

Effects of a sprint and plyometric warm-up protocol on vertical jump height and power in adolescent female volleyball players. A randomized crossover study

Efectos de un protocolo de calentamiento sprint y pliométrico sobre la altura y la potencia de salto vertical en jugadoras de voleibol adolescentes. Un estudio cruzado aleatorizado

*Carlos S. Mancilla, **Kimmy Hood Maldonado, **Matías Hebel Lorca, *Jeosselinee Castro Pérez, *Paulina Muñoz Albarrán, *Daniel Martínez-Lema, *Juan P. López Pinilla, ***Francisco Guede-Rojas
*Universidad Arturo Prat (Chile), **Universidad Santo Tomás (Chile), ***Universidad Andres Bello (Chile)

Abstract. The purpose of this study was to compare the immediate effects of a plyometric warm-up protocol (PWU) and a sprint warm-up protocol (SWU) on jumping performance in female volleyball players aged 14-16 years. Through a cross-over experimental design, 18 female players were randomly divided into two groups, each receiving both warm-up protocols (PWU and SWU). Before and after each protocol, height and jumping power were evaluated in squat jump (SJ), countermovement jump (CMJ), and Abalakov (ABK) tests using the DM jump® contact mat. Both warm-up protocols significantly improved SJ, CMJ, and ABK performance ($p < .05$), although mainly for jump height. The comparison between both warm-up protocols in the post-test showed no significant differences ($p > .05$), although the greatest percentage increase in jump height and power was obtained with the SWU. The ANOVA showed significant differences in group 1 (initially assigned to PWU) for all tests except for CMJ and ABK power. In group 2 (initially assigned to SWU), the ANOVA also showed significant differences, except for SJ and CMJ power. It is concluded that both warm-up protocols improve jump height and power; however, SWU shows a more favorable trend than PWU. From a practical perspective, the preliminary findings of this pilot study can provide useful guidelines for the warm-up process; however, further randomized controlled studies with adequate statistical power are required for more robust conclusions.

Keywords: warm-up exercise, volleyball, muscle strength, athletic performance, adolescent

Resumen. El propósito de este estudio fue comparar los efectos inmediatos de un protocolo de calentamiento pliométrico (PWU) y un protocolo de calentamiento de sprint (SWU) sobre el rendimiento de salto en jugadoras de voleibol de 14-16 años. Mediante un diseño experimental cruzado, 18 jugadoras fueron divididas aleatoriamente en dos grupos, cada uno de los cuales recibió ambos protocolos de calentamiento (PWU y SWU). Antes y después de cada protocolo, se evaluó la altura y la potencia en las pruebas de salto en cuclillas (SJ), salto con contramovimiento (CMJ) y Abalakov (ABK) utilizando la alfombra de contacto DM jump®. Ambos protocolos de calentamiento mejoraron significativamente el rendimiento en SJ, CMJ y ABK ($p < .05$), aunque principalmente para la altura de salto. La comparación entre ambos protocolos de calentamiento en la post-prueba no mostró diferencias significativas ($p > .05$), aunque el mayor incremento porcentual en la altura y potencia de salto se obtuvo con el SWU. El ANOVA mostró diferencias significativas en el grupo 1 (inicialmente asignado a PWU) para todas las pruebas, excepto para la potencia de CMJ y de ABK. En el grupo 2 (asignado inicialmente a SWU), el ANOVA también mostró diferencias significativas, excepto para la potencia de SJ y de CMJ. Se concluye que ambos protocolos de calentamiento mejoran la altura y la potencia de salto; sin embargo, SWU muestra una tendencia más favorable que PWU. Desde una perspectiva práctica, los hallazgos de este estudio piloto pueden proporcionar directrices útiles para el proceso de calentamiento; sin embargo, se requieren más estudios controlados aleatorizados con una potencia estadística adecuada para obtener conclusiones más robustas.

Palabras claves: ejercicio de calentamiento, voleibol, fuerza muscular, desempeño atlético, adolescente

Fecha recepción: 17-03-22. Fecha de aceptación: 06-02-23

Francisco Guede-Rojas
francisco.guede@unab.cl

Introduction

Vertical jumping ability is a determinant variable in volleyball performance required in most of its technical gestures (Ruffieux et al., 2020; Sattler et al., 2015). The purpose of explosive movements and vertical jumps associated with countermovements is to generate the necessary power to overcome the opponent, so these skills should be favored before training or competition (Forte et al., 2019). Overall physical performance, vertical jump, lower extremity strength, and power improve with chronological age (Karatrantou et al., 2019). In addition, gender differences in body composition and physiological responses to physical exercise make it necessary to distinguish them in sports planning (Li et al., 2016).

Adolescents' level of physical conditioning can influence their sports performance, so their preparation should be oriented to each sport discipline (Karuc et al., 2020).

Likewise, educational guidance and pre-competitive physical preparation are recommended for young volleyball players to improve their performance and prevent injuries (Mizoguchi et al., 2020). Thus, well-oriented physical education classes are essential for young adolescent athletes (Marinho et al., 2021).

Warm-up is a physical activity performed before a sports competition and usually consists of low-intensity aerobic exercises (Andrade et al., 2015). It aims to increase the metabolic activity of muscle tissue, improving contractile response and enzymatic activity (Ghareeb et al., 2017; Russell et al., 2015). Warm-up can generate other changes, such as post-activation potentiation (PAP) and elevation of basal VO₂ to improve performance (McGowan et al., 2015; Silva et al., 2018). It is also postulated that a well-designed warm-up helps to increase concentration for the subsequent task optimizing performance (Neiva et al., 2015).

It has been suggested that a warm-up routine is essential to prepare the body for the subsequent effort, so great importance is given to this process (Hassan et al., 2020). Despite this, it is complex to establish an effective and efficient warm-up routine due to the variety of existing techniques and the experience of coaches and athletes (Mizoguchi et al., 2020; Seitz & Haff, 2016).

Few studies have analyzed the effectiveness of warm-up strategies, and the current literature offers limited data on their applications adapted to sports activity (Buttifant & Hrysomallis, 2015). Furthermore, because most studies have been conducted in laboratory conditions with poor reproducibility in the field, it has been recommended to extend the evidence to different populations and with different types of exercises to provide more scientific support and more precise answers about the effects of warm-up on different neuromuscular variables (e.g., strength, power, speed, and acceleration), facilitating the formulation of protocols adapted to sports practice (Wheeler-Botero, 2021).

Active or dynamic warm-up protocols have demonstrated better results than passive warm-up (Langdown et al., 2019), so they are a commonly used strategy to promote muscle power, maximize joint ranges, and improve performance (Johnson et al., 2019). Therefore, coaches are constantly looking for the most effective strategies to improve this ability in their players (Ruffieux et al., 2020).

To date, the acute effects of dynamic warm-ups are unclear, and there is no consensus about their applications in youth and adult athletes (Turki et al., 2020). However, in preadolescents, dynamic warm-ups related to sport-specific biomechanics have been shown to improve performance and reduce injury risk (Thompson et al., 2017). Furthermore, in young volleyball players, these strategies have shown improvements in lower extremity strength and increases in height and jumping power (Kruse et al., 2015). Thus, exercises aimed at improving jumping in young volleyball players should target the reactive and explosive capabilities of the neuromuscular system (Ruffieux et al., 2020).

Agility is a determining factor for optimal performance in team sports, among which is volleyball. Its activation can be favored through various simple and high-intensity execution strategies, such as sprinting, generating greater adherence of athletes to these protocols (Raya-González et al., 2018; López-Álvarez & Sánchez-Sixto., 2021; Gómez-Álvarez et al., 2021; Carlos-Vivas et al., 2020). Thus, the sprint warm-up (SWU) has positively affected jumping and agility variables, suggesting that it is important to consider it in team sports (Silva et al., 2018). In addition, this warm-up modality involves a greater mobilization of the energy substrates available for the consecutive activity (Vargas Fuentes et al., 2015).

Plyometrics promotes the stretch-shortening cycle by combining an eccentric contraction followed by a concentric contraction, activating the stretch reflex and energy storage in the elastic elements of skeletal muscle (Reyes,

2021). Plyometric warm-up (PWU) has been reported to improve vertical jump through the PAP mechanism (Cilli et al., 2014) and has been suggested in a wide range of sports, including volleyball (Ayala et al., 2016; Zois et al., 2015; Viela et al., 2021). Plyometric activities positively affect intramuscular coordination, increased neural efficiency, proprioception, and neuromuscular control (Mroczek et al., 2018). Thus, this strategy has been widely used to increase strength and speed to improve performance in explosive muscle actions (Martinez-Rodriguez et al., 2017). However, the evidence is currently controversial. In this regard, Picón-Martínez et al. (2019) report in a systematic review the scarcity of studies in the area, including poor differentiation according to sex, training level, and experience of volleyball players. Moreover, few studies have focused specifically on young volleyball players (Marinho et al., 2021).

The purpose of this study was to compare the immediate effects of PWU versus SWU on vertical jump height and power in 14- to 16-year-old female volleyball players. Due to the greater similarity of PWU to the inherent motor gestures of volleyball, it is hypothesized that this modality offers better results than SWU.

Materials and Methods

Study design

The study was conducted under a pilot crossover design. It was carried out between the third and sixth week of an annual 8-week precompetitive period because, in this phase, coaches concentrate on improving the physical performance and technical skills of youth athletes. Subjects were coded and randomly assigned to two experimental groups (groups 1 and 2) using the online software randomizer.org. During the first experimental period, group 1 started with PWU, and group 2 started with SWU. After a 2-week washout, we proceeded to a second experimental period in which the warm-up protocols were exchanged. The washout period was established based on recommendations for crossover studies (Zurita-Cruz et al., 2018) and previous similar studies (Munshi et al., 2022; Carvalho et al., 2012). Jump height and power were evaluated before and immediately after each warm-up intervention (PWU and SWU) in the timeline: T1-T2-T3 and T4. Each experimental period was performed in a single session. Figure 1 shows the different experimental phases of the study.

Subjects

A non-probabilistic sampling was performed by invitation to all members of a local volleyball club who met the following inclusion criteria: females between 14 and 16 years old without musculoskeletal injuries (last three months). All subjects who could not perform the experimental protocols due to different health conditions were excluded. Of the 26 subjects initially invited, four expressed their refusal to participate, and four did not meet the eligibility criteria due to injury. In total, 18 female players participated in the study (age=14.6±1.0 years;

weight= 62.7 ± 10.8 kg; height= 1.63 ± 0.05 m; BMI= 23.5 ± 2.0). The participants belonged to the under-16 category with an experience of 1 to 2 years. Their training frequency was three times per week, lasting 2 to 3 hours per session. Two sessions were oriented to technical preparation and game simulation, and one session was oriented to physical preparation.

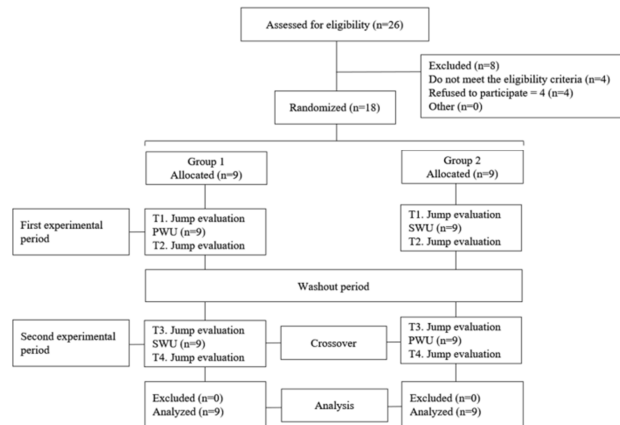


Figure 1. Flow Chart of the different phases of the study

To reduce the possible interference of uncontrolled variables, participants maintained their usual lifestyle and diet throughout the study. All participants followed their regular training plan, although to avoid fatigue, they did not train on the days of the study interventions. After the intervention and evaluation sessions, participants continued with their daily activities.

Before any study procedure, all requirements and possible risks were explained. Then, written informed consent was obtained from both the participants and their parents/guardians. This study followed the guidelines of the Helsinki declaration and was approved by the Bioethics Committee of Universidad Santo Tomás, Chile (ORD: N° 159-2019).

Warm-up protocols

The protocols were performed by a trained external professional and applied individually to each subject according to the assigned group. Group 1 started with PWU and group 2 with SWU, and after the washout period, they were reversed. Both protocols were selected based on the available evidence, which considers the sporting gesture and the type of energy metabolism predominant in volleyball (Lopes et al., 2019). In addition, the professional previously conducted a group familiarization to reduce errors and optimize the performance of the protocols.

The high-intensity PWU followed the protocol proposed by Andrade et al. (2015). First, three series of eight countermovement jumps were performed (30-second pause between series). Next, three sets of eight drop jumps (DJ) of 40 cm height were performed (30-second pause between sets). The determination of the DJ height is consistent with the evidence, which recommends heights between 20 to 60 cm (Picón-Martínez et al., 2019; Garrido-Chamorro et al., 2012).

The high-intensity SWU followed the protocol proposed by Nickerson et al. (2018). It consisted of four sets of 40-meter sprints (20 meters out and 20 meters back) with a 30-second rest between each set.

Jump evaluations

Before the measurements, the subjects were familiarized with the tests: squat jump (SJ), countermovement jump (CMJ), and Abalakov jump (ABK). The evaluations were performed at the usual training site, with the clothing and footwear used for training and competition. The Prometheus DM-Jump® model 2.5 contact platform was used to determine the height in centimeters (cm) and power in watts (W) of the jumps. The platform has been validated through its use in a previous study with similar characteristics (Véliz et al., 2016).

The initial evaluation (pre-test) was performed on the subjects without warm-up. Then, the corresponding warm-up protocols were applied, and after 2 minutes of rest, a new jump evaluation (post-test) was performed on each subject individually.

The SJ was performed from the bipedal position with the hands on the waist and maintaining an approximate knee flexion of 90° (Bosco, 1994). The posture was monitored using the PhysioCode® app (available for IOS and Android). After a verbal cue, the subject performed a vertical jump without countermovement and assistance from the upper extremities. This jump assesses explosive strength without using elastic energy or the myotatic reflex (Petrigna et al., 2019). The CMJ was performed from the neutral bipedal position with hands on the waist. After a verbal cue, the subject performed a rapid flexion-extension of the lower limbs followed by a vertical jump (Bosco, 1994). This jump assesses explosive-elastic strength (Vittori., 1990; Petrigna et al., 2019). The ABK was performed from the neutral bipedal position with hands on the waist. After a verbal cue, the subject performed a rapid flexion-extension of the lower limbs followed by a vertical jump with the assistance of the upper limbs (Vittori, 1990). This jump evaluates the explosive-elastic strength associated with the inertia provided by the countermovement of the upper limbs.

In each test (SJ, CMJ, and ABK), five jumps were performed with a 30-second pause between each one. A pause of 1 minute was established between each test. For data analysis, the best result of each attempt was considered. All evaluations were guided by a trained external professional. If a jump was incorrect, it was invalidated and repeated.

Statistical analyses

The results were described using the mean and standard deviation. Verification of normality and homoscedasticity was performed using the Shapiro-Wilk and Levene tests, respectively. Paired t-test was used for comparisons between the pretest and post-test in both protocols (PWU and SWU). Comparison between the warm-up protocols at post-test was performed using the independent t-test.

Effect size (ES) was calculated using Cohen's d to determine the magnitude of differences (<0.2 reflects an insignificant difference; between 0.2-0.49 small; between 0.5-0.79 moderate and ≥0.8 large) (Cohen, 1988). To compare the results between time points (T1, T2, T3, and T4) in each group, repeated measures ANOVA with a Bonferroni post hoc was used, previously verifying Mauchly's assumption of sphericity. IBM SPSS v.25 software was used with a significance level of $p < .05$ for all analyses.

Results

All participants complied with all study protocols, and no adverse events were reported. No statistically significant

differences were found between the two experimental conditions in the pretest for all dependent variables ($p > .05$).

Table 1 compares pretest and post-test measurements for each warm-up protocol. For PWU, except for SJ power, statistically significant differences were found in all measurements ($p < .05$). The increase in CMJ and ABK height was "moderate" with a percentage increase of 10.43% and 11.22%, respectively. For SWU, all variables showed statistically significant differences ($p < .05$). The increase in CMJ height was "large" with a percentage increase of 14.41%. In addition, the increase in CMJ power and ABK height were "moderate" with an increase of 6.28% and 12.25%, respectively.

Table 1. Pretest and post-test differences for each warm-up protocol. Results expressed as mean ± standard deviation

Jump	Outcome	PWU (n=18)				SWU (n=18)			
		Pretest	Post-test	%	ES	Pretest	Post-test	%	ES
SJ	Height (cm)	19.4 ± 3.4	20.6 ± 3.2*	6.22	0.36	19.8 ± 3.7	21.7 ± 4.0*	9.42	0.47
	Power (W)	297.0 ± 35.8	302.4 ± 34.9	1.82	0.15	297.2 ± 37.8	311.0 ± 40.6*	4.66	0.35
CMJ	Height (cm)	22.2 ± 4.1	24.5 ± 4.3*	10.43	0.54	22.5 ± 4.2	25.8 ± 3.8*	14.41	0.80
	Power (W)	315.7 ± 39.9	330.4 ± 36.6*	4.66	0.38	317.1 ± 40.8	337.0 ± 34.4*	6.28	0.52
ABK	Height (cm)	25.1 ± 4.2	27.9 ± 4.2*	11.22	0.66	25.6 ± 4.7	28.7 ± 4.5*	12.25	0.68
	Power (W)	336.0 ± 43.6	349.4 ± 35.1*	3.96	0.33	338.4 ± 45.6	354.0 ± 41.3*	4.62	0.36

cm centimeters; W watts; PWU plyometric warm-up; SWU sprint warm-up; SJ squat jump; CMJ counter movement jump; ABK Abalakov; * p value <0.05; % percentage increase in the post-test; ES Effect size (Cohen's d)

Figure 2 shows the comparison between both warm-up protocols in the post-test. A higher percentage increase was found for SWU, varying between 1.34% and 5.08%. The ES was "small" in all cases ($p > .05$).

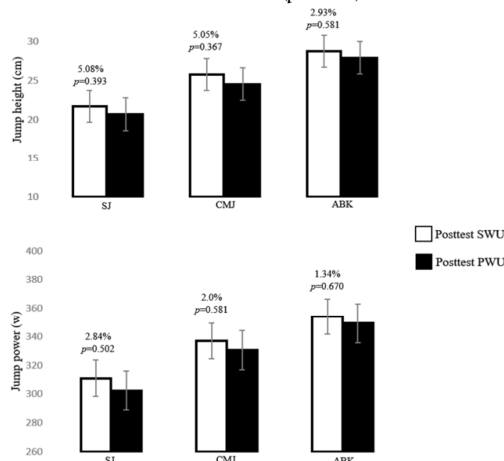


Figure 2. Differences in jump height and jump power between SWU and PWU in the Post-test

Table 2 shows the timeline comparison of group 1. The repeated measures ANOVA was statistically significant for all variables except for CMJ and ABK power. For PWU in the first experimental period (T1 vs. T2), the only statistically significant difference was found in CMJ height ($p < .05$). For SWU in the second experimental period (T3 vs. T4), a statistically significant difference was found in all results ($p < .05$), except for power in CMJ and ABK.

Table 3 shows the timeline comparison for group 2. The repeated measures ANOVA was statistically significant for all variables except for SJ and CMJ power. For SWU in the first experimental period (T1 vs. T2), a statistically significant difference was found in all results ($p < .05$), except for power in SJ and CMJ. For PWU in the second experimental period (T3 vs. T4), the only statistically significant difference was found in SJ, CMJ, and ABK height ($p < .05$). No significant differences were found in the comparisons T1 vs. T3 and T2 vs. T4.

Table 2. ANOVA and post hoc for group 1 timeline (n=9). Results expressed as mean ± standard deviation.

Jump	Outcome	PWU		SWU		p	ηp^2
		T1 (pretest)	T2 (post-test)	T3 (pretest)	T4 (post-test)		
SJ	Height (cm)	20.8 ± 2.0	21.9 ± 2.1	21.8 ± 2.5	23.8 ± 2.8 [‡]	0.000	0.543
	Power (W)	300.0 ± 34.7	299.9 ± 38.2	301.5 ± 37.0	315.6 ± 39.1 [‡]	0.002	0.451
CMJ	Height (cm)	24.3 ± 3.3	27.1 ± 2.8 [†]	24.8 ± 3.8	28.1 ± 2.9 [‡]	0.000	0.781
	Power (W)	318.3 ± 43.3	327.9 ± 25.1	320.0 ± 36.1	349.1 ± 29.7	0.077	0.341
ABK	Height (cm)	26.7 ± 3.6	29.3 ± 3.9	27.8 ± 4.3	30.9 ± 3.9 [‡]	0.002	0.536
	Power (W)	334.5 ± 15.3	343.3 ± 13.0	338.0 ± 12.5	353.2 ± 13.0	0.077	0.339

cm centimeters; W watts; PWU plyometric warm-up; SWU sprint warm-up; SJ squat jump; CMJ counter movement jump; ABK Abalakov; * post hoc T1-T3; † post hoc T1-T2; ‡ post hoc T3-T4; § post hoc T2-T4; p ANOVA value <0.05;

Table 3.
ANOVA and post hoc for group 2 timeline (n=9). Results expressed as mean \pm standard deviation.

Jump	Outcome	SWU			PWU		p	ηp^2
		T1 (pretest)	T2 (post-test)	T3 (pretest)	T4 (post-test)			
SJ	Height (cm)	17.8 \pm 3.	19.6 \pm 4.0 [†]	18.0 \pm 4.0	19.4 \pm 3.7 [‡]	0.001	0.480	
	Power (W)	292.8 \pm 40.4	306.4 \pm 43.9	293.9 \pm 38.7	304.9 \pm 33.4	0.055	0.387	
CMJ	Height (cm)	20.2 \pm 3.6	23.5 \pm 3.2 [†]	20.1 \pm 3.8	21.9 \pm 4.0 [‡]	0.002	0.730	
	Power (W)	314.1 \pm 47.0	324.9 \pm 36.1	313.0 \pm 38.7	332.9 \pm 46.9	0.066	0.274	
ABK	Height (cm)	23.3 \pm 4.0	26.61 \pm 4.1 [†]	23.5 \pm 4.3	26.6 \pm 4.2 [‡]	0.001	0.766	
	Power (W)	338.8 \pm 52.5	356.6 \pm 45.7 [†]	337.6 \pm 43.9	355.4 \pm 31.8	0.000	0.936	

cm centimeters; W watts; PWU plyometric warm-up; SWU sprint warm-up; SJ squat jump; CMJ counter movement jump; ABK Abalakov; * post hoc T1-T3; † post hoc T1-T2; ‡ post hoc T3-T4; § post hoc T2-T4; p ANOVA value <0.05; Partial Eta Square (ηp^2)

Discussion

This pilot study aimed to compare the effect of two warm-up protocols on vertical jump performance in young female volleyball players. The results indicate that both a PWU and SWU protocol achieve improved jumping performance, although the largest magnitudes of change are obtained with SWU. Eighty percent of warm-up studies favorably optimize performance; however, the effect of these interventions depends on several factors, such as intensity and duration, as well as the time elapsed between warm-up and exercise (Gil et al., 2019).

Andrade et al. (2015) compared six warm-up protocols in 10 subjects, obtaining significant increases in SJ, CMJ, and DJ height for plyometric ($p < .05$) and sprint ($p < .05$) warm-up protocols, in contrast to a reduction in jumping performance for passive warm-up protocols. In the present study, the comparison of both warm-up protocols in the post-test is not statistically significant, which agrees with a meta-analysis published by Seitz and Haff (2016), who report that there are no significant differences between high-intensity dynamic warm-up protocols. These results contrast with those presented by other authors, where electromyography showed that plyometric work improved muscle activation, resulting in better performance in explosive activities such as jumping and running (Johnson et al., 2019). Hassan et al. (2020) also suggest that a warm-up protocol considering plyometric work would improve vertical jump performance.

It is important to highlight that in this study, both protocols (PWU and SWU) tend to improve jumping performance, although SWU presents a more favorable tendency than PWU. When comparing the results in the post-test between both protocols, there are no significant differences ($p > .05$), although, in the post-hoc analysis, both protocols independently present significant improvements ($p < .05$) in SJ, CMJ, and ABK height and power. Beltrán et al. (2019) conclude that physical fitness and experience are determining factors for physical and physiological performance in plyometric activities in children and adolescents. In addition, Gil Arias et al. (2012) state that sports experience is associated with better neuromuscular responses, and Martínez-Rodríguez et al. (2017), through a systematic review, concluded that the results in jumping performance tend to be more heterogeneous in female adolescent volleyball players. Thus, considering that the subjects of the present study are adoles-

cent volleyball players in formative stages, the factors mentioned could have influenced the results of the warm-up protocols implemented; however, the greatest influence could have been linked to PWU due to its greater complexity.

Plyometric-based warm-up activities are complex to execute, require a high ability to control the movement of body segments (Marinho et al., 2021) and involve more time to influence jump execution pattern and performance (Kitamura et al., 2020). Nevertheless, Rezende et al. (2016) suggest that plyometric activities would be the most suitable to improve jumping performance compared to other high or moderate-intensity warm-up strategies, which is based on the similarity of plyometrics with the motor gestures specific to volleyball (Forte et al., 2019). On the other hand, Seitz and Haff (2016) point out that the effects of the warm-up generally depend on the muscular strength the athletes develop associated with their physical preparation. Furthermore, Kurt et al. (2018) posit that improved jumping performance is related to preventing fatigue during warm-up through exercises involving brief muscle contraction. These factors, added to the inexperience of the subjects in the present investigation, could have also affected the post-PWU versus SWU jumping performance.

The high-intensity dynamic warm-up protocol based on sprint and characterized by a lower complexity tends to generate a significant increase in jump height and power in youth volleyball players, which can be explained due to an activation of the glycolytic system and a delay in phosphocreatine (PCr) depletion, being both metabolic strategies crucial for short-duration explosive activities (Park et al., 2021). In this regard, Solon and Da Silva (2021) recommend including sprint sessions as a warm-up to improve performance; however, they also recognize that there are no significant differences concerning other dynamic warm-up protocols.

In this study, both protocols improve jumping performance, agreeing in general terms with the basics of warm-up (increase in body temperature and PAP) (Behm et al., 2016; Fradkin et al., 2010; Barbosa et al., 2020); however, a greater tendency of improvement is observed towards the SWU protocol, contrary to our initial hypothesis. This situation may be explained by the fact that the study sample is characterized by low age and motor development, incipient sports experience, and a low level of physical preparation, which may be associated with a high-

er probability of fatigue during warm-up. Therefore, all these factors are fundamental to consider when implementing warm-up protocols in this population.

Little is known about the relationship between the level of coordination and motor performance in adolescent volleyball players, being this a neglected field (Marinho et al., 2021). Therefore, more research is required about the effects of various warm-up protocols and thus elucidate the optimal methodologies to increase athletic performance depending on the discipline, competitive level, and gender of the athletes (Ghareeb et al., 2017; Creekmur et al., 2017). Then, although this study has a pilot character, it provides relevant results in the field.

The strengths of this study lie in the randomization of the experimental conditions, the blinding of the subjects, and the evaluator reducing the risk of bias. In addition, the study respected the sporting process of the subjects without affecting their training process. Finally, adolescent volleyball players in formative stages were considered, contributing to filling a knowledge gap in this population. On the other hand, the limitations of this study are related to a low sample size, the lack of a non-intervened control group, and low control over the performance of the PWU protocol.

Conclusion

It is concluded that both warm-up protocols improve jump height and power; however, SWU shows a more favorable trend than PWU. From a practical perspective, the preliminary findings of this pilot study can provide useful guidelines for the warm-up process; however, further randomized controlled studies with adequate statistical power are required for more robust conclusions.

Acknowledgments

The participation of the Victoria Volleyball Club (VI-VO) is appreciated.

References

- Alipasali, F., Papadopoulou, S. D., Gissis, I., Komsis, G., Komsis, S., Kyranoudis, A., Knechtle, B., & Nikolaidis, P. T. (2019). The Effect of Static and Dynamic Stretching Exercises on Sprint Ability of Recreational Male Volleyball Players. *International Journal of Environmental Research and Public Health*, *16*(16), 2835. <https://doi.org/10.3390/ijerph16162835>
- Andrade, D., Henriquez-Olguín, C., Beltrán, A., Ramírez, M., Labarca, C., Cornejo, M., Álvarez, C., & Ramírez-Campillo, R. (2015). Effects of general, specific, and combined warm-up on explosive muscular performance. *Biology of Sport*, *32*(2), 123-128. <http://doi.org/10.5604/20831862.1140426>
- Ayala, F., Moreno-Pérez, V., Vera-García, F. J., Moya, M., Sanz-Rivas, D., & Fernández-Fernández, J. (2016). Acute and Time-Course Effects of Traditional and Dynamic Warm-Up Routines in Young Elite Junior Tennis Players. *PLoS ONE*, *11*(4), e0152790. <https://doi.org/10.1371/journal.pone.0152790>
- Barbosa, G. M., Dantas, G. A. F., Pinheiro, S. M., Rêgo, J. T. P., Oliveira, T. L. C., Silva, K. K. F., Dantas, O. M. S. & Vieira, W. H. B. (2020). Acute effects of stretching and/or warm-up on neuromuscular performance of volleyball athletes: a randomized cross-over clinical trial. *Sport Sciences for Health*, *16*(1), 85-92. <https://doi.org/10.1007/s11332-019-00576-8>
- Behm, D. G., Blazevich, A. J., Kay, A. D., & McHugh, M. (2016). Acute effects of muscle stretching on physical performance, range of motion, and injury incidence in healthy active individuals: a systematic review. *Applied Physiology, Nutrition, and Metabolism*, *41*(1), 1-11. <https://doi.org/10.1139/apnm-2015-0235>
- Beltrán Valls, M. R., Adelantado-Renau, M., Segura-Ayala, D., Toledo-Bonifás, M., & Moliner-Urdiales, D. (2019). Nivel de desarrollo madurativo, actividad física y calidad del sueño en chicas adolescentes: proyecto DADOS (Maturational development, physical activity, and sleep quality in adolescent girls: DADOS project). *Retos*, *35*, 71–74. <https://doi.org/10.47197/retos.v0i35.60553>
- Bosco, C. (1994). *La valoración de la fuerza con el test de Bosco*. Barcelona, España: Paidotrobo.
- Buttifant, D., & Hrysonmallis, C. (2015). Effect of Various Practical Warm-up Protocols on Acute Lower-Body Power. *The Journal of Strength & Conditioning Research*, *29*(3), 656-660. <http://doi.org/10.1519/JSC.0000000000000690>
- Carlos-Vivas, J., Perez-Gomez, J., Eriksrud, O., Freitas, T. T., Marín-Cascales, E., & Alcaraz, P. E. (2020). Vertical Versus Horizontal Resisted Sprint Training Applied to Young Soccer Players: Effects on Physical Performance. *International Journal of Sports Physiology and Performance*, *15*(5), 748-758. <https://doi.org/10.1123/ijsp.2019-0355>
- Carvalho, F. L., Carvalho, M. C., Simão, R., Gomes, T. M., Costa, P. B., Neto, L. B., Carvalho, R. L., & Dantas, E. H. (2012). Acute effects of a warm-up including active, passive, and dynamic stretching on vertical jump performance. *Journal of strength and conditioning research*, *26*(9), 2447–2452. <https://doi.org/10.1519/JSC.0b013e31823f2b36>
- Cilli, M., Gelen, E., Yildiz, S., Saglam, T., & Camur, M. (2014). Acute effects of a resisted dynamic warm-up protocol on jumping performance. *Biology of Sports*, *31*(4), 277-282. <http://doi.org/10.5604/20831862.1120935>
- Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences*. New York, USA: Routledge.
- Creekmur, C. C., Haworth, J. L., Cox, R. H., & Walsh, M. S. (2017). Effects of plyometrics performed during warm-up on 20 and 40 m sprint performance. *The Journal of Sports Medicine and Physical Fitness*, *57*(5), 550-555. <http://doi.org/10.23736/S0022-4707.16.06227-7>
- de Rezende, F. N., da Mota, G. R., Lopes, C. R., da Silva, B. V. C., Simim, M. A. M., & Marocolo, M. (2016). Specific warm-up exercise is the best for vertical countermovement jump in young volleyball players. *Motriz: Revista de Educação Física*, *22*(4), 299-303. <https://doi.org/10.1590/S1980-6574201600040013>
- Forte, D., Ceciliani, A., Izzo, R., & Altavilla, G. (2019). Transition period: Pilot study on performance reduction of ability to jump in volleyball. *Journal of Human Sport and Exercise*, *14*(2proc), S221-S227. <https://doi.org/10.14198/jhse.2019.14.Proc2.09>
- Fradkin, A. J., Zazryn, T. R., & Smoliga, J. M. (2010). Effects

- of warming-up on physical performance: a systematic review with meta-analysis. *The Journal of Strength and Conditioning Research*, 24(1), 140-148. <http://doi.org/10.1519/JSC.0b013e3181c643a0>
- Ghareeb, D. M., McLaine, A. J., Wojcik, J. R., & Boyd, J. M. (2017). Effects of Two Warm-up Programs on Balance and Isokinetic Strength in Male High School Soccer Players. *The Journal of Strength and Conditioning Research*, 31(2), 372-379. <http://doi.org/10.1519/JSC.0000000000001509>
- Gil Arias, A., Del Villar Álvarez, F., Claver Rabaz, F., Moreno Domínguez, A., García González, L., & Moreno Arroyo, M. P. (2012). ¿Existe relación entre el nivel de competición y el conocimiento del juego en voleibol? (Is there a relationship between level of competition and knowledge in volleyball?). *Retos*, 21, 53-57. <https://doi.org/10.47197/retos.v0i21.34605>
- Gil, M. H., Neiva, H. P., Marinho, D. A., Sousa, A. C., & Marques, M. C. (2019). Current Approaches on Warming up for Sports Performance: A Critical Review. *Strength and Conditioning Journal*, 41(4), 70-79. <http://doi.org/10.1519/SSC.0000000000000454>
- Gómez-Álvarez, N., Schweppe-Villa, A., Parra-Gatica, A., Cid-Rojas, F., Pavez-Adasme, G., & Hermosilla-Palma, F. (2021). Efectos agudos de distintas estrategias de calentamiento sobre el rendimiento físico y las habilidades motrices en escolares (Acute effects of different warm-up strategies on physical performance and motor skills in school-children). *Retos*, 42, 18-26. <https://doi.org/10.47197/retos.v42i0.86525>
- Hassan, M. H. A., Che Muhamed, A. M., Mohd Ali, N. F., Choon Lian, D. K., Lian-Yee K., Safii, N. S., Md Yusof, S., & Mohamad Fauzi, N. F. (2020). *Proceedings of the 2019 Movement, Health & Exercise (MoHE) and International Sports Science Conference (ISSC)*, 134-141. <https://doi.org/10.1007/978-981-15-3270-2>
- Johnson, M., Baudin, P., Ley, A. L., & Collins, D. F. (2019). A Warm-Up Routine That Incorporates a Plyometric Protocol Potentiates the Force-Generating Capacity of the Quadriceps Muscles. *The Journal of Strength and Conditioning Research*, 33(2), 380-389. <http://doi.org/10.1519/JSC.0000000000002054>
- Karatrantou, K., Gerodimos, V., Voutselas, V., Manouras, N., Famisis, K., & Ioakimidis, P. (2019). Can sport-specific training affect vertical jumping ability during puberty? *Biology of Sport*, 36(3), 217-224. <http://doi.org/10.5114/biolsport.2019.85455>
- Karuc, J., Mišigoj-Duraković, M., Marković, G., Hadžić, V., Duncan, M. J., Podnar, H., & Sorić, M. (2020). Movement quality in adolescence depends on the level and type of physical activity. *Physical Therapy in Sport*, 46, 194-203. <https://doi.org/10.1016/j.ptsp.2020.09.006>
- Kitamura, K., Roschel, H., Loturco, I., Lamas, L., Tricoli, V., João, P. V., Fellingham, G., & Ugrinowitsch, C. (2020). Strength and power training improve skill performance in volleyball players. *Motriz: Revista de Educação Física*, 26(1), e10200034. <https://doi.org/10.1590/s1980-65742020000110200034>
- Kruse, N. T., Barr, M. W., Gilders, R. M., Kushnick, M. R., & Rana, S. R. (2015). Effect of different stretching strategies on the kinetics of vertical jumping in female volleyball athletes. *Journal of Sport and Health Science*, 4(4), 364-370. <https://doi.org/10.1016/j.jshs.2014.06.003>
- Kurt, C., Kafkas, M. E., Kurtdere, İ., & Selalmaz, O. (2018). Influence of traditional and cluster set plyometric warm-ups on reactive strength index and leg stiffness in male rugby players. *Isokinetics and Exercise Science*, 26(3), 237-244. <http://doi.org/10.3233/IES-182156>
- Langdown, B. L., Wells, J. E. T., Graham, S., & Bridge, M. W. (2019). Acute effects of different warm-up protocols on highly skilled golfers' drive performance. *Journal of Sports Sciences*, 37(6), 656-664. <https://doi.org/10.1080/02640414.2018.1522699>
- Lopes, J. A., da Silva, K. A., Pazetto, N. F., Rocha, M. A., & Stanganelli, L. C. R. (2019). Análise temporal no Voleibol masculino: contribuição dos sistemas energéticos a partir da relação esforço/pausa na dinâmica intermitente do jogo. *RBPFFEX - Revista Brasileira De Prescrição E Fisiologia Do Exercício*, 13(82), 234-240. Recuperado de <http://www.rbpffex.com.br/index.php/rbpffex/article/view/1672>
- López-Álvarez, J., & Sánchez-Sixto, A. (2021). Efectos de la Potenciación Post-Activación con cargas de máxima potencia sobre el rendimiento en sprint y cambio de dirección en jugadores de baloncesto (Effects of Post-Activation Potentiation with maximal power loads on Sprint and Change of Direction). *Retos*, 41, 648-652. <https://doi.org/10.47197/retos.v41i0.82105>
- Marinho, B., & das Virgens Chagas, D. (2022). ¿Puede el nivel de coordinación motora predecir el rendimiento en habilidades específicas de volea en los jóvenes? (Can motor coordination level predict performance on volleyball skills in youth?). *Retos*, 45, 195-201. <https://doi.org/10.47197/retos.v45i0.90359>
- Martínez-Rodríguez, A., Mira-Alcaraz, J., Cuestas-Calero, B. J., Pérez-Turpin, J. A., & Alcaraz, P. E. (2017). La Pliometría en el Voleibol Femenino. Revisión Sistemática (Plyometric Training in Female Volleyball Players. Systematic Review). *Retos*, 32, 208-213. <https://doi.org/10.47197/retos.v0i32.56053>
- McGowan, C. J., Pyne, D. B., Thompson, K. G., & Rattray, B. (2015). Warm-Up Strategies for Sport and Exercise: Mechanisms and Applications. *Sports Medicine*, 45(11), 1523-1546. <https://doi.org/10.1007/s40279-015-0376-x>
- Mizoguchi, Y., Akasaka, K., Otsudo, T., & Hall, T. (2020). Physical function characteristics in Japanese high school volleyball players with low back pain: A case-controlled study. *Medicine (Baltimore)*, 99(46), e23178. <http://doi.org/10.1097/MD.00000000000023178>
- Munshi, P., Khan, M.H., Arora, N.K. et al. (2022) Effects of plyometric and whole-body vibration on physical performance in collegiate basketball players: a crossover randomized trial. *Sci Rep* 12, 5043. <https://doi.org/10.1038/s41598-022-09142-8>
- Neiva, H. P., Marques, M. C., Barbosa, T. M., Izquierdo, M., Viana, J. L., Teixeira, A. M., & Marinho, D. (2015). The Effects of Different Warm-up Volumes on the 100-m Swimming Performance: A Randomized Crossover Study. *The Journal of Strength and Conditioning Research*, 29(11), 3026-3036. <http://doi.org/10.1519/JSC.0000000000001141>
- Nickerson, B. S., Mangine, G. T., Williams, T. D., & Martinez, I. A. (2018). Effect of cluster set warm-up configurations on sprint performance in collegiate male soccer players. *Applied Physiology, Nutrition, and Metabolism*, 43(6), 625-630. <https://doi.org/10.1139/apnm-2017-0610>
- Park, S.-B., Park, D.-S., Kim, M., Lee, E., Lee, D., Jung, J.,

- Son, S. J., et al. (2021). High-Intensity Warm-Up Increases Anaerobic Energy Contribution during 100-m Sprint. *Biology*, 10(3), 198. MDPI AG. <http://dx.doi.org/10.3390/biology10030198>
- Picón-Martínez, M., Chulvi-Medrano, I., Cortell-Tormo, J. M., & Cardozo, L. A. (2019). La potenciación post-activación en el salto vertical: una revisión (Post-activation potentiation in vertical jump: a review). *Retos*, 36, 44–51. <https://doi.org/10.47197/retos.v36i36.66814>
- Petrigna L, Karsten B, Marcolin G, Paoli A, D'Antona G, Palma A and Bianco A (2019) A Review of Countermovement and Squat Jump Testing Methods in the Context of Public Health Examination in Adolescence: Reliability and Feasibility of Current Testing Procedures. *Front. Physiol.* 10:1384. <https://doi.org/10.3389/fphys.2019.01384>
- Raya-González, J., Suárez-Arrones, L., Moreno-Puentedura, M., Ruiz-Márquez, J., & Sáez De Villarreal, E. S. (2018). Efectos en el rendimiento físico a corto plazo de dos programas de entrenamiento neuromuscular con diferente orientación aplicados en jugadores de fútbol de élite U-17. *Retos. Nuevas Tendencias En Educación Física, Deporte y Recreación*, 33, 106–111. <https://doi.org/10.5232/ricyde2017.04801>
- Reyes Rivera, David. (2021). Ejercicios pliométricos para mejorar la fase del salto de bloqueo en las jugadoras de voleibol femenino. Dilemas contemporáneos: educación, política y valores, 9(spe1), 00033. Epub 31 de enero de 2022. <https://doi.org/10.46377/dilemas.v9i.2940>
- Ruffieux, J., Wälchli, M., Kim, K.-M., & Taube, W. (2020). Countermovement Jump Training Is More Effective Than Drop Jump Training in Enhancing Jump Height in Non-professional Female Volleyball Players. *Frontiers in Physiology*, 11, 231. <https://doi.org/10.3389/fphys.2020.00231>
- Russell, M., West, D. J., Harper, L. D., Cook, C. J., & Kilduff, L. P. (2015). Half-time strategies to enhance second-half performance in team-sports players: a review and recommendations. *Sports Medicine*, 45(3), 353-364. <https://doi.org/10.1007/s40279-014-0297-0>
- Sattler, T., Hadžić, V., Dervišević, E., & Marković, G. (2015). Vertical Jump Performance of Professional Male and Female Volleyball Players: Effects of Playing Position and Competition Level. *The Journal of Strength & Conditioning Research*, 29(6), 1486-1493. <http://doi.org/10.1519/JSC.0000000000000781>
- Seitz, L. B., & Haff, G. G. (2016). Factors Modulating Post-Activation Potentiation of Jump, Sprint, Throw, and Upper-Body Ballistic Performances: A Systematic Review with Meta-Analysis. *Sports Medicine*, 46(2), 231-240. <https://doi.org/10.1007/s40279-015-0415-7>
- Silva, L. M., Neiva, H. P., Marques, M. C., Izquierdo, M., & Marinho, D. A. (2018). Effects of Warm-Up, Post-Warm-Up, and Re-Warm-Up Strategies on Explosive Efforts in Team Sports: A Systematic Review. *Sports Medicine*, 48(10), 2285-2299. <https://doi.org/10.1007/s40279-018-0958-5>
- Solon Junior, L. J. F., & da Silva Neto, L. V. (2021). Efecto del estiramiento estático y de la carrera sub máxima en el desempeño del salto de contramovimiento y Sprint en jugadores universitarios de voleibol (Effect of Static Stretching and Submaximal Running on Countermovement Jump Performance and Sprint on. *Retos*, 39, 325–329. <https://doi.org/10.47197/retos.v0i39.79344>
- Thompson, J. A., Tran, A. A., Gatewood, C. T., Shultz, R., Silder, A., Delp, S. L., & Drago, J. L. (2017). Biomechanical Effects of an Injury Prevention Program in Preadolescent Female Soccer Athletes. *The American Journal of Sports Medicine*, 45(2), 294-301. <https://doi.org/10.1177/0363546516669326>
- Turki, O., Dhabbi, W., Gueid, S., Hmaied, S., Souaifi, M., & Khalifa, R. (2020). Dynamic Warm-Up with a Weighted Vest: Improvement of Repeated Change-of-Direction Performance in Young Male Soccer Players. *International Journal of Sports Physiology and Performance*, 15(2), 196-203. <https://doi.org/10.1123/ijspp.2018-0800>
- Van Hooren, B., & Zolotarjova, J. (2017). The Difference Between Countermovement and Squat Jump Performances: A Review of Underlying Mechanisms with Practical Applications. *Journal of Strength and Conditioning Research*, 31(7), 2011-2020. <http://doi.org/10.1519/JSC.0000000000001913>
- Vargas Fuentes, A., Urkiza Ibaibarriaga, I., & Gil Orozko, S. M. (2015). Efecto de los partidos de pretemporada en la planificación deportiva: Variabilidad en las sesiones de entrenamiento (Effect of preseason matches in sports planning: Variability of training sessions). *Retos*, 27, 45–51. <https://doi.org/10.47197/retos.v0i27.34346>
- Véliz, C. V., Cid, F. M., & Lynch, L.E. (2016). Fuerza explosiva, explosiva-elástica y reactiva en gimnastas, voleibolistas, nadadoras y nadadoras sincronizadas del estadio mayor de Santiago de Chile. *EmásF: Revista Digital de Educación Física*, 42, 66-77.
- Vilela, G., Caniuqueo-Vargas, A., Ramirez-Campillo, R., Hernández-Mosqueira, C., & da Silva, S. F. (2021). Efecto del entrenamiento pliométrico en la fuerza explosiva de niñas puberes practicantes de voleibol (Effects of plyometric training on explosive strength in pubescent girls volleyball players). *Retos*, 40, 41–46. <https://doi.org/10.47197/retos.vi140.77666>
- Vittori, C. (1990). El entrenamiento de la fuerza para el sprint. *RED, Revista de Entrenamiento Deportivo*, 4(3), 2-8.
- Wheeler-Botero, C. A., Ramos-Parraci, C. A., & Reyes Oyola, F. A. (2021). Efectos del dropjump sobre la potenciación post-activación en atletas colombianos de rendimiento. *Retos*, 39, 691–696. <https://doi.org/10.47197/retos.v0i39.81926>
- Zois, J., Bishop, D., & Aughey, R. (2015). High-intensity warm-ups: effects during subsequent intermittent exercise. *International Journal of Sports Physiology and Performance*, 10(4), 498-503. <https://doi.org/10.1123/ijspp.2014-0338>
- Zurita-Cruz, Jessie Nallely, Márquez-González, Horacio, Miranda-Novales, Guadalupe, & Villasís-Keever, Miguel Ángel. (2018). Estudios experimentales: diseños de investigación para la evaluación de intervenciones en la clínica. *Revista alergia México*, 65(2), 178-186. <https://doi.org/10.29262/ram.v65i2.376>