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Comparison of the Acute Effects of Basket-Up and Dynamic Warm-Up on Performance in U14 Female and Male Basketball Players

U14 Basketbolcularda Basket-Up ve Dinamik Isınmanın Performansa Akut Etkilerinin Karşılaştırılması

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Öz

Bu çalışmanın amacı, U14 kız ve erkek basketbolcularda dinamik ve Basket-Up ısınma protokollerinin akut fiziksel performans üzerindeki etkilerini ve bu etkilerin cinsiyete göre farklılaşıp farklılaşmadığını incelemektir. Araştırmaya 17 kız ve 17 erkek olmak üzere toplam 34 U14 basketbol sporcusu katılmıştır. Tüm sporcular dinamik ve Basket-Up ısınma protokollerinin her ikisini de farklı test oturumlarında uygulamıştır. Her ısınma protokolünün ardından 20 m sürat, T-test çeviklik, esneklik, Countermovement Jump (CMJ) ve Drop Jump (DJ) testleri uygulanmıştır. Veriler, tekrarlı ölçümler ve cinsiyet faktörlerini içeren karma ANOVA ile analiz edilmiştir. Isınma protokolünün CMJ, DJ, RSI, 20 m sürat, T-test ve esneklik performansı üzerinde anlamlı etkileri olduğu belirlenmiştir ($p < 0,001$). Basket-Up protokolü sonrasında performans değerlerinde daha belirgin gelişimler gözlenmiştir. Kız sporcularda CMJ (%12.17), DJ (%9.98) ve RSI (%15.87) değerlerindeki yüzdesel artışlar erkek sporculara göre daha yüksek bulunmuştur. Bununla birlikte, sıçrama parametrelerinde protokol × grup etkileşiminde anlamlı fark bulunmamıştır. Çeviklik değişkeninde ise anlamlı ve büyük düzeyde protokol × grup etkileşimi bulunmuştur ($p = 0.001$, $\eta^2p = 0.363$). Esneklik açısından cinsiyetler arasında anlamlı fark tespit edilmiştir ($p = 0.031$, $\eta^2p = 0.138$). Sonuç olarak, Basket-Up ısınma protokolünün U14 basketbolcularda akut fiziksel performansı geliştirmede etkili bir yaklaşım olabileceği ve antrenman veya müsabaka öncesinde kullanılabileceği düşünülmektedir.

Anahtar Kelimeler: Basket-Up, Dinamik Isınma, Basketbol, Akut Performans

Abstract

The aim of this study was to examine the effects of dynamic and Basket-Up warm-up protocols on acute physical performance in U14 female and male basketball players and to determine whether these effects differed according to gender.. A total of 34 U14 basketball players, including 17 girls and 17 boys, participated in the study. All participants performed both the dynamic and Basket-Up warm-up protocols in separate testing sessions. Following each warm-up protocol, 20-m sprint, T-test agility, flexibility, Countermovement Jump (CMJ), and Drop Jump (DJ) tests were performed. The data were analyzed using mixed ANOVA including repeated measures and gender factors. Significant effects of the warm-up protocol were found on CMJ, DJ, RSI, 20-m sprint, T-test, and flexibility performance ($p < 0.001$). Greater improvements in performance were observed following the Basket-Up protocol. Percentage improvements in CMJ (12.17%), DJ (9.98%), and RSI (15.87%) were higher in female athletes than in male athletes. However, no significant difference was found in the protocol × group interaction for the jumping parameters. A significant and large protocol × group interaction was found for agility ($p = 0.001$, $\eta^2p = 0.363$). A significant difference was also found between gender in flexibility ($p = 0.031$, $\eta^2p = 0.138$). In conclusion, the Basket-Up warm-up protocol may be an effective approach for improving acute physical performance in U14 basketball players and may be used before training or competition.

Keywords: Basket-Up, Dynamic Warm-Up, Basketball, Acute Performance

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INTRODUCTION

Basketball is a court-based team sport that requires proficiency in various physical parameters and motor skills to achieve technical and tactical success (Petway et al., 2020; Suárez-Balsera et al., 2025). The ability to accelerate and decelerate, change direction, jump, and perform lateral movements is of considerable importance for on-court performance and success, given the intermittent and high-intensity nature of basketball-specific activities (Ramos-Campo et al., 2017) and the physical demands of the sport (Sampaio et al., 2015). In addition, under competitive conditions, these physical and motor skills must be performed effectively and economically throughout all four quarters, with contributions from both the aerobic and anaerobic energy systems (Scanlan et al., 2011).

In response to the high physical demands of basketball and the expectations for high-level performance, coaches systematically and strategically organize training loads to develop players' physiological and technical capacities (Aoki et al., 2017). While long-term training processes aim to induce progressive improvements in these parameters, activation strategies that facilitate acute performance enhancement are important for preparing athletes to achieve the performance levels required during competition (Maroto-Izquierdo et al., 2020). In this context, warm-up is considered an essential component of preparing athletes for the physiological demands encountered during training and competition (Alanazi, 2016). The primary objectives of warm-up include enhancing athletic performance and reducing the risk of injury (McGowan et al., 2015). Warm-up induces various physiological and psychological responses, including increased muscle metabolic activity, improvements in the biomechanical properties of muscle fibers, enhanced neuromuscular activity and oxygen uptake, and improved psychological readiness (Cerrillo-Sanchis et al., 2024). These physiological responses have been reported to contribute to high-intensity skills such as the countermovement jump (CMJ) (Li et al., 2023), linear sprint performance (Paradisis et al., 2014), and change-of-direction performance (Cerrillo-Sanchis et al., 2024; Lockie et al., 2017). Similarly, studies conducted specifically in basketball have demonstrated that appropriately structured warm-up routines can significantly enhance athletic performance (Cerrillo-Sanchis et al., 2024; Galazoulas et al., 2012; Sansone et al., 2025; Zelenović et al., 2024).

Sport-specific warm-ups are characterized by movements or activities that simulate the demands of a particular sport (Gomes Neto et al., 2017). Recent research suggests that sport-specific warm-ups may enhance athletic performance because they replicate the activities required by the respective sport (Mielniczek & Tillaar, 2026; Paravlic et al., 2024; Trajković et al., 2020). Unlike many other sports, basketball involves unilateral movements, changes of direction, rhythmic movements, and jumping activities, thereby imposing substantial high-intensity physiological demands (Vázquez-Guerrero et al., 2020). Accordingly, an optimal warm-up and activation strategy in basketball is expected not only to prepare athletes to perform at a high level but also to contribute to reducing the risk of injuries associated with physical loading (Longo et al., 2012). Previous research has provided evidence regarding the acute effects of the Basket-Up protocol, a

basketball-specific warm-up program developed based on the movement and performance demands of basketball (Cerrillo-Sanchis et al., 2024). However, evidence regarding the acute effects of this protocol in younger basketball players remains limited. In particular, the acute responses to Basket-Up have not been examined in U14 basketball players using a crossover design in which the same athletes perform both a general dynamic warm-up and the Basket-Up protocol. Moreover, the effects of these warm-up protocols on a broader range of performance outcomes, including countermovement jump (CMJ), drop jump (DJ), and reactive strength index (RSI), have not been comprehensively examined in this age group. Furthermore, evidence comparing the acute performance responses of female and male basketball players during early adolescence to different warm-up protocols remains insufficient. Therefore, examining these responses within the same young athletes may provide further insight into the applicability of sport-specific warm-up strategies in youth basketball.

Therefore, the aim of this study was to investigate the acute effects of dynamic warm-up and Basket-Up warm-up protocols on sprint, agility, flexibility, countermovement jump (CMJ), and drop jump (DJ) performance in U14 female and male basketball players and to determine whether these responses differ according to gender. Based on the sport-specific movement characteristics of the Basket-Up protocol, we hypothesized that Basket-Up would elicit greater acute improvements in sprint, agility, and jump performance than the general dynamic warm-up protocol. We further hypothesized that the magnitude of these acute responses would differ according to gender, with greater improvements expected in female players for selected performance outcomes.

METHOD

Research Model

This study employed a quantitative crossover experimental design with repeated measures to investigate the acute effects of different warm-up protocols on sprint, agility, flexibility, countermovement jump (CMJ), and drop jump (DJ) performance in U14 female and male basketball players. Participants were randomly assigned to two protocol-order groups using a computer-based randomization program (randomizer.org). All participants completed both the dynamic warm-up and Basket-Up protocols, with the order of protocol administration determined by the assigned sequence. A 1-week washout period was provided between the two experimental sessions to minimize potential carryover, fatigue, and familiarization effects.

Participants

A total of 34 athletes, including 17 female athletes (age: 13.70 ± 0.46 years; height: 165.47 ± 8.15 cm; body mass: 58.02 ± 10.88 kg) and 17 male athletes (age: 13.88 ± 0.85 years; height: 170.29 ± 12.13 cm; body mass: 64.85 ± 11.78 kg), who were actively participating in Mersin Beta Akademi Sports Club, voluntarily participated in this study. The participants had been regularly engaged in basketball training for at least 3 years, with training sessions conducted 4 days per week and lasting approximately 60 minutes per session. The minimum required sample size was calculated using G*Power software

based on the repeated-measures experimental design of the study. Accordingly, using the moderate effect size (f = 0.25) reported by Sansone et al. (2025) in a similar comparison of warm-up protocols, the analysis indicated that a minimum total sample size of 22 participants (n = 11 per group) was required to achieve 80% statistical power at a significance level of α = 0.05. A total of 34 athletes, with 17 participants in each group, were included in the study. The obtained sample size exceeded the minimum number of participants determined by the power analysis, indicating that the study had adequate statistical power. Throughout the study, participants were instructed not to engage in any additional physical activity outside their regular training program, to maintain their usual dietary habits, and to refrain from consuming any nutritional supplements. The exclusion criteria were the occurrence of a lower-extremity injury before or during the testing procedures that could negatively affect maximal performance and failure to complete all testing sessions.

Collection of Data

Before the data collection process, participants completed a single familiarization session. During this session, the flexibility, CMJ, DJ, sprint, and agility tests were performed in the same order, with two trials for each test, and participants were instructed to exert maximal effort during all tests. Participants' height and body mass were measured using a stadiometer and an electronic scale at the Mersin Bahçeşehir College sports hall. During the experimental data collection process, each participant completed both the dynamic warm-up and Basket-Up warm-up protocols, and the performance tests were performed in the same order following each protocol. Immediately after completing the assigned warm-up protocol, a 5-min passive recovery period was provided. Following this period, participants performed the flexibility, CMJ, DJ, 20-m sprint, and T-agility tests in the same order as during the familiarization session. All measurements were conducted in the same environment and under similar court conditions (ambient temperature: 21–23°C; relative humidity: 45–50%) to standardize the experimental conditions. In addition,

verbal encouragement was provided to the participants throughout all performance tests.

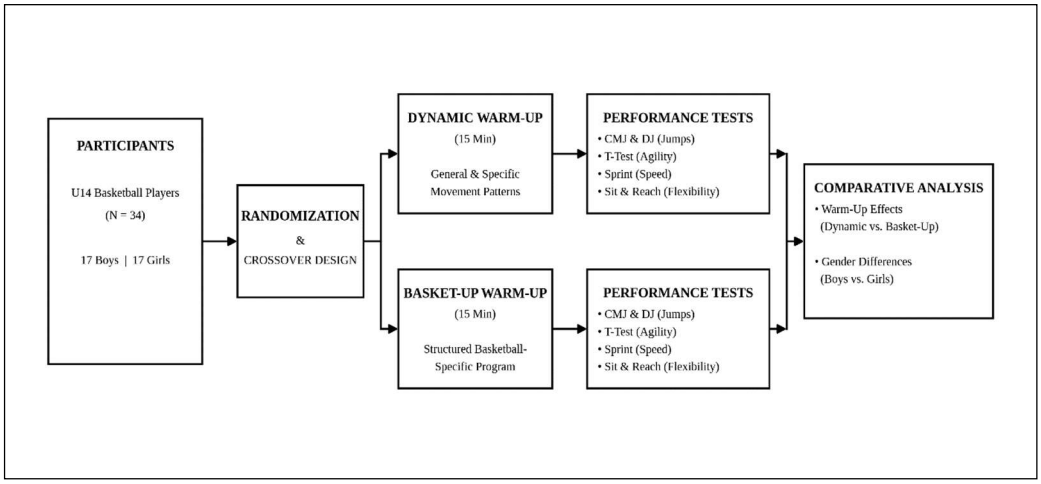


Figure 1. Study Design

Data Collection Tools

Height and Weight Measurements: Participants' height (cm) and body mass (kg) were measured using a digital height and weight measurement device capable of simultaneously assessing height and body mass. To improve measurement accuracy, participants were measured barefoot and wearing light, standardized clothing, such as shorts and a T-shirt (Salway et al., 2024).

Flexibility Measurements: Flexibility was assessed using a Sit-and-Reach test box. Participants were positioned barefoot on the Sit-and-Reach device with their legs parallel to each other and their knee joints fully extended. The soles of the feet were placed firmly against the front surface of the device. Participants were instructed to maintain full knee extension, reach forward as far as possible by flexing the trunk, and slide their hands forward along the measuring scale. Two trials were allowed, and the maximum distance reached was recorded in centimeters (cm) (Ayala et al., 2012).

Jump Performance Measurements: Jump performance was assessed using a Hawkin Dynamics dual force plate system (USA) with a sampling frequency of 1000 Hz. During the CMJ test, athletes were instructed to perform a rapid downward movement followed by an explosive vertical jump while keeping their hands on their hips (Heishman et al., 2020). During the DJ test, athletes were instructed to step off a 30-cm box and, upon landing, perform a maximal vertical jump with the shortest possible ground contact time. This test was used to calculate the reactive strength index. All tests were performed with the hands placed on the hips, and two trials were allowed for each test. The best performance was used for data analysis (Marshall & Moran, 2013).

Sprint Performance Measurements: A 20-m sprint test was performed to assess participants' linear sprint performance. Participants were positioned 1 m behind the

starting photocell and instructed to cover the distance at maximal speed without an external starting signal. Two trials were performed, and the best time (s) was used for analysis. Sprint times were measured using photocells positioned at the start and finish lines (Sánchez-Díaz et al., 2021).

Agility Performance Measurements: The T-test was used to assess agility performance. The test course was arranged with a 10-m distance between the starting point and the central cone and 5-m distances from the central cone to the cones positioned on the right and left sides. A photocell timing system was positioned at the start and finish points, and a cone was placed 1 m behind the starting photocell to standardize the starting position. Participants were allowed two trials, and the test time was recorded in seconds (s) (Čaušević et al., 2023).

Dynamic Warm-Up Protocol

The dynamic warm-up protocol was performed for approximately 20 minutes. The protocol is presented in detail in Table 1 (Taylor et al., 2009).

Table 1. Dynamic warm-up protocol

Exercise Name	Sets × Distance/Repetitions
High-Knee Running	3 x 20 m
Butt Kicks	3 x 20 m
Dynamic Hamstring Swings	1 x 10 repetitions (each leg)
Forward and Backward Arm Swings	1 x 10 repetitions (each arm)
Rapid High-Knee Running	4 x 10 m
Change-of-Direction Running	3 x 20 m
Lateral Shuffling	3 x 20 m
Lateral Squat Walk	1 x 10 repetitions (each direction)
Upper-Body Rotation	10 repetitions (each direction)
Vertical Jumps	5 consecutive repetitions
Lateral Jumps (Single- and Double-Leg)	15 repetitions
Sprint Running	5 x 20 m

Basket-Up Warm-Up Protocol

The Basket-Up warm-up program was developed by a committee of athletic performance specialists at Valencia Basketball Club. This protocol was specifically designed to address the physiological, functional, and physical demands of basketball training. It was also designed to be implemented in any sports facility without requiring additional equipment. The protocol consists of three exercises in Part 1, focusing on mobility. Part 2 comprises six exercises focusing on strength, change of direction, and plyometric exercises. Finally, Part 3 includes six exercises targeting agility and neurocognitive tasks. The protocol is presented in detail in Table 2 (Cerrillo-Sanchis et al., 2024).

Table 2. Basket-Up Warm-Up Protocol

Exercise Name	Sets × Distance/Repetitions
Ankle dorsiflexion	2 x 8 repetitions (each direction)
Hip mobility	2 x 8 repetitions (each direction)
The world's greatest stretch	2 x 8 repetitions (each direction)
Core Isometric lunge	2 x 20-30 s
Core Isometric lunge with plantar flexion	2 x 20-30 s
Hip lock dynamic	3 x 20-30 s (each direction)
Single leg squat	3 x 20-30 s (each direction)
Lunge and squat lateral	3 x 20-30 s (each direction)
Hamstring bridge single leg 30 °	3 x 20-30 s (each direction)
Hip turn	3 x 20-30 s (each direction)
Hip turn and crossover	3 x 20-30 s (each direction)
Crossover and shuffle	3 x 20-30 s (each direction)
Vertical jump	2 x 5 repetitions
Bounds	2 x 5 repetitions (each direction)
Hops	2 x 5 repetitions (each direction)
Running straight ahead	3 repetitions
Running circling partner	3 repetitions
Running quick forward and backward	3 repetitions
Running bounding	3 repetitions
COD defensive reaction	3 repetitions
COD auditive ball	3 repetitions

Ethical Approval

Participants were informed about the potential risks associated with the study. Written informed consent was obtained from the participants and their parents/guardians prior to the data collection process. The study was approved by the Ethics Committee of Mersin University Faculty of Sport Sciences (decision dated December 15, 2025, No. 096). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Data Analysis

All statistical analyses were performed using IBM SPSS Statistics (Version 27.0; IBM Corp., Armonk, NY, USA). Data are presented as mean ± standard deviation (SD). The normality of data distribution was assessed using the Shapiro–Wilk test, while the homogeneity of variances was examined using Levene's test. Baseline differences between the female and male groups were evaluated using one-way analysis of variance (ANOVA). To determine the effects of the interventions, a two-way mixed-design ANOVA was applied to all dependent variables (CMJ, DJ, sprint, agility and flexibility). Significant differences were further examined using Bonferroni-corrected post hoc analysis. Cohen's d (0.20–0.49 = small, 0.50–0.79 = medium, ≥0.80 = large effect) was calculated for within-group changes over time, and partial eta squared (ηp^2) (small: $\eta p^2 \geq .01$, medium: $\eta p^2 \geq .06$, large: $\eta p^2 \geq .14$) was calculated for interaction effects (Cohen, 1988). Statistical significance for all analyses was set at $p < 0.05$.

FINDINGS

Tablo 3. Demographic and Anthropometric Characteristics

Variables	Group	Mean	Std. Deviation	Minimum	Maximum
Age (years)	Girl (n = 17)	13.70	0.46	13.00	14.00
	Boy (n = 17)	13.88	0.85	13.00	15.00
Height (cm)	Girl (n = 17)	165.47	8.15	145.00	181.00
	Boy (n = 17)	170.29	12.13	146.00	186.00
Weight (kg)	Girl (n = 17)	58.02	10.88	36.25	78.35
	Boy (n = 17)	64.85	11.78	38.20	80.00

The participants mean age and body composition characteristics are presented in Table 3.

Table 4. Two-Way Mixed-Design ANOVA Results for CMJ, DJ, and RSI Variables

Variable	Group	Dynamic Warm-Up $\bar{x} \pm SD$	Basket-Up $\bar{x} \pm SD$	% Δ	d	p-Value (η^2p)					
						Protocol (p)	η^2p	Group (p)	η^2p	Interaction (p)	η^2p
CMJ (cm)	Girl(n=17)	24.17±4.06	27.11±3.58	12.17	0.77	0.001*	0.747	0.787	0.002	0.156	0.062
	Boy(n=17)	24.11±5.29	26.29±5.82	9.02	0.39						
DJ (cm)	Girl(n=17)	23.58±3.10	25.94±2.90	9.98	0.78	0.001*	0.660	0.337	0.029	0.681	0.005
	Boy(n=17)	24.94±4.24	27.05±4.60	8.49	0.48						
RSI (m/s)	Girl(n=17)	1.14±0.24	1.32±0.27	15.87	0.69	0.001*	0.547	0.565	0.010	0.636	0.007
	Boy(n=17)	1.20±0.27	1.36±0.24	12.87	0.60						

In the repeated-measures two-way ANOVA presented in Table 4, a significant main effect of protocol was found for all CMJ, DJ, and RSI variables (p = 0.001). CMJ values increased by 12.17% in female athletes and 9.02% in male athletes, with a large effect size observed in both groups (η^2p = 0.747). DJ values increased by 9.98% in female athletes and 8.49% in male athletes, with a large effect size (η^2p = 0.660). RSI values increased by 15.87% in female athletes and 12.87% in male athletes, with a large effect size (η^2p = 0.547). No significant main effect of gender was found for any of the variables (CMJ: p = 0.787, η^2p = 0.002; DJ: p = 0.337, η^2p = 0.029; RSI: p = 0.565, η^2p = 0.010). The effect sizes associated with gender were small for all variables. No significant protocol × group interaction was observed for any variable (CMJ: p = 0.156, η^2p = 0.062; DJ: p = 0.681, η^2p = 0.005; RSI: p = 0.636, η^2p = 0.007). The effect size of the protocol × group interaction was moderate for CMJ and small for DJ and RSI. These findings indicate that the applied protocol was similarly effective in female and male athletes.

Table 5. Two-Way Mixed-Design ANOVA Results for Sprint, Agility, and Flexibility Variables

Variable	Group	Dynamic Warm-Up $\bar{x} \pm SD$	Basket-Up $\bar{x} \pm SD$	% Δ	d	p-Value (η^2p)					
						Protocol (p)	η^2p	Group (p)	η^2p	Interaction (p)	η^2p
20 m sprint	Girl(n=17)	3.49±0.19	3.22±0.14	-7.74	1.61	0.001*	0.730	0.514	0.013	0.111	0.078

(s)	Boy(n=17)	3.49±0.20	3.30±0.23	-5.42	0.87						
Agility (s)	Girl(n=17)	11.38±0.47	11.14±0.41	-2.07	0.53	0.001*	0.685	0.819	0.002	0.001*	0.363
	Boy(n=17)	11.58±0.63	10.85±0.78	-6.31	1.03						
Flexibility (cm)	Girl(n=17)	30.47±7.02	33.05±6.20	8.49	0.41	0.001*	0.470	0.031*	0.138	0.801	0.002
	Boy(n=17)	25.94±5.82	28.29±5.83	9.07	0.40						

In the repeated-measures two-way ANOVA presented in Table 5, a significant main effect of protocol was found for all sprint, agility, and flexibility variables ($p = 0.001$). Sprint performance decreased by 7.74% in female athletes and 5.42% in male athletes, with a large effect size observed in both groups ($\eta^2p = 0.730$). Agility performance decreased by 2.07% in female athletes and 6.31% in male athletes, with a large effect size ($\eta^2p = 0.685$). Flexibility values increased by 8.49% in female athletes and 9.07% in male athletes, with a moderate effect size ($\eta^2p = 0.470$). No significant main effect of gender was found for sprint or agility performance (sprint: $p = 0.514$, $\eta^2p = 0.013$; agility: $p = 0.819$, $\eta^2p = 0.002$). However, a significant main effect of gender was observed for flexibility ($p = 0.031^*$, $\eta^2p = 0.138$), with a moderate effect size. No significant protocol × group interaction was observed for sprint or flexibility (sprint: $p = 0.111$, $\eta^2p = 0.078$; flexibility: $p = 0.801$, $\eta^2p = 0.002$). In contrast, a significant protocol × group interaction was found for agility ($p = 0.001$, $\eta^2p = 0.363$), with a large effect size. These findings indicate that the applied protocol produced similar effects on sprint performance irrespective of gender, whereas its effect on agility performance differed according to gender, as evidenced by the significant protocol × group interaction. In addition, gender-related differences were observed in the improvement of flexibility.

DISCUSSION

This study aimed to analyze the acute effects of two different warm-up protocols on athletic performance in basketball players. The results demonstrated that the Basket-Up warm-up protocol significantly improved flexibility, jump, sprint, and agility performance in basketball players. One of the main findings of the study was the significant and large effect of the protocol on CMJ, DJ, and RSI values (Table 4). The percentage increases observed in CMJ (12.17%), DJ (9.98%), and RSI (15.87%) values among female athletes were higher than those observed in male athletes (9.02%, 8.49%, and 12.87%, respectively). However, the absence of a statistically significant protocol × group interaction for the jump parameters indicates that these observed percentage differences did not result in a significant gender-specific effect. Overall, these findings demonstrate that the Basket-Up warm-up protocol significantly improved jump performance and, although the improvements observed in female athletes were greater than those in male athletes, this difference did not constitute a statistically significant gender-specific response.

These findings suggest that the movements performed during warm-up may be important for athletic performance. Andrade et al. (2015) reported that short-duration warm-ups incorporating specific jumping exercises effectively enhanced fast stretch-

shortening cycle (SSC) muscle performance, whereas a similar improvement was not observed following general warm-up procedures. This finding suggests that jump performance, particularly when it involves rapid SSC actions, may be sensitive to the content of the activities performed during warm-up. In a study by Shalom et al. (2025), the acute effects of a modern warm-up protocol incorporating open-skill components on jump, sprint, and reaction time performance were investigated in basketball players aged 15–16 years. The authors reported that the modern warm-up method incorporating specific jumping exercises produced significant improvements compared with traditional warm-up methods. Although the protocols differed in content, these findings are consistent with the present study in demonstrating that warm-up interventions may influence acute performance responses in athletes of a similar age and within the same sport.

Another important finding of the present study was the significant and large effect of the protocol on sprint, agility, and flexibility parameters (Table 5). In particular, the significant and large protocol × group interaction observed for agility ($p = 0.001$, $\eta^2p = 0.363$) indicates that changes in agility performance differed according to gender. A significant gender difference was also observed for flexibility ($p = 0.031$, $\eta^2p = 0.138$). Female athletes demonstrated higher flexibility values than male athletes both at pre-test (30.47 ± 7.02 vs. 25.94 ± 5.82) and post-test (33.05 ± 6.20 vs. 28.29 ± 5.83). Our findings regarding agility performance are consistent with those reported by Cerrillo-Sanchis et al. (2024). In their study involving 95 basketball players aged 13–17 years (49 female and 46 male), the authors compared the acute effects of the FIFA 11+ and Basket-Up warm-up protocols on physical performance. Consistent with our findings, they reported that the Basket-Up warm-up protocol produced a more pronounced improvement in agility performance; however, this effect did not differ significantly according to gender. These findings suggest that incorporating movement patterns frequently performed during basketball competition, such as changes of direction, acceleration, and deceleration, into warm-up routines may positively contribute to agility performance. However, in the same study, Cerrillo-Sanchis et al. (2024) reported, contrary to our findings, that the Basket-Up protocol did not produce a superior effect on 20-m sprint and CMJ performance compared with the FIFA 11+ protocol, and no significant gender-related differences were observed for these variables. The authors attributed the absence of performance improvements to acute muscular fatigue that may occur during the warm-up protocol, suggesting that this may temporarily limit the muscle's capacity to generate high levels of force, particularly during maximal-effort performance tasks such as the 20-m sprint. These differences may be attributable to factors such as the content and duration of the warm-up protocols and the characteristics of the participants. These differences may also be related to the characteristics of the participants and the study protocols. Specifically, the younger age of the participants in the present study (U14) compared with the broader 13–17-year-old sample of Cerrillo-Sanchis et al. (2024), as well as differences in the comparison warm-up protocol (dynamic warm-up vs. FIFA 11+), may have contributed to the greater improvements observed in CMJ and DJ performance following Basket-Up in the present study. Moreover, the crossover design used in the present study, in which the same

athletes completed both protocols, may have reduced inter-individual variability and allowed a more direct comparison of acute responses between warm-up conditions. The study by Cerrillo-Sanchis et al. (2024) represents an important reference for the development of the Basket-Up warm-up protocol and the scientific evaluation of its acute effects on basketball performance. Nevertheless, because Basket-Up is a novel warm-up approach incorporating basketball-specific movement and neurocognitive demands, further research involving different age groups, genders, performance levels, and study designs is required to determine its potential advantages over other warm-up methods. In particular, comparative studies in which the same athletes perform different warm-up protocols, as in the present study, may help control for individual differences and provide a more accurate assessment of acute responses to different protocols.

In this context, the originality of the present study lies in its comparative examination of the acute effects of dynamic warm-up and the Basket-Up warm-up protocol, which more closely reflects the movement and game demands of basketball, on physical performance in U14 female and male basketball players, as well as in its investigation of gender-related differences in these effects. The specificity of the Basket-Up program stems from its incorporation of appropriate activation of the lower-extremity muscles, as well as fundamental basketball movement patterns such as acceleration, deceleration, and changes of direction, thereby providing basketball-specific stimuli that reflect the movement demands encountered during competition. Accordingly, sprint, agility, and jump performance, which are directly related to the fundamental physical demands of basketball, as well as flexibility, were assessed to evaluate the effects of the warm-up protocols on acute performance.

Considering the findings obtained, the incorporation of fundamental basketball movement patterns and sport-specific demands into the warm-up process through the Basket-Up protocol may contribute to positive acute responses, particularly in performance components such as jumping, sprinting, and agility. However, the absence of a significant protocol × group interaction for some performance variables indicates that the effects of Basket-Up cannot be explained solely by gender and that other individual or biological characteristics may also play a role in performance responses. Although female players demonstrated greater percentage improvements than male players in CMJ (12.17% vs. 9.02%), DJ (9.98% vs. 8.49%), and RSI (15.87% vs. 12.87%), these differences did not result in statistically significant protocol × group interactions. This tendency may be related to differences in previous training experience, baseline performance characteristics, or biological maturation between female and male athletes. In addition, differences in neuromuscular responsiveness to warm-up stimuli may contribute to variability in acute performance responses during adolescence. Nevertheless, these potential explanations should be interpreted cautiously, as biological maturation and training history were not directly assessed in the present study. The plyometric components of Basket-Up, including vertical jumps, bounds, and hops, may also contribute to the observed improvements in CMJ, DJ, and RSI by inducing post-activation performance enhancement (PAPE), whereby previous high-intensity muscle activation can transiently enhance subsequent explosive performance (Maroto-Izquierdo et al., 2020). Therefore, the inclusion of sport-specific explosive movements

in Basket-Up may provide an additional neuromuscular stimulus that facilitates acute jumping and reactive strength performance. Therefore, further research involving larger samples and different age groups is warranted to determine whether Basket-Up represents an effective warm-up approach for preparing young basketball players for optimal performance.

CONCLUSION

In conclusion, the findings of this study provide evidence regarding the acute effects of a sport-specific basketball warm-up program compared with a general dynamic warm-up protocol. In the present study, the Basket-Up protocol, which incorporates fundamental basketball movement patterns and sport-specific demands, was associated with improvements in flexibility, sprint, agility, and jump performance, although the magnitude and pattern of these effects varied across performance variables and according to gender. These findings suggest that the Basket-Up protocol may be a useful sport-specific warm-up approach for U14 basketball players before training or competition. However, further studies involving larger samples and different age groups, performance levels, and genders are needed to confirm these findings and to provide a more comprehensive understanding of the acute effects of the Basket-Up protocol on physical performance.

LIMITATIONS

This study has several limitations. First, although the participants were chronologically similar in age, differences in the rate of growth and biological maturation during adolescence may represent important factors that could influence performance outcomes. Previous research has demonstrated that the effects of training on physical status may vary according to maturation level (Pichardo et al., 2019). Accordingly, although the U14 basketball players included in the present study were similar in chronological age, their levels of biological maturation may have differed, and this may represent one possible explanation for the individual differences observed in performance variables such as sprint, agility, and jumping. In addition, the relatively small sample size should be considered another limitation that may restrict the generalizability of the findings to the broader population. Moreover, the participants were recruited from a single city, which may limit the generalizability of the findings to U14 basketball players from other geographical regions and populations. Although the a priori power analysis indicated a minimum sample size of 22 participants for the main protocol effect, a separate power analysis was not performed specifically for the protocol × group interaction. Therefore, the relatively small number of participants within each gender group (n = 17) may have limited the statistical power to detect interaction effects, particularly those of small or moderate magnitude, and the non-significant interaction findings should therefore be interpreted with caution. Furthermore, because performance variables were assessed only immediately after the warm-up protocol, the findings are limited to acute responses. Therefore, in addition to the findings obtained

after a single session, longer-term intervention studies are needed to determine the potential effects of prolonged use of the Basket-Up protocol on performance.

Kısaltmalar / Abbreviations

CMJ — Countermovement Jump (Karşı Hareketli Sıçrama)

DJ — Drop Jump (Düşüş Sıçraması)

SSC — Stretch-Shortening Cycle (Gerilme-Kısalma Döngüsü)

min — Minute (Dakika)

s — Second (Saniye)

m — Meter (Metre)

Beyanlar / Declarations

Etik Onay ve Katılım Onayı / Ethics approval and consent to participate

Participants were informed about the potential risks associated with the study. Written informed consent was obtained from the participants and their parents/guardians prior to the data collection process. The study was approved by the Ethics Committee of Mersin University Faculty of Sport Sciences on December 15, 2025, under decision No. 096. The study was conducted in accordance with the principles of the Declaration of Helsinki. During the preparation and writing of this study, scientific, ethical, and citation rules were followed in accordance with the "Higher Education Institutions Scientific Research and Publication Ethics Guidelines." No alterations were made to the collected data, and this study has not been submitted to any other academic publication platform for evaluation. The authors accept full responsibility for any potential ethical violations related to this manuscript.

Veri Ve Materyal Erişilebilirliği / Availability of data and material

The data that support the findings of this study are available from the corresponding author upon reasonable request. The dataset will be accessible only for academic purposes, and any use of the data will recognize the original study and maintain the confdentiality of the participants.

Çıkar Çatışması / Competing interests

Yazarlar, bu makalede sunulan çalışmayı etkileyebilecek herhangi bir çıkar çatışması veya kişisel ilişkiye sahip olmadıklarını beyan etmektedirler.

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Yazar Katkıları / Authors' Contribution Statement

Çalışmanın tasarımı ve planlanması, veri toplama, analizi ve yorumlanması, makalenin yazımı, veri düzenleme, yöntem belirleme, yazım – özgün taslak ile yazım – gözden geçirme ve düzenleme süreçlerine eşit katkı sağlamıştır. Tüm yazarlar makalenin önemli noktalarını eleştirel bir şekilde gözden geçirmiş ve makalenin son hâlini onaylamıştır.

Contributed equally to the design and planning of the study, data collection, analysis and interpretation, manuscript preparation, data organization, methodology development, writing of the original draft, and review and editing of the manuscript. All authors critically reviewed the manuscript and approved the final version of the article.

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