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Does Plyometric Exercise Improve Jumping Performance in Volleyball Athletes? An Overview of Systematic Reviews

¿El ejercicio pliométrico mejora el rendimiento de los saltos en los atletas de voleibol?: una descripción general de las revisiones sistemáticas

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Abstract. Plyometric training is frequently used to improve the jumping performance of volleyball players. The aim of the present study was to synthesize the results of different systematic reviews that investigated the effects of plyometric training on the jumping performance of volleyball players. Systematic research was performed in PubMed, Scopus, and Web of Science databases, looking for systematic reviews of randomized clinical trials. Methodological quality was independently assessed by two authors using AMSTAR. Four systematic reviews were included in the evidence synthesis, representing 983 volleyball players, 541 women and 314 men (128 were not declared). In summary, the studies lasted from 2 to 26 weeks of intervention, weekly frequency between 1-3, 1-6 sets, 1-25 repetitions and between 1-9 exercises per training session. AMSTAR indicated two studies with low quality of evidence, one moderate and one with high quality. The vertical jump was the main skill assessed in plyometric training interventions compared to the horizontal jump. According to the evidence, plyometric training had a positive effect on the vertical jump performance and on the maintenance of horizontal jumps of volleyball athletes. Further studies should look at mechanisms that lead to improvements in horizontal jump, and plyometric training programs should possibly include more horizontal jump exercises to optimize this skill.
Keywords: strength and conditioning, stretch-shortening cycle, sport performance, sport science.

Resumen. El entrenamiento pliométrico se utiliza con frecuencia para mejorar el rendimiento de salto de los jugadores de voleibol. El objetivo del presente estudio fue sintetizar los resultados de diferentes revisiones sistemáticas que investigaron los efectos del entrenamiento pliométrico en el rendimiento de salto de los jugadores de voleibol. Se realizó una investigación sistemática en las bases de datos PubMed, Scopus y Web of Science, buscando revisiones sistemáticas de ensayos clínicos aleatorizados. Dos autores evaluaron de forma independiente la calidad metodológica mediante AMSTAR. Se incluyeron cuatro revisiones sistemáticas en la síntesis de la evidencia, que representan a 983 jugadores de voleibol, 541 mujeres y 314 hombres (128 no declaradas). En resumen, los estudios tuvieron una duración de 2 a 26 semanas de intervención, frecuencia semanal entre 1-3, 1-6 series, 1-25 repeticiones y entre 1-9 ejercicios por sesión de entrenamiento. AMSTAR indicó dos estudios con baja calidad de evidencia, uno moderado y otro con alta calidad. El salto vertical fue la principal habilidad evaluada en las intervenciones de entrenamiento pliométrico en comparación con el salto horizontal. Según la evidencia, el entrenamiento pliométrico tuvo un efecto positivo en el rendimiento del salto vertical y en el mantenimiento de los saltos horizontales de los atletas de voleibol. Futuros estudios deberían analizar los mecanismos que conducen a mejoras en el salto horizontal, y los programas de entrenamiento pliométrico posiblemente deberían incluir más ejercicios de salto horizontal para optimizar esta habilidad.
Palabras clave: fuerza y acondicionamiento, ciclo estiramiento-acortamiento, rendimiento deportivo, ciencia del deporte.

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Introduction

Volleyball is a sport characterized by intermittent, high-intensity efforts, with periods of short duration, interspersed with recovery periods (Lidor & Ziv, 2010; Polglaze & Dawson, 1992; Ramirez-Campillo et al., 2021; Reeser & Bahr, 2017). The game involves repeated jumps, frequent runs, decelerations and vertical and horizontal changes of direction, which requires a lot of speed, agility, muscular power of the upper and lower body and maximum aerobic power of the player (García-de-Alcaraz et al., 2020; Reeser & Bahr, 2017; Silva et al., 2019; Weldon et al., 2021). Jumping is one of the most important factors for successful volleyball performance (Marques et al., 2009), as it is one of the components present in service, blocking and attacking (Ikeda et al., 2018).

Horizontal jump and vertical jump are two fundamental techniques that play a crucial role in the performance of volleyball athletes (Reeser & Bahr, 2017). Both skills are essential for the execution of effective offensive and defensive actions during the game. The horizontal jump allows players to quickly move laterally, extending their reach and enabling them to attack balls that would otherwise be out of their reach. For example, when executing a quick attack through the middle of the net, the horizontal jump allows the player to move laterally to reach the ball and direct it accurately. On the other hand, the vertical jump is crucial for reaching great heights in the air, enhancing the ability to attack, block, and defend. During an attack, the vertical jump enables players to surpass the opponent's block and direct the ball towards the floor of the court. In blocking, the vertical jump provides an advantage by closing gaps in the net and making it difficult for the opposing team to attack. Additionally, in defense, a well-executed vertical jump increases the player's range and their ability to react quickly to powerful attacks. Therefore, coaches and professionals look for different effective training to improve the conditioning abilities of volleyball players (Pereira et al., 2015; Weldon et al., 2021).

In particular, plyometric training to develop players' performance in jumps has been increasingly studied (Silva et al., 2019). Plyometric training is based on the stretch-

shortening cycle (SSC), a physiological phenomenon characterized by rapid stretching of a pre-activated muscle before the shortening of this same muscle (Aeles & Vanwanseele, 2019), enabling the increase of the capacity of the neuromuscular system to produce maximum force in the shortest time possible (Gjinovci et al., 2017; Markovic & Mikulic, 2010). What benefits performance, in addition to preventing injuries (Aeles & Vanwanseele, 2019), in volleyball practice, especially in vertical and horizontal jumps and changes of direction. Evidence related to the effectiveness of plyometric training in improving the jumping performance of volleyball players is often synthesized in specific reviews of performance and general aptitude. Clinicians usually search for systematic reviews to support evidence-based decisions. An overview of assessments has the potential to improve access to evidence spread across multiple reviews. This relatively new methodological approach provides a way to systematically synthesize evidence of the effect of a number of different interventions on a specific outcome (Higgins et al., 2022), such as jumping performance. Therefore, the aim of this study was to synthesize the findings of different systematic reviews that investigated the effect of plyometric training on the jumping performance of volleyball players.

Material and Method

Search Strategy

The study is an overview of systematic reviews. A search for systematic reviews and meta-analysis published until August 2022 was carried out in the PubMed, Scopus, and Web of Science databases, addressing studies that investigated the effect of plyometric training on jumping in volleyball players. The following terms were used: (volleyball OR volleyball athletes OR volleyball players)" AND (strength training OR resistance training OR power training OR strength exercise OR ballistic exercise OR plyometrics exercise OR weightlifting exercise OR complex exercise). Three steps were taken to select the studies: reading the title, abstract and the entire text. "Systematic Review" or "Review" was used as filter term when the database showed this option. Some reviews were excluded after reading the title because they did not involve volleyball athletes, others were also not included because their summaries talked about plyometric exercise only in relation to strength. The selection of reviews was made by two researchers independently, and when there was a disagreement between the two in the selection of reviews, a third researcher who in this case was the advisor, entered. The Methodological Quality Assessment Checklist for Systematic Reviews (AMSTAR 2) was used to assess the quality of the selected reviews. The review protocol was prospectively registered at INPLASY (International platform of registered systematic reviews and meta-analysis protocols, INPLASY202140056).

Inclusion Criteria and Exclusion Criteria

A PICOS (participants, intervention, comparators, outcomes, and study design) approach was used to rate studies' eligibility (Liberati et al., 2009). The respective inclusion/exclusion criteria adopted in our overview are reported in Table 1.

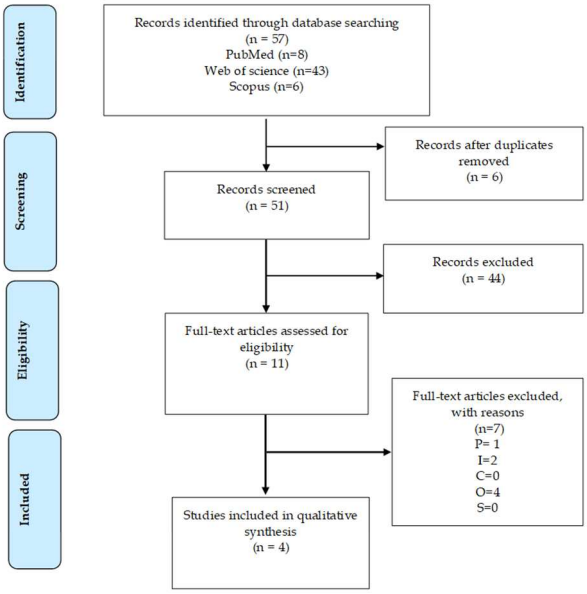

Figure 1. PRISMA diagram showing flow of the study selection

Study Quality

The Methodological Quality Assessment Checklist for Systematic Reviews (AMSTAR) was used to assess the quality of the selected reviews (Shea et al., 2007). The sixteen multiple choice questions related to the AMSTAR 2 tool checklist (https://amstar.ca/Amstar_Checklist.php) were responded for each study included (Shea et al., 2007). Two examiners went through the process, independently, using 'no', 'partial yes' or 'yes'.

Results

According to the database search, 57 files were found. This data was transferred to (Mendeley), reference management software and 6 duplicates were eliminated. The remaining 51 files were selected by reading the titles and abstracts. After reading the full 11 remaining reviews, in the final stage of the screening procedure, 7 other reviews were eliminated either because they weren't about volleyball (n=1), did not use plyometric exercise as an intervention (n=2), only comprised vertical jump in weightlifting (n=1), used plyometric to improve strength performance (n=2), or for not investigating the effect of plyometric exercise on performance (n=1). At the end of the screening process, it was concluded that four systematic reviews were suitable for inclusion in the present review. A schematic summary of this research is shown in the flowchart (Figure 1).

Table 1.
Selection criteria used in the meta-analysis.

Category	Inclusion criteria	Exclusion criteria
Population	Healthy volleyball athletes, with no restrictions on their playing level, sex, or age.	Volleyball athletes without any injuries
Intervention	A plyometrics exercise program	Intervention of exercises that do not have plyometric training or that use plyometric training as a complementary form (complex training).
Comparator	Active control group	Absence of active control group
Outcome	Vertical jump Horizontal jump Jump with countermovement Drop jump Squat jump	Lack of baseline and or follow-up data.
Study design	Systematic review and meta-analysis.	Non-systematic review and meta-analysis.

Four systematic reviews were selected for this study: Stojanovic et al. (2017); Martínez-Rodríguez et al. (2017); Silva et al. (2019) and Ramirez-Campillo et al. (2020). Moreover, Stojanovic et al. (2017), Ramirez-Campilo et al. (2020) also performed a meta-analysis. The characteristics and main conclusions of these reviews are shown in Table 2.

Table 2.
Characteristics and main findings of the reviews included: sample, number of studies, number of subjects, study designs, intervention, outcomes and results e conclusions (n=4).

Study	Subject	Number of studies included	Total (n)	Studies Design	Intervention	Outcomes	Results e conclusions
(Stojanović et al., 2017)	Collegiate team elite female athletes	16	NR woman	This review included studies randomized and non-randomized	Plyometric training interventions should be at least 4 weeks long. Control groups participated in a general sports program without plyometric training or did not exercise.	CMJ CMJA SJ DJ	They demonstrated that plyometric training improves vertical jump performance in female athletes, regardless of age. Training duration also appears to influence the effectiveness of plyometric training, as longer training durations (weeks C10) provide greater improvements in jumping performance.
(Martínez-Rodríguez et al., 2017)	Women volleyball players	7	84 woman	Experimental draw	Intervention of 4 to 12 weeks, with 2-3 weekly sessions.	SJ CMJ ABK DJ-30 DJ-60	All the plyometric training programs proposed by the different authors, seem to contribute to the improvement of the height of the vertical jump in volleyball players. The authors who analyzed young athletes obtained better results than studies with more experienced players. It was observed that the increase in the load does not always increase the performance in the jump.
(Silva et al., 2019)	Male and female volleyball players	19	577 Woman – 356 Male – 142 NR- 79	10 Case reports 9 Randomized controlled	The training protocols varied between two and three sessions per week, and the total intervention period ranged from 2 to 16 weeks. They were carried out either on traditional gymnasium, grass, or aquatic floors. So much for evaluating the vertical, horizontal jump.	Vertical jump: SJ, CMJ, DJ, standing vertical jump, single leg jump and repeated jumps (15 and 30 s). Horizontal jump: SLJ; DLLJ	14 studies demonstrated that plyometric training is effective in vertical jumping, 2 studies revealed a significant increase in horizontal jump performance, 1 study showed no difference and 1 showed only a small effect.
(Ramirez-Campillo et al., 2020)	Healthy volleyball players with no restriction for age or sex.	14	322 Woman - 101 Man – 172 NR- 49	Randomized-controlled and cohort.	Protocols range from 2 to 16 weeks. CMJ CMJA	Plyometric training program with the combination of two or more of the following jumping exercises: vertical, horizontal, unilateral repeated, non-repeated, lateral, specific sports cyclic, stretching-shortening cycle and fast stretching-shortening cycle.	In all included studies, there was a very large and significant improvement in VJH. No significant difference was observed for the duration of the PJT total volume of sex (female vs. male) or age. The study found that men and women showed equally significant increases in JVH. In addition, improvements can be achieved by both sexes at various age groups, with relatively low volume programs.

Abbreviations: CMJ: Countermovement Jump; CMJA: Countermovement Jump with Arm Swing; SJ: Squat Jump; DJ: Drop Jump; ABK: Abalakov Jump; SLJ: Standing Long Jump; DLLJ: Depth Leap Long Lump; NR: Not reported.

The 4 systematic reviews included were published between 2010 and 2020. The designs of the evaluated studies varied between: Case reports (Silva et al., 2019), randomized control (Ramirez-Campillo et al., 2020; Silva et al., 2019; Stojanović et al., 2017), experimental drawing (Martínez-Rodríguez et al., 2017). The studies obtained for the review evaluated whether plyometric training has any influence on improving jumping performance in volleyball athletes, without age restriction. Two reviews recruited only female athletes (Martínez-Rodríguez et al., 2017; Stojanović et al., 2017) and the others had both sexes participating (Ramirez-Campillo et al., 2020; Silva et al., 2019).

Synthesis of Findings

Our results indicated that the effect of plyometric training on vertical jump performance was the most investigated relationship. The plyometric training protocol improved vertical jump performance. However, no significant improvement was observed for horizontal jump performance (Table 3). Training frequency, intensity, volume, sex, age and duration did not influence performance. Furthermore, improvements can be achieved by both sexes and in various age groups, even with a relatively low volume program.

Table 3.
Effect of plyometric training on different populations and outcomes.

Study	Subjects	Follow-up length	Vertical Jump	Horizontal Jump
(Stojanović et al., 2017)	Collegiate and elite female athletes	8-26 weeks 1-3 times a week 2-6 series 4-25 repetitions 1-9 exercise per session	↑	NR
(Martínez-Rodríguez et al., 2017)	Female volleyball players	4-12 weeks 2-3 times a week Mix of combined exercises.	↑	NR
(Silva et al., 2019)	Male and female volleyball players	4-16 weeks 1-6 series 1-12 repetitions 1-9 exercise per session	↑	↔
(Ramirez-Campillo et al., 2020)	Healthy volleyball players with no restriction for age or sex.	2-16 weeks 1-3 times a week Mix of combined exercises.	↑	NR

Abbreviations: ↑: Improvement; ↓: Decrement; ↔: No significant alterations; NR: Not reported.

Table 4.
Exercises used to assess vertical and horizontal jump.

Study	Vertical jump					Horizontal Jump	
	CMJ	CMJA	SJ	DJ	ABK	SLJ	DLLJ
(Stojanović et al., 2017)	↔	↑	↓	↑	NR	NR	NR
(Martínez-Rodríguez et al., 2017)	↑	NR	↑	NR	↓	NR	NR
(Silva et al., 2019)	↔	↔	NR	NR	NR	NR	NR
(Ramirez-Campillo et al., 2020)	↑	NR	↔	↑	NR	↔	↔

Abbreviations: ↑: Improvement; ↓: Decrement; ↔: No significant alterations; CMJ: Countermovement Jump; CMJA: Countermovement Jump with Arm Swing; SJ: Squat Jump; DJ: Drop Jump; ABK: Abalakov Jump; SLJ: Standing Long Jump; DLLJ: Depth Leap Long Lump; NR: Not reported

Table 4 presents the exercises used to assess the effect of plyometric training on vertical and horizontal jump performance. In the vertical jump, some types of exercises such as: countermovement jump (CMJ) (Martínez-Rodríguez et al., 2017; Silva et al., 2019), countermovement jump with arm swing (CMJA) (Stojanović et al., 2017), squat jump (SJ) (Martínez-Rodríguez et al., 2017) and drop jump (DJ) (Stojanović et al., 2017) interfered for the best performance in the jump. As for the horizontal jump, the standing long jump (SLJ) and depth leap long jump (DLLJ) (Silva et al., 2019) did not show significant improvements in the performance of the jump.

AMSTAR provided the quality of evidence for the systematic reviews. In terms of quality of evidence (Table 5).

Table 5.
AMSTAR classification of systematic reviews included

	AMSTAR	(Stojanović et al., 2017)	(Martínez-Rodríguez et al., 2017)	(Silva et al., 2019)	(Ramirez-Campillo et al., 2020)
1	Did the research questions and inclusion criteria for the review include the components of PICO?	Yes	Yes	Yes	Yes
2	Did the report of the review contain an explicit statement that the review methods were established prior to the conduct of the review and did the report justify any significant deviations from the protocol?	Partial yes	Partial yes	Partial yes	Yes
3	Did the review authors explain their selection of Did the review authors use a comprehensive literature search strategy?	No	No	No	Yes
4	Did the review authors use a comprehensive literature search strategy?	No	Partial yes	Partial yes	Partial yes
5	Did the review authors perform study selection in duplicate?	Yes	No	Yes	Yes
6	Did the review authors perform data extraction in duplicate?	Yes	No	Yes	Yes
7	Did the review authors provide a list of excluded studies and justify the exclusions?	No	No	Yes	Partial yes
8	Did the review authors describe the included studies in adequate detail?	Partial yes	Partial yes	Partial yes	Yes
9	Did the review authors use a satisfactory technique for assessing the risk of bias (RoB) in individual studies that were included in the review?	Partial yes	No	Partial yes	Yes
10	Did the review authors report on the sources of funding for the studies included in the review?	Yes	No	Yes	Yes
11	If meta-analysis was performed did the review authors use appropriate methods for statistical combination of results?	Yes	no meta-analysis conducted	No meta-analysis conducted	Yes
12	If meta-analysis was performed, did the review authors assess the potential impact of RoB in individual studies on the results of the meta-analysis or other evidence synthesis?	Yes	no meta-analysis conducted	No meta-analysis conducted	Yes
13	Did the review authors account for RoB in individual studies when interpreting/ discussing the results of the review?	Yes	Yes	No	Yes
14	Did the review authors provide a satisfactory explanation for, and discussion of, any heterogeneity observed in the results of the review?	Yes	Yes	Yes	Yes
15	If they performed quantitative synthesis did the review authors carry out an adequate investigation of publication bias (small study bias) and discuss its likely impact on the results of the review?	Yes	no meta-analysis conducted	No meta-analysis conducted	Yes
16	Did the review authors report any potential sources of conflict of interest, including any funding they received for conducting the review?	Yes	No	Yes	Yes
	Total	11,5	4,5	8,5	15
	Score	Moderate	Low	Low	High
	Details	Meta-analysis	No Meta-analysis	No Meta-analysis	Meta-analysis

Discussion

The present study provides an overview of four systematic reviews on the effectiveness of plyometric exercise on jumping performance in volleyball players. Based on the findings of the systematic reviews, which indicated that plyometric exercises appear to be effective in improving the performance of volleyball players in the vertical jump (Martínez-Rodríguez et al., 2017; Ramirez-Campillo et al., 2020; Silva et al., 2019; Stojanović et al., 2017) and horizontal (Silva et al., 2019), regardless of age and sex. When using AMSTAR to assess the quality of systematic reviews

included in the study, two were identified with low quality of evidence (Martínez-Rodríguez et al., 2017; Silva et al., 2019), one moderated (Stojanović et al., 2017), and one high (Ramirez-Campillo et al., 2020). The main weaknesses of the quality of the reviews were the statement of the review methods not explicitly presented, indicating the use of a protocol; not a justification for the inclusion of different study designs and a justification of excluded studies and insufficient details of those included risk of bias from individual studies; and not performing meta-analysis. Identifying these weaknesses undermines confidence in the results of low-quality reviews (Shea et al., 2017).

Due to the characteristics of volleyball, which involve repeated jumps, frequent runs and changes in direction, players need individual physical performance skills (Gjinovci et al., 2017; Weldon et al., 2021). The skill of jumping is one of the most fundamental elements to perform various fundamentals in the game such as serve, block and attack (Ikeda et al., 2018). Considering the tactical nature of jumping activities and the frequency with which they occur in volleyball practice, these activities are considered crucial performance indicators (Ben Ayed et al., 2020). In this context, plyometric training has stood out, as it is used to increase strength and explosion, and includes a wide range of jumps, such as the DP, SJ, CMJ, CMJA, among others (Gjinovci et al., 2017).

The results of this overview show that the vertical jump is the main skill studied in the plyometric training interventions, compared to the horizontal jump. Silva et al. (Silva et al., 2019), evaluated the effectiveness of plyometric training programs in the performance of vertical and horizontal jump in male and female volleyball players. The review identified 19 studies and included inferences about the effects of plyometric training on vertical jump performance, where improvements in performance were observed after intervention with plyometric exercises such as: DJ, SJ, CMJ, CMJA, standing vertical jump, single-legged jump and jumping repeatedly. While the horizontal jump was evaluated in four studies through the long jump and the deep jump. A significant increase in jumping performance was seen in only two of the four studies. The horizontal jump requires vertical and horizontal actions, therefore, the increased complexity of the technique may be responsible for the smaller effects of plyometric training (Silva et al., 2019).

Despite the popularity of vertical jumps as a test of lower limb power, many sports such as volleyball require strength to be produced in both the vertical and horizontal planes of motion (Dobbs et al., 2015). A limited amount of research has been conducted on the effect of plyometric training on the horizontal jump (Silva et al., 2019). However, some tests used for jumping performance, such as the CMJA and bilateral DJ, have been evaluated (Martínez-Rodríguez et al., 2017; Ramirez-Campillo et al., 2020; Stojanović et al., 2017).

The systematic review with meta-analysis carried out by Ramirez-Campillo et al. (2020) and Stojanovic et al. (2017) focused only on the effect of plyometric training on vertical jump, being the two reviews included in this overview having better methodological quality. The review by Ramirez-Campillo et al. (2020) included 14 randomized controlled trials that contained a pre-post-intervention assessment, with no restrictions on age or sex. Stojanovic et al. (2017) evaluated the effectiveness of plyometric training on the vertical jump performance of female, amateur, collegiate and elite athletes, through randomized and non-randomized studies. It was observed through the studies included in the review by Ramirez-Campillo et al. (2020) that plyometric training significantly improves vertical jump performance in volleyball players, even if performed with relatively low volume and frequency (8 weeks). Stojanovic et al. (2017) observed a more significant effect in training longer than 10 weeks. It is more effective in jumps such as CMJ and DJ, as it increases neuromuscular coordination through nervous system training, thus allowing the SSC and its elastic effects of the muscle-tendon unit and neural sequencing (Seiberl et al., 2021). Short- and long-term adaptation of the muscle-tendon unit to SSCs after a plyometric training intervention significantly increases jumping performance (Seiberl et al., 2021). Ruffieux et al. (2020) concludes in their study that training with a high percentage of slower SSC jumps, such as counter-movement jumps, is more effective than training with a high percentage of fast SSCs, such as drop-jumps on non-professional volleyball players. Therefore, inferences about training volume and frequency remain limited.

An athlete's experience can influence the effect of plyometric training (Stojanović et al., 2017). Differences in muscle cross-section, fiber type distribution, and neurophysiological patterns, as well as training over the years, may help explain the differences in magnitudes exhibited between trained and amateur athletes. Martínez-Rodríguez et al. (2017) also corroborates these results, indicating that amateur and untrained athletes can obtain more positive results with plyometric training.

This overview is predefined, which helps to narrow down the likelihood of biased decisions in the review, in addition, comprehensive search strategies were conducted for a wide range of data. However, a limitation of the overviews of the reviews, and therefore of the present study, is that the analyses are based on secondary reports of what the authors of the reviews interpreted and reported based on the primary studies, and these may have provided more information than the reported information of the reviews we have included. The quality of evidence supporting the results was limited by the small number of studies and methodological limitations of the included systematic reviews and since this is an overview of systematic reviews, we did not conduct any additional indirect comparisons. More high-quality randomized controlled trials (RCTs) are necessary.

According to the evidence, we conclude that plyometric training had a positive effect on the vertical jump and moderate effect in horizontal jump performance of volleyball athletes. Further studies should look at the mechanisms that

lead to improvements in horizontal jump, and the plyometric training program should possibly include more horizontal jump exercises to optimize this ability.

Conclusions

It is evident that both the horizontal jump and the vertical jump play crucial roles in the performance of volleyball athletes. Based on this information, there are significant practical implications for coaches and trainers who seek to enhance their teams' performance. Firstly, it is important to incorporate specific training programs that develop players' ability to execute horizontal jumps, improving their speed and lateral movement skills. This will enable players to attack balls that would otherwise be out of their reach, providing a valuable offensive advantage. Additionally, enhancing vertical jump technique is essential for increasing players' height reached, resulting in more effective attacks, solid blocks, and powerful defenses. Therefore, coaches and trainers should emphasize the development of explosive leg strength, along with proper jumping technique, to maximize players' potential in both skills. By incorporating these aspects into training sessions, coaches can optimize athletes' performance and increase their chances of success in volleyball competitions.

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