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ORIGINAL ARTICLE

The Effects of Different Warm-Up Protocols on Vertical Jump Height in Elite and Sub-Elite Women Volleyball Players

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ABSTRACT

Background. Volleyball warm-up protocols can lead to improvements in vertical jump performance. **Objectives.** This study aimed to compare the immediate effects of short-term high-intensity and traditional warm-up protocols on vertical jump height in elite and sub-elite women volleyball players. **Methods.** Thirty healthy volleyball players (aged 26.53±3.72 years; elite group n=14; sub-elite group n=16) performed a short-term high-intensity warm-up protocol (27 min) and a traditional warm-up protocol (45 min) over three days at 48-hour intervals. After each protocol, the vertical jump height was evaluated using the VERT wearable jump device. The ANOVA test for repeated measurements revealed a significant difference, and a Bonferroni post-hoc test was used. **Results.** In all groups, vertical jump height was significantly changed and increased from the short-term high-intensity warm-up protocol compared to the traditional warm-up protocol (Diff=-3.103; 95% CI=-4.118 to -2.088; d=0.81; p<0.001; ηp2=0.762) and the without warm-up (Diff=-4.973; 95% CI=-6.153 to -3.793; d=1.36; p<0.001). In the elite group, vertical jump height was significantly changed and increased from the short-term high-intensity warm-up protocol compared to the traditional warm-up protocol (Diff=3.943; 95% CI=1.962 to 5.924; d=1.24; p<0.001; ηp2=0.818) and the without warm-up (Diff=-6.543; 95% CI=-8.609 to -4.476; d=2.13; p<0.001). Similarly, in the sub-elite group, vertical jump height was also significantly changed and increased from the short-term high-intensity warm-up protocol compared to the traditional warm-up protocol (Diff=1.231; 95% CI=-0.717 to -1.746; d=0.68; p<0.001; ηp2=0.856) and the without warm-up (Diff=-3.600; 95% CI=-4.375 to -2.825; d=1.04; p<0.001). **Conclusion.** In conclusion, the results revealed that, in practical terms, the short-term high-intensity warm-up protocol is the best to improve vertical jump performance in women volleyball players immediately. Robust conclusions, however, need randomized controlled trials with sufficient statistical power.

KEYWORDS: ***Short-Term High-Intensity Warm-Up, Traditional Warm-Up, Women Volleyball Players, Explosive Strength, Vertical Jump.***

INTRODUCTION

Improving performance is the primary objective of athletic training and sports participation. However, performance has many facets and depends on many factors, such as warm-up exercises (1). Warm-up is a series of conditioning exercises designed to maximize performance and reduce injury risk while increasing body temperature, muscle temperature, and blood flow prior to athletic activity (2). It has also been shown to affect vertical jump performance positively (3-5). The goal of a volleyball warm-up is to assist players in making the physiological transition from their resting state to the competitive state needed for

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the upcoming match (6, 7). In volleyball, players use rapid-explosive movements and high vertical jumps as part of their pre-training warm-up routines (8). Volleyball players must attempt to imitate the demands of the game during their warm-up in order to tolerate explosive movements on the court and perform at their peak (9).

Given the significance of warm-ups in volleyball, it is imperative to comprehend the variables influencing jumping ability (10). Limiting variables like volleyball players' strength and muscle power, joint flexibility during jumping motions, and particular techniques seem sensible (10). In volleyball, performing vertical jumps is essential and crucial for success. They are employed in offensive and defensive motions, such as blocking, attacking, passing, and serving (11, 12). To counter the opposing attack spike over the net, vertical jumps are typically executed during a block jump or countermovement (CMJ) block jump (13). Volleyball players routinely perform vertical jumps during practice and competition, and some studies have examined the best ways for athletes to enable themselves to jump (10, 14-17). However, current literature offers limited data on their applications adapted to sports activities. Rodriguez-Ruiz et al. (2011) proposed that a proficient block jump could potentially enhance the efficacy of front-row defense, particularly in sets lasting longer than 25 points or during the fifth set (18). Langdown et al. (2019) suggested that short-term, high-intensity warm-up protocols have demonstrated better results than passive warm-up (19). So, short-term high-intensity warm-ups are a common strategy to promote muscle power, maximize joint ranges, and improve performance (20). Therefore, coaches are constantly looking for the most effective strategies to improve this ability in their players (21). Woolstenhulme et al. (2006) found that after applying a six-week protocol, there were no differences in jumping performance (5). Herman & Smith (2008) and Turki-Belkhiria et al. (2014) suggested that implementing a dynamic lower limb stretching protocol lasting four to six weeks significantly increases jumping ability (22, 23).

To date, the effects of different warm-up protocols are unclear. There is no consensus about their applications for athletes (24). However, for volleyball players, these strategies have shown improvements in lower extremity strength and increases in height and jumping performance (25). Thus, warm-up protocols aimed at improving volleyball players' jumping should target the neuromuscular system's reactive and explosive strength capabilities (21). Although the above results were controversial, they prompted researchers to design a new study to examine the relationship between different warm-ups and women volleyball players' vertical jump abilities. Therefore, this study aimed to compare the immediate effects of short-term high-intensity and traditional warm-up protocols on vertical jump height in elite and sub-elite women volleyball players. We hypothesized that the short-term, high-intensity warm-up would improve immediate vertical jump performance and height more effectively.

MATERIALS AND METHODS

Participants. Thirty women volleyball players were recruited for this study through convenience sampling (age: 26.53±3.72 years; body mass: 70.32±9.34 kg; height: 182.67±9.21 m; body mass index (BMI): 20.67±2.09 kg/m2; Table 1) in Istanbul, Turkey, who were members of the same local volleyball club and continued to compete in Elite (age: 27.79±4.92 years; body mass: 70.49±8.12 kg; height: 185.50±7.73 m; body mass index (BMI): 20.60±1.22 kg/m2) and Sub-Elite (age: 25.44±2.55 years; body mass: 70.18±10.55 kg; height: 180.19±9.91 m; body mass index (BMI): 20.73±2.68 kg/m2) leagues. All players in the Elite group had national team experience. Players had prior plyometric or strength training experience. The research protocol and potential risks and benefits of participating were communicated to the players before the study. They then signed an informed consent form. The Haliç University Non-Interventional Clinical Research Ethics Committee approved, and the study complied with the Declaration of Helsinki (25.01.2023; ref no: 2023/3). A volleyball player must meet the following requirements in order to be considered for inclusion: they must play in Elite or Sub-Elite leagues, have five years or more of experience, hold a volleyball license valid for the 2023 season, be in good health as determined by the medical examination required in order to obtain a volleyball license, and engage in organized volleyball training for a minimum of three months straight without missing any time. There are no uncured musculoskeletal conditions. No lower-

extremity reconstructive surgery was performed in the previous 24 months. No past three-month history of pathology related to the ankle, knee, or spine. To willingly take part in the study.

Procedures and Different Warm-up Protocols. Body mass and height were recorded using a digital scale to the nearest 0.1 cm and 0.1 kg, respectively (SECA-769 by Seca, Hamburg, Germany). After determining the demographic information of the players, their vertical jump performance was first measured without any warm-up. The vertical jump performance was measured after a traditional warm-up was applied on the next test day. The vertical jump performance was measured after a short-term high-intensity warm-up on the last test day. Players jumped thrice on each test day and passively rested for 1 minute between each jump (Figure 1). The best of the three jumps was recorded for analysis. All players underwent two warm-up protocols: the traditional and the short-term high-intensity warm-up protocols on non-consecutive days (Table 2). All test sessions were performed at the same time of the day and in a sports hall with polyurethane ground. Women volleyball players were instructed to avoid caffeine intake or any energetic beverages for 24 hours before each test and to maintain the same training and nutrition routine. The players' individual strength and conditioning program was controlled to avoid the confounding effects of training. The same researchers performed the tests for three days at 48-hour intervals.

Table 1. Characteristics of volleyball players (Mean±SD)

Variables	All Group (n=30)	Elite Group (n=14)	Sub-Elite Group (n=16)
Age (year)	26.53±3.72	27.79±4.92	25.44±2.55
Body Mass (kg)	70.32±9.34	70.49±8.12	70.18±10.55
Height (cm)	182.67±9.21	185.50±7.73	180.19±9.91
BMI (kg/m2)	20.67±2.09	20.60±1.22	20.73±2.68

Table 2. Different Warm-Up Protocols

Traditional Warm-Up (Total: 45 min.)	Short-Term High Intensity Warm-Up (Total: 27 min.)
Running (3 min.)	*Balance and stabilization (7 min.)*
Run circularly for 3 min.	Ball-shaped foam roller (15 seconds, 2 sets)
	Plank (30 second, 2 sets)
	Crossed arm and leg lifts (15 seconds, 2 sets)
	Crunch (30 second, 2 sets)
	Achilles stretching (15 seconds, 2 sets)
	Theraband exercises (15 seconds, 2 sets)
	Kneeling hip flexor stretch (15 seconds, 2 sets)
Static and dynamic stretching exercises (10 min.)	*Short-term high-intensity warm-up (8 min.)*
Overhead stretch	Free body squat (30 seconds, 2 sets)
Shoulder stretch	Single-leg glute bridge (15 seconds, 2 sets)
Trunk Stretch	Alternating back lunges (15 seconds, 2 sets)
Ankle balance exercises	Single leg RDL (15 seconds, 2 sets)
Hamstring and quadriceps stretches	Single leg squat (15 seconds, 2 sets)
	Air squat (30 seconds, 2 sets)
Sprint (4 min.)	*Warming up with volleyball ball (12 min.)*
15 and 30 second sprints.	Pass, bump pass, block jump, defense, volleyball spike, serve
Sprints were performed in front of the volleyball net, and each session consisted of 15 seconds of rest.	
Block jump (3 min.)	
These are the jumps made by everyone in front of the volleyball net in their position, lined up one after the other. 15 seconds rest between jumps.	
Exercises with resistance tires and balance exercises (5 min.)	
Exercises performed on the knee, shoulder, ankle, waist, and wrist areas.	
Warming up with volleyball ball (20 min.)	
Pass, bump pass, defense, volleyball spike, serve.	

Vertical Jump Test. Before the measurements, the players were familiar with the vertical jump test. The evaluations were performed using the clothing and footwear for training and competition. The VERT wearable jump device (Mayfonk Athletic, Florida, USA) was used to determine the vertical jumping performance's height in centimeters (cm). The VERT has been validated through its use in previous studies with similar characteristics (26, 27). Three-axis accelerometers, gyroscopes, and magnetometers are all part of VERT. As recommended by the developers, the 5.3×2.3×0.9 cm device was worn on an elastic belt at the L3 or L4 vertebrae level to be close to the body's center of mass. The device was connected via Bluetooth to the Vert Coach application. Players were only told to put their hands on their hips, squat (approximately 90º determined with a goniometer), and then jump straight up while keeping their lower limbs extended in the air from a standing position (28). The players then executed three consecutive vertical jumps. All jumps were downloaded, and the highest jump was recorded for analysis.

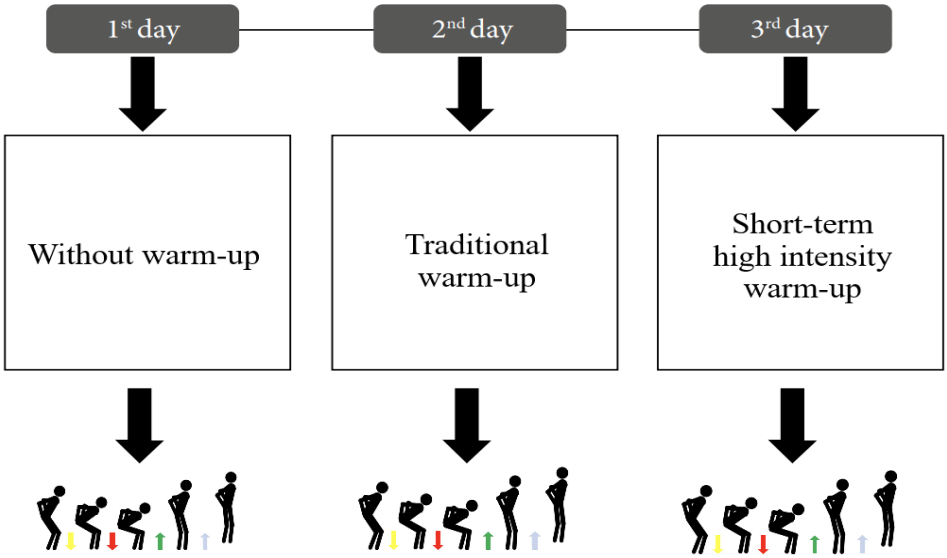

Figure 1. Study design overview.

Statistical Analysis. The data were presented as frequency (percentage) or means ± standard deviations. Descriptive statistics were performed for every variable (Table 1). Kurtosis and skewness were used to confirm the assumption of normality prior to the use of parametric tests. The kurtosis and skewness values of the data for the whole group were between +2.0 and -2.0 (29). This was considered an indicator of a normal distribution ($p>0.05$). The ANOVA test was utilized to assess the repeated measurements of the various protocols, which included without warm-up, traditional warm-up, and short-term high-intensity warm-up. The Mauchly test of sphericity and the Greenhouse-Geisser correction were used to assess the homogeneity of variances. For every pairwise comparison, Cohen's d was used as the measure of effect size and was calculated. We used the following criteria: d=0.20, minor; d=0.50, medium; and d=0.80, large, to interpret the magnitude of the effect size (30, 31). Results were considered statistically significant when p-values were <0.05 and the Bonferroni post-hoc test was used. All statistical operations were performed using IBM SPSS version 22 software (New York, USA).

RESULTS

In the vertical jump test, the without warm-up measurements and short-term high-intensity warm-up measurements showed a significant difference in mean scores, with the short-term high-intensity warm-up having a higher mean score (Diff=-4.973; 95% CI=-6.153 to -3.793; d=1.36; p=0.001). The without warm-up measurements and traditional warm-up measurements also showed a significant difference in mean scores, with the traditional warm-up measurements having a higher mean score (Diff=-1.870; 95% CI=-2.323 to -1.417; d=0.58; p=0.001). The traditional warm-up measurements

and short-term high-intensity warm-up measurements also showed a significant difference in mean scores, with the short-term high-intensity warm-up measurements having a higher mean score (Diff=-3.103; 95% CI=-4.118 to -2.088; d=0.81; p=0.001). Finally, the short-term high-intensity warm-up measurements had a significantly higher vertical jump score, indicating the highest jump performance among the three measurements (Figure 2; Table 3).

Table 3. Changes in vertical jump performance between measurements and all group

				Group×Measurements				
Protocols (n=30)	**Mean±SD**	**Mean Difference**	**95% CI**	**F**	***p***	**η_p^2**	**d**	**Bonferroni Post Hoc**
Without warm-up[a]	36.83±3.04	[b]=-1.870	[b]=-2.323 -1.417	93.031	0.000	0.762	1.36	c>a
		[c]=-4.973	[c]=-6.153 -3.793					
Traditional warm-up[b]	38.70±3.38	[c]=-3.103	[c]=-4.118 -2.088				0.81	c>b
		[a]=1.870	[a]=1.417 2.323					
Short-term high-intensity warm-up[c]	41.80±4.16	[a]=4.973	[a]=3.793 6.153				0.58	b>a
		[b]=3.103	[b]=2.088 4.118					

p<0.05

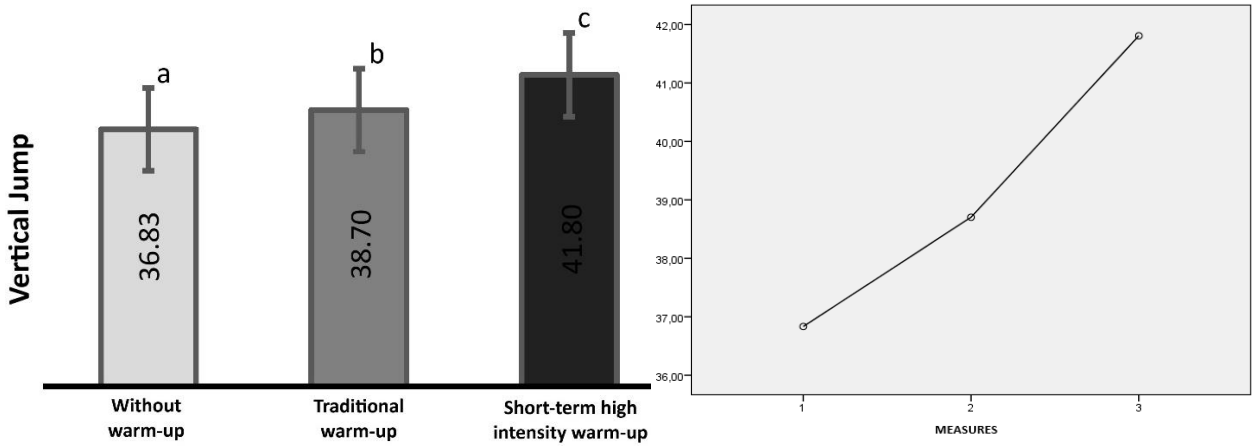

Figure 2. Vertical jump scores between measurements and marginal means plot.

Within-group changes in the vertical jump test of elite group and sub-elite group, the without warm-up measurements and short-term high-intensity warm-up measurements showed a significant difference in mean scores, with the short-term high-intensity warm-up having a higher mean score (Elite: Diff=-6.543; 95% CI=-8.609 to -4.476; d=2.13; p=0.001; Sub-elite: Diff=-3.600; 95% CI=-4.375 to -2.825; d=1.04; p=0.001). The without warm-up measurements and traditional warm-up measurements also showed a significant difference in mean scores, with the traditional warm-up measurements having a higher mean score (Elite: Diff=-2.600; 95% CI=-2.149 to -3.051; d=1.05; p=0.001; Sub-elite: Diff=1.231; 95% CI=-0.717 to -1.746; d=0.35; p=0.001). The traditional warm-up measurements and short-term high-intensity warm-up measurements also showed a significant difference in mean scores, with the short-term high-intensity warm-up measurements having a higher mean score (Elite: Diff=3.943; 95% CI=1.962 to 5.924; d=1.24; p=0.001; Sub-elite: Diff=1.231; 95% CI=-0.717 to -1.746; d=0.68; p=0.001). Finally, the short-term high-intensity warm-up measurements had a significantly higher vertical jump score, indicating the highest jump performance among the three measurements (Figure 3; Table 4).

DISCUSSION

This study explored the immediate effects of different warm-up protocols on vertical jump performance in elite and sub-elite women volleyball players. Results showed a strong positive effect on vertical jump height. Compared to traditional warm-up and without warm-up, the short-term high-intensity warm-up showed significant improvements in vertical jump height.

Table 4. Within-group changes in vertical jump performance between measurements

				Group×Measurements				
Protocols (Elite group n=14)	**Mean±SD**	**Mean Difference**	**95% CI**	**F**	***p***	**η_p^2**	**d**	**Bonferroni Post Hoc**
Without warm-up[a]	37.64±2.33	[b]= -2.600 [c]= -6.543	[b]=-3.051 -2.149 [c]=-8.609 -4.476	58.451	0.000	0.818	2.13	c>a
Traditional warm-up[b]	40.24±2.59	[c]= -3.943 [a]= 2.600	[c]=-5.924 -1.962 [a]=2.149 3.051				1.24	c>b
Short-term high-intensity warm-up[c]	44.18±3.66	[a]= 6.543 [b]= 3.943	[a]=4.476 8.609 [b]=1.962 5.924				1.05	b>a
Protocols (Sub-elite group n=16)								
Without warm-up[a]	36.12±3.46	[b]=-1.231 [c]=-3.600	[b]=-1.746 -0.717 [c]=-4.375 -2.825	88.997	0.000	0.856	1.04	c>a
Traditional warm-up[b]	37.35±3.48	[c]=1.231 [a]=-2.369	[c]=0.717 1.746 [a]=-3.248 -1.490				0.68	c>b
Short-term high-intensity warm-up[c]	39.72±3.46	[a]=3.600 [b]=2.369	[a]=2.825 4.375 [b]=1.490 3.248				0.35	b>a

p<0.05

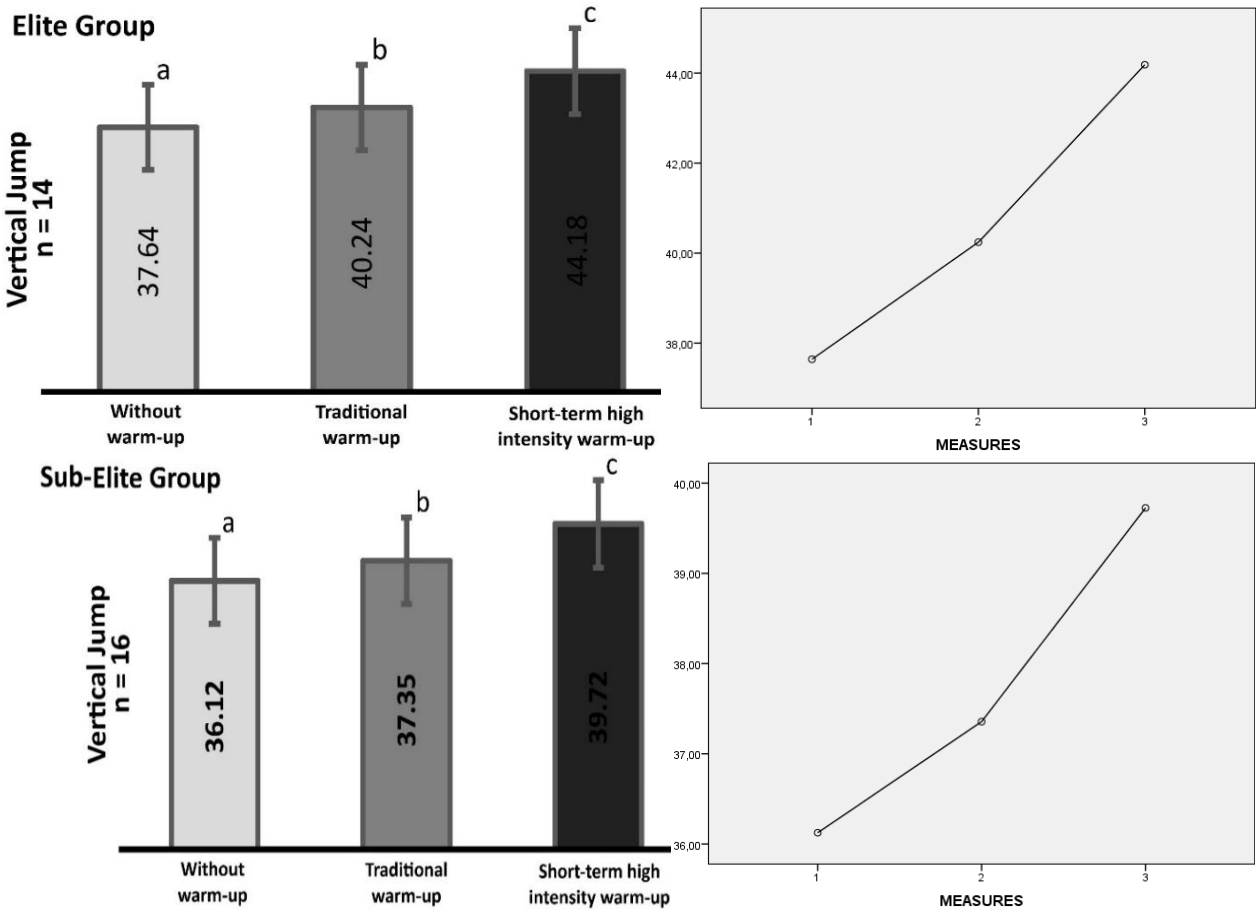

Figure 3. Vertical jump scores of elite and sub-elite groups before warm-up, after traditional warm-up, and after short-term high-intensity warm-up and marginal means plot.

The study's primary conclusion was that, when used alone, a short-term high-intensity warm-up was the most effective (largest effect size) for increasing vertical jump height. As a result, using this warm-up protocol before practice and games seems beneficial, but alternative techniques can

be used as complimentary warm-up exercises. It is thought that the exercises used in short-term high-intensity warm-ups stimulate the neuromuscular system compared to other warm-up protocols and enable muscle strength to be quickly converted into power by activating the lengthening-shortening cycle that affects jumping performance (32-34). According to Gil et al. (2019), warm-up studies mostly 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 (35). Andrade et al. (2015) compared different warm-up protocols in ten physical education students, obtaining significant increases in vertical jump height for plyometric and sprint warm-up protocols, in contrast to a reduction in jumping performance for passive warm-up protocols (36). In the present study, the comparison of traditional warm-up protocols, short-term high-intensity warm-up protocols, and without warm-up measurements is statistically significant, which agrees with a research article published by Mancilla et al. (2023), who report that there are significant differences between high-intensity warm-up protocols (37). These results are similar to previous studies where an increase in only vertical jump height was observed after a general, traditional, specific, or short-term high-intensity warm-up protocol (36, 38-40). However, not all research agrees, and discrepancies between our findings and earlier studies could be attributed to how fatigued participants were during the short-term high-intensity and traditional warm-up protocols (20, 41, 42). For instance, despite using high intensity during the high-intensity warm-up protocol, only a tiny amount of muscle activity was needed. This increased the likelihood of causing a post-activation potentiation effect and decreased the likelihood of fatigue (42, 43).

It is essential to highlight that in this study, the short-term high-intensity warm-up protocol tends to improve vertical jump height compared to without warm-up and traditional warm-up. Significant differences exist when comparing the measurement results with the post-hoc analysis between protocols and without warm-up ($p<0.001$). The short-term high-intensity warm-up protocol significantly improves vertical jump height ($p<0.001$). Jumping performance has a great place in volleyball. Warm-up protocols have significant effects on performance. Some studies in recent years have emphasized that biomotor properties other than flexibility (balance, anaerobic power, agility, coordination, reaction time, and speed) are negatively affected by static stretching (44-46). A study of ten collegiate and ten recreational athletes examined the acute effect of different static stretching exercises on jumping performance. Two, four, and six sets of 15-second static stretching exercises were performed on different days. The vertical jump performance recorded after six sets of static stretching exercises was lower than that of those who performed two and four sets of static stretching exercises. As a result of the research, six static stretching exercises were not recommended before strength activities such as jumping to ensure optimal working performance (46).

Similarly, in our study, the effect of the traditional warm-up protocol containing static stretching exercises on vertical jump height was lower than the short-term, high-intensity warm-up protocol containing dynamic stretching exercises. In addition, it was observed that the shorter duration of the short-term high-intensity warm-up protocol compared to the traditional warm-up protocol had a positive effect on vertical jump height. Physical fitness and experience in plyometric activities can determine physical and physiological performance (47). Sports experience is associated with better neuromuscular responses, and a systematic review concluded that the results in jumping performance tend to be more heterogeneous in women volleyball players (48, 49). Thus, considering that the subjects of the present study are women volleyball players, the factors mentioned could have influenced the results of the warm-up protocols implemented; however, the most significant influence could have been linked to the short-term high-intensity warm-up protocol due to its greater complexity. According to Kitamura et al. (2020) and Marinho et al. (2022), short-term high-intensity-based warm-up activities are complex to execute, require a high ability to control the movement of body segments, and involve more time to influence jump execution pattern and performance (50, 51).

Nevertheless, it is suggested that short-term high-intensity activities would be the most suitable to improve vertical jumping performance compared to other high- or moderate-intensity warm-up strategies, which are based on the similarity of plyometrics with the motor gestures

specific to volleyball (10, 52). In this study, short-term high-intensity warm-up protocols improve vertical jump height, agreeing in general terms with the basics of warm-up (53-55), and a greater tendency of improvement is observed towards our hypothesis. This situation may be explained by the fact that the study sample is characterized by good motor development, at least five years of volleyball experience, and a high level of physical preparation, which may be associated with a low probability of fatigue during warm-up. In contrast to isolated traditional or specific warm-ups, combining traditional and specific warm-up activities might not produce noticeably better explosive performance despite prior reports to the contrary (56). Therefore, more research is required about the effects of various warm-up protocols to elucidate the optimal methodologies and to increase athletic performance depending on the discipline, competitive level, and gender of the athletes (57, 58).

CONCLUSION

It is concluded that the short-term high-intensity and traditional warm-up protocols improve vertical jump height. However, the short-term high-intensity warm-up protocol shows a more favorable trend than the traditional warm-up protocol. From a practical perspective, the study's conclusions can offer helpful recommendations for the warm-up procedure. Robust conclusions, however, need randomized, controlled trials with sufficient statistical power.

APPLICABLE REMARKS

- Research results show that using less duration and a smaller number of repetitions of static stretching exercises and more dynamic stretching exercises in the applied warm-up protocols is beneficial.
- It can be said that individual warm-up exercises combined with a short-term high-intensity warm-up protocol, as opposed to the traditional 45-minute warm-up protocol, increase the vertical jump performance of women volleyball players.
- A short-term high-intensity warm-up protocol is the best to acutely improve vertical jump height in women volleyball players, when compared to traditional warm-up protocol and when each one is applied by itself.
- It is thought that a short-term high-intensity warm-up protocol has a positive effect on vertical jump height and that including it in warm-up programs in sports where vertical jump is a performance criterion may have positive effects.

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AUTHORS' CONTRIBUTIONS

Study concept and design: Polen Ünver, Nalan Suna, Mert Kurnaz. Acquisition of data: Polen Ünver, Nalan Suna. Analysis and interpretation of data: Polen Ünver, Nalan Suna, Mert Kurnaz. Drafting the manuscript: Polen Ünver, Nalan Suna, Mert Kurnaz. Critical manuscript revision for important intellectual content: Nalan Suna, Mert Kurnaz. Statistical analysis: Polen Ünver, Nalan Suna, Mert Kurnaz. Administrative, technical, and material support: Polen Ünver, Nalan Suna, Mert Kurnaz. Study supervision: Nalan Suna, Mert Kurnaz.

CONFLICT OF INTEREST

The authors declared that there is no conflict of interest.

FINANCIAL DISCLOSURE

We declare no financial interest in the article "Effects of Different Warm-Up Protocols on Vertical Jump Height in Elite and Sub-Elite Women Volleyball Players." Furthermore, we confirm that we have no financial interest in the material discussed in this article.

Our involvement in the research and publication of this article is solely based on academic and professional interest in the subject matter, and we affirm that no financial gain or benefit has influenced the research or its presentation.

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ETHICAL CONSIDERATION

All participants signed the informed consent form. The Haliç University Non-Interventional Clinical Research Ethics Committee approved, and the study complied with the Declaration of Helsinki (25.01.2023; ref no: 2023/3).

ROLE OF THE SPONSOR

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ARTIFICIAL INTELLIGENCE (AI) USE

AI and its variations were not used in any part of this article.

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