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Effects of plyometric training techniques on vertical jump performance of basketball players

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Abstract

The aim of our study was to compare the effects of two different plyometric training programs (targeting knee extensors or plantar flexors) on jump height and strength of leg muscles. Twenty-nine male basketball players were assigned to the knee-flexed (KF), knee-extended (KE), or control groups. In addition to regular training, the KF group performed plyometric jumps (10 sets of 10 jumps, 3 sessions/week, 4 weeks) from 50 cm boxes with the knee flexed (90°–120°), whereas the KE group performed the jumps from 30 cm boxes with the knee much more extended (130°–170°). Jumping ability was evaluated with squat jumps (SJs), countermovement jumps (CMJs), and drop jumps from 20 cm (DJ_{20}) and 40 cm (DJ_{40}). Knee and ankle muscles were assessed during maximal isokinetic and isometric tests, and EMG activity was recorded from vastus lateralis and medial gastrocnemius. The KF group increased SJ (+10%, $d = 0.86$) and CMJ (+11%, $d = 0.70$) but decreased DJ_{40} height (–7%, $d = –0.40$). Conversely, the KE group increased DJ_{20} (+10%, $d = 0.74$) and DJ_{40} (+12%, $d = 0.77$) but decreased SJ height (–4%, $d = –0.23$). The reactivity index during DJs increased (+10% for DJ_{20}, $d = 0.47$; +20% for DJ_{40}, $d = 0.91$) for the KE group but decreased (–10%, $d = –0.48$) for the KF group during DJ_{40}. Plantar flexor strength increased for the KE group ($d = 0.72–1.00$) but not for the KF group. Negative transfer across jumps is consistent with the principle of training specificity. Basketball players interested to perform fast rebounds in their training should avoid plyometric jumps with large knee flexions and long contact times.

KEYWORDS
jumping ability, knee extensors, plantar flexors, training specificity

Highlights

- Plyometric training specificity: different jump techniques (knee flexed vs. knee extended) elicited specific adaptations in jumping performance. Training with the knees flexed

improved squat jump and countermovement jump height, whereas training with the knees extended augmented drop jump height.
- Negative transfer: the different jump techniques can have a negative influence on jump height and reactivity index. Drop jump height declined after knee-flexed training, whereas squat jump height decreased after knee-extended training.
- Plyometric training exercises should be aligned with sport-specific movements to optimize performance. Basketball players who perform fast, powerful movements should avoid plyometric jumps with large knee flexions and long contact times.

1 | INTRODUCTION

Plyometric ("πλείων μέτρου"—more length than isometric in ancient Greek) exercises are quick, strong actions that involve the stretch-shortening cycle to increase power production by leg muscles and vertical jump height (Markovic & Mikulic, 2010). The sequence, which involves a lengthening contraction followed by a shortening contraction, increases the total amount of force, power, and rate of force development (Bobbert et al., 1986; Bosco, Tarkka, & Komi, 1982; Komi & Nicol, 2010).

One of the most popular plyometric exercises is the drop jump (DJ), which requires an individual to jump down from an elevated surface and, upon landing, immediately perform a vertical jump (Bobbert, 1990). Although most studies have shown a positive effect on vertical jump performance, research on the effectiveness of training with different jumps, such as squat jumps (SJs), countermovement jumps (CMJs), and DJs from various heights, is mixed (Markovic & Mikulic, 2010). Some studies have found that plyometric training increases jump height (Markovic & Mikulic, 2010; Taube et al., 2012), whereas others have failed to find a significant effect (Young et al., 1999), and some studies have even reported negative effects even when participants were instructed to minimize ground contact (Luebbers et al., 2003). For example, 6 weeks of training by active males (19–35 years) with DJs from 30 to 45 cm (optimal length), with the instruction to perform DJ for maximum height, did not improve jumping performance and reactivity index (Young et al., 1999).

The contradictory results found after plyometric training likely reflect variation in the jumping technique (Holcomb et al., 1996a) and differences in training volume and duration (Jeffreys et al., 2019). For example, variation in the range of motion about a joint during training could impact power production during an exercise (Holcomb et al., 1996b) with different effects across individuals. This possibility emphasizes the importance of standardizing the duration, volume, and performance of plyometric exercises when the goal is to compare outcomes produced by different techniques. In a seminal meta-analysis, Markovic (2007) reported the effects of plyometric training on vertical jump, which was assessed with SJs, CMJs without arm swings, CMJs with arms swing, and DJs. They found that plyometric training is more effective for slow stretch-shortening cycle jumping performance, such as the CMJ without arm swings (+7.5%) and CMJ with arm swing (+8.7%), than for fast stretch-shortening cycle jumps, such as the DJ (+4.7%). However, the peak height achieved during SJ increased similarly (+4.7%) after plyometric training (Markovic, 2007). The absence of a speed effect (slow vs. fast) on the SJ may have been the result of not considering the jumping technique in the meta-analysis. Findings suggest that slow DJ (the CMJ technique) is more effective than the bounce-type DJ (fast ground contact) for augmenting CMJ jump height (Marshall & Moran, 2013), whereas DJ height increases more after training with DJs than with CMJs (Holcomb et al., 1996b).

Although the effects of plyometric training on neuromuscular and muscle-tendon adaptations are relatively well known (Duchateau & Amiridis, 2023; Moran et al., 2023), few studies have compared different techniques and rarely distinguish between slow (CMJ-type) and fast (bounce-type) DJs. In a recent study, Laurent et al. (2020) compared two 10-week plyometric interventions (2 sessions/week) in which participants jumped with extended knees (knee angle close to full extension to minimize ground contact time; bounce-DJ) or with flexed knees (braking the downward movement with a lengthening contraction that allows a knee angle of 80–90° and then jumping as high as possible; CMJ-DJ). While the training with bounce DJs increased Achilles tendon stiffness, CMJ height increased more after training with CMJ-DJ (+17.5%) than bounce-DJ (+11.8%). However, the increase in jump height and decrease in contact time were greater after the bounce-DJ than after the CMJ-DJ when performed from 20 cm only but not at 40 cm or 60 cm (Laurent et al., 2020). In contrast, other studies found no difference in vertical jump height during the SJ, CMJ, and DJ between both training groups (DJ group and CMJ group) (Gehri et al., 1998). Similarly, Ruffieux et al. (2020) found that a training intervention with CMJs for 6 weeks (60 jumps/session and 2 sessions/week) was more effective than the training with DJs (+17 vs. +7% on average) for nonprofessional female volleyball players when performing different jump types (CMJ, CMJ with arm swing, and DJ with arm swing from a height of 37 cm).

These mixed findings require additional studies to assess the influence of different techniques used during plyometric training on jump performance in specific sports. As an example, basketball is a sport that is characterized by high physical demands on the legs, including as brief sprints, lateral movements, vertical jumps, and controlled landings. Moreover, jumping ability influences the skills of shooting, rebounding, and shot blocking (Laver et al., 2020). The aim of our study was to compare the effects of two plyometric training techniques (knees flexed vs. knees extended) on vertical jump height, the reactivity index (jump height/ground contact time), and the strength and electromyographic (EMG) activity of knee and ankle muscles during isometric and isokinetic movements. Based on the concept of training specificity and the results of previous studies (Gehri et al., 1998; Laurent et al., 2020), we hypothesized that plyometric training with the knees flexed would mainly increase SJ and CMJ heights and the strength of the knee extensors, whereas plyometric training with the knees extended was expected to increase more specifically jump height during DJs from 20 to 40 cm and the strength of plantar flexors.

2 | MATERIALS AND METHODS

2.1 | Participants

A power analysis (G*Power, v3.1.9.2) showed that a repeated-measures ANOVA analysis would require a minimum of 21 participants to detect a significant within–between interaction with a large effect size ($f = 0.40$; power = 80% and $r = 0.5$) based on previous studies (Palma-Muñoz et al., 2021) taking the improvement in jump performance as the reference variable. Thirty male basketball players (National II - regional level) with >4 years of training experience volunteered to participate in the study after written informed consent was obtained. Twenty-nine completed the program; one player withdrew from the study because he was transferred to another team. Following the baseline measurements, they were randomly assigned by a blinded investigator, using a computer-generated program, to either the knee-extended (KE) group (age: 21.6 ± 2.0 years, body mass: 90.0 ± 6.2 kg, and height: 191.1 ± 7.4 cm), the knee-flexed (KF) group (age: 21.3 ± 2.1 years, body mass: 82.2 ± 8.7 kg, and height: 189.8 ± 7.2 cm), or the control group (age: 21.5 ± 3.0 years, body mass: 88.2 ± 8.1 kg, and height: 186.2 ± 6.6 cm). Participants reported no cardiovascular or neurological disorders and no lower limb injuries.

Throughout the study, all players maintained their normal training routine (4 sessions/week, 90 min/session, and 1 match/week). A typical training session included drills for shooting, passing and dribbling, dynamic stretching (warm-up), fundamentals, one on one, defensive steps, speed and agility exercises, fast-break and five on five player, and team development exercises in offense and defense. Approval (ERC-008/2022) for the experimental procedures was obtained from the University Ethics Committee on Human Research in accordance with the Declaration of Helsinki.

2.2 | Plyometric training

One week before the study began, the training groups were familiarized with plyometric training during two practice sessions. The experimental groups performed 12 sessions (3 sessions/week separated by at least 48 h) during a 4-week period in addition to their regular training program. These sessions were performed indoors in a long 30-m corridor, independently of basketball sessions, and they were supervised by the first and third authors. Each training session began with warm-up activities (~10 min) and comprised 10 sets of 10 DJs with a 2-min rest between sets. Because the main objective of the study was to use the two types of plyometric jumps with different contact times and landing technique, the KF group performed DJs between boxes that were 50 cm in height with the knee flexed (range of motion: 90°–120°) at ground contact, whereas the KE group performed DJs between boxes that were 30 cm in height with the knee almost extended (range of motion: 130°–170°) (Figure 1). The heights were chosen to maximize activation of the knee extensors when participants jumped with knee flexed and plantar flexors when jumping with knee extended and fast ground contact time. It is reported that DJs from 60 cm height have greater eccentric muscle activity of knee extensors and more knee flexion than from lower heights (Peng et al., 2011). In contrast, the 30 cm height is more optimal to achieve fast and maximal force from plantar flexors (Peng, 2011). Moreover, it is difficult to use the same box height to train the knee extensors and plantar flexors explicitly. For example, it is difficult to keep the knee fully extended when performing plyometric jumps from 50 cm to train plantar flexors. Similarly, 30 cm boxes impose only a moderate load for the knee extensors (Bosco, Viitasalo, et al., 1982). The control group maintained their regular basketball training program.

The knee and ankle angles were controlled for all participants during the 2 familiarization sessions using Kinovea (video annotation tool for sport analysis, version 0.8.27, 30 Hz) to capture angular kinematics of the lower limbs. An experienced researcher gave instructions during training on the required range of motion of the knee and ankle joints (visual inspection). Moreover, in random training sessions and in different participants, the kinematic characteristics of the jumps were recorded to ensure the specified range of motion. The wooden boxes were placed on a nonslip floor mat (thickness: 8 mm). All jumps were performed with the arms akimbo (hand on hips and elbows facing outward). In pilot tests, we found that the contact time (Ergo Tester; Globus Italia, Codogne, IT) during DJs from 50 cm height (knee flexed) was >300 ms, whereas it was <200 ms during DJs from 30 cm (knee extended). The distance between boxes was set at 2 m to achieve the required performance of the plyometric exercises by tall athletes.

2.3 | Jump testing

A familiarization session with all experimental procedures was conducted 1 week prior to beginning the experiment. Baseline measurements were completed 3–4 days before the start of the intervention, and the final evaluation session was performed 2–3 days after the last training session. Jump performance was evaluated with 4 different jumps on a force-plate (Kistler 9253B, Winterthur) as described by Asmussen & Bonde-Petersen (1974): SJ, CMJ, and DJ from 20 cm (DJ_{20}) and 40 cm (DJ_{40}).

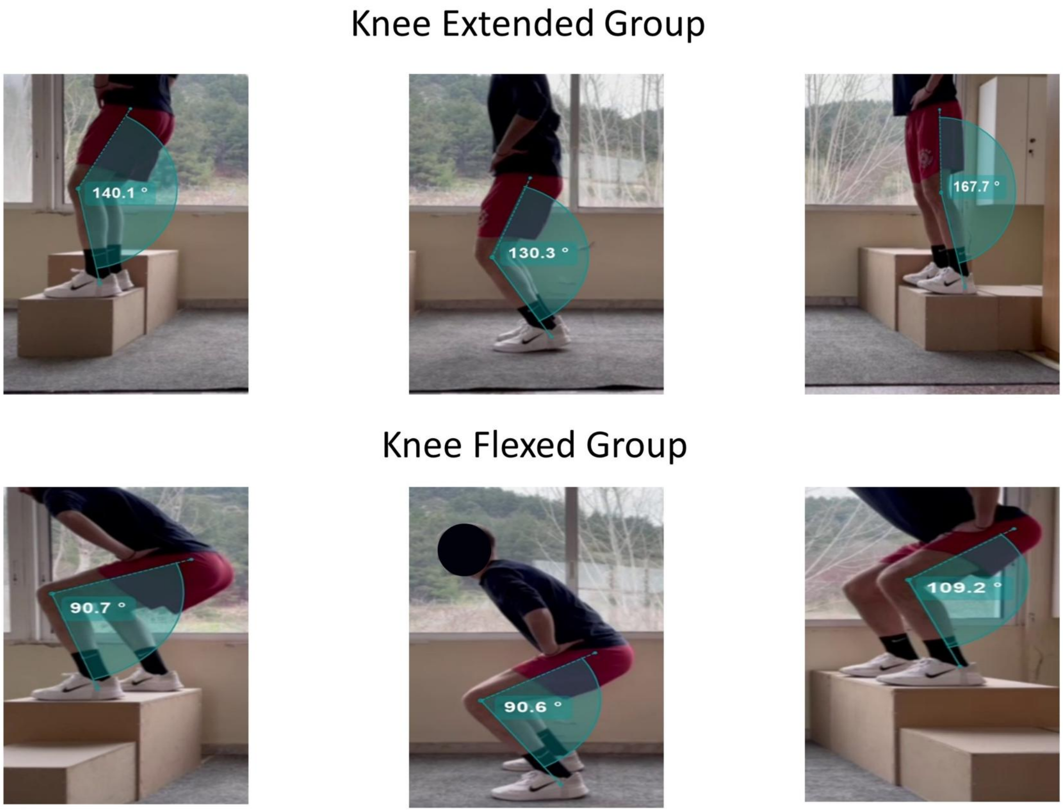

FIGURE 1 The knee-extended group (upper panel) performed plyometric jumps between boxes that were 30 cm in height with the knee extended (range of motion: 130°–170°), whereas the knee-flexed group (lower panel) performed plyometric jumps between boxes that were 50 cm in height with the knee flexed (range of motion: 90°–120°).

The SJ was assessed starting from a half-squat position (knee angle 90°) with the arms akimbo. The participants were instructed to avoid any preliminary downward movement and to extend upward as fast as possible. After each SJ, an experimenter examined the vertical component of the ground reaction force to ensure that no countermovement was performed; when one was detected, the trial was repeated. The CMJ began from a standing position and involved lowering down to a knee angle of 90° and then extending the knee in one continuous movement to jump as high as possible. The DJs required participants to avoid heel contact with the ground and to jump quickly as high as possible with minimal knee flexion. Each jump was performed three times, and the best performance was retained for further analysis.

The jumps were performed in a randomized order at the same time of the day to minimize any chronobiological effect (Racinais et al., 2005). There was high within session test–retest reliability in jump height for the SJ, CMJ, and DJs: ICC: 0.97 (95% CI: 0.94–0.99); SEM: 1.24% (95% CI: 0.5%–2.1%); and coefficient of variation: 2.55 (95% CI: 1.12%–3.4%), respectively.

2.4 | Strength testing

The torque-angular velocity (T-AV) relation for the right knee extensors and flexors was determined with an isokinetic dynamometer (Humac Norm, CSMI, Stoughton, MA). Participants were seated, and straps were applied across the chest, mid-thigh, and lower leg to minimize hip and thigh motion during the contractions. The tasks were performed at 2 eccentric (120°·s^{-1} and 60°·s^{-1}) and 3 concentric (60°·s^{-1}, 120°·s^{-1}, and 180°·s^{-1}) contractions in a randomized order. Also, the torque–angular position (T–AP) relation was determined with maximal isometric (5 s) contractions with the knee extensors at 3 knee angles (90°, 120°, and 150°; full extension: 180°). A 3–5 min rest period was given between trials.

The T–AV relation for the right plantar flexors and dorsiflexors was determined by performing maximal contractions at 2 eccentric (120°·s^{-1} and 60°·s^{-1}) and 3 concentric (60°·s^{-1}, 120°·s^{-1}, and 180°·s^{-1}) contractions in a randomized order. The T–AP relation was also determined from maximal isometric contractions at 3 ankle angles (75°, 90°, and 105°; 180°: full plantar flexion). The plantar flexor tests were done in a prone position with the knee fully extended. Ample rest time (3–5 min) was provided between trials.

Participants performed 3 trials for each condition, and the greatest peak torque for the isokinetic and isometric trials was used for further analysis. The measured torques were gravity corrected at each joint angle, and the dynamometer was calibrated according to the manufacturer's instructions. Participants received verbal encouragement during all trials and were provided with online visual feedback of the applied torque on a computer monitor placed 1 m in front of them. All strength tests were performed after the jumping tests to minimize declines in force capacity (fatigability). The isokinetic and isometric tests had a high test–retest reliability: ICC: 0.98 (0.95–0.99); SEM: 3.83% (1.88%–4.5%); and coefficient of variation: 3.05 (1.93%–4.51%), respectively.

2.5 | Electromyography (EMG)

The EMG signals were acquired during the strength tests using bipolar bar surface electrodes (interelectrode distance 1 cm, TSD 150B). Torque and EMG signals were recorded concurrently at 1000 Hz using a Biopac MP100 Acquisition Unit (Biopac Systems Inc., Goleta, CA). According to SENIAM guidelines, the electrodes for vastus lateralis (VL) were placed at 2/3 on the line from the anterior spina iliaca superior to the lateral side of the patella, and those for medial gastrocnemius (MG) were attached over the most prominent bulge of the muscle (Hermens et al., 2000). The skin area was shaved and rubbed with sandpaper and rinsed only with water to remove the flaky residuals. Contrary to common practice, rubbing with alcohol or solvents leaves the skin dry and with high impedance (Merletti et al., 2010). The electrodes were placed at the same position before and after training by marking the skin with indelible ink. The input impedance of the apparatus for EMG signal was set at 100 MΩ, the common rejection ratio was 130 dB, and the amplification gain at 1000. A band-pass filter (15–450 Hz) was applied to reduce noise that originated from surrounding sources of electricity and movement artifacts.

2.6 | Data analysis

Jump height (*m*) was calculated from the net impulse with the following formula: height peak = ½ * ($V_{takeoff}$/9.81). The reactivity index corresponded to the ratio between the maximal jump height and the contact time during DJ_{20} and DJ_{40}. This index reflects the ability to produce high forces in a brief period of time (Taube et al., 2012).

After filtering, the EMG signals were full-wave rectified, and the root mean square (RMS) was calculated using a 10-sample sliding window with custom-made MATLAB scripts (version 2022a, Math Works Inc). A 10-point moving average was used to smooth the signal to identify the peak RMS value. The EMG signals obtained during the maximal voluntary contractions (MVCs) at the joint angle where force was maximum for each muscle group were subsequently used for normalizing the signals (Kellis et al., 2019). The EMG normalization was performed using the average RMS during the 3 s plateau of the MVC. The average value from the maximal isometric contraction where the torque signal's least variable was used. All signals obtained during isokinetic tests were normalized to the isometric MVC values, and the peak normalized RMS signal during each trial was used in the analysis.

2.7 | Statistical analysis

The statistical analysis was performed using SPSS software (version 26, IBM, Chicago). The normality of the data was assessed with the Shapiro–Wilk test. To investigate the effect of jump technique on performance, separate two-way (groups [KF group, KE group, and control group] × time [before and after training]) analysis of variance (ANOVA) with repeated measures on the time factor was applied. Additionally, two-way ANOVAs were used to explore the impact of plyometric training on torque profile and EMG activity separately for each muscle group, angular velocity, and joint position. When significant interactions were found, post hoc Tukey tests were used to identify differences between pairs of means. To gain further insight on the effect of jump technique, one-way ANOVAs were performed to compare changes (%) between groups in jump height, isokinetic, isometric torque, and normalized RMS values. The effect sizes were calculated with partial Eta squared (ηp^2) where $0.01 < \eta^2 < 0.06$ constitutes a small effect, $0.06 < \eta^2 < 0.14$ a medium effect, and $\eta^2 > 0.14$ a large effect (Lakens, 2013). The statistical significance was set at $p < 0.05$. Additionally, when post hoc tests found differences between the KE and KF groups, Cohen's *d* was quantified to indicate small ($d = 0.2$), medium ($d = 0.5$), and large ($d = 0.8$) effect sizes (Cohen, 2013).

3 | RESULTS

3.1 | Anthropometric characteristics

There were no differences in any of anthropometric characteristics between the three groups ($p > 0.05$).

3.2 | Jump performance

Jump height before and after plyometric training for all groups are presented in Figure 2. There were no significant between-group differences at the baseline for any jump-related variables ($p > 0.05$). The ANOVA revealed a group × time interaction for the SJ ($F_{2,26} = 16.62$, $p < 0.001$, and $\eta p^2 = 0.56$). Jump height increased for the KF group (before: 0.33 ± 0.04 m and after: 0.36 ± 0.04 m), decreased for the KE group (before: 0.36 ± 0.06 m and after: 0.34 ± 0.06 m), and was unchanged for the control group (before: 0.33 ± 0.06 m and after: 0.32 ± 0.05 m). One-way ANOVA ($F_{2,26} = 15.71$, $p < 0.001$, and $\eta p^2 = 0.55$) indicated that the changes in jump height were significantly different between the KF group (+10.4 ± 7.9%, $d = 0.86$) and the KE group (−3.9 ± 5.0%, $d = -0.23$) as well as the control group (−2.8 ± 5.3%).

The CMJ exhibited a group × time interaction ($F_{2,26} = 15.20$, $p < 0.001$, and $\eta p^2 = 0.54$): jump height increased for the KF group (before: 0.33 ± 0.05 m and after: 0.37 ± 0.06 m) but remained unchanged for the KE group (before: 0.34 ± 0.06 m and after: 0.33 ± 0.06 m) and the control group (before: 0.32 ± 0.05 m and after: 0.32 ± 0.06 m). The one-way ANOVA indicated an increase in CMJ height was significant ($F_{2,26} = 14.38$, $p < 0.001$, and$\eta p^2 = 0.48$) for the KF group (+11.2 ± 5.5%, $d = 0.70$), but there were no changes for either the KE group (−0.4 ± 5.6%, $d = -0.03$) or the control group (−2.9 ± 6.8%).

The ANOVA yielded a significant group × time interaction ($F_{2,26} = 11.08$, $p < 0.001$, and $\eta p^2 = 0.46$) for the DJ_{20}: jump height increased for the KE group (before: 0.29 ± 0.04 m and after: 0.32 ± 0.04 m) but remained unchanged for the KF group (before: 0.30 ± 0.04 m and after: 0.29 ± 0.04 m) and for the control group (before: 0.28 ± 0.03 m and after: 0.28 ± 0.02 m). In addition, one-way ANOVA ($F_{2,26} = 14.38$, $p < 0.001$, and $\eta p^2 = 0.38$) showed that the change in DJ_{20} height differed between the KE group (+10.0 ± 6.3%, $d = 0.74$) and the KF group (−2.4 ± 7.8%, $d = -0.19$) as well as the control group (−1.8 ± 5.5%).

The ANOVA yielded a significant group × time interaction ($F_{2,26} = 16.82$, $p < 0.001$, and $\eta p^2 = 0.56$) for the DJ_{40}: jump height increased for the KE group (before: 0.29 ± 0.04 m and after: 0.33 ± 0.05 m), decreased for the KF group (before: 0.31 ± 0.05 m and after: 0.29 ± 0.05 m), and remained unchanged for the control group (before: 0.29 ± 0.03 m and after: 0.28 ± 0.04 m). The one-way ANOVA showed that the change in DJ_{40} performance was significant ($F_{2,26} = 16.82$, $p < 0.001$, and $\eta p^2 = 0.48$) for the KE group (+11.8 ± 9.2%, $d = 0.77$) and the KF group (−6.8 ± 6.0%, $d = -0.40$) but not for the control group (−2.4 ± 7.6%).

3.3 | Contact time and reactivity index

Table 1 reports the average values for contact time and the reactivity index for DJ_{20} and DJ_{40}. The contact time remained unchanged after the plyometric training, whereas a significant group × time interaction ($F_{2,26} = 4.30$, $p < 0.05$, and $\eta p^2 = 0.25$) was found for the reactivity index in DJ_{20}. The one-way ANOVA showed a significant increase ($F_{2,26} = 3.75$, $p = 0.037$, and $\eta p^2 = 0.22$) for the KE group (+10.3 ± 8.5%, $d = 0.47$) but was unchanged for the KF group (−2.3 ± 17.0%, $d = -0.15$) and the control group (−3.0 ± 9.6%). Similarly, the contact time in DJ_{40} did not differ between the three

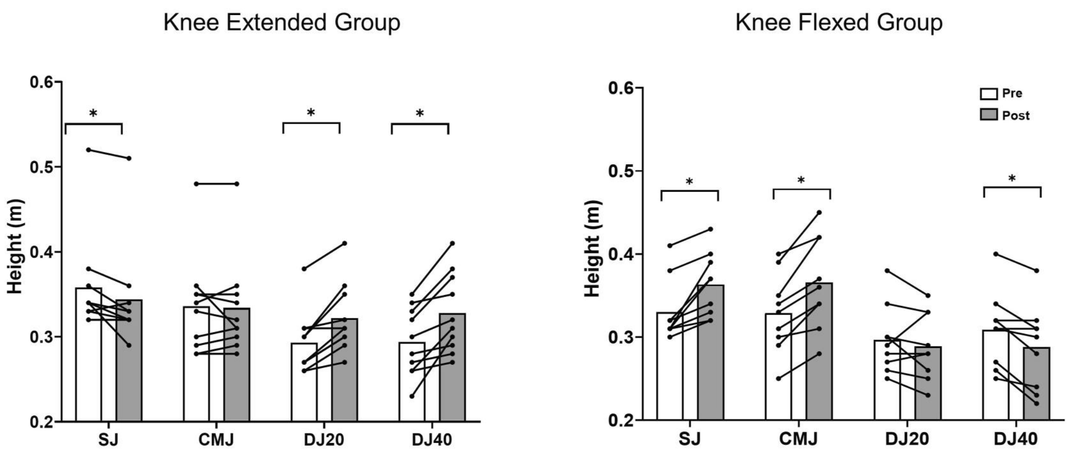

FIGURE 2 The jump height (m) for the squat jump (SJ), countermovement jump (CMJ), drop jump from 20 cm (DJ_{20}), and drop jump from 40 cm (DJ_{40}) before and after the 4-week plyometric training program. The results for the knee-extended group are displayed in the left panel, and those for the knee flexed are displayed in the right panel. *significantly different after post hoc analysis ($p < 0.05$).

TABLE 1 The average contact time and reactivity index of DJ20 and DJ40 before and after plyometric training for control, knee-extended, and knee-flexed groups.

	Knee extended group		Knee flexed group		Control group	
	DJ_{20}	DJ_{40}	DJ_{20}	DJ_{40}	DJ_{20}	DJ_{40}
Contact time						
Before (s)	0.217 ± 0.042	0.222 ± 0.028	0.214 ± 0.028	0.204 ± 0.027	0.217 ± 0.023	0.207 ± 0.020
After (s)	0.217 ± 0.045	0.207 ± 0.020	0.217 ± 0.033	0.218 ± 0.038	0.220 ± 0.022	0.208 ± 0.010
Gain (%)	−0.2 ± 4.8	−6.1 ± 5.1	1.9 ± 10.7	6.9 ± 15.4	1.4 ± 6.4	1.2 ± 11.2
Reactivity index						
Before (cm/s)	1.39 ± 0.27	1.35 ± 0.27	1.42 ± 0.36	1.54 ± 0.36	1.32 ± 0.18	1.38 ± 0.16
After (cm/s)	1.53 ± 0.32	1.59* ± 0.26	1.37 ± 0.33	1.37* ± 0.32	1.27 ± 0.18	1.36 ± 0.21
Gain (%)	10.3* ± 8.5	19.5* ± 13.8	−2.3 ± 17.0	−10.1* ± 11.3	−3.0 ± 9.6	−0.6 ± 15.6

Note: DJ_{20}: drop jump from 20 cm; DJ_{40}: drop jump from 40 cm; *: $p < 0.05$ from before to after.

groups after training. Nevertheless, there was a significant time × group interaction for the DJ_{40} reactivity index ($F_{2,26} = 6.93$, $p < 0.05$, and $\eta p^2 = 0.34$). The one-way ANOVA showed a significant improvement ($F_{2,26} = 11.553$, $p < 0.001$, and $\eta p^2 = 0.47$) for the KE group (+19.5 ± 13.8%, $d = 0.91$) and a significant decrement for the KF group (−10.1 ± 11.3%, $d = -0.48$), but no change was observed for the control group (−0.6 ± 15.6%).

3.4 | Muscle strength

No significant between-group differences were identified at baseline for any of the strength tests ($p > 0.05$). Additionally, no significant changes were observed for isokinetic (Figure 3) and isometric (see supplementary material 1) maximal contractions ($p > 0.05$) for the knee extensors, knee flexors, and dorsiflexors. However, a time × group interaction for plantar flexors was found for the eccentric torque at 120° s^{-1} ($F_{2,26} = 5.00$, $p < 0.05$, and $\eta p^2 = 0.27$), concentric torque at 60° s^{-1} ($F_{2,26} = 4.35$, $p < 0.05$, and $\eta p^2 = 0.25$), and 120° s^{-1} ($F_{2,26} = 3.96$, $p < 0.05$, and $\eta p^2 = 0.23$). The KE group experienced an increase in eccentric torque at 120° s^{-1} (18.2 ± 24.8%, $p < 0.05$, and $d = 0.94$), concentric torque at 60° s^{-1} (19.3 ± 25.4%, $p < 0.05$, and $d = 1.00$), and 120° s^{1} (18.0 ± 28.2%, $p < 0.05$, and $d = 0.75$). No changes were observed for the KF group and the control group. Furthermore, there was a main effect for time ($p < 0.05$) during the isometric contractions with plantar flexors at 90° (see supplementary material 1). The isometric torque significantly increased for the KE group (+19.4 ± 28.2%, $p < 0.01$, and $d = 0.72$) but remained unchanged for the KF group (+5.4 ± 13.5%, $p > 0.05$, $d = 0.21$) and for the control group (+5.6 ± 19.8%, $p > 0.05$).

3.5 | EMG activity

There were no significant effects of training for any group for the RMS values for VL and MG during eccentric and concentric contractions with the knee extensors and plantar flexors ($p > 0.05$) (the RMS values for VL and MG before and after plyometric training are shown in supplementary material 2).

4 | DISCUSSION

The main finding of our study was that 4 weeks of plyometric training with the knees flexed increased jump height for the SJ (+10%) and CMJ (+11%) but decreased the jump height (−7%) and the reactivity index for the DJ_{40} (−10%). In contrast, plyometric training with the knees extended increased jump height for the DJ_{20} (+10%) and DJ_{40} (+12%) and the reactivity index in DJ_{20} (+10%) and DJ_{40} (+20%) but reduced jump height for the SJ (−4%). Moreover, isokinetic and isometric strength for the two muscles did not change for the KF group, whereas peak eccentric, concentric, and isometric torque for plantar flexors increased for the KE group. The absence of benefits transferred across jumps is consistent with the specificity of training principle especially in the choice of the jumping technique used in basketball. The control group, who received standard basketball training, did not experience changes in any of the variables tested during this period.

4.1 | Training specificity principle

Plyometric training with different jumping techniques leads to specific adaptations mainly in the muscles and types of actions that are trained. The principle of training specificity (Duchateau & Baudry, 2010; Hawley, 2008), a fundamental concept in exercise science states that training responses are tightly coupled to the intensity (how hard), frequency (how often), and volume (how much) of the exercise that is performed (Young, 2006). Our results are consistent with this principle.

Nonetheless, the results of our study also underscore the great variation in the outcomes of plyometric training protocols (Markovic, 2007). Although the specificity of neuromuscular adaptations elicited by training is usually well accepted in the field, specific adaptations in jump performance, when different techniques are used during plyometric training, are not well known and are typically not often considered by coaches (Laurent et al., 2020). Furthermore, the concept of specificity predicts that the closer the training routine mimics the desired outcome (i.e., a specific exercise task to match a performance criterion), the better will be the outcome (Hawley, 2008). However, we acknowledge that our training program was relatively brief (only 4 weeks) and likely too short to induce muscle-tendon adaptations, which presumes that the observed adaptations likely had a neural origin.

4.2 | Reactivity index and contact time

The specificity of the adaptations is underscored by the results for the reactivity index and contact time during DJs. The reactive strength is a major determinant of the performance in basketball and several other sports when athletes are required to absorb negative work (lengthening contraction) and then perform positive work (shortening contraction) (Duchateau & Amiridis, 2023). These attributes result in superior jump performances in DJs compared with CMJs (Bompa & Coaching Association of Canada, 1996; Markwick et al., 2015). In our study, the reactivity index for the group trained with knees extended increased jump height for the DJ_{20} (+10%) and DJ_{40} (+20%), whereas it decreased for the group trained with the knees flexed in DJ_{40} (−10%). Similarly, Young et al. (1999) reported that plyometric training with DJs from optimal heights (30–45 cm) elicited greater improvements of the reactivity index on the DJ from 30 cm height instead of DJs from other heights (45 cm, 60 cm, and 75 cm). The contact time remained unaltered for both experimental groups even though there was a nonsignificant decrease during the DJ_{40} for the knee-extended group (−6%) and a nonsignificant increase during DJ_{20} (+2%) and DJ_{40} (+7%) for the group that trained with the knees flexed.

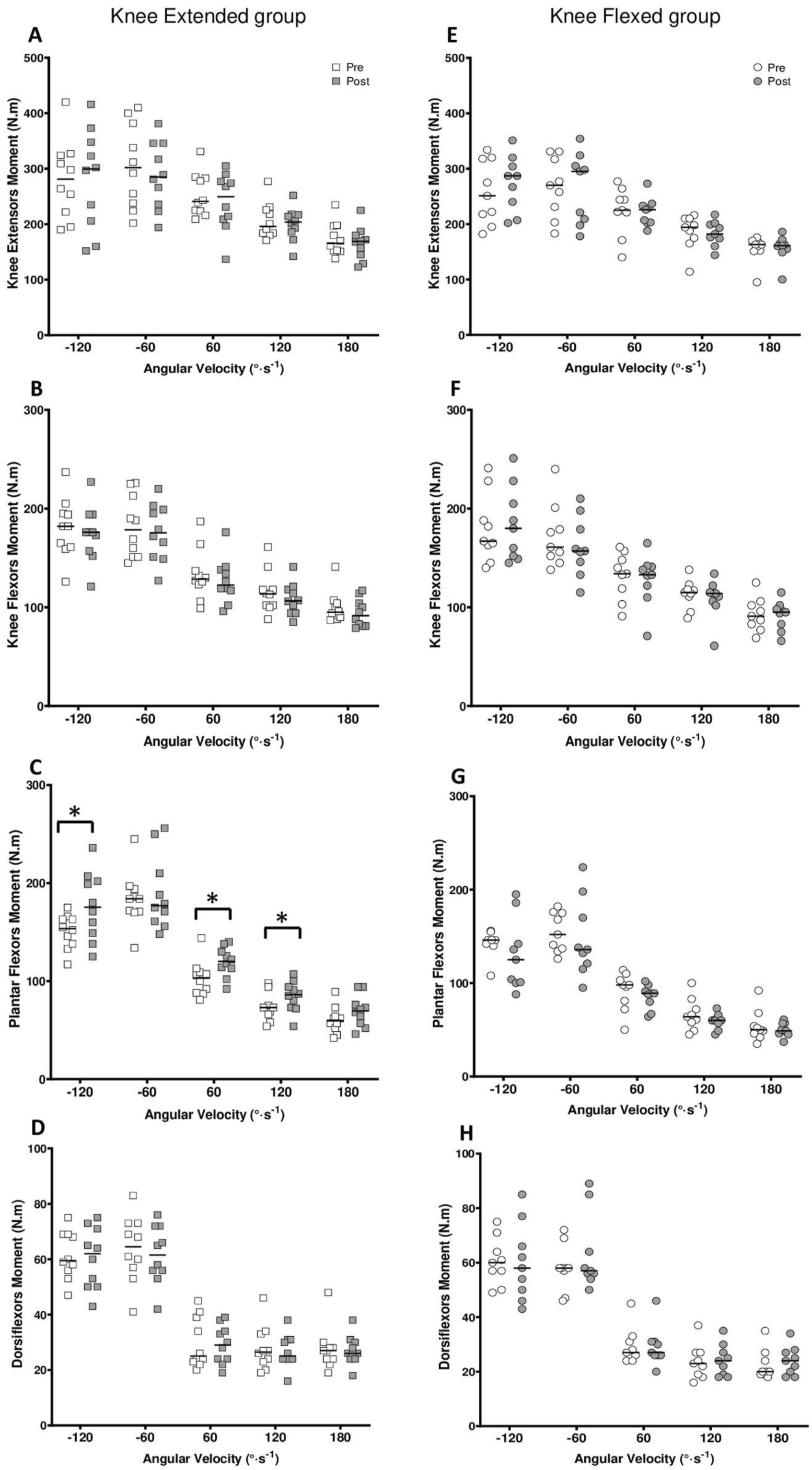

FIGURE 3 The relation between torque and angular velocity during eccentric (120°·s^{-1} and 60°·s^{-1}) and concentric (60°·s^{-1}, 120°·s^{-1}, and 180°·s^{-1}) contractions with the knee extensors (A, E), knee flexors (B, F), plantar flexors (C, G), and dorsiflexors (D, H). The results for the knee-extended group are displayed with squares, and those for the knee-flexed group are indicated with circles both before (open symbols) and after (filled symbols) training. *significantly different after post hoc analysis ($p < 0.05$).

4.3 | Negative transfer to other jumping tasks

Although the specificity principle was expected to yield a positive transfer to performance in the short-term and in experienced athletes, it can also produce negative outcomes, such as overtraining, muscle imbalances, increased injury risk, and boredom in the long-term (Bompa & Coaching Association of Canada, 1996; Young, 2006). Thus, the answer to the questions about why there is a decrease in SJ performance after 1-month of plyometric training with the knee extended or why there is a decrease in DJ performance after the same period of plyometric training with the knee flexed can be related to the title of the seminal paper of Bobbert and Van Soest (2001) entitled “Why do people jump the way they do?”. The answer is the jumping technique.

In terms of biomechanics, it is the jumping technique that is the critical variable (Bobbert, 1990). The mechanical output of the muscles and the pattern of segmental rotations and joint kinetics during the push-off phase are quite different for DJs with knees flexed (CMJ-type DJ) compared with DJs with the knees extended (bounce-type DJ). In the bounce-DJ, individuals reverse the downward movement after the drop as soon as possible into an upward push-off, and the mechanical output of the knee extensors and plantar flexors is much greater than that during a regular CMJ. In contrast, larger downward displacement upon landing reduces the mechanical output relative to the bounce-DJ, but the push-off phase more closely resembles that of a CMJ. Minimizing the amount of knee flexion during ground contact increases the peak reaction forces at the knee and ankle joints and the force transmitted by the Achilles tendon relative to those observed during larger knee-flexion jumps (Van Ingen Schenau et al., 1997).

Negative transfer also refers to the phenomenon in which unidimensional training in a task can interfere with the performance of the same muscles in another task (Schmidt & Young, 1987). It can be caused by a number of factors, including learned habits or routines, preconceived notions about how the task should be performed, and interference from previously learned movements or muscle synergies (Bizzi et al., 2008). In the process of learning a novel task, the CNS creates neural circuits that are specific to that movement and, over time, are reinforced and become the preferred way of performing that movement (see fig. 4 in Daneshgar et al., 2023). Therefore, different plyometric exercises may require the reorganization of muscle activation patterns, and previous experience with one type of exercise may interfere with the proper muscle activation patterns required for another type of exercise.

For example, if an athlete uses the muscle activation pattern required for bounce-DJ repetitively, this pattern may carry over and interfere with a more optimal muscle activation pattern for the SJ and CMJ. Similarly, the development of an overreliance on certain muscle groups, such as quadriceps femoris, may impede the engagement of other muscle groups that are needed for plyometric exercises, such as the plantar flexors. This can result in negative transfer and reduced DJ performance. Our results confirm, at least partially, the study of Young et al. (1999) that a 6-week plyometric training comprising DJs performed for maximal height and for maximal height with minimal ground contact time lead to an average decrease in SJ height of −3.2% and −5.9%, respectively [see tab. 2 in Young et al. (1999)]. Future studies using high-density EMG will need to be done to record more detailed information about the activation of the knee extensors and plantar flexors and to compare the variance in their common modulation during both plyometric protocols.

Basketball skills, such as a jump shot against opponent and rebounding the ball, need to make fast movements quickly. When a training program targets the plantar flexor muscles, coaches must use plyometric exercises with short contact times and the knees nearly extended. Previous studies found that a combined plyometric training with CMJs and DJs improved jump height similarly for both types of jumps (Ruffieux et al., 2020), whereas others find that a combination of training with DJs from different heights (30, 45, 60, 75, and 90 cm), CMJs, and weighted-CMJs elicited similar gains in CMJ and DJ height (Hunter & Marshall, 2002).

4.4 | Isokinetic and isometric strength

Plyometric training with the knees flexed failed to produce any strength gains despite the use of a higher drop height (50 vs. 30 cm). However, plyometric training with the knees extended led to increases in maximal torque of plantar flexors during eccentric ($-120^{o}s^{-1}$), isometric (90°), and concentric ($60^{o}s^{-1}$ and $120^{o}s^{-1}$) actions. Some studies have found significant increases in strength after plyometric training (Pamuk et al., 2022) suggesting greater neuromuscular adaptations (greater activation of the agonists), whereas others have reported no increase in strength (Kannas et al., 2012). In addition to the landing technique, such differences could be due to the training status of the subjects, DJ intensity, or the duration/volume of training (Duchateau & Amiridis, 2023). The current training program was relatively brief (4 weeks), and for this reason neural, but not muscular, adaptations were expected to increase jump performance. The increase in plantar flexors torque during all types of contractions, without changes in EMG of MG, was somewhat surprising, but surface EMG recordings with bipolar electrodes are relatively insensitive to underlying motor unit activity (Mottram et al., 2005). Moreover, there may have been some adaptations in the stiffness of elastic components of the muscle-tendon complex (Moran et al., 2023). Additional studies are needed to analyze the underlying mechanisms of these specific adaptations.

5 | LIMITATIONS

Although we found specific training adaptations in jumping performance and strength profile of basketball players, it is necessary to mention some limitations. First, even though the box heights were intentionally chosen to maximize activation of the main muscle groups involved in each jumping technique, it is possible that not only the jumping technique but also the height of boxes could influence the present findings. Second, the duration of the training program was relatively short. Third, the outcome variables need to be expanded to include the activation patterns of VL and MGAS across training sessions of plyometric training as well as during the jump tests. Nonetheless, our study generated new knowledge in this field.

6 | CONCLUSION

The results highlight the importance of training specificity demonstrating that plyometric exercises with the knees flexed improved SJ and CMJ heights, whereas those with the knees extended improved DJ height. Changes in the reactivity index paralleled the increases in jump height. Importantly, there was a negative transfer effect between the two plyometric techniques. Additionally, peak isokinetic and isometric torque for the plantar flexors increased in the group that trained with the knees extended but not the other groups underscoring the specificity of the neuromuscular adaptations.

These results inform coaches and athletes seeking to optimize training programs emphasizing the need to customize exercises for specific movement patterns and performance gains. Athletes who perform fast, explosive rebounds in their sports activity, such as basketball players, should avoid plyometric jumps with large knee flexions and long contact times. However, the neuromuscular adaptations underlying these specific outcomes remain unknown.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

DATA AVAILABILITY STATEMENT

Data are available from the corresponding author on request.

ETHICS APPROVAL STATEMENT

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of Aristotle University of Thessaloniki (ERC–008/2022).

INFORMED CONSENT STATEMENT

Informed consent was obtained from all subjects involved in the study.

PERMISSION TO REPRODUCE MATERIAL FROM OTHER SOURCES

Not applicable.

CLINICAL TRIAL REGISTRATION

Not applicable.

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REFERENCES

Asmussen, E, and F Bonde-Petersen. 1974. "Storage of Elastic Energy in Skeletal Muscles in Man." *Acta Physiologica Scandinavica* 91(3): 385–92. https://doi.org/10.1111/j.1748-1716.1974.tb05693.x.

Bizzi, E., V. C. K. Cheung, A. d'Avella, P. Saltiel, and M. Tresch. 2008. "Combining Modules for Movement." *Brain Research Reviews* 57(1): 125–33. https://doi.org/10.1016/j.brainresrev.2007.08.004.

Bobbert, Maarten F. 1990. "Drop Jumping as a Training Method for Jumping Ability." *Sports Medicine* 9(1): 7–22. https://doi.org/10.2165/00007256-199009010-00002.

Bobbert, M. F., M. Mackay, D. Schinkelshoek, P. A. Huijing, and G. J. van Ingen Schenau. 1986. "Biomechanical Analysis of Drop and Countermovement Jumps." *European Journal of Applied Physiology and Occupational Physiology* 54(6): 566–73. https://doi.org/10.1007/bf00943342.

Bobbert, M. F., and A. J. Van Soest. 2001. "Why Do People Jump the Way They Do?" *Exercise and Sport Sciences Reviews* 29(3): 95–102. https://doi.org/10.1097/00003677-200107000-00002.

Bompa, T. O., and Coaching Association of Canada. 1996. *Power Training for Sport: Plyometrics for Maximum Power Development*. Gloucester, Ont.: Oakville, Ont.: Coaching Association of Canada: New Rev.

Bosco, C., I. Tarkka, and P. Komi. 1982. "Effect of Elastic Energy and Myoelectrical Potentiation of Triceps Surae during Stretch-Shortening Cycle Exercise." *International Journal of Sports Medicine* 3(3): 137–40. https://doi.org/10.1055/s-2008-1026076.

Bosco, C., J. T. Viitasalo, P. V. Komi, and P. Luhtanen. 1982. "Combined Effect of Elastic Energy and Myoelectrical Potentiation during Stretch-Shortening Cycle Exercise." *Acta Physiologica Scandinavica* 114(4): 557–65. https://doi.org/10.1111/j.1748-1716.1982.tb07024.x.

Cohen, J. 2013. *Statistical Power Analysis for the Behavioral Sciences*. Academic press.

Daneshgar, S., T. Tvrdy, and R. M. Enoka. 2023. "Practice-Induced Changes in Manual Dexterity of Older Adults Depend on Initial Pegboard Time." *Medicine & Science in Sports & Exercise* 55(11): 2045–52. https://doi.org/10.1249/MSS.0000000000003245.

Duchateau, J., and I. G. Amiridis. 2023. "Plyometric Exercises: Optimizing the Transfer of Training Gains to Sport Performance." *Exercise and Sport Sciences Reviews* 51(4): 117–27. https://doi.org/10.1249/JES.0000000000000320.

Duchateau, J., and S. Baudry. 2010. "Training Adaptation of the Neuromuscular System." In *Neuromuscular Aspects of Sport Performance*, edited by P. V. Komi, Vol. 17, 216–53. https://doi.org/10.1002/9781444324822.ch13.

Gehri, D. J., M. D. Ricard, D. M. Kleiner, and D. T. Kirkendall. 1998. "A Comparison of Plyometric Training Techniques for Improving Vertical Jump Ability and Energy Production." *The Journal of Strength & Conditioning Research* 12(2): 85–9. https://doi.org/10.1519/00124278-199805000-00005.

Hawley, J. A. 2008. "Specificity of Training Adaptation: Time for a Rethink?" *Journal of Physiology* 586(1): 1–2. https://doi.org/10.1113/jphysiol.2007.147397.

Hermens, H. J., B. Freriks, C. Disselhorst-Klug, and G. Rau. 2000. "Development of Recommendations for SEMG Sensors and

Sensor Placement Procedures." *Journal of Electromyography and Kinesiology* 10(5): 361–74. https://doi.org/10.1016/S1050-6411(00)00027-4.

Holcomb, W. R., J. E. Lander, R. M. Rutland, and G. D. Wilson. 1996a. "A Biomechanical Analysis of the Vertical Jump and Three Modified Plyometric Depth Jumps." *The Journal of Strength & Conditioning Research* 10(Issue 2): 83–8. https://doi.org/10.1519/00124278-199605000-00004.

Holcomb, W. R., J. E. Lander, R. M. Rutland, and G. D. Wilson. 1996b. "The Effectiveness of a Modified Plyometric Prgram on Power and Vertical Jump." *The Journal of Strength & Conditioning Research* 10(2): 89–92. https://doi.org/10.1519/1533-4287(1996)010<0089:teoamp>2.3.co;2.

Hunter, J.P., and R. N. Marshall. 2002. "Effects of Power and Flexibility Training on Vertical Jump Technique." *Medicine & Science in Sports & Exercise* 34(3): 478–86. https://doi.org/10.1097/00005768-200203000-00015.

Jeffreys, M. A., M. B. A. De Ste Croix, R. S. Lloyd, J. L. Oliver, and J. D. Hughes. 2019. "The Effect of Varying Plyometric Volume on Stretch-Shortening Cycle Capability in Collegiate Male Rugby Players." *The Journal of Strength & Conditioning Research* 33(1): 139–45. https://doi.org/10.1519/JSC.0000000000001907.

Kannas, T. M., E. Kellis, and I. G. Amiridis. 2012. "Incline Plyometrics-Induced Improvement of Jumping Performance." *European Journal of Applied Physiology* 112(6): 2353–61. https://doi.org/10.1007/s00421-011-2208-5.

Kellis, E., A. Ellinoudis, and N. Kofotolis. 2019. "Effect of Hip Flexion Angle on the Hamstring to Quadriceps Strength Ratio." *Sports* 7(2): 43. https://doi.org/10.3390/sports7020043.

Komi, P. V., and C. Nicol. 2010. "Stretch-Shortening Cycle of Muscle Function." In *Neuromuscular Aspects of Sport Performance*, edited by P. V. Komi, 15–31. Oxford: Wiley-Blackwell.

Lakens, D.. 2013. "Calculating and Reporting Effect Sizes to Facilitate Cumulative Science: a Practical Primer for T-Tests and ANOVAs." *Frontiers in Psychology* 4: 863. https://doi.org/10.3389/fpsyg.2013.00863.

Laurent, C., S. Baudry, and J. Duchateau. 2020. "Comparison of Plyometric Training with Two Different Jumping Techniques on Achilles Tendon Properties and Jump Performances." *The Journal of Strength & Conditioning Research* 34(6): 1503–10. https://doi.org/10.1519/JSC.0000000000003604.

Laver, L., B. Kocaoglu, B. Cole, A. J. H. Arundale, J. Bytomski, and A. Amendola. 2020 *Basketball Sports Medicine and Science*. https://doi.org/10.1007/978-3-662-61070-1.

Luebbers, P. E., J. A. Potteiger, M. W. Hulver, J. P. Thyfault, M. J. Carper, and R. H. Lockwood. 2003. "Effects of Plyometric Training and Recovery on Vertical Jump Performance and Anaerobic Power." *The Journal of Strength & Conditioning Research* 17(4): 704–9. https://doi.org/10.1519/00124278-200311000-00013.

Markovic, G., and P. Mikulic. 2010. "Neuro-musculoskeletal and Performance Adaptations to Lower-Extremity Plyometric Training." *Sports Medicine* 40(10): 859–95. https://doi.org/10.2165/11318370-000000000-00000.

Markovic, G., and R. U. Newton. 2007. "Does Plyometric Training Improve Vertical Jump Height? A Meta-Analytical Review." *British Journal of Sports Medicine* 41(6): 349–55. https://doi.org/10.1136/bjsm.2007.035113.

Markwick, W. J., S. P. Bird, J. J. Tufano, L. B. Seitz, and G. G. Haff. 2015. "The Intraday Reliability of the Reactive Strength Index Calculated from a Drop Jump in Professional Men's Basketball." *International Journal of Sports Physiology and Performance* 10(4): 482–8. https://doi.org/10.1123/ijspp.2014-0265.

Marshall, B. M., and K. A. Moran. 2013. "Which Drop Jump Technique Is Most Effective at Enhancing Countermovement Jump Ability,"countermovement" Drop Jump or "Bounce" Drop Jump?" *Journal of Sports Sciences* 31(12): 1368–74. https://doi.org/10.1080/02640414.2013.789921.

Merletti, R., M. Aventaggiato, A. Botter, A. Holobar, H. Marateb, and T. M. M. Vieira. 2010. "Advances in Surface EMG: Recent Progress in Detection and Processing Techniques." *Critical Reviews in Biomedical Engineering* 38(4): 305–45. https://doi.org/10.1615/CritRevBiomedEng.v38.i4.10.

Moran, J., B. Liew, R. Ramirez-Campillo, U. Granacher, Y. Negra, and H. Chaabene. 2023. "The Effects of Plyometric Jump Training on Lower-Limb Stiffness in Healthy Individuals: A Meta-Analytical Comparison." *Journal of Sport and Health Science* 12(2): 236–45. https://doi.org/10.1016/j.jshs.2021.05.005.

Mottram, C. J., J. M. Jakobi, J. G. Semmler, and R. M. Enoka. 2005. "Motor-Unit Activity Differs with Load Type during a Fatiguing Contraction." *Journal of Neurophysiology* 93(3): 1381–92. https://doi.org/10.1152/jn.00837.2004.

Palma-Muñoz, I., R. Ramírez-Campillo, J. Azocar-Gallardo, C. Álvarez, A. Asadi, J. Moran, and H. Chaabene. 2021. "Effects of Progressed and Nonprogressed Volume-Based Overload Plyometric Training on Components of Physical Fitness and Body Composition Variables in Youth Male Basketball Players." *The Journal of Strength & Conditioning Research* 35(6): 1642–9. https://doi.org/10.1519/JSC.0000000000002950.

Pamuk, O., E. Hancı, N. Ucar, N. Hasanlı, A. Gundogdu, and Y. G. Ozkaya. 2022. "Resisted Plyometric Exercises Increase Muscle Strength in Young Basketball Players." *Revista Brasileira de Medicina do Esporte* 28(4): 331–6. https://doi.org/10.1590/1517-8692202228042020_0125.

Peng, H.-Te. 2011. "Changes in Biomechanical Properties during Drop Jumps of Incremental Height." *Strength and Conditioning* 25(9): 2510–8. https://doi.org/10.1519/JSC.0b013e318201bcb3.

Peng, H.-Te, T. W. Kernozek, and C.-Yi Song. 2011. "Quadricep and Hamstring Activation during Drop Jumps with Changes in Drop Height." *Physical Therapy in Sport* 12(3): 127–32. https://doi.org/10.1016/j.ptsp.2010.10.001.

Racinais, S., S. Blonc, S. Jonville, and O. Hue. 2005. "Time of Day Influences the Environmental Effects on Muscle Force and Contractility." *Medicine & Science in Sports & Exercise* 37(2): 256–61. https://doi.org/10.1249/01.MSS.0000149885.82163.9F.

Ruffieux, J., M. Wälchli, K.-M. Kim, and W. Taube. 2020. "Countermovement Jump Training Is More Effective Than Drop Jump Training in Enhancing Jump Height in Non-professional Female Volleyball Players." *Frontiers in Physiology* 11(March): 1–6. https://doi.org/10.3389/fphys.2020.00231.

Schenau, G. J. I., M. F. Bobbert, and A. de Haan. 1997. "Does Elastic Energy Enhance Work and Efficiency in the Stretch-Shortening Cycle?" *Journal of Applied Biomechanics* 13(4): 389–496. https://doi.org/10.1123/jab.13.4.389.

Schmidt, R. A., & Young, D. E. (1987). *Transfer of Movement Control in Motor Skill Learning*. Academic Press (S. M. Cormier & L. Hagman (eds.); pp. 47–79). https://doi.org/10.1016/B978-0-12-188950-0.50009-6

Taube, W., C. Leukel, B. Lauber, and A. Gollhofer. 2012. "The Drop Height Determines Neuromuscular Adaptations and Changes in Jump Performance in Stretch-shortening Cycle Training." *Scandinavian Journal of Medicine & Science in Sports* 22(5): 671–83. https://doi.org/10.1111/j.1600-0838.2011.01293.x.

Young, W., C. Wilson, and C. Byrne. 1999. "A Comparison of Drop Jump Training Methods: Effects on Leg Extensor Strength Qualities and Jumping Performance." *International Journal of Sports Medicine* 20(5): 295–303. https://doi.org/10.1055/s-2007-971134.

Young, W. B. 2006. "Transfer of Strength and Power Training to Sports Performance." *International Journal of Sports Physiology and Performance* 1(2): 74–83. https://doi.org/10.1123/ijspp.1.2.74.

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