement: Quantified through indicators of muscle strength growth, such as PTP and maximum repetitions.

Dependent Variables: 1. Athletic Performance: Specific performance indicators such as vertical jump reaction force, lateral jump resultant force, step-back resultant force, and jump shot accuracy. 2. Sports injury rate: This evaluates the risks of the training plan, helping to reduce the risk of injuries among athletes and improve overall athletic performance.

2.3. Research Tools and Variables

2.3.1. Research Tools

This study used the PASCO PS-3230 wireless dual-axis platform, manufactured in Roseville, California, USA. PASCO SCIENTIFIC is a voltage-sensing force plate with product parameters including four corner force elements with a range of ±1100 N, and a vertical resultant force up to 4400 N. Each force element has an overload protection of 1700 N, with a total vertical overload protection force of up to 6600 N. The device's sampling frequency was set to 1000 Hz, allowing for 1000 force measurements per second. The PASCO force plate was used to analyze human jump dynamics, including vertical, lateral, and horizontal jump analysis [32].

2.3.2. Research Variables

The variables in the study of vertical jumps in basketball athletes include the rate of force development (RFD), ground reaction force (GRF), duration of passage, and jump height. The variables in the study of lateral jumps include the jump distance, horizontal component of ground reaction force (H-GRF), vertical component of ground reaction force (V-GRF), resultant ground reaction force (R-GRF), and trajectory of the resultant force (T-PRF) (θ). The variables in the study of horizontal jumps include the jump distance, maximum slope of left and right foot take-off, horizontal force of step-back take-off (H-GRF), vertical force of step-back landing (V-GRF), resultant force (R-GRF), step-back resultant force trajectory (T-PRF) (θ), and action time of the step-back.

2.4. Test Method

2.4.1. Vertical Jump Test

Each participant had 5 test attempts, with a 10 s rest between each attempt. The best three jumps were recorded and averaged to obtain the final score. The parameters measured by the force plate for the vertical jumps included the rate of force development (RFD), ground reaction force (GRF), duration of passage, and jump height.

2.4.2. Lateral Jump Test

The participants first practiced lateral jumps on flat ground to determine the optimal force and distance for left and right jumps. Before testing, each participant adjusted their maximum lateral jump distance (the distance at which they could land stably on one foot, which was considered their maximum reasonable distance) [33]. The participants followed a metronome's pace to perform lateral jumps on one foot, with arm swings allowed. The jump was repeated four times on each foot, and the task had to be completed within 15 s. Finally, the average force exerted by each foot was calculated.

The dynamic analysis of lateral jumps using a force plate includes the following variables: jump distance, H-GRF, V-GRF, R-GRF, and T-PRF (θ) [34]. The angle of θ was calculated. tanθ = length of opposite side (vertical side)/length of adjacent side (horizontal side). When tanθ is larger, the angle of θ is larger.

2.4.3. Horizontal Jump Test

Each participant first practiced the step-back movement on flat ground to determine the optimal distance for the step-back take-off. The step-back movement instructions were as follows: The participants stood firmly between two force plates (optimal force position). To initiate the step-back, they stepped forward with their right foot onto the force plate (their left foot was naturally suspended). Upon landing, their right foot pushed back onto the rear force plate. The left foot landed first on the rear force plate, followed by the right foot quickly retracting to achieve a stable posture (alternating between the left and right foot). Each participant performed the step-back movement three times with each foot. The jump distance was determined based on the individual's optimal performance.

The parameters measured by the force plate for horizontal jumps include the jump distance, maximum slope of left and right foot take-off, horizontal force of step-back take-off (H-GRF), vertical force of step-back landing (V-GRF), resultant force (R-GRF), step-back resultant force trajectory (T-PRF) (θ), and action time of the step-back [35]. The angle of θ was calculated. tanθ = length of opposite side (vertical side)/length of adjacent side (horizontal side). When tanθ is larger, the angle of θ is larger.

2.4.4. Sports Injury Rate Test

The study recruited healthy participants and recorded sports injuries in both the pre-test and post-test phases. These injuries included leg muscle strains, calf cramps, bruises from falls, mild sprains of the ankle or wrist, tendinitis, knee pain, and muscle tension in the back or neck. Initially, the sports injury rate during basketball training and practice games over the previous three months, for both the experimental group and the control group, was surveyed as the pre-test. During the experiment, the sports injury rate for both groups was recorded as the post-test. The sports injury rates for both the pre-test and post-test were standardized to a 12-week (three-month) period.

Both the experimental and control groups received basketball training five times per week, for 2 h per session, totaling 120 h. The experimental group additionally underwent plyometric training program (PTP) interventions twice a week, for 2 h per session, totaling 48 h. Therefore, the total training time for the experimental group was 168 h, while the control group's total training time was 120 h. The specific calculation formula for the sports injury rate was as follows: Sports injury rate = [Number of sports injuries occurring within a certain period/Total training time (hours)] × 1000. It is usually expressed per thousand hours of training.

2.4.5. Sports Performance Test

The literature indicates that vertical, lateral, and horizontal jump abilities are related to basketball jump shot performance. Therefore, this study tested three types of jump shots: the step-forward vertical jump shot, dominant-side lateral step-up jump shot, and step-back jump shot. The differences between the pre- and post-tests were compared to understand jump shot performance.

2.5. Control Variables

Targeted at college-level male basketball athletes from Taiwanese universities, this study recruited participants and noted background variables including age, weight, height, years of athletic experience, and number of sports injuries. These background variables showed homogeneity, and this study's control variables included dietary control, recovery control, and consistent training conditions. Dietary control involved posting standardized meal plans and providing verbal dietary guidance at the beginning of and throughout the study, to ensure that each participant's nutrient intake was similar. Recovery control involved requiring the participants to maintain consistent sleep durations and quality, and to record their daily sleep times. Additionally, after each training session, the participants were instructed to perform stretching, massage, and ice therapy for recovery. Because the control group and the experimental group underwent two hours of basketball training simultaneously in the same location, consistent training conditions were ensured.

2.6. Statistical Analysis

Statistical analyses were performed using SPSS 28.0 software (IBM®, Armonk, NY, USA). Initially, a homogeneity *t*-test was conducted to assess the standard deviations and means of age, height, years of athletic experience, and number of sports injuries between the experimental and control groups. To compare the differences in sports injury rates between the two groups, an independent-sample *t*-test was applied. For the analysis of athletic performance, which included three types of jumping abilities and three types of basketball jump shot performances, a two-way and a three-way mixed ANOVA were used to examine the interactions between the different types of jumps and jump shot performances for both groups. The significance level for all the tests was set at $p < 0.05$. The partial eta squared (η^2) was calculated to measure the effect size, with values closer to 1 indicating a larger contribution of the independent variables to the dependent variables. An η^2 value greater than 0.14 was considered indicative of a large effect size [36].

3. Results

3.1. Vertical Jump Dynamics Analysis

After 12 weeks of PT, all the parameters in the experimental group were superior to those in the control group. The two-way mixed ANOVA showed that the *F*-values for all the parameters showed significant differences ($p < 0.05$). Next, the sizes of the effects of the independent variables (experimental group and control group) on the dependent variables

(RFD, GRF, duration of passage, and jump height) were explored. The results showed that η^2 ranged from 0.156 to 0.769, indicating large effect sizes, as shown in Table 3.

Table 3. Analysis of kinetic parameters of vertical jump.

Parameter		EG (n = 15) M ± SD	CG (n = 15) M ± SD	F-Value	p-Value	η^2
RFD (N/s)						
	Pre	8060 ± 580	8066 ± 624	20.91 *	<0.05	0.428
	Post	9115 ± 629	8070 ± 542			
GRF (N)						
	Pre	1956 ± 222	1952 ± 301	5.17 *	<0.05	0.156
	Post	2119 ± 263	1958 ± 301			
Duration of passage (s)						
	Pre	0.48 ± 0.04	0.47 ± 0.03	38.18 *	<0.05	0.577
	Post	0.59 ± 0.03	0.46 ± 0.06			
Jump height (m)						
	Pre	0.44 ± 0.06	0.43 ± 0.06	93.36 *	<0.05	0.769
	Post	0.58 ± 0.03	0.44 ± 0.06			

EG denotes the experimental group, while CG denotes the control group. The rate of force development is referred to as RFD (r), the ground reaction forces are represented as GRF (N), and the duration of passage is measured in seconds (symbolized as s). The data are presented as the mean ± standard deviation (M ± SD), and were statistically analyzed using an F-test, with a significance level set at * $p < 0.05$.

After the lower-limb PT in the experimental group, the RFD increased by 13.1%, the lower-limb GRF increased by 8.33%, the average duration of passage increased by 22.92%, and the average jump height also increased by 28.89%. This indicates that lower-limb PT can enhance the vertical jump ability of college-level male university basketball athletes.

3.2. Analysis of Lateral Jump Dynamics

Kinematic analysis of the pre- and post-tests was conducted for lateral jumps (using the left and right foot) in both the experimental and control groups. This analysis included measurements of jump distance, horizontal ground reaction force (H-GRF), vertical ground reaction force (V-GRF), rear-ground reaction force (R-GRF), and time to peak rate of force (T-PRF, θ). After 12 weeks of PT, all the parameters of the experimental group, except for T-PRF (θ), were superior to those of the control group. The two-way mixed ANOVA showed that the F-values were all significantly different ($p < 0.05$). Next, the size of the effects of the independent variable (experimental group and control group) on the dependent variables (jump distance, H-GRF, V-GRF, R-GRF, and T-PRF) were explored. The results showed that, except for the T-PRF (θ) of the left and right feet, all the measures showed large effect sizes, with η^2 ranging from 0.209 to 0.761, as shown in Table 4.

The average values of the lateral jump's T-PRF (θ) across the four repetitions ranged from 66.1 to 66.8 degrees, with no significant difference. This indicated that the lateral take-off angles for both the left and right feet of all the participants were approximately distributed around 66.4 ± 0.4 degrees. Additionally, there was a significant difference in jump distance between the experimental group and the control group. This was mainly due to the increased horizontal force in lateral jumps of the lower limbs in the experimental group after undergoing PT, which also increased the R-GRF. Finally, the lack of significant difference in T-PRF (θ) between the experimental group and the control group can be explained by the formula for calculating tanθ (tanθ = V-GRF/H-GRF). Although the posterior H-GRF and V-GRF increased in the experimental group, the calculated angle θ showed no significant difference. The above results confirm that 12 weeks of PT (PT) significantly improved the lateral jumping ability of the college-level male basketball athletes in the experimental group.

Table 4. Analysis of dynamic parameters of lateral jump.

Parameter	EG (n = 15) M ± SD	CG (n = 15) M ± SD	F-Value	p-Value	η^2
JD (m)					
L-R Pre	1.47 ± 0.12	1.48 ± 0.10	89.37 *	<0.05	0.761
L-R Post	1.66 ± 0.08	1.49 ± 0.10			
H-GRF (N)					
L-Pre	735 ± 82	733 ± 86	13.98 *	<0.05	0.333
L-Post	823 ± 53	737 ± 83			
R-Pre	741 ± 78	740 ± 91	7.39 *	<0.05	0.209
R-Post	810 ± 75	738 ± 62			
V-GRF (N)					
L-Pre	1719 ± 198	1718 ± 189	12.51 *	<0.05	0.309
L-Post	1928 ± 130	1721 ± 142			
R-Pre	1733 ± 183	1735 ± 160	16.69 *	<0.05	0.373
R-Post	1903 ± 174	1739 ± 171			
R-GRF (N)					
L-Pre	1870 ± 209	1869 ± 201	13.26 *	<0.05	0.321
L-Post	2096 ± 134	1873 ± 159			
R-Pre	1885 ± 194	1887 ± 176	17.42 *	<0.05	0.384
R-Post	2069 ± 180	1890 ± 176			
T-PRF (θ)					
L-Pre	66.7 ± 1.3	66.8 ± 1.5	0.024	>0.05	0.001
L-Post	66.7 ± 1.1	66.7 ± 1.2			
R-Pre	66.7 ± 1.3	66.8 ± 1.5	0.778	>0.05	0.027
R-Post	66.1 ± 1.5	66.8 ± 1.4			

EG represents the experimental group, and CG represents the control group. Abbreviations: The jump distance (m) is JD (m). The horizontal force of take-off is H-GRF. The vertical ground reaction force (N) is V-GRF (N). The resultant ground reaction force (N) is R-GRF (N). The trajectory at peak resultant force (degrees) is T-PRF (θ). The data are presented as the mean ± standard deviation (M ± SD), and were statistically analyzed using the F-test, with the significance level set at * $p < 0.05$.

3.3. Horizontal Jump Dynamics Analysis

After 12 weeks of PT, except for the angle of T-PRF, all the parameters in the experimental group were superior to those in the control group. Additionally, the two-factor mixed ANOVA showed that the F-values for all the parameters were significantly different ($p < 0.05$). Next, the sizes of the effects of the independent variables (experimental group and control group) on the dependent variables (jump distance, RFD, H-GRF, V-GRF, R-GRF, T-PRF, and action time of the step-back) were explored. The results showed that, except for the T-PRF (θ) of the left and right feet during take-off, which did not show a high effect size, all the other measures showed large effect sizes, with η^2 ranging from 0.138 to 0.849, as shown in Table 5.

The average values of T-PRF (θ) for the three step-back jumps ranged between 56.2 and 57.2 degrees, indicating no significant difference in the step-back take-off angles for both the left and right feet of all the participants, with an approximate distribution around 56.7 ± 0.5 degrees. Additionally, the horizontal jump distance of the experimental group significantly increased, and the action time of the step-back significantly decreased (shortened action time). This was mainly due to the increased take-off H-GRF, landing V-GRF, and R-GRF in the lower limbs during the step-back after undergoing PT. Finally, the lack of significant difference in T-PRF (θ) between the two groups can be explained by the formula for calculating tanθ (tanθ = V-GRF/H-GRF). Although the experimental group showed an increase in both H-GRF and V-GRF, the calculated angle θ did not show a significant difference. The above results confirm that 12 weeks of PT significantly improved the horizontal (step-back) jump ability of college-level male basketball athletes in the experimental group.

Table 5. Analysis of dynamic parameters of horizontal jump.

Parameter	EG (n = 15) M ± SD	CG (n = 15) M ± SD	F-Value	p-Value	η^2
JD (m)					
L-Pre	0.86 ± 0.07	0.87 ± 0.06	79.33 *	<0.05	0.739
L-Post	1.15 ± 0.11	0.88 ± 0.06			
R-Pre	0.89 ± 0.07	0.90 ± 0.05	36.71 *	<0.05	0.567
R-Post	1.14 ± 0.09	0.88 ± 0.06			
RFD (N/S) Left and right foot take-off					
L-Pre	6386 ± 291	6353 ± 239	16.70 *	<0.05	0.374
L-Post	6816 ± 373	6349 ± 233			
R-Pre	6269 ± 312	6268 ± 298	9.44 *	<0.05	0.252
R-Post	7160 ± 311	5939 ± 592			
H-GRF (N) Step-back take-off					
L-Pre	954 ± 221	948 ± 233	23.68 *	<0.05	0.458
L-Post	1072 ± 194	954 ± 215			
R-Pre	913 ± 224	906 ± 203	4.49 *	<0.05	0.138
R-Post	1053 ± 236	926 ± 184			
V-GRF (N) Step-back landing					
L-Pre	1448 ± 268	1443 ± 269	23.19 *	<0.05	0.453
L-Post	1606 ± 204	1454 ± 251			
R-Pre	1422 ± 281	1420 ± 239	4.99 *	<0.05	0.151
R-Post	1582 ± 245	1430 ± 218			
R-GRF (N) Resultant force of step-back					
L-Pre	1734 ± 345	1728 ± 350	24.83 *	<0.05	0.470
L-Post	1932 ± 276	1740 ± 325			
R-Pre	1690 ± 356	1686 ± 307	5.62 *	<0.05	0.167
R-Post	1906 ± 304	1704 ± 279			
T-PRF (θ) Step-back resultant force trajectory					
L-Pre	56.7 ± 1.4	56.8 ± 2.0	1.69	>0.05	0.057
L-Post	56.3 ± 1.8	56.7 ± 1.9			
R-Pre	57.2 ± 2.0	57.2 ± 2.4	1.98	>0.05	0.066
R-Post	56.2 ± 1.9	57.1 ± 1.9			
Action time of step-back (s)					
L-Pre	1.38 ± 0.09	1.36 ± 0.07	157.08 *	<0.05	0.849
L-Post	1.06 ± 0.04	1.35 ± 0.05			
R-Pre	1.19 ± 0.07	1.18 ± 0.06	47.63 *	<0.05	0.630
R-Post	1.03 ± 0.06	1.19 ± 0.06			

EG represents the experimental group, and CG represents the control group. Abbreviations: The jump distance is JD. The maximum RFDs of the left and right foot take-off (m = N/s) are L-RFD (m = N/s) and R-RFD (m = N/s). The vertical ground reaction force of take-off (N) is V-GRF (N). The horizontal force of step-back take-off is H-GRF. The vertical force of step-back landing is V-GRF. The resultant force of the step-back is R-GRF. The take-off resultant force trajectory is T-PRF (θ). The data are presented as the mean ± standard deviation (M ± SD), and were statistically analyzed using the F-test, with the significance level set at * $p < 0.05$.

3.4. Analysis of Differences in Three Jumping Abilities

The vertical, lateral, and horizontal jumps were analyzed using the same parameters, including jump distance (height), R-GRF, and T-PRF (θ). The differences were analyzed as shown in Table 6. Through a three-factor ANOVA, it was found that the lateral jump distance was the longest, followed by the horizontal jump distance, with the vertical jump height being the shortest. The differences in the three jump distances indicated that lateral jumps generate more horizontal force. In contrast, vertical jumps do not produce horizontal force, requiring the lower limbs to generate a high-intensity GRF. Additionally, in terms of R-GRF ranking, vertical jumps require the most GRF, followed by lateral jumps, with horizontal (step-back) jumps requiring the least force. Finally, for the T-PRF (θ) of vertical, lateral, and horizontal jumps, the study found that the angle for lateral jumps was approximately 66.4 ± 0.3 degrees, while the take-off angle for horizontal (step-back) jumps was about 56.7 ± 0.5 degrees.

Table 6. Analysis of differences in three types of jumping abilities in the post-test of the experimental group.

Parameter	Vertical Jump M ± SD	Lateral Jump M ± SD	Horizontal Jump M ± SD	*F*-Value	*p*-Value	η^2
JD (m)	0.58 ± 0.03	1.66 ± 0.08	1.15 ± 0.05	1758.37 *	<0.05	0.99
R-GRF (N)	2119 ± 263	2040 ± 134	1909 ± 277	18.81 *	<0.05	0.57
T-PRF (θ)	90.0 ± 0.0	66.4 ± 0.9	56.7 ± 1.6	6465.28 *	<0.05	0.98

Abbreviations: Jump distance is denoted as JD. Resultant force during the step-back is represented as R-GRF. Take-off resultant force trajectory is indicated as T-PRF (θ). Data are presented as the mean ± standard deviation (M ± SD). F-test results are presented as F-values (*p*-values), * $p < 0.05$.

3.5. Sports Performance Analysis

All three types of jump shots were set at a distance of 5 m: vertical jump shots, dominant-side lateral jump shots, and step-back jump shots. These three types of jump shots were analyzed using a two-way ANOVA. The results showed that the F-value for vertical jump shots was 4.43, that for lateral jump shots was 5.52, and that for step-back jump shots was 5.47, all of which reached significant differences ($p < 0.05$). In terms of improvement, the vertical jump shot in the experimental group improved by 59.6% (the average hit rate increased from 41% to 75%), the lateral jump shot in the experimental group improved by 94.3% (the average hit rate increased from 35% to 68%), and the step-back jump shot in the experimental group improved by 116.1% (the average hit rate increased from 31% to 67%), indicating that the experimental groups outperformed the control group, as shown in Figure 1. Additionally, in terms of the average hit rate, the vertical jump shot had the highest hit rate, followed by the lateral jump shot, with the step-back jump shot having the lowest. These results confirm that 12 weeks of PT significantly improved the hit rates of the three types of jump shots among the college-level male basketball athletes in the experimental group, indicating a significant enhancement in jump shot performance.

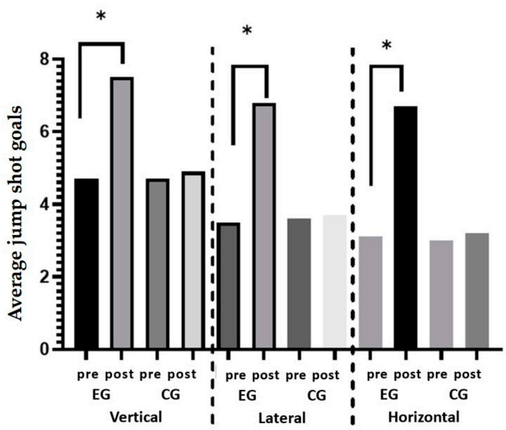

Figure 1. Average numbers of goals scored in the pre- and post-tests for the three types of jump shots. EG is the experimental group, and CG is the control group. * There is a significant difference between the pre-test and post-test in the experimental group.

3.6. Analysis of Sports Injury Rate

The sports injury rate for the three months prior to the training (five days a week, for 2 h a day, totaling 120 h) was used as a pre-test in this study. The 12-week experiment served as the post-test (168 total training hours for the experimental group, and 120 total training hours for the control group). The independent-sample *t*-test revealed that there was no significant difference between the pre-test results of the two groups (t = −0.79, $p < 0.05$).

However, a significant difference in the post-test results was found (t = −5.44 *, $p < 0.05$). The statistical results indicated that the sports injury rate index in the experimental group dropped to 6% after the PTP intervention. This suggests that the strength enhancement in the experimental group contributed to a reduction in the sports injury rate as shown in Table 7.

Table 7. Independent-sample *t*-test for pre-test and post-test sports injury rates between the two groups.

	Test	Group	M ± SD	*df*	*t*-Value	*p*-Value
SIR (%)	Pre	Experimental	22 ± 12.06	28	−0.79	0.44
SIR (%)	Pre	Control	15 ± 3.80			
SIR (%)	Post	Experimental	6 ± 5.26	28	−5.44 *	0.00
SIR (%)	Post	Control	25 ± 12.20			

Abbreviations: Sports injury rate is presented as SIR (%). The mean ± standard deviation is presented as M ± SD. The *t*-test values are presented as *t*-values. * $p < 0.05$.

4. Discussion

For the participants in this study, the kinetic differences in three types of jumping movements and their impact on the performance of three types of basketball jump shots were assessed, as was the role of strength enhancement in reducing injury risk. The hypothesis of this study was fully supported, as the kinetic parameters of vertical jumps, lateral jumps, and horizontal jumps all showed significant improvement after augmented training.

4.1. PTP and Jumping Ability

The research results indicated an increase in the rate of force development (RFD) in the lower limbs of the experimental group, indicating an improvement in lower-limb explosive power. The increase in ground reaction force (GRF) suggests that augmented training led to changes in the muscle structure of the lower limbs, thereby enhancing leg strength. The increase in lower-limb strength was attributed to augmented training, which scholars have pointed out leads to changes in muscle structure due to increases in muscle fascicle angle and length [11]. Additionally, changes in the stiffness of various elastic components, such as the plantar flexor tendon complex, contribute to this improvement [37]. Another finding was that PT improves the time to muscle activation [38], which helps to enhance muscle strength and jumping ability. This indicated an increase in vertical jump height, as well as lateral and horizontal jump distances [39]. Additionally, many studies have confirmed a positive correlation between jumping ability and sports performance [40–42]. For example, a basketball player's success in rebounding, dunking, and jump shots depends on their vertical jumping ability [17]. An increase in lateral jumping ability indicates improved lateral change of direction speed and agility in basketball athletes [43]. PT, specifically squat rocket jumps, is the best way to enhance horizontal jumping ability [44].

4.2. Analysis of Three Types of Jump Dynamics

This study evaluated the kinetic parameters of three types of jumping movements: vertical jumps, lateral jumps, and horizontal (step-back) jumps. The analysis did not include forward horizontal jumps, because forward jumps are directly related to vertical jumps [45], and, therefore, were not separately explored in this study. All three types of jumps share the common characteristic of generating vertical force and utilizing the stretch-shortening cycle [46]. In particular, lateral and horizontal jumps have already been supported by previous research [47]. This study's PT supports the effectiveness of lateral and horizontal jumps, including movements such as the single-leg squat (MSLS), lunge split squat (LRSS), and bilateral squat (BS), in enhancing change of direction (COD) and. movements related to jumping. In fact, many basketball movements require the combination of lateral and horizontal jumps to complete a skill, including the Euro step, crossover, and step-back.

The more precise the movements and the greater the take-off speed, the better the sports performance [48].

The height of a vertical jump is lower than the distances of lateral and horizontal jumps. This is because lateral and horizontal jumps involve horizontal force components and a horizontal impulse generated by the GRF, resulting in the vertical jump height being less than the distances of lateral and horizontal jumps. Scholars believe that lateral and horizontal jumps are more complex than vertical jumps [49]. This is because horizontal jumps also include vertical components. For example, in basketball, a player performing a step-back jump shot needs to jump backward (horizontally) and upward (vertically). Compared to athletes performing a countermovement jump (CMJ), horizontal jumps are more complex than vertical jumps [50]. Therefore, the results of this study are consistent with existing literature, as PT led to greater percentage improvements in lateral and horizontal jump shots compared to vertical jump shots. To clarify, this does not mean that vertical jump training was ineffective for improving horizontal jumps. On the contrary, incorporating horizontal jump training into PT was more effective than solely focusing on vertical jump training.

An important finding of this study is that lateral jumps and horizontal (step-back) jumps both involve horizontal forces. The actual force generated was the R-GRF, and the force generated at take-off was the T-PRF, resulting in different jump distances. More specifically, the experimental results showed that the optimal angle range for the take-off foot in lateral jumps was between 66.1 and 66.8 degrees, while for step-back jumps, it was between 56.2 and 57.2 degrees. Additionally, the jump height provided by the flight time calculated for vertical jumps, as well as the distances of lateral and horizontal jumps, were influenced by the rate of force development (RFD) at take-off and the body's center of gravity [51]. Previous research has indicated that RFD is influenced by jump take-off momentum. Additionally, both jump momentum and sprint momentum contribute to the take-off momentum during a jump [52]. Horizontal and vertical jump distances are influenced by Newton's second law of motion, which involves changes in momentum (momentum is the product of force and time; $\Delta p = F \cdot \Delta t$, $F = M \cdot a$ "horizontal", $F = M \cdot g$ "vertical"). Increasing the horizontal force reduces the vertical force.

In summary, a 12-week PT intervention led to an increase in GRF (ground reaction force) in the experimental group, resulting in greater jump take-off momentum. Consequently, this allowed for superior vertical jump height, as well as improved horizontal and lateral jump distances.

4.3. Kinetic Differences in Three Types of Jumps

Jumping performance is primarily indicated by flight time, jump height, and ground reaction force GRFP. However, among the three types of jumps (vertical, horizontal, and lateral), the results showed that both horizontal and lateral jumps are influenced by horizontal forces, indicating the effect of the muscle stretch reflex [53]. Especially, when initiating horizontal and lateral jumps, the muscles in the lower limbs are activated, generating muscle force and elastic energy storage [51]. At this point, the muscle force in the lower limbs is distributed horizontally and laterally, so the take-off force should be calculated as the resultant force of both vertical and horizontal forces.

Vertical, lateral, and horizontal jumps are related to the stretch reflex. When initiating the jump with a rapid downward squat, the lower-limb muscles generate increased momentum, resulting in a greater take-off velocity and jump height [54]. However, the explanations for the stretch reflex in the three types of jumps still show significant differences. Research indicates that the average eccentric force development in lateral and horizontal jumps contributes to jump performance [15]. Additionally, vertical jump height is related to concentric force, as maximum concentric muscle contraction in vertical jumps leads to better jump height [55]. These findings are relevant to the relationship between lower-limb muscle strength, RFD, and jump height (or distance) in college-level basketball athletes [56]. Previous studies have shown that vertical forces differ from lateral and horizontal forces, due to the different jumping techniques required by different basketball movements, resulting in different peak values during evaluation [57]. Based on jump shot techniques, vertical jumps require the greatest GRF to produce a peak profile. Lateral jumps are influenced by average lateral eccentric force, resulting in a moderate curve peak. Lastly, the step-back jump shot involves a backward parallel jump to the previous position, with the shortest distance and the smallest average eccentric force, resulting in a low curve peak. These results align with existing scholarly research [58], which suggests that the closer the take-off angle of lateral and horizontal jumps to vertical, the shorter the distance produced.

Research has also found that the RFD generated by the GRF in lateral and horizontal jumps varies. This includes movements like the Euro step, crossover, and step-back jump shot. These differences are mainly influenced by the GRF and the take-off foot's peak reaction force (T-PRF), resulting in different rhythms for each step in lateral and horizontal jumps. Studies have shown that RFD is an important parameter of muscle strength. The instantaneous jumping ability of basketball athletes is influenced by the RFD of the quadriceps femoris muscle group, which is the knee extensor muscles [59].

4.4. PT and Sports Injury Prevention

This study's PTP utilized box jumps, a type of explosive training that involves jumping onto a stable platform or box to enhance athletes' jumping ability, coordination, and lower-limb strength [60]. This training is particularly important in basketball, as it effectively enhances players' performance, both offensively and defensively. The findings also confirmed that the PTP improved lower-limb strength. This study indicates that athletes who regularly engage in PT have a lower injury occurrence rate, with the likelihood of injury ranging from only 0.24 to 1.00 instances per 1000 h of training [61].

Due to frequent jumping and directional changes in basketball, athletes are prone to both chronic and acute knee injuries, including the risk of developing jumper's knee [7,8]. For some athletes, the high intensity of plyometric exercises may lead to diminished effectiveness and an increased risk of injury [62]. Studies indicate that physical stress during PT can elevate the likelihood of injuries [63]. To mitigate the risk of injury, a 2–3 min rest between each plyometric exercise has been recommended. Athletes with basic fitness and strength should aim for eight sets, with an optimal rest period of 48–72 h between sessions [16]. Additionally, PT can enhance the connection between the nervous and muscular systems [3], which is crucial for coordinating movements and preventing injuries. Studies have shown that single-leg hops can help to improve balance and stability in the ankle joint after a sprain [64]. PT can help athletes to regain specific movement abilities after an injury. For example, lateral jumps can assist basketball athletes with ankle injuries in recovering their explosive directional change capabilities [43].

4.5. Integration of PT into Practical Training

The PTP intervention in this study has been effectively translated into practical training programs [65]. Therefore, coaches should consider the following points: 1. Developing personalized training plans: Coaches should tailor training plans based on the individual differences among athletes, such as differences in age, gender, athletic abilities, and fitness levels [66]. 2. Determining an appropriate training load and frequency: Based on the research results, coaches should establish an appropriate load and frequency for each training session to avoid overtraining and injury. 3. Introducing a variety of training methods: Plyometric training includes various exercises such as bounding, squat jumps, and vertical jumps. Coaches should design training sessions based on the specific methods used in research, and should periodically rotate these methods to maintain the novelty and effectiveness of the training [67]. 4. Conducting regular assessments and feedback: Coaches should regularly evaluate athletes' training outcomes, such as measuring jump height, explosive power, and muscle strength, and should make necessary adjustments based on the assessment results. Additionally, immediate feedback should be provided to help athletes to understand their progress and areas for improvement. 5. Educating athletes:

Coaches should explain the theoretical foundations and practical benefits of plyometric training to athletes, helping them to understand the purpose and importance of the training. This will enhance their motivation and focus during training sessions.

By following these specific steps, coaches can effectively apply the principles of plyometric training to practical training programs, thereby enhancing athletes' performance and reducing the risk of injuries.

4.6. Limitations

This study is not without its limitations. Because the participants were male college basketball players, the results might not be applicable to different sports or female basketball players. Furthermore, vertical, lateral, and horizontal jumps are considered fundamental abilities, while vertical jump shots, lateral jump shots, and step-back jump shots are regarded as sports techniques. When connecting jumping abilities with technical movements, many potential factors remain, such as ball handling and the proficiency of technical movements. Additionally, the distance covered in lateral and horizontal jumps might have been influenced by the athlete's leg length and flexibility, which could have increased the jump distance, but not necessarily result in terms of greater force output. Because this study had a small sample size, the results cannot be broadly generalized. Future research on these three types of jumps, using different intervention measures, is needed.

5. Conclusions

This study explored the effects of vertical, lateral, and horizontal jumping abilities on jump shot performance, and evaluated the role of strength enhancement training in reducing the risk of sports injuries. The findings indicate that various jumping skills significantly influence jump shot performance, with vertical jump explosiveness and height positively correlating with shooting accuracy, while lateral and horizontal jumps improve mobility and reaction speed. Strength enhancement training not only increased lower-limb strength and stability, but also significantly reduced the incidence of sports injuries, particularly in the experimental group, in which injury rates were notably lower compared to the control group. These results suggest that strength training improves lower-limb muscle strength, coordination, and stability, thus reducing injury risk. Additionally, this study clearly defined injuries (both acute and chronic), and discussed how these injuries impact training and performance. Overall, these findings underscore the importance of integrating both jump and strength training into athlete development programs, providing valuable theoretical support for coaches to design comprehensive training regimens aimed at enhancing athletic performance while minimizing injury risk.

Author Contributions: Conceptualization, W.-Y.H., H.H. and C.-E.W.; methodology, W.-Y.H.; software, C.-E.W.; validation, W.-Y.H. and C.-E.W.; formal analysis, C.-E.W.; investigation, C.-E.W. and H.H.; resources, W.-Y.H.; data curation, C.-E.W. and H.H.; writing—original draft preparation, C.-E.W.; writing—review and editing, W.-Y.H. and C.-E.W.; supervision, W.-Y.H., H.H. and C.-E.W.; project administration, W.-Y.H. and C.-E.W. All authors have read and agreed to the published version of the manuscript.

Funding: The authors have received no funding for any research relevant to the present study.

Institutional Review Board Statement: This study was conducted according to the guidelines of the Declaration of Helsinki and approved by a local institutional review board (protocol code: A-ER-113-165, 15 December 2023).

Informed Consent Statement: Informed consent was obtained from all the participants in this study.

Data Availability Statement: Data on the participants were obtained before and after training. All the authors confirm the authenticity and availability of the data. All the datasets on which this paper's conclusions are based have been made available to the editors, reviewers, and readers.

Acknowledgments: We thank all the subjects for actively participating in the experimental courses and following the independent exercises, as well as the Human Trials Review Meeting at National Cheng Kung University Hospital (NCKUH) for reviewing the ethics-related details of this study.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Barrera-Domínguez, F.J.; Carmona-Gómez, A.; Tornero-Quiñones, I.; Sáez-Padilla, J.; Sierra-Robles, Á.; Molina-López, J. Influence of Dynamic Balance on Jumping-Based Asymmetries in Team Sport: A between-Sports Comparison in Basketball and Handball Athletes. *Int. J. Environ. Res. Public Health* **2021**, *18*, 1866. [CrossRef] [PubMed]
2. Gottlieb, R.; Shalom, A.; Calleja-Gonzalez, J. Physiology of Basketball—Field Tests. Review Article. *J. Hum. Kinet.* **2021**, *77*, 159–167. [CrossRef] [PubMed]
3. Cao, S.; Liu, J.; Wang, Z.; Geok, S.K. The effects of functional training on physical fitness and skill-related performance among basketball players: A systematic review. *Front. Physiol.* **2024**, *15*, 1391394. [CrossRef] [PubMed]
4. Wilczyński, B.; Wąż, P.; Zorena, K. Impact of Three Strengthening Exercises on Dynamic Knee Valgus and Balance with Poor Knee Control among Young Football Players: A Randomized Controlled Trial. *Healthcare* **2021**, *9*, 558. [CrossRef]
5. Kondo, H. Changes in the Ground Reaction Force, Lower-Limb Muscle Activity, and Joint Angles in Athletes with Unilateral Ankle Dorsiflexion Restriction During A Rebound-Jump Task. *J. Funct. Morphol. Kinesiol.* **2018**, *3*, 52. [CrossRef]
6. Cabarkapa, D.; Eserhaut, D.A.; Fry, A.C.; Cabarkapa, D.V.; Philipp, N.M.; Whiting, S.M.; Downey, G.G. Relationship between Upper and Lower Body Strength and Basketball Shooting Performance. *Sports* **2022**, *10*, 139. [CrossRef] [PubMed]
7. Aksović, N.; Bubanj, S.; Bjelica, B.; Kocić, M.; Lilić, L.; Zelenović, M.; Stanković, D.; Milanović, F.; Pajović, L.; Čaprić, I.; et al. Sports Injuries in Basketball Players: A Systematic Review. *Life* **2024**, *14*, 898. [CrossRef] [PubMed]
8. Andreoli, C.V.; Chiaramonti, B.C.; Biruel, E.P.; Pochini, A.d.C.; Ejnisman, B.; Cohen, M. Epidemiology of sports injuries in basketball: Integrative systematic review. *BMJ Open Sport—Exerc. Med.* **2018**, *4*, e000468. [CrossRef] [PubMed]
9. Tummala, S.V.; Morikawa, L.; Brinkman, J.; Crijns, T.J.; Economopoulos, K.; Chhabra, A. Knee Injuries and Associated Risk Factors in National Basketball Association Athletes. *Arthrosc. Sports Med. Rehabil.* **2022**, *4*, e1639–e1645. [CrossRef] [PubMed]
10. Luo, S.; Soh, K.G.; Zhao, Y.; Soh, K.L.; Sun, H.; Nasiruddin, N.J.M.; Zhai, X.; Ma, L. Effect of core training on athletic and skill performance of basketball players: A systematic review. *PLoS ONE* **2023**, *18*, e0287379. [CrossRef] [PubMed]
11. Chen, L.; Zhang, Z.; Huang, Z.; Yang, Q.; Gao, C.; Ji, H.; Sun, J.; Li, D. Meta-Analysis of the Effects of Plyometric Training on Lower Limb Explosive Strength in Adolescent Athletes. *Int. J. Environ. Res. Public Health* **2023**, *20*, 1849. [CrossRef]
12. Zhang, Y.; Li, D.; Gómez-Ruano, M.; Memmert, D.; Li, C.; Fu, M. Effects of plyometric training on kicking performance in soccer players: A systematic review and meta-analysis. *Front. Physiol.* **2023**, *14*, 1072798. [CrossRef] [PubMed]
13. Davies, G.J.; Riemann, B.L. Current concepts of plyometric exercises for the lower extremity. In *Return to Sport After ACL Reconstruction and Other Knee Operations*; Springer: Berlin/Heidelberg, Germany, 2019; pp. 277–304. [CrossRef]
14. Slimani, M.; Chamari, K.; Miarka, B.; Del Vecchio, F.B.; Chéour, F. Effects of Plyometric Training on Physical Fitness in Team Sport Athletes: A Systematic Review. *J. Hum. Kinet.* **2016**, *53*, 231–247. [CrossRef] [PubMed]
15. Kurt, C.; Canli, U.; Erdaş, S.; Poli, L.; Carvutto, R.; Cataldi, S.; Fischetti, F.; Greco, G. Effectiveness of Vertical versus Horizontal Plyometric Training on Stretch-Shortening Cycle Performance Enhancement in Adolescent Soccer Players. *Healthcare* **2023**, *11*, 1615. [CrossRef]
16. Soto García, D.; Díaz Cruz, J.; Bautista, I.J.; Martínez Martín, I. Effects of a Strength Training Protocol with Self-loading and Plyometry on Handball Physical Performance: First National Female Category. *E-balonmano com J. Sports Sci.* **2023**, *18*, 83–92. [CrossRef]
17. Caamaño-Navarrete, F.; Delgado-Floody, P.; Martinez-Salazar, C.; Jerez-Mayorga, D. Speed and throwing the ball are related to jump capacity and skeletal muscle mass in university basketball players. *J. Sports Med. Phys. Fitness* **2021**, *61*, 771–778. [CrossRef]
18. Lee, H.M.; Oh, S.; Kwon, J.W. 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. [CrossRef] [PubMed]
19. Afonso, J.; Ramirez-Campillo, R.; Moscão, J.; Rocha, T.; Zacca, R.; Martins, A.; Milheiro, A.A.; Ferreira, J.; Sarmento, H.; Clemente, F.M. Strength Training versus Stretching for Improving Range of Motion: A Systematic Review and Meta-Analysis. *Healthcare* **2021**, *9*, 427. [CrossRef]
20. Gu, H.; Yao, J.; Zhou, L.; Cheung, A.; Abrami, P. A Quasi-Experimental Study of a Web-Based English Literacy Tool for Grade 3 Students in China. *ECNU Rev. Educ.* **2020**, *4*, 209653112097270. [CrossRef]
21. Mills, G.E.; Gay, L.R. *Education Research: Competencies for Analysis and Applications*; Pearson Education: London, UK, 2016.
22. Martínez-Mesa, J.; González-Chica, D.A.; Bastos, J.L.; Bonamigo, R.R.; Duquia, R.P. Sample size: How many participants do I need in my research? *An. Bras. Dermatol.* **2014**, *89*, 609–615. [CrossRef]
23. Fischetti, F.; Vilardi, A.D.; Cataldi, S.; Greco, G. Effects of Plyometric Training Program on Speed and Explosive Strength of Lower Limbs in Young Athletes. *J. Phys. Educ. Sport* **2018**, *18*, 2476–2482. [CrossRef]
24. Hammami, M.; Gaamouri, N.; Shephard, R.J.; Chelly, M.S. Effects of Contrast Strength vs. Plyometric Training on Lower-Limb Explosive Performance, Ability to Change Direction and Neuromuscular Adaptation in Soccer Players. *J. Strength. Cond. Res.* **2019**, *33*, 2094–2103. [CrossRef]

25. Fathi, A.; Hammami, R.; Moran, J.; Borji, R.; Sahli, S.; Rebai, H. Effect of a 16-Week Combined Strength and Plyometric Training Program Followed by a Detraining Period on Athletic Performance in Pubertal Volleyball Players. *J. Strength. Cond. Res.* **2019**, *33*, 2117–2127. [CrossRef] [PubMed]
26. Ramirez-Campillo, R.; Castillo, D.; Raya-González, J.; Moran, J.; de Villarreal, E.S.; Lloyd, R.S. Effects of Plyometric Jump Training on Jump and Sprint Performance in Young Male Soccer Players: A Systematic Review and Meta-analysis. *Sports Med.* **2020**, *50*, 2125–2143. [CrossRef] [PubMed]
27. Kapsis, D.P.; Tsoukos, A.; Psarraki, M.P.; Douda, H.T.; Smilios, I.; Bogdanis, G.C. Changes in Body Composition and Strength after 12 Weeks of High-Intensity Functional Training with Two Different Loads in Physically Active Men and Women: A Randomized Controlled Study. *Sports* **2022**, *10*, 7. [CrossRef]
28. Schoenfeld, B.J.; Ogborn, D.; Krieger, J.W. Effects of Resistance Training Frequency on Measures of Muscle Hypertrophy: A Systematic Review and Meta-Analysis. *Sports Med.* **2016**, *46*, 1689–1697. [CrossRef]
29. Cigerci, A.E.; Genc, H. The effect of strength training with different frequency on untrained university students. *Phys. Educ. Stud.* **2020**, *24*, 186–193. [CrossRef]
30. Camargo, L.D.R.; Doneda, D.; Oliveira, V.R. Whey protein ingestion in elderly diet and the association with physical, performance and clinical outcomes. *Exp. Gerontol.* **2020**, *137*, 110936. [CrossRef]
31. Wang, X.; Soh, K.G.; Samsudin, S.; Deng, N.; Liu, X.; Zhao, Y.; Akbar, S. Effects of high-intensity functional training on physical fitness and sport-specific performance among the athletes: A systematic review with meta-analysis. *PLoS ONE* **2023**, *18*, e0295531. [CrossRef]
32. Lee, C.H.; Sun, T.L. Evaluation of postural stability based on a force plate and inertial sensor during static balance measurements. *J. Physiol. Anthropol.* **2018**, *37*, 27. [CrossRef] [PubMed]
33. Sannicandro, I.; Cofano, G.; Piccinno, A. Can the Core Stability Training Influences Sprint and Jump Performances in Young Basketball Players? *Adv. Phys. Educ.* **2020**, *10*, 196–206. [CrossRef]
34. Fatahi, F.; Ghasemi, G.; Karimi, M.; Beyranvand, R. The effect of eight weeks of core stability training on the lower extremity joints moment during single-leg drop landing article. *Balt. J. Health Phys. Act.* **2019**, *11*, 34–44. [CrossRef]
35. Struzik, A.; Pietraszewski, B.; Zawadzki, J. Biomechanical analysis of the jump shot in basketball. *J. Hum. Kinet.* **2014**, *42*, 73–79. [CrossRef] [PubMed]
36. Nakagawa, S.; Lagisz, M.; Yang, Y.; Drobniak, S.M. Finding the right power balance: Better study design and collaboration can reduce dependence on statistical power. *PLoS Biol.* **2024**, *22*, e3002423. [CrossRef] [PubMed]
37. Moran, J.; Liew, B.; Ramirez-Campillo, R.; Granacher, U.; Negra, Y.; Chaabene, H. The effects of plyometric jump training on lower-limb stiffness in healthy individuals: A meta-analytical comparison. *J. Sport. Health Sci.* **2023**, *12*, 236–245. [CrossRef]
38. Caron, K.E.; Burr, J.F.; Power, G.A. The Effect of a Stretch-Shortening Cycle on Muscle Activation and Muscle Oxygen Consumption: A Study of History-Dependence. *J. Strength. Cond. Res.* **2020**, *34*, 3139–3148. [CrossRef]
39. Voisin, M.; Scohier, M. Effect of an 8-Week Plyometric Training Program with Raised Forefoot Platforms on Agility and Vertical Jump Performance. *Int. J. Exerc. Sci.* **2019**, *12*, 491. [CrossRef] [PubMed]
40. Xie, L.; Chen, J.; Dai, J.; Zhang, W.; Chen, L.; Sun, J.; Gao, X.; Song, J.; Shen, H. Exploring the potent enhancement effects of plyometric training on vertical jumping and sprinting ability in sports individuals. *Front. Physiol.* **2024**, *15*, 1435011. [CrossRef] [PubMed]
41. Uysal, H.; Dalkıran, O.; Korkmaz, S.; Akyildiz, Z.; Nobari, H.; Clemente, F. The Effect of Combined Strength Training on Vertical Jump Performance in Young Basketball Players: A Systematic Review and Meta-Analysis. *Strength Cond. J.* **2023**, *45*, 554–567. [CrossRef]
42. Gisladottir, T.; Petrović, M.; Sinković, F.; Novak, D. The relationship between agility, linear sprinting, and vertical jumping performance in U-14 and professional senior team sports players. *Front. Sports Act. Living* **2024**, *6*, 1385721. [CrossRef] [PubMed]
43. Ramirez-Campillo, R.; García-Hermoso, A.; Moran, J.; Chaabene, H.; Negra, Y.; Scanlan, A.T. The effects of plyometric jump training on physical fitness attributes in basketball players: A meta-analysis. *J. Sport Health Sci.* **2022**, *11*, 656–670. [CrossRef] [PubMed]
44. Aztarain-Cardiel, K.; López-Laval, I.; Marco-Contreras, L.A.; Sánchez-Sabaté, J.; Garatachea, N.; Pareja-Blanco, F. Effects of Plyometric Training Direction on Physical Performance in Basketball Players. *Int. J. Sports Physiol. Perform.* **2023**, *18*, 135–141. [CrossRef] [PubMed]
45. Le Pellec, A.; Maton, B. Initiation of a vertical jump: The human body's upward propulsion depends on control of forward equilibrium. *Neurosci. Lett.* **2002**, *323*, 183–186. [CrossRef] [PubMed]
46. Reiter, C.R.; Killelea, C.; Faherty, M.S.; Zerega, R.J.; Westwood, C.; Sell, T.C. Force-plate derived predictors of lateral jump performance in NCAA Division-I men's basketball players. *PLoS ONE* **2023**, *18*, e0284883. [CrossRef] [PubMed]
47. Cooley, C.; Simonson, S.R.; Maddy, D.A. The Force-Vector Theory Supports Use of the Laterally Resisted Split Squat to Enhance Change of Direction. *J. Strength. Cond. Res.* **2024**, *38*, 835–841. [CrossRef]
48. Hernández-Davó, J.L.; Loturco, I.; Pereira, L.A.; Cesari, R.; Pratdesaba, J.; Madruga-Parera, M.; Sanz-Rivas, D.; Fernández-Fernández, J. Relationship between Sprint, Change of Direction, Jump, and Hexagon Test Performance in Young Tennis Players. *J. Sports Sci. Med.* **2021**, *20*, 197–203. [CrossRef] [PubMed]

49. Nobari, H.; Clemente, F.M.; Vali, N.; Silva, A.F.; van den Hoek, D.; Ramirez-Campillo, R. Effects of horizontal compared to vertical-based plyometric jump training on semi-professional soccer player's performance. *Sci. Rep.* **2023**, *13*, 10039. [CrossRef] [PubMed]
50. Nagano, A.; Komura, T.; Fukashiro, S. Optimal coordination of maximal-effort horizontal and vertical jump motions--a computer simulation study. *Biomed. Eng. Online* **2007**, *6*, 20. [CrossRef] [PubMed]
51. Zhang, Q.; Nassis, G.P.; Chen, S.; Shi, Y.; Li, F. Not Lower-Limb Joint Strength and Stiffness but Vertical Stiffness and Isometric Force-Time Characteristics Correlate With Running Economy in Recreational Male Runners. *Front. Physiol.* **2022**, *13*, 940761. [CrossRef] [PubMed]
52. McErlain-Naylor, S.A.; Beato, M. Factors influencing the jump momentum—Sprint momentum correlation: A data simulation. *Eur. J. Sport. Sci.* **2022**, *22*, 1847–1855. [CrossRef]
53. Miyaguchi, K.; Sugiura, H.; Demura, S. Possibility of stretch-shortening cycle movement training using a jump rope. *J. Strength. Cond. Res.* **2014**, *28*, 700–705. [CrossRef] [PubMed]
54. Meylan, C.; McMaster, T.; Cronin, J.; Mohammad, N.I.; Rogers, C.; Deklerk, M. Single-leg lateral, horizontal, and vertical jump assessment: Reliability, interrelationships, and ability to predict sprint and change-of-direction performance. *J. Strength. Cond. Res.* **2009**, *23*, 1140–1147. [CrossRef]
55. Laffaye, G.; Wagner, P.P.; Tombleson, T.I. Countermovement jump height: Gender and sport-specific differences in the force-time variables. *J. Strength. Cond. Res.* **2014**, *28*, 1096–1105. [CrossRef]
56. Meylan, C.M.; Nosaka, K.; Green, J.; Cronin, J.B. Temporal and kinetic analysis of unilateral jumping in the vertical, horizontal, and lateral directions. *J. Sports Sci.* **2010**, *28*, 545–554. [CrossRef] [PubMed]
57. Scott, T.; Andrew, S.; Mathew, O.G.; Matthew, M.; Warren, Y. The Occurrence of Different Vertical Jump Types in Basketball Competition and their Relationship with Lower-Body Speed-Strength Qualities. *Int. J. Strength Cond.* **2021**, *1*. [CrossRef]
58. Wakai, M.; Linthorne, N.P. Optimum take-off angle in the standing long jump. *Hum. Mov. Sci.* **2005**, *24*, 81–96. [CrossRef] [PubMed]
59. Suchomel, T.J.; Stone, M.H. The Relationships between Hip and Knee Extensor Cross-Sectional Area, Strength, Power, and Potentiation Characteristics. *Sports* **2017**, *5*, 66. [CrossRef]
60. dos Santos, M.L.; Berton, R.; Shields, J.; Bishop, C.; Dinyer-McNeely, T.; Anderson, O.; Dawes, J. Influence of Box Height on Inter-Limb Asymmetry and Box Jump Performance. *Symmetry* **2023**, *15*, 1359. [CrossRef]
61. Al Attar, W.S.A.; Bakhsh, J.M.; Khaledi, E.H.; Ghulam, H.; Sanders, R.H. Injury prevention programs that include plyometric exercises reduce the incidence of anterior cruciate ligament injury: A systematic review of cluster randomised trials. *J. Physiother.* **2022**, *68*, 255–261. [CrossRef]
62. Zhao, Y.; Sun, M.; Wang, X.; Xu, Q. Unilateral Plyometric Jump Training Shows Significantly More Effective than Bilateral Training in Improving Both Time to Stabilization and Peak Landing Force in Single-Leg Lend and Hold Test: A Randomized Multi-Arm Study Conducted Among Young Male Basketball Players. *J. Sports Sci. Med.* **2024**, *23*, 647–655. [CrossRef]
63. Ho, I.; Wong, S.T.; Yong, J.; Fang, H. Plyometric stress index: A novel method for quantifying plyometric training French "L'indice d'intensité pliométrique: Une nouvelle méthode pour quantifier l'entraînement pliométrique". *Sci. Sports* **2022**, *37*, 788–797. [CrossRef]
64. Lee, J.; Martin, J.; Wildehain, R.; Ambegaonkar, J. 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.* **2020**, *56*, 005–012. [CrossRef]
65. Watkins, C.M.; Storey, A.G.; McGuigan, M.R.; Gill, N.D. Implementation and Efficacy of Plyometric Training: Bridging the Gap Between Practice and Research. *J. Strength. Cond. Res.* **2021**, *35*, 1244–1255. [CrossRef]
66. Marta, C.; Alves, A.R.; Casanova, N.; Neiva, H.P.; Marinho, D.A.; Izquierdo, M.; Nunes, C.; Marques, M.C. Suspension vs. Plyometric Training in Children's Explosive Strength. *J. Strength. Cond. Res.* **2022**, *36*, 433–440. [CrossRef] [PubMed]
67. Kons, R.L.; Orssatto, L.B.R.; Ache-Dias, J.; De Pauw, K.; Meeusen, R.; Trajano, G.S.; Dal Pupo, J.; Detanico, D. Effects of Plyometric Training on Physical Performance: An Umbrella Review. *Sports Med. Open* **2023**, *9*, 4. [CrossRef]