PLYOMETRIC TRAINING EFFECTIVENESS ON VERTICAL JUMP IN JUNIOR FEMALE VOLLEYBALL PLAYERS: A SYSTEMATIC REVIEW

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Abstract*. Modern volleyball mainly relies on the explosive power of the lower extremities to reach maximum height when specific actions that require jumping need to be performed: spiking, blocking, jump set and jump serve. The purpose of this systematic review is to identify the effects/effectiveness of plyometric training on vertical jump height in junior female volleyball players. The search was performed in the PubMed, Medline, Google Scholar and ScienceDirect databases. The selection included randomised and non-randomised controlled studies that were published in the last 30 years, used samples of junior female volleyball players (aged 10-19) and incorporated plyometric training performed for at least 2 weeks to develop vertical jump; in the reviewed studies, vertical jump height was measured using the squat jump, countermovement jump or drop jump. Analysis of the 14 selected studies highlighted that the effects of plyometric training on vertical jump performance were moderate when the intervention lasted about 4-6 weeks and considerably improved when plyometric training lasted over 8 weeks. In conclusion, regardless of the duration or volume of the intervention, plyometric training seems to be safe and effective but not always sufficient to improve vertical jump height in junior female volleyball players. However, we believe that further studies are needed to determine the potentially moderating effects of age, gender and expertise level, taking into account the physical parameters specific to the development of vertical jump in junior female volleyball players through plyometric training.*

Keywords: *plyometrics, training, vertical jump, volleyball.*

Introduction

Volleyball, one of the best-known team sports on the planet, is characterised by short and explosive movements involving intense aerobic exercise combined with relatively short recovery periods. Modern volleyball mostly relies on the explosive power of the lower extremities to reach maximum height when specific actions that require jumping need to be performed (Mroczek et al., 2017). In addition to technical and tactical knowledge, the ability to jump is an important element for success in both men's and women's volleyball. "A successful player must not only be able to jump high but must also be able to reach that point quickly. This requires an ability to generate power in a very short time". (Powers, 1996)

Volleyball training should focus on the development of strength and power through fast and explosive movements (Tant et al., 1993).

Vertical jump is used by players to perform spikes, blocks, jump sets and jump serves. Sattler et al. (2015) state that vertical jump height during a block jump "represents the potential for a reduction in effectiveness of the attacking opponent" (p. 1486) and that vertical jump height during spiking or serving "enables the player to achieve the contact with the ball above the net, allowing better spiking or serving angles" (p. 1486).

Jastrzebski et al. (2014) have noted that, during a volleyball match, each player "performs over 100 jumps in either of the four elements: attack, block, serve or playing the ball" (p. 80), adding that the number of jumps differs according to the player's role and specialisation. The conclusion of this study is that exercises aimed at developing the players' ability to jump high (such as plyometric exercises) are the key element of a training programme.

"Plyometrics are a natural part of most movements, as evidenced by the jumping, hopping, and skipping movements typically seen on any school playground." (Brown & Faigenbaum, 2000, p. 45) In the opinion of these authors, even walking can be considered a plyometric exercise because the quadriceps muscles go through a stretch-shortening cycle every time the foot hits the ground.

Plyometric training is commonly used to develop vertical jump ability and leg power (Markovic, 2007). Plyometric exercises are highly effective in increasing strength and significantly contribute to developing physical performance (Piirainen et al., 2014). This training method is frequently used for conditioning in volleyball (Lehnert, 2009). Yessis and Hatfield (1986) state that plyometric training "is the key to developing maximal explosive power and speed of movement, which, in turn, are the key elements involved in sports" (p. 14) and "is designed to increase two critical elements of strength, starting strength and explosive strength" (p. 15). In fact, strength is important in all aspects of life, not just in sport.

Bompa and Buzzichelli (2015) highlight that plyometric training improves "an athlete's high-velocity strength or ability to recruit and engage the high-powered fast-twitch motor units" (p. 35), "improves sport performance by heightening the physiological properties of the prime movers for quick and explosive concentric actions" (p. 140) and "causes muscular and neural changes that facilitate and enhance the performance of more rapid and more powerful movements" (p. 283).

Squat jumps, countermovement jumps and drop jumps are the best-known plyometric exercises. The last two are characterised by a stretch-shortening cycle that allows studying "normal and fatigued muscle function" (Komi, 2000, p. 1197).

Two distinct phases can be observed during the stretch-shortening cycle: an eccentric muscle contraction (lengthening), which is immediately followed by a fast concentric muscle contraction (shortening). In the eccentric phase, the muscles contract to perform a rapid deceleration in order to impede the downward movement of the body mass centre, which causes the contracting agonist muscles to lengthen (stretch). During the rapid concentric contraction, the body mass centre is accelerated in an upward direction. There are three main mechanisms that explain how a stretch-shortening cycle allows a large production of force at a higher speed: mechanical potentiation, high-force application time and post-activation potentiation. In terms of mechanical potentiation, it appears that the stretch-shortening cycle "evokes the elastic properties of the muscle fibers after a quick stretching of the tendon-muscle structure, which allows muscles to store energy in the series elastic elements during the eccentric phase" (Perez-Gomez & Calbet, 2013, p. 340). This energy is quickly released and, if a concentric muscular action occurs immediately after the stretching, part of this energy contributes to increasing the power generated during the concentric phase (Asmussen & Bonde-Petersen, 1974).

Svantesson et al. (1994) have demonstrated in their study that, during a stretch-shortening cycle, the concentric muscle contraction is increased by both a previous eccentric contraction that allows for the storage of elastic energy and a previous eccentric contraction that does not allow for a significant accumulation of elastic energy. Plyometric training can stimulate muscle hypertrophy, especially of type II fibres that appear to be dominant in volleyball players (Sleivert et al., 1995). Potteiger et al. (1999) noted a significant increase in type I and II fibre areas after 8 weeks of plyometric training, suggesting that an increase in vertical jump performance (VJP) and power output could be correlated with an increased muscle fibre size.

Plyometric training is usually performed on a surface that does not change much in shape when pressed but is not completely hard (wood, grass); however, if performed on sand, it seems to reduce muscle damage and soreness due to lower impact on the musculoskeletal system (Miyama & Nosaka, 2004; Impellizzeri et al., 2008; Arazi et al., 2016).

Lephart et al. (2002) believe that plyometric training requires careful progress over a long period in order to allow adaptation to occur; given that women generally tend to be physically weaker than men, more visible gains in performance can be obtained through improved and increased strength training.

Even if recent studies suggest that the jumping ability of young volleyball players is significantly improved by plyometric training (Eraslan et al., 2020; Gül et al., 2020; Idrizovic et al., 2018), more research is needed to clarify the potentially moderating effects of age, gender and expertise level on their physical parameters (Ramirez-Campillo et al., 2021).

The *purpose* of this systematic review is to identify the effects/effectiveness of plyometric training on vertical jump height in junior female volleyball players.

Methodology

This study was conducted through a systematic review of the literature, following the instructions of the Cochrane Collaboration. The outcome was reported according to PRISMA recommendations (Page et al., 2021).

The search was performed in the PubMed, Medline, Google Scholar and ScienceDirect databases, and the keywords used were: plyometrics, volleyball, training, vertical jump.

Inclusion criteria revealed several characteristics regarding the studied materials:

- Type of studies: randomised and non-randomised studies written in English, French, Spanish or Portuguese and published in the last 30 years;
- Participants: studies using samples of junior female volleyball players (aged 10-19);
- Type of interventions: studies incorporating plyometric training performed for at least 2 weeks to develop vertical jump;
- Type of assessment methods: studies that measured and reported the height of vertical jumps using the squat jump (SJ), countermovement jump (CMJ) or drop jump (DJ).

Exclusion criteria:

- Studies focused on male volleyball players or related to other sports;
- Studies that did not address the effects of plyometric training on vertical jump height;
- Studies for which only abstracts were available.

In the data collection process, information was extracted on the characteristics of players (age), the size of the study group and the characteristics of plyometric training (frequency - days per week and session duration, number of weeks, methodology for vertical jump assessment).

Results

A total of 6942 articles were identified in the following databases: PubMed - 32, Medline - 409, Google Scholar - 6370, ScienceDirect - 131. After removing duplicates and screening titles and abstracts, 162 studies were retained and assessed independently by the two researchers. After the final screening process, 14 studies were included in the systematic literature review. The selection process was presented in a PRISMA diagram (Figure 1) (Page et al., 2020).

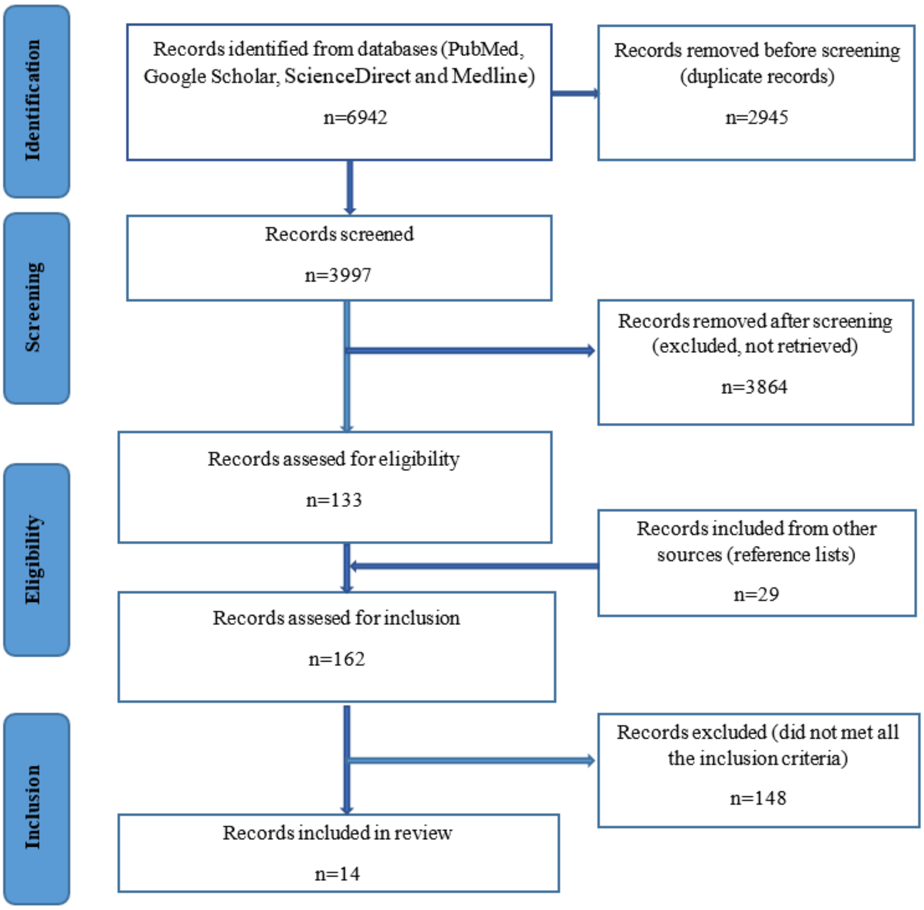

Figure 1. PRISMA 2020 flow diagram for the systematic literature review

All articles that met the inclusion criteria were published between 1996 and 2020. The total number of participants in the included studies was 365, and the sample size ranged from 10 to 78 participants. Their main characteristics and the interventions in the studies investigating the effects of plyometric training programmes on vertical jump performance in junior female volleyball players are summarised in Table 1 and Table 2. In addition, the elements of specific plyometric training are shown in Table 3 and Table 4. To note that only some of the studies included in this research gave a detailed description of the interventions aimed at increasing vertical jump height.

Table 1. *Main characteristics of athletes, duration and frequency of the interventions based on plyometric exercises in the studies investigating their effects on vertical jump performance in junior female volleyball players*

Study	Age of athletes (years)	Number of participants	Duration (weeks)	Frequency of training (days/week)
Martel et al., 2005	SG[1]: 15 ± 1 CG[2]: 14 ± 1	SG: 10 CG: 9	6	2
Perreira et al., 2015	SG: 15 ± 1 CG: 14 ± 1	SG: 10 CG: 10	8	2
Lehnert et al., 2009	SG:14.8 ± 0.9	SG: 11	8	2
Idrizovic et al., 2018	16.6	PG[3]: 13 SBG[4]: 17 CG: 17	12	2
Veličković et al., 2018	14-16	SG: 15 CG: 15	12	2
Radu et al., 2015	SG: 16-17	SG: 15	10	2
Trajković et al., 2016	17	SG: 30 CG: 30	6	2
Çankaya et al., 2018	SG: 16 ± 0.8	SG: 10	4	6
Vilela et al., 2021	12.18 ± 1.27 SG1: 10.5 ± 1.3 SG2: 11.8 ± 1.1 SG3: 13.2 ± 0.5 CG1: 11.7 ± 1.3 CG2: 11.7 ± 1.3 CG3: 13.0 ± 0.6	 SG 1: 10 SG 2: 10 SG 3: 10 CG 1: 10 CG 2: 19 CG 3: 19	8	3
Cojocaru & Cojocaru, 2019	SG: 16.3	SG: 10	13	NA[5]
Lleshi, 2015	SG: 17 ± 1.6 CG: 18 ± 0.8	SG: 10 CG: 10	12	2
Saaed, 2013	11 ± 1.36	SG: 10 CG: 10	9	3
Gül et al., 2020	SG: 13.5 CG: 13.4	SG: 7 CG: 7	8	3
Hewett et al., 1996	SG: 15	SG: 11	6	3

Legend: 1 - SG: study group; 2 - CG: control group; 3 - PG: plyometric group; 4 - SBG: skill-based group; 5 - NA: not available.

Table 2. *Main characteristics of the interventions based on plyometric exercises in the studies investigating their effects on vertical jump performance in junior female volleyball players*

Study	Training protocol	Vertical jump assessment	Results
Martel et al., 2005	SG[1]: Aquatic PT[5] + RVT[6] CG[2]: Flexibility training + RVT	CMJ[7]	SG and CG (pre-/post-test) VJ[8] increased ($p < 0.05$) SG: VJ increased by 11.08% CG: VJ increased by 4.08%
Perreira et al., 2015	SG: PT + RVT CG: RTV	CMJ	SG: VJ increased (pre-/post-test) by 25.19% ($p < 0.05$) SG vs. CG post-test $p = 0.05$
Lehnert et al., 2009	SG: PT	CMJ	VJ increased (pre-/post-test) by 13.69% ($p = 0.04$)
Idrizovic et al., 2018	PG[3]: PT + RVT SBG[4]: Skill-based conditioning + RVT CG: RVT	CMJ	PG: VJ increased (pre-/post-test) by 16.9% ($p < 0.01$) SBG: VJ increased by 9% CG: VJ increased by 8.5%
Veličković et al., 2018	SG: PT + RVT CG: RVT	CMJ SJ[9] DJ[10]	SG: VJ(CMJ) increased by 20.11% , VJ(SJ) increased by 27.07%, VJ(DJ) increased by 17.23% (for all, $p = 0.000$) CG: no significant differences ($p > 0.05$)
Radu et al., 2015	SG: Different types of exercises for strength and explosive power	SJ	VJ (SJ - 15-sec test) increased by 12.98% ($p < 0.05$) VJ (SJ - 30-sec test) increased by 26.13% ($p < 0.05$)
Trajković et al., 2016	SG: PT + RVT	CMJ	No significant differences pre-/post-test ($p > 0.05$)
Çankaya et al., 2018	SG: PT + RVT	SJ	VJ increased (pre-/post-test) by 7.69% ($p < 0.001$)
Vilela et al., 2021	SG1-3: PT + RVT CG1-3: RVT	CMJ SJ DJ	No significant differences (pre-/post-test) in SG1-3 SG1/CG1: VJ(DJ) increased by 31%, VJ(SJ) decreased by 1%, VJ(CMJ) decreased by 9%
Cojocaru & Cojocaru, 2019	SG: strength training + PT + RVT	CMJ	SG: VJ increased by 9.6% (p - NA)
Lleshi, 2015	SG: PT + RVT	CMJ SJ	SG: VJ(CMJ) increased by 7.79%, VJ(SJ) increased by 6.03% (pre-/post-test - NA)
Saaed, 2013	SG: resistance training + PT + RVT CG: RVT	CMJ	SG: VJ increased (pre-/post-test) by 8.58% ($p < 0.05$) CG: VJ increased (pre-/post-test) by 7.71% ($p < 0.05$)
Gül et al., 2020	SG: RVT + PT CG: RVT	CMJ	SG: VJ increased (pre-/post-test) by 16.83% ($p = 0.02$) CG: VJ increased (pre-/post-test) by 2.08% ($p = 0.23$)
Hewett et al., 1996	SG: Jump training programme	CMJ	VJ increased (pre-/post-test) by 9.2% ($p = 0.016$)

Legend: 1 - SG: study group; 2 - CG: control group; 3 - PG: plyometric group; 4 - SBG: skill-based group; 5 - PT: plyometric training; 6 - RVT: regular volleyball training; 7 - CMJ: countermovement jump; 8 - VJ: vertical jump; 9 - SJ: squat jump; 10 - DJ: drop jump.

Table 3. *Type of exercises used in plyometric training protocols in the studies investigating their effects on vertical jump performance in junior female volleyball players*

Study	Plyometric training protocol – Type of exercises
Martel et al., 2005	Exercises used in the aquatic PT were: - power skips - continuous jumping for height - single/double leg bounding - depth jumps - spike approaches - squat jumps (blocking technique)
Perreira et al., 2015	In each session after the RVT[2], SG[3] performed 4 jump exercises following medicine ball throwing drills: a. Bilateral jump (without bending knees) b. Bilateral jump (with bending knees) c. Unilateral jump short and as fast as possible (with the dominant leg on the floor) d. Unilateral jump as far as possible (with the dominant leg on the floor) e. Bilateral jump (without bending knees), for one stair f. Bilateral jump (with bending knees) as far as possible g. Unilateral jump short and as fast as possible (with the dominant leg on the floor)
Trajković et al., 2016	PT: a. Hurdle hops b. Depth jumps c. Lateral jumps over box d. Lunge hops e. Vertical jumps Moderate to high intensity
Lehnert et al., 2009	PT was separated into three cycles: *Cycle I (2 weeks)* a. Alternating push off (one foot on a 30 cm box) b. Two foot ankle hop (using only ankles for momentum) c. Front barrier hops (eight 30 cm boxes set up in a row) d. Spike jump at the net *Cycle II (4 weeks)* e. Zigzag double leg jump over the line f. Tuck jump with knees up g. Lateral box jump (landing on two feet on the 30 cm box and on one foot on the floor) h. Single foot side ankle jumps over medicine ball *Cycle III (2 weeks)* i. Lateral medicine ball jumps with a 180 degree turn (five medicine balls lined up 90 cm apart) j. Front barrier hops back and forth (five 30 cm boxes set up in a row) k. Block jumps at the net l. Alternate bounding with single arm action
Saaed, 2013	The training plan included a series of plyometric exercises performed after a set of resistance exercises.
Çankaya et al., 2018	Jumping with double feet on a 50 cm high platform, and then to the ground with double feet. Then, jumping back from the ground on the platform with double feet, and again, jumping back to the ground where the movement started. Plyometric exercises were performed after 10 minutes of active rest following normal training.
Hewett et al., 1996	Jump training programme: a. Wall jumps b. Tuck jumps c. Broad jumps stick land d. Squat jumps

	e. Double leg cone jumps f. 180˚ jumps g. Bounding in place h. Jump, jump, jump, vertical jump i. Bounding for distance j. Scissor jump k. Hop, hop, stick l. Step, jump up, down, vertical m. Mattress jumps n. Single-legged jumps distance o. Jump into bounding p. Single-legged hop, hop stick Before jump exercises, athletes performed stretching (15-20 min), skipping (2 laps) and side shuffle (2 laps). After training, they did a cool-down walk (2 min) and stretching (5 min).
Gül et al., 2020	PT: 1. Double foot forward and backward jump at obstacle 2. Double foot right and left jump at obstacle 3. Jump forward and backward with the right/left foot in the obstacle 4. Jump right and left with the right/left foot in the obstacle 5. Squat jump 6. Jump pulling knees to chest 7. Obstacle jump between height with double foot 8. Double foot jump on rings 9. Zigzag jump right/left foot 10. Obstacle jump and jump into the vault 11. Commando dance 12. Burpee 13. Jump and obstacle jump by changing feet in rings 14. Jump from the vault and jump the obstacle 15. Double leg obstacle jump 16. Right/Left foot obstacle jump 17. Vault jump 18. Right and left foot jump obstacle from different heights 19. Zigzag double feet jump on rings
Idrizovic et al., 2018	Lower body PT: a. Stiff knee leg hops (2-leg) b. Maximal vertical jumps (2-leg) c. Maximal tuck jumps (2-leg) d. Maximal lateral/diagonal jumps (2-leg) e. Maximal broad jumps (2-leg) f. Obstacle jumps (2-leg; 30 cm high) g. Box jumps (2-leg; 40 cm high) h. Box shuffles (40 cm high) i. Drop jumps (2-leg; 40 cm depth) j. Drop jumps (2-leg; 60 cm depth) k. Drop jump + max vertical jump (2-leg; 40 cm depth) l. Lateral/Diagonal jumps (1-leg) m. Broad jumps (1-leg) n. Obstacle jumps (1-leg; 20 cm high) o. Box jumps (1-leg; 20 cm high)
Vilela et al., 2021	PT programme: a. Two-leg jump b. Jump forward with leg change c. Diagonal zigzag jumps d. Double-leg hurdle jumps e. Depth jumps

Legend: 1 - PT: plyometric training; 2 - RVT: regular volleyball training; 3 - SG: study group.

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Table 4. *Details related to the plyometric training specifics in the studies investigating their effects on vertical jump performance in junior female volleyball players*

Study	Sets/Repetitions	Number of sessions/week
Martel et al., 2005	Exercises progressively increased from 2 to 5 per session. Rest periods increased from 10 s to 30 s during the set. Athletes performed depth jumps involving submerged boxes and work time increased during the stage (2/session in week 1; 3/session in week 2; 4/session in weeks 3, 4; 5/session in weeks 5, 6). Total time for each session = 45 min Rest periods of at least 30 s were given between each maximum lift. A rest period of at least 2 min was given before starting the testing protocol for the non-dominant leg. CG[1]: flexibility training 2 times/week (3 sets of 8-10 static stretches/30 s each)	2 12 total
Perreira et al., 2015	a. 3 x 20 (weeks 1-3) & 3 x 25 (weeks 4-5) b. 3 x 10 (weeks 1-4) & 4 x 10 (week 5) c. 3 x 10 (week 1-4) & 2 x 10 (week 5) d. 2 x 8 (week 1-4) & 3 x 8 (week 5) e. 4 x 20 (weeks 6-7) & 5 x 20 (week 8) f. 4 x 10 (weeks 6-8) g. 3 x 10 (weeks 6-8) Rest intervals of 2 min between sets and 3 min between exercises	2 16 total
Trajković et al., 2016	a. 2 x 6 (week 1), 3 x 6 (weeks 2, 4, 5), 4 x 6 (weeks 3, 6) b. 2 x 10 (week 1), 3 x 10 (weeks 2-6) c. 2 x 30 s (week 1), 3 x 30 s (week 2), 3 x 60 s (weeks 3-4), 3 x 90 s (weeks 5-6) d. 2 x 9 (week 1), 3 x 10 (week 2), 3 x 12 (week 3), 3 x 10 (week 4), 3 x 11 (week 5), 3 x 13 (week 6) e. 2 x 8 (week 1), 3 x 9 (week 2), 3 x 11 (week 3), 3 x 9 (week 4), 3 x 11 (week 5), 3 x 12 (week 6) 1 minute rest between attack jumps	2 12 total
Lehnert et al., 2009	*Cycle I* a. 2 x 10 (week 1) & 3 x 10 (week 2) b. 2 x 10 (week 1) & 3 x 10 (week 2) c. 2 x 8 (week 1) & 3 x 8 (week 2) d. 2 x 10 (week 1) & 3 x 10 (week 2) *Cycle II* e. 2 x 10 (week 1) & 3 x 10 (weeks 2-4) f. 2 x 10 (week 1) & 3 x 10 (weeks 2-4) g. 2 x 10 (week 1) & 3 x 10 (weeks 2-4) h. 2 x 10 (week 1) & 3 x 10 (weeks 2-4) *Cycle III* i. 3 x 10 (week 1) & 4 x 10 (week 2) j. 3 x 10 (week 1) & 4 x 10 (week 2) k. 3 x 8 (week 1) & 4 x 8 (week 2) l. 3 x 8 (week 1) & 4 x 8 (week 2) The resting period between exercise series was 2 minutes.	2 24 total
Saaed, 2013	Complex 1: 3 × 12RM & 3 × 10 Complex 2: 3 × 12RM & 3 × 10 Complex 3: 3 × 12RM & 3 × 10 Complex 4: 3 × 12RM & 3 × 10 Complex 5: 3 × 12RM & 3 × 10 Complex 6: 3 × 12RM & 3 × 10 All sets of exercises involving weights were followed by a pause of 100 s per set. A 4-min resting time was added after all sets with weights. Recovery for the plyometric routine was 120 s per set.	3 27 total

Çankaya et al., 2018	15 jumps on the platform (SJ[2]) + 15 jumps off the platform (DJ[3]) = 1 set 3 sets/training, 30 jumps/set A total of 72 sets and 2160 plyometric jumps (SJ + DJ) 5-min resting time between sets	6 24 total
Hewett et al., 1996	a. 20 s (week 1), 25 s (week 2), 30 s (weeks 3, 4) b. 20 s (week 1), 25 s (week 2), 30 s (weeks 3, 4) c. 5 reps[4] (week 1), 10 reps (week 2) d. 10 s (week 1), 15 s (week 2), 20 s (weeks 3, 4), 25 s (weeks 5, 6) e. 30/30 s (weeks 1-4) f. 20 s (week 1), 25 s (week 2) g. 20 s (week 1), 25 s (week 2) h. 5 reps (week 3), 8 reps (week 4) i. 1 run (week 3), 2 runs (week 4) j. 30 s (weeks 3, 4) k. 5 reps/leg (weeks 3, 4) l. 5 reps (week 5), 10 reps (week 6) m. 30 s (weeks 5, 6) n. 5 reps/leg (weeks 5, 6) o. 3 runs (week 5), 4 runs (week 6) p. 5 reps/leg (week 5, 6) Each jump exercise was followed by a 30-sec rest period.	3 18 total
Gül et al., 2020	Day: 1; EN[5]: 1, 2, 3 (each foot), 4 (each foot); 10 x 1 Day: 2; EN: 1, 2, 3 (each foot), 4 (each foot); 10 x 1 Day: 3; EN: 1, 2, 5, 6, 8, 9 (each foot); 10 x 1 - 5 x 1 Day: 4-6; EN: 11, 12, 7, 9 (each foot); 10 x 2 - 5 x 2 Day: 7-9; EN: 6, 11, 13, 15, 1, 18; 10 x 2 - 5 x 2 Day: 10-12; EN: 6, 12, 13, 17, 15; 10 x 2 - 5 x 2 Day: 13-15; EN: 6, 12, 17, 19, 10 10 x 2 - 5 x 2 Day: 16-18; EN: 5, 6, 8, 13, 14, 15, 17; 10 x 2 - 5 x 2 Day: 19-21; EN: 11, 12, 17, 10, 13, 14, 15; 10 x 2 - 5 x 2 Day: 22-24; EN: 5, 6, 14, 17, 19; 10 x 2 Rest between reps = 60 seconds Rest between sets = 2 minutes	3 24 total
Idrizovic et al., 2018	a. 5 x 5 (week 1) b. 5 x 5 (week 1), 5 x 3 (weeks 3, 6) c. 5 x 5 (week 1), 5 x 2 (week 8), 5 x 3 (week 11) d. 5 x 3 (weeks 2, 4), 4 x 4 (week 7) e. 5 x 3 (weeks 2, 5) f. 5 x 3 (weeks 3, 4, 6), 5 x 4 (week 9) g. 5 x 3 (week 5), 4 x 4 (week 7), 5 x 2 (week 8) h. 5 x 4 (week 3), 5 x 3 (weeks 4, 5, 9), 5 x 2 (week 6) i. 5 x 2 (weeks 5, 8), 5 x 1 (week 6), 5 x 4 (weeks 10, 12) j. 5 x 1 (week 7), 5 x 2 (week 9), 5 x 3 (week 11) k. 5 x 1 (weeks 7, 10), 5 x 4 (week 12) l. 6 x 1 (week 8), 5 x 2 (week 10), 5 x 3 (week 12) m. 6 x 1 (week 9), 5 x 2 (week 11) n. 6 x 1 (week 8), 5 x 2 (week 10), 5 x 4 (week 12) o. 6 x 1 (week 9), 6 x 2 (week 11) Rest between sets was not strict but varied from 2 to 5 min.	2 24 total
Vilela et al., 2021	a. 3 x 10 (week 1), 4 x 10 (week 2), 5 x 10 (week 3) b. 3 x 10 (week 1), 4 x 10 (week 2), 5 x 10 (weeks 3-8) c. 3 x 10 (week 1), 4 x 10 (week 2), 5 x 10 (weeks 3-8) d. 5 x 10 (weeks 4-8) e. 10 x 1 (week 4, 6, 8), 15 x 1 (weeks 5, 7) Rest: NA[6] Total: 1170 jumps	3 24 total

Legend: 1 - CG: control group; 2 - SJ: squat jump; 3 - DJ: drop jump; 4 - reps: repetitions; 5 - EN: exercise number; 6 - NA: not available.

Discussion

Vertical jump is a very important element for success not only in volleyball but also in many other sports and can be used to assess muscle power. There are several training methods aimed at improving vertical jump performance but plyometrics is the most commonly used. "Since the vertical jump is a complex polyarticular dynamic movement that requires inter-muscular coordination, any training program designed to improve VJP should include jumps to optimize coordination." (Perez-Gomez & Calbet, 2013, p. 352)

"The benefits of plyometric training include increased activation of fast-twitch motor units and, more important, a higher rate of firing. [...] Plyometric training produces the following results: quick mobilisation of greater innervation activity; recruitment of most, if not all, motor units and their corresponding muscle fibers; increased firing rate of motor neurons; transformation of muscle strength into explosive power; development of the nervous system so that it reacts with maximum speed to the lengthening of a muscle, which develops the athlete's ability to shorten (contract) rapidly with maximum force." (Bompa & Buzzichelli, 2015, p. 283)

Plyometric training increases muscle strength and contraction speed; these effects have been demonstrated in the case of children, physically active people and elite athletes. Plyometric training enhances the average cross-sectional areas of type I, IIa and IIa/Iix fibres and maximum strength in all fibres (type II fibres show the greatest improvement), muscle stiffness allowing greater storage and release of elastic energy. Although there is no conclusive experimental evidence, it has been suggested that plyometric training may cause increased inhibition of antagonistic muscles after training, better co-contraction or increased activation of synergistic muscles, reduction of neural inhibitory mechanisms and increased excitability and synchronisation of agonist motor neurons. It appears that combining plyometric training and weight training (WT) is the most effective method to increase vertical jump performance probably due to their positive effects on muscle strength and contraction speed (plyometrics) and on maximum dynamic strength (WT). (Perez-Gomez & Calbet, 2013) Studies (Martel et al., 2005) have demonstrated that plyometric exercises performed in the aquatic environment reduce the risk of injury due to the water density and viscosity.

Coaches who use plyometrics in the training process should know that this method is effective but does not guarantee success in increasing the height of vertical jumps. Equipment, participants, diet, training time, recovery, economic opportunities and various situations arising during training can be variables that need to be taken into account in order to improve vertical jump performance.

Most authors state that the volume and intensity of plyometric training should be periodically adjusted according to the results of intermediate tests.

The most common assessment method used in the studies included in this systematic review was the countermovement jump (nine studies), followed by the squat jump, and the least used method was the drop jump (Vilela et al., 2021).

This systematic review is one of the few studies or perhaps the only one that has tried to highlight ways to increase VJP by means of plyometrics in junior female volleyball players.

Most of the studies selected for this systematic review reported increases in vertical jump in junior volleyball players, but there were also cases where the intervention did not produce positive effects on vertical jump (Trajković et al., 2016; Vilela et al., 2021). Reported increases for study groups ranged from 7% to 8% (Lleshi, 2015; Saeed, 2013; Çankaya et al., 2018) to 27.7% (Veličković et al., 2018).

The duration of the intervention was between 4 weeks (Çankaya et al., 2018) and 13 weeks (Cojocaru & Cojocaru, 2019), generally emphasising a frequency of 2-3 training sessions per week.

Given the participants' age, it can be seen that very few studies have been conducted so far on pubertal volleyball players, most interventions being performed on adolescent athletes (aged 14-18). Since initiation to the game of volleyball occurs around the age of 10, it appears that these studies were focused on athletes with consistent motor skills.

Obviously, this systematic review also had some limitations:

• the analysis was performed on a rather small number of studies (14 in total), which did not lead to very clear conclusions;

• some shortcomings were related to the assessment methodology for SJ, DJ and CMJ, which might have diminished the validity of the results;

• some studies did not have any group of control, and the comparison was made between the initial and final assessments of the same group.

Conclusion

The results of this systematic review confirm the effectiveness of plyometric training on vertical jumps in the case of junior volleyball players.

Although some studies reported insignificant increases in vertical jump height, the effects of plyometric training on vertical jump performance were moderate when the intervention lasted about 4-6 weeks and considerably improved when the intervention lasted over 8 weeks. This indicates that the benefits of plyometric training on vertical jumps are more complex as a result of interventions exceeding 8 weeks.

The volume and intensity of plyometric training should be periodically adjusted according to the results of intermediate tests. Based on these results, coaches who use plyometrics in the training process should know that this method is effective but does not guarantee success in increasing the height of vertical jumps.

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