

The acute effects of neuromuscular and dynamic warm-up protocols on performance parameters in young female soccer players

MERVE CAN KARTAL¹, İBRAHİM CAN², MUSTAFA AYDIN³, İNAN ATIŞ⁴, AHMET ATLI⁵, GÜLHAN ERDEM SUBAK⁶

¹ Directorate of Sports Affairs, Batman Municipality, Batman, TÜRKİYE.

^{2,5} Department of Coaching Education, Faculty of Sports Sciences, Iğdır University, Iğdır, TÜRKİYE.

³ Department of Sports Management, Faculty of Sports Sciences, Gümüşhane University, Gümüşhane, TÜRKİYE.

⁴ Department of Therapy and Rehabilitation, Tuzluca Vocational School, Iğdır University, Iğdır, TÜRKİYE.

⁶ Department of Physical Education and Sport, Faculty of Sports Sciences, Iğdır University, Iğdır, TÜRKİYE.

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Abstract

This study compared the acute effects of dynamic and neuromuscular warm-up protocols on sprint, agility, and jumping performance in young female soccer players. A total of twenty-eight young female soccer players (age: 15.71±1.49 years; height: 163±6 cm; body weight: 53.18±5.52 kg; training experience: 2.96±1 year) participated in crossover experimental design. Short-term performance measures including sprint, agility, and jumping, were assessed under 3 distinct warm-up conditions: dynamic warm-up (DWU), neuromuscular warm-up (NWU), and a general warm-up (GWU) with each session separated by a rest period. In the analysis of the data, the effects of the participants' performance measurements under three different warm-up conditions were analyzed using a repeated measures ANOVA test. Normality assumption was assessed using the Shapiro-Wilk test, while sphericity assumption was assessed using the Mauchly test, and Greenhouse-Geisser correction was applied where necessary. For variables where significant differences were found, multiple comparison analyses were performed using the Bonferroni method. According to the analysis results, warm-up conditions were found to have a statistically significant effect on 30 m sprint ($F=10.69$, $p<0.001$, $\eta^2=0.284$), 20 m sprint ($F=16.49$, $p<0.001$, $\eta^2=0.379$), vertical jump height ($F=62.35$, $p<0.001$, $\eta^2=0.698$) and agility ($F=7.03$, $p=0.002$, $\eta^2=0.207$) values. Effect size (η^2) values indicate that warm-up conditions have a moderate to high level of impact on performance variables. The high η^2 value observed particularly in jumping performance reveals that the type of warm-up has a strong influence on this variable. Bonferroni-corrected pairwise comparisons revealed that dynamic warm-up was more effective for 30 and 20 m sprint and agility performances, while neuromuscular warm-up was more effective for jumping performance ($p<0.05$). In conclusion, it can be argued that instead of applying a uniform approach to warm-up protocols for young women's soccer players, they should be customized to meet specific performance goals before training and competition.

Keywords: women's football, neuromuscular warm-up, dynamic warm-up, performance

Introduction

The rapid global development of women's soccer has led to an increasing number of studies examining players' physiological characteristics, match demands, and performance-related factors (Lagunas et al., 2014). Although the fundamental structure of the game is similar to men's football, several physiological and biomechanical differences distinguish female players. In particular, variations in lower extremity biomechanics, hormonal factors, and neuromuscular control have been associated with a higher incidence of knee injuries, especially anterior cruciate ligament (ACL) injuries, in women's soccer players (Hewett et al., 2006; Montalvo et al., 2019). These differences emphasize the need for training approaches that not only enhance performance but also minimize injury risk, making the optimization of warm-up strategies particularly important in women's football.

Warm-up can be considered a comprehensive preparation strategy that extends beyond increasing muscle temperature. It contributes to improved neuromuscular activation, better movement control, and enhanced readiness for high-intensity activities such as sprinting, jumping, and rapid changes of direction (Bishop, 2003; Bizzini and Dvorak, 2015). Traditional warm-up methods, such as static stretching, aim to increase range of motion (ROM) and reduce muscle stiffness by maintaining muscles in a stretched position for a certain period. However, evidence suggests that prolonged static stretching may have negative or limited acute effects on anaerobic performance parameters such as strength, sprinting, and jumping. This reduction in

performance has been linked to temporary decreases in neuromuscular activation and alterations in muscle-tendon unit behavior. In contrast, dynamic warm-up involves active, multi-joint, sport-specific movements performed with gradually increasing intensity, aiming to both enhance mobility and prepare the neuromuscular system for explosive performance demands. Previous studies have indicated that dynamic stretching produces more consistent positive effects on performance, particularly in lower extremity function and ROM (Behm and Chaouachi, 2011).

Neuromuscular warm-up represents a more integrative approach, combining elements such as strength, balance, proprioception, coordination, and movement control. This type of warm-up is designed to enhance both central and peripheral nervous system activation, thereby preparing athletes for short-duration, high-intensity efforts such as sprinting, jumping, and agility tasks. Additionally, it contributes to improving lower extremity biomechanics and dynamic stability, particularly around the knee and ankle joints. In sports characterized by repetitive high-intensity actions like football, neuromuscular warm-up not only supports performance preparation but also plays an important role in reducing injury risk (Bishop, 2003; Bizzini and Dvorak, 2015).

Among neuromuscular warm-up strategies, the FIFA 11+ program is one of the most commonly used and extensively studied protocols. Research conducted on young female soccer players has shown that long-term implementation of the FIFA 11+ program significantly reduces lower extremity injuries (Soligard et al., 2008). In addition, several studies have reported that neuromuscular warm-up protocols have positive effects on performance variables such as vertical jump, agility, and balance (Kilding et al., 2008; Ayala et al., 2017). Considering its effects on both movement quality and explosive performance components, neuromuscular warm-up may serve as a strong alternative or complement to dynamic warm-up during pre-competition preparation (Myer et al., 2005; Bizzini and Dvorak, 2015).

In football, performance is largely determined by short-duration, high-intensity actions such as sprinting, jumping, and changes of direction. Although these actions are brief, they play a decisive role during critical moments of the match. Analyses of goal-scoring situations have demonstrated that sprinting and rapid directional changes are among the most frequent actions preceding goals (Faude et al., 2012). Moreover, sprint performance is influenced not only by maximal running speed but also by acceleration and deceleration capabilities, while change-of-direction ability is associated with lower extremity strength, reactive force production, and neuromuscular control (Spiteri et al., 2014). Similarly, jumping performance is considered an important indicator of explosive power and is closely related to sprint acceleration and agility performance (Loturco et al., 2015).

Although numerous studies have investigated warm-up strategies, most have focused on injury prevention or general performance outcomes. Research specifically examining the acute effects of different warm-up protocols on short-term performance parameters in women's soccer players remains limited. Therefore, the aim of the present study is to compare the acute effects of dynamic and neuromuscular warm-up procedures on sprinting, change-of-direction ability, and jumping performance in young female soccer players. It is anticipated that the findings of this study will provide practical insights for coaches and sports scientists in optimizing warm-up strategies according to specific performance demands.

Material & Methods

Participants

A total of 28 young female soccer players (age: 15.71 ± 1.49 years; height: 163.0 ± 6.0 cm; body weight: 53.18 ± 5.52 kg; training experience: 2.96 ± 1.0 years) voluntarily participated in this study. All participants were actively competing in the 1955 Batman Municipality Sports Club. The inclusion criteria required participants to have at least two years of licensed football experience, to be regularly involved in training and competitions, and to be willing to complete all testing procedures. In addition, participants were required not to use any medication that could affect performance and to have no history of injury in the lower or upper extremities within the last six months. Participants who did not complete the testing protocol or who experienced injury during the study were excluded.

All participants were informed in detail about the purpose, procedures, potential risks, and benefits of the study, and written informed consent was obtained prior to participation. Ethical approval was granted by the Iğdır University Scientific Research and Publication Ethics Board (Approval No: 50/25-12.2025). All procedures were conducted in accordance with the principles of the Declaration of Helsinki.

Procedures

The study was designed as a quasi-experimental crossover model to investigate the acute effects of three different warm-up protocols: dynamic warm-up (DWU), neuromuscular warm-up (NWU), and general warm-up (GWU). Each protocol was implemented on separate days with a 48-hour recovery interval between sessions. Before the experimental trials, all participants completed a familiarization session one week prior to testing. During each testing session, participants first performed a standardized 10-minute run at approximately 40% of their maximal heart rate, followed by the assigned warm-up protocol. The duration of both DWU and NWU protocols ranged between 12 and 15 minutes, with rest intervals of 20–30 seconds between exercises (Yanci et al., 2019; Eken, 2022).

Following the completion of the warm-up protocols, performance tests were administered after a 2–3 minute passive recovery period, which corresponds to the typical time interval between warm-up and competition (Bizzini et al., 2013; Ayala et al., 2017). The testing sequence was standardized as vertical jump, agility, and sprint performance (Ratamess, 2012). Each test was performed twice, and the best result was recorded for analysis.

All measurements were conducted by the same researcher to ensure consistency, and testing sessions were scheduled between 09:00 and 11:00 a.m. to minimize circadian variability. The tests were performed in an indoor environment under standardized conditions. Participants were instructed to avoid alcohol and strenuous physical activity for 24 hours prior to testing, refrain from smoking for at least two hours before the session, and avoid caffeine intake and food consumption within three hours prior to testing.

Sprint and agility performances were measured using a photocell timing system (Brower Timing Systems, USA) with an accuracy of 0.01 seconds. Vertical jump performance was assessed using an optical measurement system (Microgate, Italy).

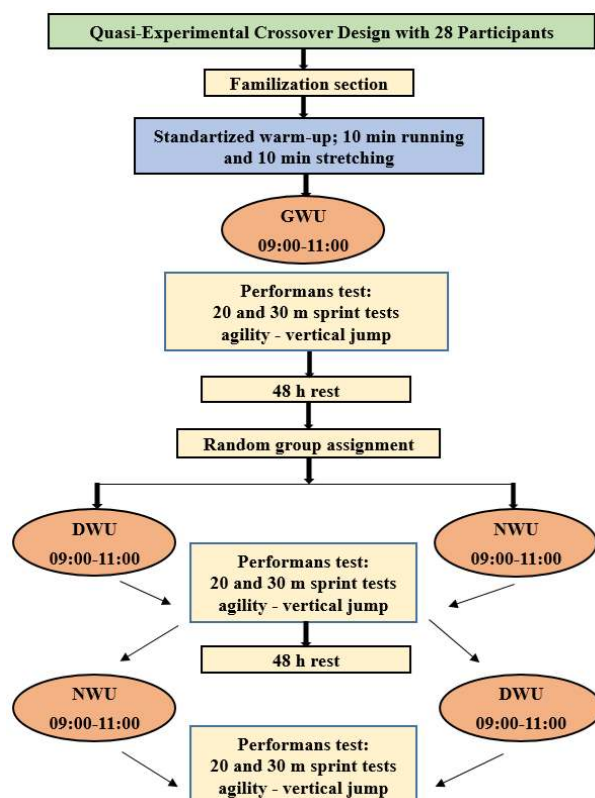


Figure 1. Schematic Overview of the Experimental Design of the Study

In this study, participants underwent two different warm-up protocols: neuromuscular warm-up and dynamic warm-up. The neuromuscular warm-up (NWU) protocol, based on the FIFA 11+ program, includes balance, strength, core muscle activation, and jumping exercises (Steffen et al. 2013; Ayala et al., 2017). The Dynamic Warm-Up Protocol (DWU) includes examples of dynamic exercise movements (Devore and Hagerman, 2006). Exercise examples from both warm-up protocols are presented in Table 1.

Table 1. Exercises Included in Neuromuscular Warm-up and Dynamic Warm-up Protocols

Neuromuscular Warm-up Exercises		Dynamic Warm-up Exercises	
Front Plank (Push-Up Position)	3x30 (sec)	High Knee Running	3x4 (reps)
Front Plank with Alternating Leg Lifts	3x30 (sec)	Knee-Draw with Alternating Foot Touch on the Ball	3x30 (sec)
Partner-Assisted Hamstring Exercise	3x5 (reps)	Cross-Over Toe Touch	3x4 (reps)
Holding the Ball on One Leg	2x30 (sec)	Forward Lunge with Trunk Rotation	3x4 (reps)
Side Jumps	2x 30 (sec)	Side Stepping	3x4 (reps)
Squat with Heel Raise	2x30 (sec)		

Data Collection

The participants' agility values were determined using the Illinois agility test, designed by Getchell (1979) to evaluate athletes' acceleration, change of direction, and agility characteristics. To define the test area (10 m long and 5 m wide), four funnels (start, finish and two turning points) were used, each 2.5 m away from the central funnel (Lennemann et al., 2017). Additionally, there are four more funnels in the middle of the test area, each with a 3.3-m gap between them (Raya et al., 2013). The test involves 40-m straight runs with 180° turns every 10 m, and slalom (zigzag) runs between 20-m cones (Mackenzie, 2005). Participants begin the test lying prone behind the starting line with their hands on the ground at shoulder level, and upon hearing the "start" command, they must run as fast as possible, follow a planned route, and slalom without knocking over or jumping over cones (Fiorilli et al., 2017). 20 and 30-m sprint tests were administered to evaluate the participants' sprint performance. Participants started the sprint tests from a static position (0 m behind the first photocell sensor) when they were ready and were instructed to run with maximum effort to the finish line (Can, 2018).

Participants' vertical jump height was measured using a jump mat (Microgate Jump Contact Mat, Microgate S.r.l., Italy). Before beginning the jump test, participants assumed a standard starting position on the mat with their feet shoulder-width apart, then squatted down to approximately 90° of knee flexion, and then jumped as high as possible (Pomares-Noguera et al., 2018). Participants were allowed to swing their arms during the jump. Participants were not permitted to take a step or run towards the finish line during the jump. During the measurement, jumps were deemed invalid if the participant exhibited excessive (>45°) hip flexion during their time in the air, excessive knee flexion causing the heels to approach the hip (gluteal) area, or failure to land fully on the contact mat (Kilding et al., 2008).

Statistical Analysis

Statistical analyses of the data were performed using the SPSS 25.0 (Statistical Package for the Social Sciences) software package. Descriptive statistics for continuous variables were presented as mean and standard deviation (Mean±SD). Since the study compared performance measurements obtained from the same participants under three different warm-up conditions (general warm-up, dynamic warm-up, and neuromuscular warm-up), repeated measures ANOVA was used to examine the differences between the conditions. Prior to analysis, the normality of the data was assessed using the Shapiro-Wilk test, and it was determined that the variables showed a normal distribution.

The sphericity assumption was assessed using the Mauchly test before repeated measures ANOVA; if a violation was found, the Greenhouse–Geisser correction was applied. For variables that showed statistically significant differences in the repeated measures ANOVA results, pairwise comparisons (post-hoc analyses) with Bonferroni correction were performed to determine which conditions differed significantly. Partial eta squared (η^2) values are reported as an effect size indicator to reveal the relative magnitude of the effect of warm-up conditions on performance. In Cohen's classification, a η^2 value of 0.01 was interpreted as small, 0.06 as medium, and ≥ 0.14 as large effect. The statistical significance level was accepted as $p < 0.05$ in all analyses.

Results

Table 2. Demographic Characteristics of Participants

Variable	N	Min.	Max.	Mean ± SD
Age (years)	28	14.0	18.00	15.71 ± 1.49
Height (cm)	28	154.00	173.00	163.00 ± 6.00
Body Weight (kg)	28	42.30	67.00	53.18 ± 5.52
Sports Experience (years)	28	2.00	5.00	2.96 ± 1.00

Table 3. Performance Variables According to Warm-Up Conditions (Mean±SD)

Variable	N	GWU	DWU	NWU
30 m Sprint (s)	28	5.32 ± 0.42	5.22 ± 0.41	5.30 ± 0.41
20 m Sprint (s)	28	4.07 ± 0.33	3.83 ± 0.31	3.96 ± 0.31
Vertical Jump (cm)	28	31.65 ± 1.24	31.83 ± 1.30	32.69 ± 1.31
Agility (s)	28	17.23 ± 0.58	17.05 ± 0.64	17.20 ± 0.59

GWU: General warm-up; DWU: Dynamic warm-up; NWU: Neuromuscular warm-up

The demographic characteristics of the participants are summarized in Table 2, and their performance values according to warm-up conditions are summarized in Table 3. The average age, height, weight, and sports experience of the participants were obtained as 15.71 (±1.49 years), 163.0 (±6.0 cm), 53.18 (±5.52 kg), and 2.96 (±1.0 year), respectively (Table 2). It was found that participants' 20 and 30-m sprint times and agility values were lower in the dynamic warm-up condition compared to other conditions, while their vertical jump height was significantly higher in the neuromuscular warm-up condition (Table 3).

Table 4. Repeated Measurements ANOVA Results According to Warm-Up Conditions

Variable	N	F	P	η^2
30 m Sprint (s)	28	10.69	0.001	0.284
20 m Sprint (s)	28	16.49	0.001	0.379
Vertical Jump (cm)	28	62.35	0.001	0.698
Agility (s)	28	7.03	0.002	0.207

Table 5. Bonferroni Post-Hoc Comparison Results According to Warm-Up Conditions

Variable	Ranking Between Conditions	P
30 m Sprint (s)	DWU < GWU	0.001
	DWU < NWU	0.019
	GWU = NWU	1.000
20 m Sprint (s)	DWU < GWU	0.001
	DWU < NWU	0.001
	GWU = NWU	0.051
Vertical Jump (cm)	NWU > GWU	0.001
	NWU > DWU	0.001
	DWU = GWU	0.112
Agility (s)	DWU < GWU	0.005
	DWU < NWU	0.028
	GWU = NWU	1.000

Note: Lower times in sprint and agility variables, and higher values in vertical jump indicate better performance. GWU: General warm-up procedure; DWU: Dynamic warm-up procedure; NWU: Neuromuscular warm-up procedure

The results of the repeated measures ANOVA conducted to examine the effect of warm-up conditions on performance variables are presented in Table 4. According to the repeated measures ANOVA results, warm-up conditions were found to have statistically significant effects on 30 m sprint ($F=10.69$, $p<0.001$, $\eta^2=0.284$), 20 m sprint ($F=16.49$, $p<0.001$, $\eta^2=0.379$), vertical jump height ($F=62.35$, $p<0.001$, $\eta^2=0.698$) and agility ($F=7.03$, $p=0.002$, $\eta^2=0.207$). The obtained effect size (η^2) values indicate that warm-up conditions have moderate to high effects on performance variables. The $\eta^2=0.698$ value observed particularly in vertical jump performance reveals that the type of warm-up has a very strong effect on this variable. The results of the Bonferroni-corrected pairwise comparisons, conducted to determine which groups were responsible for the differences, are presented in Table 5. In 30 and 20 m sprint performances, times obtained under dynamic warm-up conditions were found to be significantly shorter than those obtained under general and neuromuscular warm-up conditions ($p<0.05$). The dynamic warm-up procedure resulted in an average improvement of 0.24 seconds in 20-m sprint time. In vertical jump performance, the neuromuscular warm-up condition produced significantly higher values compared to both the general and dynamic warm-up conditions ($p<0.001$). The average difference is approximately in the range of 0.9-1.0 cm. In terms of agility performance, dynamic warm-up resulted in better performance with shorter durations compared to the other two conditions ($p<0.05$).

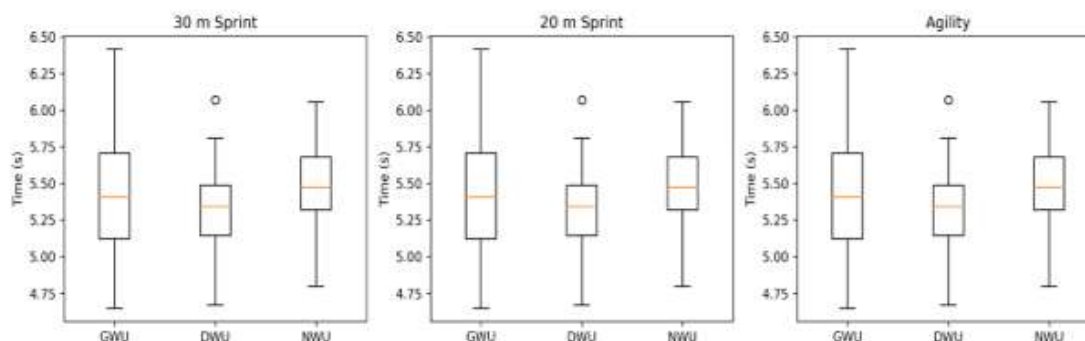


Figure 2. Sprint and Agility Performance under Different Warm-Up Conditions

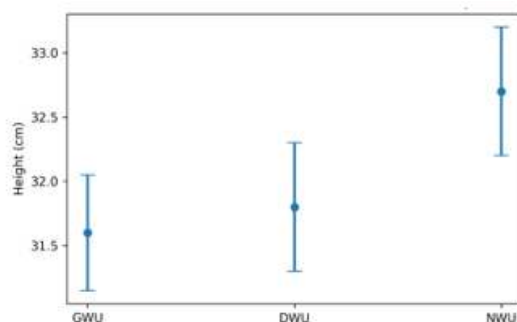


Figure 3. Vertical Jump Height (Mean $\pm$ 95% CI)

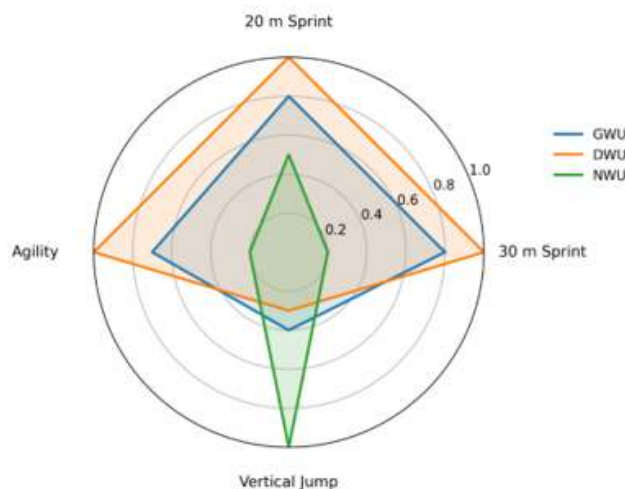


Figure 4. Overall Performance Profile under Different Warm-Up Conditions

The distributions of sprint and agility performance are presented in Figure 2. using boxplot diagrams. As shown in the figure, dynamic warm-up conditions resulted in lower (better) results in 30 m and 20 m sprint times. Dynamic warm-up has also been observed to provide an advantage in agility performance. The mean and 95% confidence interval values for vertical jump performance are shown in Figure 3. The values obtained under neuromuscular warm-up conditions were found to be significantly higher, and the low level of overlap in the confidence interval supported the statistical significance of this difference. The radar graph showing the overall effect of the warm-up conditions on all performance variables is given in Figure 4. Graphically, it was determined that dynamic warm-up conditions were prominent in sprint and agility performances, neuromuscular warm-up conditions were prominent in vertical jump performance, and general warm-up showed a lower profile compared to the other two protocols.

Discussion

The aim of the present study was to examine the acute effects of different warm-up strategies on key performance parameters in young female soccer players. The findings indicate that the effectiveness of warm-up protocols varies depending on the specific performance task. Dynamic warm-up was found to be more effective in improving sprint and agility performance, whereas neuromuscular warm-up resulted in superior outcomes in vertical jump performance. These results suggest that warm-up strategies should be selected according to the specific performance demands of the activity.

In a study conducted by Gök et al. (2023) on football players, participants were divided into groups performing general warm-up and FIFA 11+ warm-up protocols, and sprint performance was evaluated. The results indicated no significant differences between the groups, although the FIFA 11+ protocol was reported to be more beneficial in terms of injury prevention and movement quality. These findings are consistent with the results of the present study. However, other studies in the literature have demonstrated that long-term implementation of FIFA 11+ protocols may lead to improvements in sprint performance. For example, Durukan et al. (2019) reported significant improvements in sprint performance following an eight-week FIFA 11+ training program applied three times per week. Similarly, Ayala et al. (2017) found that FIFA 11+ protocols applied over several weeks improved sprint performance compared to neuromuscular training. These findings suggest that the duration of the intervention plays a critical role in determining performance outcomes.

In contrast, studies examining the acute effects of warm-up protocols have shown different results. Asgari et al. (2023) reported that dynamic warm-up was more effective than FIFA 11+ in improving sprint performance in university football players. Similarly, Ayala et al. (2017) demonstrated that sprint performance increased significantly following dynamic warm-up protocols. Faigenbaum et al. (2006) also reported that dynamic warm-up exercises applied before performance testing improved sprint performance in young female athletes. These findings support the results of the present study, indicating that dynamic warm-up provides an immediate performance advantage in speed-related tasks.

On the other hand, some studies have reported conflicting findings. Çelgin and Arslanoğlu (2024) found that the FIFA 11+ warm-up protocol produced greater improvements in sprint performance compared to the dynamic warm-up (RAMP) protocol. The authors suggested that this difference might be related to the inclusion of strength-based exercises in the FIFA 11+ program. Therefore, inconsistencies in the literature may be explained by differences in exercise content, duration, and intensity of the applied warm-up protocols. It can be argued that further research is needed to determine the most effective warm-up strategies.

Although the present study showed that neuromuscular warm-up produced better results than general warm-up, these differences were not statistically significant. However, dynamic warm-up resulted in significantly better performance compared to both general and neuromuscular warm-up in sprint and agility tasks. Similar findings have been reported in studies examining agility performance. For example, Mota et al. (2019) and Hameed et al. (2022) found that both general warm-up and FIFA 11+ protocols improved agility performance, although no significant differences were observed between the protocols. In contrast, Asgari et al. (2022) reported that dynamic warm-up significantly improved agility performance compared to other conditions when applied over a longer period.

The effectiveness of dynamic warm-up in improving agility performance may be explained by its ability to enhance neuromuscular activation and movement efficiency. The FIFA 11+ program includes both static and dynamic components (Grooms et al., 2013), whereas dynamic warm-up protocols typically involve plyometric and sport-specific exercises performed with gradually increasing intensity. These exercises may stimulate post-activation potentiation (PAP), which enhances explosive performance by increasing muscle contractile capacity following prior activation (Young and Behm, 2003; Faigenbaum et al., 2006; Sale, 2002). Since agility requires rapid force production, acceleration, and directional changes (Young et al., 2002), improvements in neuromuscular activation may explain the superior performance observed following dynamic warm-up in the present study.

In terms of vertical jump performance, the results of the present study indicate that neuromuscular warm-up was more effective than both general and dynamic warm-up protocols. Similar findings have been reported in previous studies. Kahraman et al. (2023) found that vertical jump performance was significantly higher following FIFA 11+ warm-up compared to static and dynamic warm-up protocols. Likewise, Şar et al. (2025) reported improvements in vertical jump performance following FIFA 11+ interventions in female soccer players. These findings may be attributed to the inclusion of strength and stability exercises targeting the lower extremity muscles in neuromuscular warm-up protocols.

Further supporting these findings, Daneshjoo et al. (2013) demonstrated that FIFA 11+ programs applied over an eight-week period significantly improved vertical jump performance compared to control conditions. Similarly, studies conducted by Silva et al. (2015), Zarei et al. (2018), and Nawed et al. (2018) reported improvements in vertical jump performance following long-term FIFA 11+ training programs. It has been suggested that these improvements are related to increased neuromuscular control and activation of core and lower extremity muscles (Nakase et al., 2013; Whittaker and Emery, 2014). In contrast, dynamic warm-up protocols may not include sufficient lower extremity strength components to elicit similar improvements in explosive power.

Based on these findings, it can be suggested that combining elements of both dynamic and neuromuscular warm-up protocols may provide a more comprehensive approach to performance enhancement. Integrating strength-based exercises from neuromuscular warm-up into dynamic warm-up routines may help improve both speed-related and power-related performance parameters.

Conclusions

In conclusion, based on the short-term and explosive movement pattern results measured after general warm-up, dynamic warm-up, and FIFA 11+ warm-up programs applied to women football players, a significant improvement was observed in sprint and agility values after the dynamic warm-up program, and in vertical jump height after the neuromuscular warm-up program. According to the study results, the type of warm-up for women football players should be chosen according to the content of the training program to be implemented. Conducting dynamic warm-ups before training sessions involving sprinting and agility, and applying neuromuscular warm-ups before training sessions emphasizing strength, jumping, and tackles, can provide an advantage in terms of performance improvement. Using both warm-up protocols together can contribute to improved performance in footballers while also helping to reduce the risk of injury. Therefore, instead of

applying a uniform approach to warm-up routines, it is important for coaches to plan them according to training goals and the performance characteristics they want to improve.

Limitations

This study has some limitations. The first is that the study group consisted of a small number of participants, all of whom were women football players. This situation could lead to an imbalance in the generalizability of the study to other sports and could negatively impact the results due to gender-specific differences. Another limitation of the study is that only the acute effects of warm-up methods on performance were investigated. This results in a lack of information regarding the effects of warm-up procedures on performance parameters after an intervention period. The age of the participants can be mentioned as another limitation. Because the results achieved in young athletes may not yield the same results in adult women athletes. Other limitations of our study include the use of only field tests as an evaluation method and the investigation of short-term explosive performance parameters. This would limit our understanding of the effects of warm-up procedures on other motor skills important for athletic performance.

Conflicts of Interest. The authors declare no conflict of interest.

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