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ORIGINAL RESEARCH

Acute effects of the FIFA 11+ warm up protocol on distal mechanical and physiological tissue properties and performance in male and female soccer players

Patricia Caudet Sánchez [a], Ernest Baiget [b], Abraham Batalla Gavalda [c,d,e], Joshua Colomar [f,g] and Francisco Corbi [h]

[a]National Institute of Physical Education (INEFC), University of Lleida, Lleida, Spain; [b]National Institute of Physical Education (INEFC), University of Barcelona, Barcelona, Spain; [c]EUSES School University of Health and Sport, Rovira I Virgili University, Tarragona, Spain; [d]Sport Science Group Research of National Institute of Physical Education (INEFC), University of Barcelona, Barcelona, Spain; [e]Department of Education and Specific Didactics, Faculty of Humanities and Social Sciences, University Jaume I, Castellón de la Plana, Spain; [f]Sports and Physical Activity Studies Centre (CEEAF), University of Vic - Central University of Catalonia, Vic, Spain; [g]Sports Performance Analysis Research Group (SPARG), University of Vic-Central University of Catalonia, Vic, Spain; [h]Department of Clinical Sciences, Faculty of Medicine and Health Sciences, University of Barcelona, Barcelona, Spain

ABSTRACT

Objective: Soccer is one of the sports with the highest number of injuries in both sexes with a prevalence of 13% around the ankle-foot area. Various strategies have been proposed to prevent injuries like FIFA 11+ warm-up. Its reliability has been questioned due to the diversity of results obtained depending on the movement pattern studied and the body region analyzed. Few studies have analyzed its acute effects on distal structures, such as plantar soft tissue properties, local perfusion or temperature. The objective of this study was to determine the acute effects of performing the FIFA 11+ on mechanical and physiological properties in ankle-foot regions.
Method: The sample included 120 amateur men and women soccer players. Various mechanical properties of the muscle and tendon such as oxygen saturation in the muscle, skin temperature, range of motion of the ankle and maximum isometric force of the toes were analyzed, before and after performing the FIFA 11 +. Results: indicate the absence of significant differences in any of the variables analyzed, except for the mechanical response of the plantar fascia ($p < 0.0014$).
Conclusion: FIFA 11+ may not provide a sufficiently strong local stimulus to generate mechanical and metabolic responses in the different structures of the foot and ankle, even though it remains an established long-term injury-prevention program. Other warm-up strategies to enhance its effects may consider incorporating.

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Warm-up; foot; ankle; soccer; prevention; injury

1. Introduction

Soccer is one of the sports with the greatest number of injuries in both sexes. The injury incidence ranges from 6.77 to 8.1 injuries per 1000 h of exposure [1]. Over the last 10 years, this incidence during match competition has been increasing in all age groups [2], with most injuries occurring in lower extremities, especially in the ankle, knee, and thigh [1,2].

As a lower number of injuries seems positively correlated with team success [3] many strategies have been proposed to avoid it. Specific neuromuscular programs focusing on strength and balance such as the FIFA 11+ warm-up program could be an example [4]. The FIFA 11+ was created by the Fédération Internationale de Football Association in collaboration with the Oslo Sports Trauma Research Centre and the Santa Monica Orthopaedic and Sport Medicine Center experts to prevent common soccer injuries. The primary aim of the FIFA 11+ is to reduce injury risk through long-term neuromuscular adaptations, rather than to acutely enhance performance at a single time point [4]. It is based on a specific warm-up structure that introduces cardiovascular, neuromuscular, and cognitive exercises, with a duration of 20–25 min [5], focusing on central stability, eccentric and plyometric work, proprioception, and dynamic stability [6].

Several studies suggest a favorable functional response following the use of the FIFA 11+ [3,7], while others found no significant improvements or negative effects [7–9]. Given these mixed findings, implementation may be questionable when acute effects are desired [5,10] or warming up specific body areas is challenging [11]. Furthermore [12] assessed acute physiological and mechanical effects on the knee joint and found no significant differences in most of their records. Achilles tendon ruptures (ATRs) can have a devastating impact on an elite soccer player's career, due to decreased match participation caused by persistent symptoms [13] associated with high relapse rates and long recovery time [14]. It was found that inadequate or absent warm-up, and associated lack of increase in Achilles' tendon temperature and blood perfusion during the first 10 min of activity, could predispose to tendon injury [15]. Consequently, there may not be enough

CONTACT Patricia Caudet Sánchez patriciacaudet@gmail.com National Institute of Physical Education (INEFC), University of Lleida, 25192, Complejo de La Caparrella, s/n, Lleida, Spain

scientific evidence to confirm that the FIFA 11+ warm-up effectively activates regions prone to injury.

The effects of the FIFA +11 on dynamic and large motor patterns have been widely studied. However, understanding its acute mechanical and physiological effects on tissues prone to injury, such as the foot and ankle, is relevant to determine whether a single bout of the program provides sufficient local activation prior to training or competition. The exercise components of the FIFA 11+ could theoretically induce acute effects on tissue mechanical properties, muscle oxygenation, skin temperature, and functional performance. These parameters, therefore, provide an integrated understanding of the immediate physiological and mechanical responses elicited by warm up. Few studies have simultaneously examined the acute mechanical, physiological and functional responses to a warm-up protocol in specific tissues, such as tendons and facia, or in body areas with high injury prevalence. This multimodal approach, combined with a large and sex-balance sample, addresses a relevant gap in the literature and provides a novel perspective on the immediate effects of this widely implemented program. Importantly, although the FIFA 11+ has demonstrated effectiveness as a long-term injury-prevention program, it was not originally designed to induce strong acute local responses in specific tissues. Consequently, when the program is used as a pre-training or pre-competition warm-up, its capacity to acutely activate distal structures such as the foot and ankle remains uncertain. Therefore, this study aimed (a) to determine the mechanical and physiological properties of the FIFA 11+ warm-up protocol on the foot and ankle, including soccer specific performance indicators; (b) to compare its acute effects between sex. Our hypothesis is that although FIFA 11+ exercises may improve specific performance indicators, they may not acutely activate these regions regardless of sex, decreasing performance.

2. Methods

2.1. Study design

A descriptive observational study employing a pre-post design was conducted, in which the FIFA 11+ warm-up protocol served as the independent variable. The research protocol included two separate data collection sessions. During the initial session, baseline measurements were obtained prior to the implementation of the FIFA 11+ warm-up. Subsequently, following completion of the warm-up routine, all assessments were repeated in a second session. Evaluations focused on the dominant lower limb, defined as the leg preferentially used for kicking. FIFA 11+ warm-up was completed in 21.8 ± 2.3 min, consistent with the standard duration of 20–25 min. Exercise intensity was monitored using the Borg CR-10 scale and heart rate (HR). Continuous HR monitoring was recorded using an HR sensor, and all data were processed using Polar® software (Polar Bluetooth H10, Oy, Finlandia). RPE was assessed using Borg's CR-10 scale, where 0 represents rest and 10 maximal efforts. Reliability was found to be high (ICC = 0.898))[16]. Players reported a mean RPE of 6.7 ± 1.4 and a post – warm-up HR of 138 ± 24.4 beats·min^{-1}. Using age-predicted HRmax (208 – 0.7 × age [17]), this corresponded to 71.7 ± 12.7% of HRmax, indicative of a moderate-intensity warm-up. All FIFA 11+ warm-up sessions were supervised by two trained researchers with experience in soccer warm-up protocols to ensure correct execution and compliance. All physiological, mechanical, and performance assessments were conducted by the same research team, who were fully familiar with the testing procedures and equipment. Dependent variables comprised mechanical properties of muscle and tendon tissues, muscle oxygen saturation (SmO_2), cutaneous temperature (Tsk), ankle dorsiflexion range of motion assessed via the weight-bearing lunge test (WBLT), and maximal voluntary isometric contraction during the short foot exercise (MVIC). Additionally, three soccer-specific performance tasks were measured: countermovement jump (CMJ), ball kicking speed (KS), and the modified 505 agility test (Figure 1). To minimize potential confounding from fatigue or psychological factors, the order of tests within each session was randomized. The order of assessments (mechanical properties, SmO_2, skin temperature, performance tests) was randomized using a computer-generated permutation list (randomizer.org). Each participant was assigned an identification code, and the testing sequence was generated automatically prior to data collection. The same order was used for both pre- and post-warm-up assessments to avoid order-related bias. Participants were instructed to refrain from vigorous physical activity for 24 h, to maintain their usual diet and to avoid caffeine and alcohol for 12 h and to ensure at least 7 h of sleep prior to testing. Compliance was verbally confirmed at arrival. To capture acute effects of the warm-up intervention, post-intervention measurements were collected immediately after

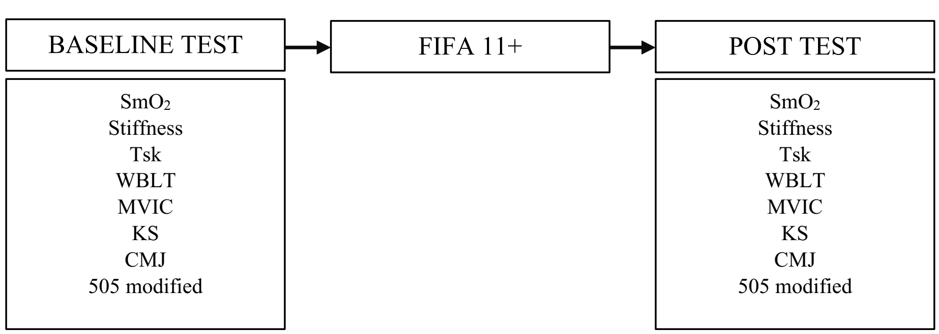

Figure 1. Study design timeline.

completion of the FIFA 11+ protocol. Data collection took place 2 days following match play, between 7.00pm and 9.00pm, under comparable environmental conditions (Ambiental temperature was 18.8 ± 2.3°C, and relative humidity 60 ± 6%; monitored using a calibrated digital thermohygrometer (PCE-HT 70)).

2.2. Participants

About 120 amateur soccer players, 60 males (age 21.8 ± 5.3 years, height 179.0 ± 5.5 cm; body mass 75.2 ± 78.0 kg; mean ± SD) and 60 females (age 22.6 ± 5.0; height 164.0 ± 5.8; body mass 60.2 ± 9.4 kg; mean ± SD) participated in this study (Table 1). The sample size was justified by a priori power analysis (GPower Version 3.1.9.5, University of Düsseldorf, Düsseldorf, Germany) for a repeated measures (within-between interaction), introducing the following parameters: effect size index (0.25) assuming a small partial eta-squared (0.03), α error probability (0.05), power (0.95), number of groups (2) and measurements (2), and correlation among repeated measurements (0.5) which resulted in a sample size of 108 subjects. Participants were recruited from 14 soccer teams from Official Amateur Championships of the Spanish Football Federation. They usually trained 3–4 days per week, with 1.5-2 h per session and one match played on weekends. Also, they were instructed to continue their lifestyle and normal diet during the previous days. Exclusion criteria was related to previous lower extremity injury in the last 6 months. No participants received economic benefits or other incentives to participate in this study. They signed an informed consent, and a protocol was established for the delivery and explanation of the results. Voluntary right to leave the study was also emphasized, in case the participants ultimately did not want to be admitted without prejudice or harm and guaranteeing their anonymity. The study was approved by the Bioethics committee and was carried out considering the principles of the Declaration of Helsinki for research with human beings [18] and in accordance with the Data Protection Law.

2.3. Procedures

2.3.1. Warm up FIFA 11+

The FIFA 11+ program is structured to be completed within approximately 20 to 25 min [5]. It is divided into three distinct sections: (a) an initial phase comprising six running drills performed at low to moderate intensity, which are integrated with dynamic stretching and involve controlled physical interactions among participants; (b) a second segment featuring six progressively challenging exercises designed to enhance muscular strength, plyometric ability, agility, and postural balance; and (c) a final component consisting of three running activities executed at moderate to high intensity that incorporate directional changes [2].

2.3.2. Stiffness

To evaluate compression stiffness, the MyotonPro® device (MyotonPRO, Myoton AS, Tallinn, Estonia), a noninvasive digital palpation instrument, was employed. Measurement sites were precisely identified using a marking pen to ensure consistent anatomical referencing across participants, following the methodology described by Konrad et al. [19]. The device's probe was positioned perpendicularly to the target muscle in a relaxed state, with its tip placed at a depth of 3 mm from the skin surface. A brief mechanical impulse of 0.4 N lasting 15 ms was delivered by the device, generating a displacement-time curve that facilitated subsequent analysis of tissue mechanical characteristics. For each site, five consecutive measurements were recorded at a sampling frequency of 3200 Hz; their mean value was used for further analysis [20]. The parameters assessed included oscillation frequency (F, Hz), stiffness, logarithmic decrement, relaxation time, and creep [12]. The anatomical structures examined comprised: (1) the Achilles tendon at a point located 2 cm proximal to the superior border of the calcaneus – an area frequently associated with injury incidence [21]. (2) the central region of the medial gastrocnemius muscle belly [22]. (3) the tibialis anterior muscle at one-third of the distance between the fibular head and medial malleolus, situated approximately 2 cm lateral to the tibia [23] and (4) the central portion of the plantar fascia aligned with the lateral base of the fifth metatarsal bone [24]. Previous studies have demonstrated that MyotonPro® exhibits excellent test-retest reliability for these measurements, with intraclass correlation coefficients ranging from 0.95 to 0.99 and coefficients of variation between 0.3 and 0.9 [25]. For these reasons, MyotonPro® was selected to provide a reliable, noninvasive assessment of tissue oscillation frequency, stiffness, and viscoelastic properties, which are sensitive to acute mechanical changes induced by warm-up protocols.

2.3.3. Muscular oxygen saturation (SmO_2)

Localized muscle oxygen saturation was measured noninvasively using near-infrared spectroscopy (NIRS) with the Humon Hex device (Dynometrics Inc., Cambridge, USA) [26]. This portable and cost-effective tool provides real-time SmO_2

Table 1. Descriptive characteristics of participants.

	Sex groups		
	Male (n = 60)	Female (n = 60)	Total (n = 120)
Chronological age (years)	21.8 ± 5.3	22.6 ± 5.0	22.2 ± 5.2
Training background (years)	14.7 ± 5.3*	10.1 ± 5.0	12.4 ± 5.6
Training volume (h·week^{-1})	6.2 ± 1.4	5.9 ± 0.5	6.0 ± 1.0
Height (cm)	179.0 ± 5.5*	164.0 ± 5.8	171.5 ± 9.4
BM (kg)	75.2 ± 8.0*	60.2 ± 9.4	67.7 ± 11.5
BMI (Kg·m^{-2})	23.7 ± 2.5*	19.0 ± 3.0	21.4 ± 3.6

The values presented are means ± SD.
*significantly different from female group ($p < 0.001$).
Abbreviations: BM = body mass, BMI = body mass index.

data and has demonstrated validity and precision [27]. The device uses light detectors positioned 18–24 mm apart and samples at 4 Hz [27], reporting a weighted median value [26]. It was placed on the medial gastrocnemius on the central cross-section [24] and recorded for 20 s, while the player sat with hips and knees flexed at 90°. Data were transmitted via Bluetooth to the Moxzones mobile application. The device's reliability is high (ICC = 0.77–0.99) [26]. Thus, monitoring SmO_2 provides insight into acute physiological adjustments related to local oxygen delivery and consumption during and immediately after the warm-up.

2.3.4. Skin temperature (Tsk)

Thermographic data were collected following the termoINEF Group protocol [28,29] using a FLIR T540-EST infrared camera (FLIR Systems, Inc., USA), analyzed by FLIR Research Software (FLIR Systems, Inc., United States). The camera was calibrated with a black body; emissivity was set at 0.97–0.98. Room temperature was maintained at 21°C, with indirect lighting and ventilation [29]. Four pictures were taken, two with participants standing perpendicular to the camera (1.5 m distance) for anterior and posterior views of the lower limb; one focused on the knees (1 m distance); and one of participants lying supine with feet extended beyond the stretcher to capture only the feet. Reliability was excellent (ICC = 0.989) [28]. Skin temperature is a validated measure for detecting variations in Tsk, reflecting changes in regional perfusion and thermoregulatory responses associated with warm-up intensity.

2.3.5. Maximum voluntary isometric toe flexor muscle strength (MVIC)

Toe flexor strength was measured using a dynamometer (TKK 3361, Takei Scientific Instrument Co., Niigata; range: 1–400 N; sensitivity: 0.98 N). Participants sat with hips and knees at 90°, feet neutral to minimize plantar fascia tension, arms crossed over shoulders. Three submaximal trials were conducted to familiarize. Then, they performed three maximum trials during 3 s each, with a 30 s recovery between them. High reliability, substantial to almost perfect, has been shown in this test (ICC = 0.71–0.96) [30]. Foot flexor strength was evaluated because intrinsic foot muscle contributes to ankle-foot stability and may be sensitive to warm-up-induced neuromuscular activation.

2.3.6. Weight bearing dorsiflexion lunge test (WBLT)

Ankle dorsiflexion range of motion was assessed using an EasyAngle digital goniometer (Meloq AB, Stockholm, Sweden). The foot was placed perpendicular to a wall; knee aligned over the second toe toward a marked spot on the wall for consistency [31]. The inclinometer was positioned at 15 cm above the tibial tuberosity [31]. Three trials were conducted after one familiarization attempt, separated by a 10-s passive rest [2]. Inter- and intra-clinician reliability are good (ICC = 0.80–0.99 and ICC = 0.65–0.99 respectively) [32]. Ankle dorsiflexion range of motion was assessed through the weight-bearing lunge test, as mobility is known to influence lower-limb mechanics and performance.

2.3.7. Kick speed (KS)

Kick speed was measured using a Stalker ATS II radar gun (Acceleration Testing System®, frequency: 34.7 GHz [Ka-Band], ±50 MHz), which has high absolute (CV = 4.0%) and relative reliability (ICC = 0.958) [33]. Players performed three maximal kicks from a static position 1 m from the goal, with 45 s recovery between attempts; the highest speed was used for analysis.

2.3.8. Countermovement squat jump (CMJ)

The CMJ test followed Pardos-Mainer et al. [2], replicating Bosco's protocol using a Chronojump platform (Chronojump, Boscosystem, Barcelona, Spain). Three repetitions were analyzed with a 45 s recovery. The highest jump height was chosen. The test shows good reliability (ICC = >0.989) [34].

2.3.9. 505 modified

Change-of-direction ability was assessed via a modified 505 test: players sprinted 10 m, starting 0.5 m before timing gates (Chronojump, Boscosystem, Barcelona, Spain), crossed a line at 5 m, executed a 180° turn on either leg, and returned to the start/finish line. Two trials were performed with 1 min rest; best time was recorded [2,35]. Reliability is excellent (ICC = 0.90–0.93; CV = 1.9–5.4) [35].

Performance tests (CMJ, 505 modified and KS) were selected to evaluate movement patterns highly specific to soccer. The CMJ reflects lower-limb explosive capacity required for actions such as jumping, heading, or accelerating. KS represents the functional expression of striking mechanics, a fundamental technical action. 505 modified test assesses rapid change-of-direction ability, which is essential for both defensive and offensive maneuvers. Together, these tests provide an ecologically valid assessment of how warm-up may acutely influence soccer-specific functional patterns.

2.4. Statistical analysis

Data are presented as mean ± SD. Normality and homogeneity of variances were assessed using the Kolmogorov–Smirnov test. Sex differences were analyzed with independent sample t-tests. Independent variables were sex (male, female) and time (pretest, posttest); dependent variables were physiological and kinematic parameters. A 2 × 2 repeated-measures ANOVA with Bonferroni post-hoc tests was used, with sex as the between-group factor and time as the within-group factor. Partial eta-squared (η^2) was calculated for effect size: 0.01–0.05 (small), 0.06–0.13 (medium), >0.14 (large). Within-group changes were assessed by Cohen's d: 0.0–0.2 (trivial), 0.2–0.6 (small), 0.6–1.2 (moderate), 1.2–2.0 (large), >2.0 (very large). Thirty-three planned comparisons were made; Bonferroni correction set alpha at 0.0014. Intrasession reliability was determined by intraclass correlation coefficient (ICC) and coefficient of variation (CV); ICC values: excellent (>0.85), high (0.75–0.85), moderate (0.40–0.75), poor (<0.40). Statistical significance was set at $p < 0.05$, and analyses were performed using IBM SPSS Statistics 23.0 software (SPSS, Inc., Chicago, IL).

Table 2. Pre- and post-warm up physiological and mechanical muscle characteristics scores.

	Sex groups								Two-way ANOVA	
	Women ($n = 60$)				Men ($n = 60$)				Time effect	Time × sex effect
	Pre	Post	Δ (%)	ES	Pre	Post	Δ (%)	ES	*p*-value	
SmO_2										
Minimum (%)	54.0 ± 9.0	62.5 ± 9.9	15.8	0.91	54.7 ± 13.2	61.0 ± 12.8	11.4	0.36	0.152	0.657
Mean (%)	54.5 ± 8.8	62.9 ± 9.8	15.4	0.92	55.8 ± 12.4	61.7 ± 11.8	10.6	0.37	0.139	0.581
Maximum (%)	54.9 ± 8.7	63.2 ± 9.9	15.1	0.93	56.7 ± 12.1	62.5 ± 11.1	10.3	0.39	0.127	0.553
Foot-ankle local test										
Strength Foot (kg)	12.0 ± 5.1	13.7 ± 5.3	14.3	0.56	21.2 ± 10.4	22.6 ± 11.0	6.6	0.25	0.876	0.619
WBTL (º)	41.6 ± 8.0	41.1 ± 8.2	−1.1	0.05	35.9 ± 9.11	37.0 ± 9.6	3.0	0.19	0.809	0.432
Muscular properties										
Plantar fascia										
Frequency (Hz)	24.8 ± 3.0	23.7 ± 2.3	−4.5	0.75	25.4 ± 4.4	24.3 ± 2.54	−4.5	0.32	0.215	0.998
Stiffness (N/m)	512.8 ± 76.5	487.3 ± 65.4	−5.0	0.71	540.9 ± 83.9	503.9 ± 67.5	−6.8	0.68	0.032	0.399
Decrement (n.u.)	1.28 ± 0.15†	1.22 ± 0.13	−4.6	0.51	1.38 ± 0.19†	1.26 ± 0.13	−8.8	0.76	<0.001	0.020
Relaxation (ms)	10.2 ± 1.4	10.7 ± 1.32	4.9	0.30	9.44 ± 1.90	10.4 ± 1.42	10.0	0.17	0.027	0.060
Creep (n.u.)	0.65 ± 0.08	0.68 ± 0.07	4.2	0.28	0.61 ± 0.09	0.66 ± 0.08	7.2	0.17	0.017	0.126
Achilles Tendon										
Frequency (Hz)	33.0 ± 3.4	32.5 ± 2.7	−1.6	0.14	33.5 ± 3.89	32.7 ± 3.46	−2.4	0.24	0.475	0.882
Stiffness (N/m)	829.1 ± 110.1	825.0 ± 87.3	−0.5	0.03	849.7 ± 105.3	826.6 ± 143.3	−2.7	0.16	0.808	0.731
Decrement (n.u.)	0.80 ± 0.18	0.79 ± 0.17	−1.0	0.04	0.83 ± 0.18	0.82 ± 0.15	−1.0	0.04	0.703	0.961
Relaxation (ms)	6.2 ± 1.0	6.18 ± 0.78	−0.1	0.01	5.93 ± 0.98	5.93 ± 1.18	−0.1	0.01	0.938	0.996
Creep (n.u.)	0.41 ± 0.06	0.41 ± 0.05	0.0	0.01	0.40 ± 0.07	0.40 ± 0.06	0.4	0.03	0.980	0.990
Medial gastrocnemius										
Frequency (Hz)	19.4 ± 3.4	18.7 ± 1.88	−3.8	0.26	20.5 ± 2.00	19.9 ± 3.18	−3.2	0.25	0.317	0.951
Stiffness (N/m)	351.0 ± 83.4	333.8 ± 44.7	−4.9	0.23	378.1 ± 44.3	367.8 ± 51.6	−2.7	0.27	0.384	0.811
Decrement (n.u.)	1.40 ± 0.38	1.36 ± 0.22	−3.1	0.12	1.22 ± 0.21	1.20 ± 0.22	−2.2	0.16	0.768	0.938
Relaxation (ms)	15.5 ± 2.5	16.0 ± 2.08	3.5	0.27	14.0 ± 1.76	14.3 ± 1.99	2.4	0.24	0.199	0.707
Creep (n.u.)	0.96 ± 0.14	0.99 ± 0.12	3.0	0.25	0.87 ± 0.10	0.88 ± 0.11	1.7	0.18	0.233	0.639
Tibialis anterior										
Frequency (Hz)	26.8 ± 4.5	25.3 ± 3.2	−5.7	0.44	28.8 ± 3.85	27.0 ± 3.08	−6.2	0.54	0.003	0.261
Stiffness (N/m)	589.2 ± 90.6	554.7 ± 72.7	−5.9	0.56	637.9 ± 126.7	609.1 ± 88.5	−4.5	0.23	0.274	0.942
Decrement (n.u.)	1.30 ± 0.44	1.20 ± 0.26	−7.6	0.23	1.15 ± 0.26	1.10 ± 0.20	−3.9	0.20	0.038	0.230
Relaxation (ms)	8.95 ± 1.79	9.45 ± 1.31	5.6	0.42	7.99 ± 1.49	8.55 ± 1.36	7.0	0.44	0.077	0.835
Creep (n.u.)	0.58 ± 0.11	0.61 ± 0.08	4.9	0.40	0.52 ± 0.09	0.55 ± 0.08	6.4	0.44	0.082	0.815
Thermography										
Posterior foot										
Mean (º)	27.3 ± 1.75	28.7 ± 1.8	5.4	1.03	27.4 ± 1.62	29.1 ± 1.43	6.2	1.17	0.026	0.425
Maximum (º)	30.2 ± 1.37	32.0 ± 1.5	5.7	1.18	30.6 ± 1.28	32.1 ± 1.02	5.0	1.30	0.03	0.659
Achilles Tendon										
Mean (º)	29.4 ± 1.21	29.3 ± 1.2	−0.1	0.04	29.7 ± 1.08	30.0 ± 0.96	0.8	0.26	0.969	0.269
Maximum (º)	30.5 ± 1.10	31.5 ± 1.2	3.1	0.87	31.0 ± 1.06	31.8 ± 0.93	2.7	0.83	0.098	0.598
Medial posterior leg										
Mean (º)	30.1 ± 0.99	29.2 ± 1.1	−3.2	1.0	30.9 ± 0.88	30.5 ± 1.04	−1.5	0.57	0.025	0.016
Maximum (º)	31.3 ± 0.89	31.2 ± 1.0	−0.3	0.1	32.0 ± 0.76	32.0 ± 0.90	−0.0	0.01	0.271	0.404
Lateral anterior leg										
Mean (º)	30.3 ± 0.97	29.5 ± 1.0	−2.5	0.9	30.7 ± 1.00	30.1 ± 0.99	−1.9	0.61	0.004	0.449
Maximum (º)	31.5 ± 0.93	31.4 ± 1.0	−0.4	0.1	32.0 ± 0.89	31.9 ± 0.85	−0.3	0.09	0.117	0.419

The values presented are means ± SD. Time and time × group interaction *p*-values were obtained by two-way ANOVA (2 sex groups × 2 times).
†$p_{Bonferroni} < 0.0014$ different to posttest values.
Abbreviations: SmO_2 = muscle oxygen saturation, WBTL = weight-bearing lunge test.

Table 3. Pre- and post-warm up performance results.

	Sex groups								Two-way ANOVA	
	Women ($n = 60$)				Men ($n = 60$)				Time effect	Time × sex effect
	Pre	Post	Δ (%)	ES	Pre	Post	Δ (%)	ES	*p*-value	
CMJ (cm)	23.2 ± 3.52	23.5 ± 3.7	1.4	0.1	32.3 ± 4.97	34.4 ± 5.10	6.5	0.65	0.544	0.002
Kick (km/h)	58.1 ± 6.09	60.9 ± 7.1	4.7	1.0	76.8 ± 8.44	79.6 ± 7.24	3.7	0.53	0.086	0.973
505 modified (s)	2.93 ± 0.20	2.90 ± 0.21	−0.8	0.2	2.71 ± 0.17	2.70 ± 0.20	−0.3	0.06	0.119	0.391

The values presented are means ± SD. Time and time ×group interaction *p*-values were obtained by two-way ANOVA (2 sex groups × 2 times).
†$p_{Bonferroni} < 0.0014$ different to posttest values.
Abbreviation: CMJ = countermovement jump.

3. Results

Physiological, muscle characteristics and performance changes in the selected variables from pre- to post-warm up for each sex are reported in Tables 2 and Tables 3. After completing the standardized warm-up, a medium main effect of time was found in the mechanical property 'decrement' of the fascia plantae ($F[2,166] = 11.87$; $p < 0.001$; $\eta^2 = 0.093$). The post-hoc test showed moderate and small significant reductions of plantar fascia decrement in men and women from pre- to posttest ($p < 0.001$; $\Delta = -4.6$ and to -8.8%; ES $= -0.76$ and -0.51). No significant sex × time interactions were observed for any other variable ($p = 0.002$–0.998).

Despite moderate percentage increases in SmO2 (≈10–-15%), high inter-individual variability led to wide confidence intervals, reducing statistical power at the within-player level. Therefore, these changes did not reach statistical significance after Bonferroni correction ($p = 0.127$–0.152).

4. Discussion

The aims of this study were to determine the acute local effects of the FIFA 11+ warm-up on the foot and ankle tissues and to analyze whether there were any differences between sex. To our knowledge, this is the first study to simultaneously evaluate its influence on functional and structural responses. The results did not find significant warm up effects in any performance and physiological parameters, nor differences between sex, with the only exception of a moderate and small significant reduction in the decrement mechanical property of the fascia plantae in both sexes, with a medium main effect of time. These results are consistent with our hypothesis that the FIFA 11+ warm-up exercises do not produce sufficient acute effects on distal body regions such as the foot or ankle, regardless of sex, in this population, at least when only a single session is considered. It is important to note that FIFA 11+ was originally designed as an injury-prevention program with cumulative effects over multiple weeks of implementation rather than as an isolated pre-competition warm-up for immediate performance enhancement. Our findings should therefore be interpreted as evidence that one bout of the FIFA 11+ may not provide enough local activation for the specific distal structures analyzed, without questioning its potential long-term preventive benefits in other regions. Previously, only Veith et al. [11] evaluated the time to stabilization after jumping from a double leg stance to a single limb, and Lopes et al. [36] analyzed peroneus brevis and peroneus longus latency time with electromyography after sudden inversion in futsal players. In both studies, dynamic patterns were evaluated, and no differences were observed, neither acute nor chronic.

In this context and given that the results must be interpreted within a broader physiological and mechanical framework, certain mechanisms described below should be understood as theoretical interpretation based on previous literature, as they were not directly evaluated in the present study. Nevertheless, considering these mechanisms provides an integrated perspective on how different tissues and performance measures may interact, helping to contextualize the absence of acute changes observed.

In our study, none of the variables studied seemed to acute change after performing the FIFA 11+, suggesting a low local effect, at least in the distal areas studied. A possible explanation for these results could be related to the overall load applied during the warm-up. Several studies suggest that part 2 of this warm-up may not generate sufficient intensity to stimulate acute effects [37]. In both cases, the FIFA 11+ may not generate sufficient metabolic demand or induce blood flow redistribution to stimulate distal regions, despite being considered a moderate-intensity warm-up at a whole-body level [38]. Further, increases in blood flow should be proportional to workload [39], therefore reducing injury risk [38]. Both metabolic dysregulation and oxygen delivery, besides an excessive load during practice could be contributed to ankle pathology [38]. Additionally, vasodilation dissipates heat through the skin, which can be detected by infrared thermography (ITR) [40]. Variations in Tsk are influenced by sympathetic noradrenergic nerve activity due to vasodilation [40]. In our study, neither muscle oxygenation measured by wearable devices nor ITR reflected significant differences. ITR could be affected by type, time, and intensity of exercise to show marked patterns [40] and it seems that FIFA 11+ may not meet these requirements in distal tissues, even if it provides moderate activation at a whole-body level.

Conversely, we hypothesized that the type of exercise used in the warmup could influence tissues mechanical response. For example, during plank exercises, dorsiflexion of the toes is maintained throughout; this position increases plantar fascia stiffness when phalanges are dorsiflexed – a phenomenon observed both in vitro and via finite element analysis [41]. Additionally, monopodal actions could increase plantar fascia stiffness because it is a major stabilizer of the longitudinal arch [42], especially during changes of direction due to increased torsional torque and mechanical stress. Although this could enhance windlass mechanics and increase tension in the plantar aponeurosis, stiffening the foot [43]. We cannot fully explain why only the variable decrement was modified.

Furthermore, we attempted to assess whether FIFA 11+ affects common soccer-specific functional patterns such as vertical jump, kicking speed and change of direction. No significant alterations were found in any parameter, which aligns with previous studies confirming limited functionality for this warm-up protocol [5,10]. It appears that the effects vary depending on duration and whether FIFA 11+ is used as a warmup or training method [5,10] as well as the specific movement patterns assessed, which may partially explain inconsistencies reported across studies [44]. While some studies have reported improvements in jumping and running performance following FIFA 11+ [10], others found opposite results. This inconsistency may stem from insufficient dynamic actions, execution speed, or intermuscular coordination typical of soccer actions. As previously noted, part 2 contains predominantly static exercises. These arguments support concerns regarding the limited applicability of FIFA 11+, especially in foot and ankle regions. Generally, warm up protocols should acutely increase body temperature, nerve conduction velocity, pain tolerance, enzymatic cycling, and mechanical tissue response [45]. Another primary aim is injury prevention during practice. Although long-term effectiveness should be evaluated further, preventive benefits may vary depending on factors such as exercise selection, protocol duration, number of repetitions performed, external weather conditions, and may differ according to injury type or anatomical region analyzed [46]. Therefore, caution is warranted when using FIFA 11+ as a pre-competition warm-up protocol [10,37]. Our findings confirm that the use of FIFA 11+ does not improve performance in the tests analyzed, consistent with previous published studies [7]. Moreover, patterns studied (jumping, kicking and changing of direction) are associated with severe lower limb muscle injuries and performance [47] justifying their inclusion here.

Regarding mechanical tissue properties, certain exercises can alter viscoelastic muscle properties, increasing tendon stiffness, which may help reduce injury incidence. For example, running and plyometric exercises can modify Achilles tendon stiffness in short-term activities [38], likely due to changes in tendon hydration state. This state increases when intensity is higher [48]. A large water volume can decrease tendon Young's modulus [49]. Thus, high intensity exercises are needed to increase stiffness and improve tendons' capacity to bear stress [38]. Recent studies have affirmed that a decrease in the intratendinous fluid mobility and/or movement out of the tendon disrupts homeostasis and alters collagen structure [50]. Exercises' influence on velocity and type of contraction on the collagen structure and the kind of fibers affected by muscle fiber conduction velocity (MFCV) and functional capacity seems clear [51]. One explanation for MFCV benefits lies in muscle fiber swelling and faster activation inked to metabolic mechanisms; increases of 1–3°C in muscle temperature can yield performance improvements around 2–5% due to enhanced MFCV (force-velocity) and power (power-velocity) [51], which also relates to ITR dissipation processes. Additionally, neural mechanism could influence the production of a PAP effect. In strength foot test, there was no appreciable difference in contraction capacity and maximal isometric voluntary contraction (MVC). Poor functional capacity caused by limited fluid movement out of tendons affects dorsiflexion actions and promotes pathologies like flat feet [50]. Our results did not show improved range-of-motion on WBTL testing post-warmup; similar findings have been reported elsewhere [11]. Pardos-Mainer et al. [2] indicated no differences in ankle dorsiflexion ROM in female soccer players. Therefore, although it is generally accepted that FIFA 11+ improves static or quasi-static balance tests, this assertion remains questionable [10], especially because FIFA 11+ includes many static exercises that do not specifically stimulate evertor muscles [36].

This study had some limitations. First, it analyzed a heterogeneous sample from different playing levels; thus, effects obtained might differ according to players' characteristics, including individual anthropometric factors known to influence acute performance responses [52]. Second, we could not control training loads in the previous days, daily fatigue levels could fluctuate from days. Third, all participants were regularly training amateur soccer players; therefore, their baseline mechanical and physiological answer to chronic loading could attenuate the magnitude of any additional acute response to a single warm-up session. As we did not include a control group, we cannot directly compare our values with those of a sedentary population. Nevertheless, this reflects real-world team settings where individualized warm-ups are rarely feasible amid diverse populations and environmental conditions.

5. Conclusion

We conclude that a single FIFA 11+ warm-up does not produce significant acute effects on the ankle-foot mechanical and physiological variables or on the performance movement patterns. These findings are limited to acute responses in distal regions and do not consider the FIFA 11+ as a long injury prevention program. No influence was observed on specific actions such as jumping, kicking, or changing direction, regardless of sex – except for a change in decrement in the fascia plantae, possibly due to the kind of exercises applied that increases stiffness in this region and enhances windlass mechanics in the foot.

Future studies should explore whether including isometric [25] or higher intensity [10] components may enhance acute responses in distal regions. Given soccer's inherent unpredictability and varied demands, warm-up routines should emphasize activation through high-intensity tasks such as running, plyometrics, or maximal isometric contractions [38], which may help overcome some limitations coaches face when implementing FIFA 11+.

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Consent

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Data

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ORCID

Patricia Caudet Sánchez http://orcid.org/0000-0003-0924-977X
Ernest Baiget http://orcid.org/0000-0002-2059-2846
Abraham Batalla Gavalda http://orcid.org/0000-0003-4337-8890
Joshua Colomar http://orcid.org/0000-0002-7686-6594
Francisco Corbi http://orcid.org/0000-0003-2630-6684

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