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Effect of plyometric and sprint training on repeated sprint and vertical jump capacities in volleyball players aged 11 to 14 Years: A longitudinal study

Efeito do treinamento pliométrico e de sprint nas capacidades de sprint repetido e salto vertical em jogadores de vôlei de 11 a 14 anos: Um estudo longitudinal

Efecto del entrenamiento pliométrico y de sprint sobre las capacidades de sprint repetido y salto vertical en jugadores de voleibol de 11 a 14 años: Un estudio longitudinal

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Abstract
In adults, plyometric training can positively influence repeated sprint ability, and sprint training can influence vertical jump capacity. However, in children and adolescents, such influences are not yet clear. The aim of this study was to evaluate the effect of plyometric training on repeated sprinting ability and the effect of repeated sprint training on vertical jump performance in young volleyball players of both sexes. Longitudinal study with a sample of 30 adolescents, aged 11 to 14 years. The volunteers were divided into a control group, a plyometric training group, and a sprint training group, and they underwent six weeks of training (two sessions per week). Their repeated sprint ability was assessed using photocell technology, and their vertical jump capacity was evaluated on a platform with an interruption system. There was a significant difference in pre- and post-training within the groups. The Sprint Group showed improvement in the best sprint (p=0.023) and worst sprint (p=0.10). The group that performed additional plyometric training also showed improvement in the best sprint (p=0.004) and worst sprint (p=0.008). As for the countermovement vertical jump, the Sprint Group showed a significant difference from pre-training (5.04±0.67) to post-training (5.37±0.54). The repeated sprint training proved to be effective in improving both repeated sprint and vertical jump capabilities.
Keywords: Sports; Adolescents; Plyometric exercise; Running.

Resumo
Em adultos, o treinamento pliométrico pode influenciar positivamente a capacidade de sprint repetido, e o treinamento de sprint pode influenciar a capacidade de salto vertical. Entretanto, em crianças e adolescentes, essas influências ainda não estão claras. Desta forma, o estudo tem como objetivo avaliar o efeito do treinamento pliométrico sobre a capacidade de sprint repetido e o efeito do treinamento de sprint repetido sobre o desempenho de salto vertical em jovens atletas de vôlei de ambos os sexos. Estudo longitudinal com uma amostra de 30 adolescentes, com idades entre 11 e 14 anos. Os voluntários foram divididos em um grupo de controle, um grupo de treinamento pliométrico e um

grupo de treinamento de corrida, e foram submetidos a seis semanas de treinamento (duas sessões por semana). A capacidade de sprint repetido foi avaliada usando a tecnologia de fotocélula e a capacidade de salto vertical foi avaliada em uma plataforma com um sistema de interrupção. Houve uma diferença significativa no pré e pós-treinamento entre os grupos. O Grupo Sprint apresentou melhora no melhor sprint (p=0,023) e no pior sprint (p=0,10). O grupo que realizou treinamento pliométrico adicional também apresentou melhora no melhor sprint (p=0,004) e no pior sprint (p=0,008). Quanto ao salto vertical de contramovimento, o Grupo Sprint apresentou uma diferença significativa do pré-treinamento (5,04±0,67) para o pós-treinamento (5,37±0,54). O treinamento de sprint repetido demonstrou ser eficaz para melhorar as capacidades de sprint repetido e de salto vertical.
Palavras-chave: Esportes; Adolescentes; Exercício pliométrico; Corrida.

Resumen
En los adultos, el entrenamiento pliométrico puede influir positivamente en la capacidad de sprint repetido, y el entrenamiento de sprint puede influir en la capacidad de salto vertical. Sin embargo, en niños y adolescentes, estas influencias aún no están claras. El objetivo de este estudio fue evaluar el efecto del entrenamiento pliométrico en la capacidad de sprint repetido y el efecto del entrenamiento de sprint repetido en el rendimiento de salto vertical en jóvenes jugadores de voleibol de ambos sexos. Estudio longitudinal con una muestra de 30 adolescentes, de edades comprendidas entre los 11 y los 14 años. Los voluntarios se dividieron en un grupo de control, un grupo de entrenamiento pliométrico y un grupo de entrenamiento de sprint, y se sometieron a seis semanas de entrenamiento (dos sesiones por semana). Se evaluó su capacidad de sprint repetido mediante tecnología de fotocélulas y su capacidad de salto vertical en una plataforma con un sistema de interrupción. Hubo una diferencia significativa entre los grupos antes y después del entrenamiento. El grupo de sprint mostró una mejora en el mejor sprint (p=0,023) y en el peor sprint (p=0,10). El grupo que realizó un entrenamiento pliométrico adicional también mostró mejoras en el mejor sprint (p=0,004) y el peor sprint (p=0,008). En cuanto al salto vertical con contramovimiento, el grupo de sprint mostró una diferencia significativa entre el pre-entrenamiento (5,04±0,67) y el post-entrenamiento (5,37±0,54). El entrenamiento de sprint repetido demostró ser eficaz para mejorar tanto la capacidad de sprint repetido como la de salto vertical.
Palabras clave: Deportes; Adolescentes; Ejercicio pliométrico; Carrera.

1. Introduction

In the realm of sports, the primary goal of training is to promote adaptations that enhance an individual's competitive performance. Therefore, in order to conduct an effective and appropriate training program, it is necessary to understand the specific physical and physiological demands of each sport (Buchheit & Laursen, 2013). In volleyball, the strength and power of the lower limbs have gained prominence in sports science due to the physical capacities required in competitive practice, such as jumps, sprints, and frequent changes of direction (Kim & Park, 2016; Pereira et al., 2015; Kaynak et al., 2017; Nazaraki et al., 2009).

Therefore, it is important to design training sessions aimed at helping athletes achieve better performance in these capacities. To achieve this, increasing the strength and power of the lower limbs is essential, for which methods like plyometric training and repeated sprint training are commonly used (De Vilarreal et al., 2009; De Vilarreal et al., 2012; Taylor et al., 2015). Plyometric training involves generating greater force in a short amount of time to perform a movement, such as a vertical jump, for example (Asadi et al., 2017); whereas repeated sprint training involves performing short-duration, high-intensity stimuli with brief intervals of passive recovery (Bishop et al., 2011). The Repeated Sprint Ability (RSA) has been used as an important parameter of athletic performance.

For both capacities, the stretch-shortening cycle is present, characterized by the enhancement of a concentric muscle contraction through the prior performance of an eccentric muscle contraction (Markovic & Mikulic, 2010; Gantois et al., 2018; Bishop et al., 2011). Previous studies have demonstrated that plyometric training can lead to improvements in RSA. Hopper (2017) showed that after six weeks of combined resistance and plyometric training, there was a significant improvement in sprint speed for 10 and 20-meter tests. Additionally, it is known that repeated sprint training was able to cause adaptations for the improvement of vertical jump performance and RSA in adults (Gantois et al., 2018).

With that being said, the repeated sprint training method can be used as an alternative to plyometric training (Gjinovci et al., 2017). During a vertical jump, the body undergoes a flight phase against gravitational force, and upon landing, the impact on the joints is 100% of its original weight (Máximo & Alvarenga, 2006), which can have a negative impact on the athlete's sports performance. Therefore, considering the excessive volume of jumps performed by volleyball players, repeated sprint training can be a strategy to minimize jump volume (Moraes & Bassedone, 2007; Gjinovci et al., 2017).

Furthermore, the excess impact generated by the large number of jumps increases the likelihood of injury to the athletes' joints (Lysens et al., 1995; Moraes & Bassedone, 2007). Considering the pediatric population, it is necessary to employ strategies that minimize this impact and prolong the athlete's longevity, as training overload can lead to physical and mental stress, ultimately resulting in the abandonment of the sport (Weinberg & Gould, 2017).

Thus, this study is based on the initial hypothesis that there will be no significant differences between plyometric training and repeated sprint training in terms of improving repeated sprint capacity and vertical jump performance. Therefore, the study aims to evaluate the effect of plyometric training on repeated sprint capacity and the effect of repeated sprint training on vertical jump performance in male and female volleyball players aged between 11 and 14 years old.

2. Methodology

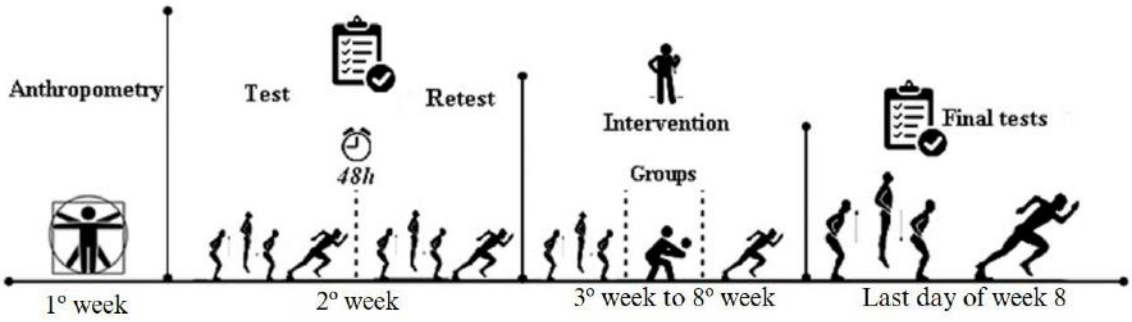
This is a longitudinal study with a parallel design (Thomas; Nelson & Silverman, 2009), involving a sample of 30 participants of both genders, aged between 11 and 14 years. The subjects were selected non-probabilistically from participants in social projects for volleyball initiation in the city of Natal, RN, Brazil. The tests were conducted strictly following chosen protocols to observe the variables in question, following procedures previously authorized by the Ethics and Research Committee (CEP) of the Federal University of Rio Grande do Norte - Lagoa Nova (#2.825.006). The approval followed the Guidelines for data collection in humans, according to Resolution 466/12 of the National Health Council, on 12/12/2012, strictly respecting the ethical principles contained in the Helsinki Declaration.

The sample was randomly divided into three groups: the Control Group (n=10), subjected to regular volleyball training; the Plyometric Group (n=10), subjected to regular training with the addition of plyometric training intervention; and the Sprint Group (n=10), also subjected to regular training with the addition of repeated sprint training intervention.

As inclusion criteria, research participants should be between 11 and 14 years old and should not present musculoskeletal injuries, any type of disability, or health problems. Additionally, it was necessary to provide a duly signed Informed Consent Form and Assent Form by the guardians to participate in the study. Those who refused to participate in at least one of the proposed test stages were not included in the sample.

The present study lasted for eight weeks. The first week was dedicated to characterizing the samples through the collection of anthropometric measurements and pre-intervention assessments of repeated sprint and vertical jump capacities. Following this, in the second week, the reproducibility of the repeated sprint and vertical jump tests was conducted. Subsequently, six weeks of intervention with training were carried out, comprising two sessions per week, each lasting 60 minutes. The weekly interval between sessions was 48 hours. At the end of the eighth week (sixth week of intervention), we repeated the assessments (See Figure 1).

Figure 1 - Study design.



Source: Authors.

The assessment of repeated sprint capacity involved performing 6 sprints of 20 meters with a 20-second interval between each sprint. For analysis, the following parameters were used: best sprint (sprint 1); worst sprint (sprint 6); total time (sum of all sprints); average time (sum of all sprints divided by 6); and sprint decrement (Equation 1).

Equation 1: Sprint Decrement = (total time/ideal time - 1) x 100

Ideal time = best performance multiplied by six (SPENCER et al., 2006).

Each sprint was recorded using the photocell system (Speed Test 6.0 CEFISE® Brazil), positioned every 10 meters along the total 20-meter distance. The test demonstrated reproducibility for the analyzed sample (Sprint 1: ICC = 0.960. Sprint 6: ICC = 0.910. Average time: ICC = 0.970. Total test time: ICC = 0.950. Sprint decrement %: ICC = 0.680).

The vertical jump performance was assessed using the countermovement jump test with an interruption system provided by CEFISE® (São Paulo, Brazil) connected to the Jump System software (CEFISE® Brazil). For the test, participants followed Bosco's recommendations (1983), standing on the platform with hands on the waist, performing the eccentric phase by flexing the hip, knee, and ankle joints, and then executing the jump (triple extension of the ankle, knee, and hip). Participants were instructed to land at the same take-off point and keep their legs extended during the airborne phase. Two jumps were performed with a 60-second interval between them, and the highest value in centimeters was recorded. The test demonstrated reproducibility for the analyzed sample (ICC = 0.980).

Biological age was determined using the prediction equation described by Cabral (2013), where skeletal age is represented as biological age. It is defined by the following equation:

Skeletal Age = -11.620 + 7.004 (height (m)) + 1.226 (Dsex) + 0.749 (age (years)) – 0.068 (Tr (mm)) + 0.214 (CAC (cm)) – 0.588 (Du (cm)) + 0.388 (Df (cm)).

(m): Meters. Dsex: 0 for male and 1 for female. Tr: Tricipital skinfold thickness. (mm): Millimeters. CAC: Corrected arm circumference. (cm): Centimeters. Du: Humerus diameter. Df: Femur diameter.

For anthropometric assessments with participants barefoot and wearing light clothing, body mass was measured using a Filizola® digital scale with a capacity of 150 kg and a variation of 0.10 kg (São Paulo, Brazil). Height was determined using a Sanny® stadiometer (precision of 0.1 mm) (São Paulo, Brazil). For these procedures, we followed the protocols of the International Society for the Advancement of Kinanthropometry (ISAK) (Silva e Vieira, 2020).

Circumferences and Diameters: To measure circumferences and diameters, we followed the procedures outlined by Marfell-Jhones et al., 2006 using a SANNY anthropometric tape (precision of 0.1 mm) for circumference measurements, and a SANNY caliper for diameter measurements, both of Brazilian manufacture. We measured the Arm Circumference (AC),

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Corrected Arm Circumference (CAC), which refers to the arm circumference in centimeters minus the value of the tricipital skinfold (TS) converted into centimeters. We also measured the Biepicondylar Femur Diameter (BD) and Biepicondylar Humerus Diameter (BH).

Skinfolds: Skinfold measurements were taken on the right side of the subjects and repeated three times. The mean was used as the measurement value. The SANNY scientific skinfold caliper was used to measure the skinfolds. Only the Tricipital Skinfold was measured.

Chronological Age in years was determined by summing the individual's months of life from their date of birth, divided by 12, resulting in their chronological age in years (Malina, Bouchard e Bar-or, 2009).

The training program lasted for 6 weeks, with 2 sessions per week, each lasting 60 minutes, totaling 12 training sessions by the end of the intervention. Volunteers performed the protocols outlined in Tables 1 and 2. The intervention was conducted in conjunction with the participants' regular volleyball training.

Table 1 - Training program of the group that performed Repeated Sprints.

Sprint Trainning				
Week	**Set**	**Reps**	**Sprint**	**Rest interval**
1	1	6	20m	3'
2	2	6	20m	3'
3	2	8	20m	3'
4	3	6	20m	3'
5	3	6	20m	3'
6	2	6	20m	3'

Source: Authors.

Table 2 - Training program for the group that performed Plyometrics.

Plyometric Jump Training			
Week	**Exercises**	**Set**	**Reps**
1	CMJ with arms free	2	6
	Horizontal with arms free	2	6
	Lateral	2	6
2	CMJ with arms on hips	2	6
	Horizontal with arms on hips	2	6
	Drop Jump	2	7
3	Drop jump + jump	3	4
	Multiple horizontal jumps	2	6
	Lateral alt.	2	8
4	CMJ with arms free	3	6
	Horiz alt.	2	4
	Drop jump	2	8
5	Drop jump + jump	3	6
	Multiple horizontal jumps	3	4
	Lateral	2	7
6	Box Jump	2	6
	CMJ lateral	2	6
	Drop Jump	2	8

Source: Authors.

For statistical analysis the normality of the data was assessed using the Shapiro-Wilk test and z-scores for skewness and kurtosis (-1.96 to 1.96). Results were presented as mean and standard deviation. Variance homogeneity was evaluated using the Levene test, and sphericity was tested using the Mauchly test. For sprint data, assumptions were not violated. However, vertical jump data indicated a non-parametric distribution. Consequently, data were transformed using the square root, and after transformation, assumptions of normality, homogeneity, and sphericity were not violated.

To compare the intervention's effect on dependent variables, a three-way mixed ANOVA ([3] condition × [2] time) was employed with Bonferroni post-hoc tests for repeated measures, considering interaction effects between groups and time. Delta was used to compare the variation in physical capacities within groups (post-pre), and a one-way ANOVA was utilized to compare the variation in physical capacities between groups, with Bonferroni post-hoc tests. The significance level was set at $p < 0.05$.

3. Results

Table 3 depicts the characterization of the volunteers, showing no differences in any analysis ($p > 0.05$), particularly concerning biological age, which is a variable with a strong influence on various other study variables.

Table 3 - Sample characterization.

Variables	Control $_{(n=10)}$	Jump $_{(n=10)}$	Sprint $_{(n=10)}$	P value
BMI	19,95 ± 2,56	18,79 ± 2,56	19,07 ± 1,83	0,531
Age	13,31 ± 1,35	13,00 ± 1,16	13,16 ± 1,46	0,730
Mass	50,45 ± 8,19	47,08 ± 11,60	48,94 ± 10,94	0,777
Height	1,57 ± 0,19	1,54 ± 0,10	1,65 ± 0,22	0,703
BA	13,92 ± 2,46	14,46 ± 2,21	14,08 ± 4,48	0,994

Height shown in median and interquartile range. BMI (Body Mass Index); BA (Biological age by skeletal age). Source: Authors.

Table 4 displays the comparison of groups at the pre-intervention moment, indicating no significant differences ($p > 0.05$). This suggests that all groups exhibited similar characteristics at the commencement of the intervention procedures.

Table 4 - Capacity comparisons of repeated sprints.

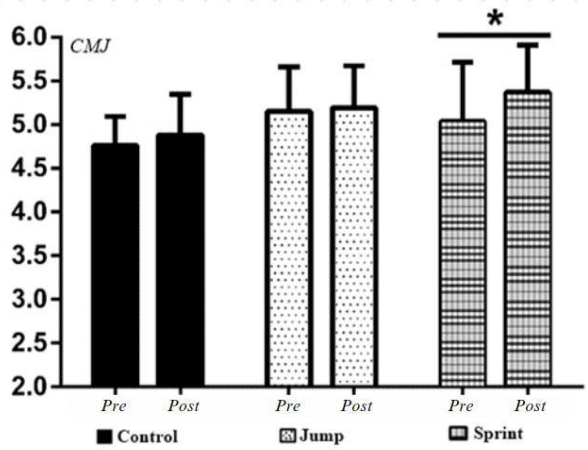
Variables	Control $_{(n=10)}$		Plyometrics $_{(n=10)}$		Sprint $_{(n=10)}$	
	Pre	Post	Pre	Post	Pre	Post
Sprint 1	3,75 ± 0,31	3,72 ± 0,24	3,64 ± 0,27	3,50 ±0,30*	3,69± 0,35	3,57 ± 0,41*
Sprint 6	4,11 ± 0,37	4,07 ± 0,34	4,02 ± 0,39	3,80 ± 0,32*	4,08 ± 0,39	3,86 ± 0,42*
Sum	23,62 ± 2,07	23,20 ± 1,56	22,84 ± 1,69	21,97 ± 1,80*	23,13 ± 2,03	22,22 ± 2,42*
Average	3,94 ± 0,35	3,87 ± 0,26	3,81 ± 0,28	3,66 ± 0,30*	3,86 ± 0,34	3,70 ± 0,40*
Decrease %	4,88 ± 1,99	3,91 ± 0,88	4,49 ± 2,23	4,60 ± 1,30	4,69 ± 1,68	3,83 ± 1,50

* Significant difference in the effect of time. Results expressed in seconds. Source: Authors.

After the intervention period, no significant time effect was demonstrated in the comparison between groups ($p > 0.05$). However, a significant difference was observed in the pre- and post-intervention within groups, particularly for those who underwent the jump and sprint protocol. Group 3 showed improvement in the best sprint ($p = 0.023$), worst sprint ($p = 0.10$), average time ($p = 0.003$), and total time ($p = 0.003$). The group that engaged in additional jump training also exhibited improvement in the best sprint ($p = 0.004$), worst sprint ($p = 0.008$), average time ($p = 0.004$), and total time ($p = 0.003$).

Figure 2 illustrates that the only group displaying a difference in pre- and post-intervention conditions concerning vertical jump was the sprint group.

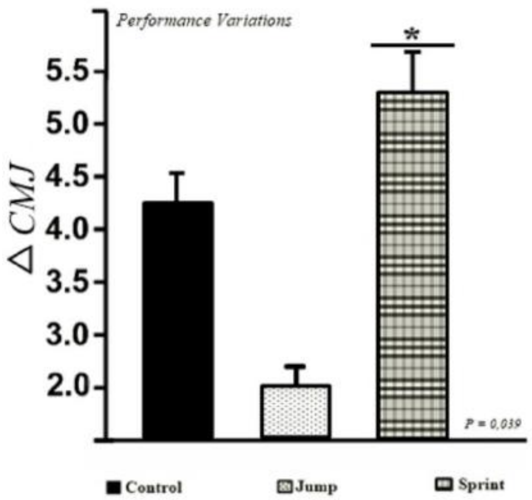
Figure 2 - Effect of interventions on vertical jump countermovement transformed by the square root.



*Significant difference in time effect. Source: Authors.

Figure 3 presents the delta values regarding intra-group performance variations, wherein the sprint group shows statistical significance.

Figure 3 - Comparison between performance variations. CMJ: Countermovement jump.



*Differences between sprinting and jumping. Source: Authors.

4. Discussion

The present study aimed to assess the effect of plyometric training on repeated sprint ability (RSA) and evaluate the effect of repeated sprint training on vertical jump performance in male and female volleyball players aged 11 to 14. Our initial hypothesis was that there would be no significant differences between plyometric and repeated sprint training regarding improvements in RSA and vertical jump capacity (VJC). Our hypothesis was partially confirmed as we found that both repeated sprint and plyometric training were effective in improving RSA. However, there was no significant difference compared to the control group, suggesting that additional training (plyometric or repeated sprint) did not significantly enhance RSA. Furthermore, for improving VJC, repeated sprint training proved superior to plyometric training.

Repeated sprint involves high-intensity, short-duration stimuli with short rests, characterized as an activity with greater anaerobic capacity, where the stretch-shortening cycle enhances motor actions (Taylor et al., 2015). Soares-Caldeira et al., (2014) found no improvement in RSA after an 11-week intervention in futsal athletes, suggesting that additional training may not be necessary due to the regular futsal training already incorporating sprint characteristics. However, improvements were noted in sprint ability. In a study by Kaynak et al. (2017), six weeks of repeated sprint training before conventional volleyball training resulted in favorable outcomes, including improvements in sprint, aerobic, and anaerobic capacities. Gjinovci (2017) evaluated the influence of 12 weeks of plyometric training on 20-meter sprint and body composition, showing positive results in performance.

When comparing VJC between groups, no statistical differences were observed between the types of training; both repeated sprint and plyometric training led to improvements in vertical jump capacity. However, analyzing variations, the group engaging in additional sprint training showed a significant difference compared to the plyometric training group. These results may be justified by the biomechanical similarity between sprinting and plyometric jumping movements (Buhrle & Schmidtbleicher, 1981; Abdelkrim et al., 2007; Gjinovci et al., 2017).

The finding that repeated sprint training led to improvements in vertical jump capacity may be related to enhanced synchronization of motor units (Harrison et al., 2004; Markovic & Mikulic, 2010). In this condition, efficient utilization of the stretch-shortening cycle of muscles leads to proportional energy elastic utilization. Higher displacement speed results in greater force, allowing for more efficient stretch-shortening cycles (Shalfawi et al., 2011; Gantois et al., 2018).

Consistent with our findings, Taylor et al., (2015) showed that sprint training effectively improved power, speed, sprint capacity, and endurance. A similar outcome was observed in the study by Buchheit et al., (2010), where repeated sprint training induced more significant improvements in jump height than vertical jump training with countermovement in young football players.

Attene et al. (2015) analyzed two types of sprint training in adult basketball players, repeated sprint with one change of direction (SR1) and intensive repeated sprint with two changes of direction (SR2). Both types of training led to improved jump performance. Dello Iacono et al., (2016) also found positive results with repeated sprints in handball players, with a significant improvement in vertical jump capacity.

Regarding the interaction between groups, it's important to note that the study results were not influenced by maturation or other variables, as the groups did not show homogeneity in their characteristics.

5. Conclusion

Based on the study results, we can conclude that both the repeated sprint training method and the plyometric training method lead to improvements in repeated sprint capacity, with no significant differences observed between the applied methods. However, concerning the enhancement of vertical jump capacity, repeated sprint training demonstrated better performance results compared to the plyometric training method.

The results of this study provide sports professionals with the opportunity to optimize training prescription by demonstrating methodologies that improve both jump and sprint performance. Additionally, the study suggests strategies that can help minimize the risks of impact-related injuries in this age group.

The limitations of the present study include influential variables that may affect the results, such as the lack of data on participants' sleep, assessment of dietary patterns, and the study's sample size. Therefore, it is suggested that future studies be conducted with control over these variables.

Despite the relevant findings of this study, some gaps need to be filled by future research, given its limitations. We therefore suggest that further studies include data on the participants' sleep, evaluate the dietary patterns of youth athletes in detail, and use these training methodologies in different age groups and sports that require jumping and sprinting in order to gain a more comprehensive understanding of the effects in a wide variety of contexts. In this way, it will open up a basic range for participants involved in everyday sports training.

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