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.

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.

Material and Method

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).
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-Campillo et al. (2020) also performed a meta-analysis. The characteristics and main conclusions of these reviews are shown in Table 2.

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 (Martín-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 (Martín-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, with relatively low volume programs.
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 (Ramírez-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; Ramírez-Campillo et al., 2020; Stojanović et al., 2017).

The systematic review with meta-analysis carried out by Ramírez-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 Ramírez-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 Ramírez-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 neuro-physiological 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.

**References**


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