Acute skin temperature responses to the 30-15 intermittent fitness test in professional male soccer players

Respuestas agudas de la temperatura cutánea a la prueba de aptitud intermitente 30-15 en jugadores de fútbol masculinos profesionales

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Abstract

Introduction: Thermal imaging technology provides detailed insights into the skin temperature patterns and asymmetries of athletes, offering valuable data to enhance performance, assess the effectiveness of rehabilitation, monitor fatigue, and prevent injuries.
Methods: The aim of this study was to assess acute skin temperature responses before and after the 30-15 Intermittent Fitness Test in professional male soccer players. Twenty-one professional soccer players performed a 30-15 IFT, and the running time, peak velocity, and true velocity were calculated. Thermal images of the players were acquired using an infrared thermal camera before and immediately after the 30-15 IFT, and skin temperature measurements were analyzed from the anterior thigh, anterior leg, posterior thigh, and posterior leg.
Results: The skin temperature asymmetries differed significantly between all regions of interest, with the greatest difference in the anterior and posterior thighs. Pearson correlation analysis revealed that the 30-15 IFT parameters were not correlated with the posttest skin temperature asymmetry for any of the region of interests. However, there were significant negative correlations between pretest skin temperature asymmetry in the posterior leg region and all 30-15 IFT parameters for running time ($r=0.30$; $p<.05$), peak velocity ($r=0.3$; $p<.05$), and true velocity ($r=0.25$; $p<.05$). Finally, athletes with lower baseline skin temperature asymmetries in the posterior leg region have better 30-15 IFT performance.
Conclusion: Thermal imaging can be used to assess muscular asymmetries following specific endurance tests or conditioning training, and this information can provide valuable information for optimizing performance and injury prevention.

Keywords

Infrared thermography, thermal imaging, muscular imbalance, injury prevention, fatigue monitoring, football.

Resumen

Introducción: La tecnología de imagen térmica ofrece información detallada sobre los patrones de temperatura cutánea y las asimetrías en los atletas, proporcionando datos valiosos para mejorar el rendimiento, evaluar la rehabilitación, monitorizar la fatiga y prevenir lesiones.
Métodos: El objetivo de este estudio fue analizar las respuestas agudas de la temperatura cutánea antes y después de la prueba de Aptitud Intermitente 30-15 en futbolistas profesionales masculinos. Veintiún jugadores realizaron la prueba, y se calcularon el tiempo de carrera, la velocidad pico y la velocidad real. Las imágenes térmicas fueron obtenidas mediante una cámara infrarroja antes e inmediatamente después del test, registrándose valores en muslo anterior, pierna anterior, muslo y pierna posteriores.
Resultados: Se encontraron diferencias significativas en las asimetrías de temperatura entre todas las regiones, siendo más marcadas en los muslos. El análisis de Pearson mostró que los parámetros del 30-15 IFT no se correlacionaron con la asimetría posprueba en ninguna región. Sin embargo, existieron correlaciones negativas significativas entre la asimetría preprueba en la pierna posterior y el tiempo de carrera ($r=0,30$; $p<0,05$), la velocidad pico ($r=0,3$; $p<0,05$) y la velocidad real ($r=0,25$; $p<0,05$).
Conclusión: Los jugadores con menores asimetrías basales en la pierna posterior obtuvieron mejor rendimiento en el 30-15 IFT. Estos hallazgos sugieren que la termografía es una herramienta útil para evaluar asimetrías musculares tras pruebas de resistencia o entrenamientos de acondicionamiento, aportando información relevante para optimizar el rendimiento y la prevención de lesiones.

Palabras clave

Termografía infrarroja, termografía, desequilibrio muscular, prevención de lesiones, monitoreo de la fatiga, fútbol.

Introduction

The thermal state of the human body is indicated by both surface and internal temperature. The variations in body surface temperature provide information about the effectiveness of the body's natural heat dissipation mechanisms during exercise and the metabolic adaptations induced by the body's attempt to restore homeostasis after activity (Afanaceva et al., 1985; Chudecka & Lubkowska, 2012; Jay et al., 2007). The center of the body and the skin are frequently considered to have different temperatures. Core temperature is linked to the risk of heat illness, whereas skin temperature (Tsk) has been demonstrated to be closely correlated with exercise intensity (Pérez-Guarner et al., 2019; Sawka et al., 2012; Schlader et al., 2011), recovery status (de Carvalho et al., 2021; Ferreira-Júnior et al., 2021), fatigue level (González-Alonso et al., 1999; Priego-Quesada et al., 2020), and different performance test conditions (Cerezci Duygu et al., 2019; Jastrzębska et al., 2022; Kapoor et al., 2022).

The surface of the human body is a complex network of isotherms with a wide range of temperatures that are influenced by both endogenous (genetics, hormones, etc.) and exogenous factors (climate, location, etc.) (Chen, 2019). For example, if an athlete has a significantly warmer Tsk on one side of the body, this may indicate increased blood flow, which can indicate inflammation or injury. Conversely, if an athlete has a significantly cooler Tsk on one side of the body, this may indicate decreased blood flow, which can indicate poor circulation or nerve damage (Aylwin et al., 2021). Tsk can be analyzed through thermal radiation, which can be captured using thermal imaging cameras as a noninvasive and noncontact method that records the heat emitted by human skin, allowing the measurement of temperatures in specific areas of the body (Chudecka & Lubkowska, 2012). Thus, by comparing bilateral body parts (e.g., the left and right knees or the dominant and nondominant limbs), infrared thermography (IRT) can assist in identifying thermal asymmetries.

In recent years, the application of IRT for monitoring athletes' skin temperature has grown considerably, highlighting its growing role in sports science research (Catalá-Vilaplana et al., 2023). IRT, which monitors Tsk, has been widely utilized in a variety of industries, and IRT is an extremely useful tool for preventing injuries and monitoring the individual assimilation of training load in amateur and professional team sports based on the evolution and asymmetries of Tsk (Fernández-Cuevas et al., 2017; Hadžić et al., 2019). These asymmetries may occur before other indicators such as pain, which is extremely useful for implementing prevention strategies prior to injuries occurring (Piñonosa Cano, 2016). In this way, IRT can be used not only to identify the response to different types of training (Fernández-Cuevas et al., 2023) but also to determine the causes of Tsk asymmetries and modify the training load to restore thermal balance. Therefore, considering the concept of anatomical proportionality, the thermal response is expected to be symmetrical between two contralateral body parts (Vardasca, 2008; Vardasca et al., 2012). Overall, the development of IRT monitoring tools can provide valuable information about training load quantification, muscle damage detection, injury prevention, and monitoring fatigue (Fernández-Cuevas et al., 2015; Sillero-Quintana et al., 2021), and monitoring Tsk asymmetries can be a useful tool in athlete monitoring, allowing coaches and trainers to identify potential injuries and imbalances and take steps to address them before they become more serious.

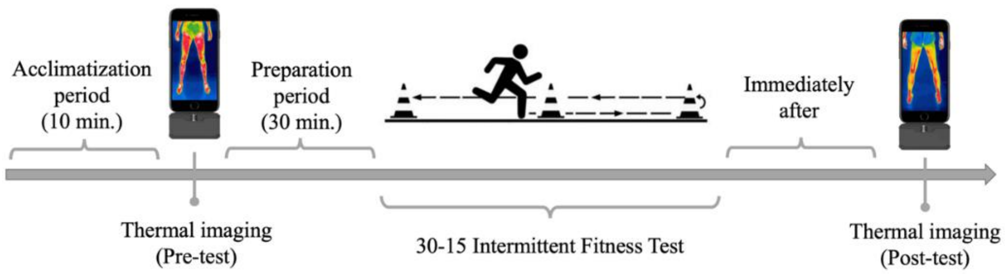
On the other hand, numerous studies (D'Isanto et al., 2019; Mirkov et al., 2008; Rampinini et al., 2006) have shown the significance of field testing and its impact on conditioning in team sports. The evaluation of physiological responses during these tests provides both coaches and players with useful information about players' recovery status, the prescription of appropriate training loads and the monitoring of fatigue. The 30-15 Intermittent Fitness Test (IFT), which is one of the most used endurance tests, is an incremental and intermittent running test that validly determines maximum oxygen uptake (VO2max) and maximal heart rate (HRmax) through frequent changes in direction and regular low-intensity recovery phases between running bouts. The final speed reached at the end of the test is simultaneously related to aerobic capacity, anaerobic capacity, the neuromuscular system and recovery between efforts (Buchheit, 2010). This test provides coaches and practitioners with information on their athletes' conditions and assists them in reaching their peak athletic performance. The 30-15 IFT has the advantages of being able to be used in both individual and team sports and of being individualized to each athlete and providing an indication of multiple physiological capacities (Stanković et al., 2021).

Although the acute responses of Tsk immediately after endurance performance have been evaluated in many studies in individual sports, as evidenced in a systematic review (Romão et al., 2021), the interpretation of Tsk measured by IRT is a challenging research subject, and no research has been conducted on Tsk responses to field tests in team sports. Therefore, the aims of this study were to a) assess Tsk responses before and after the 30-15 IFT in professional soccer players, b) analyze Tsk asymmetries before and after the 30-15 IFT, and c) determine the correlation between Tsk asymmetries and 30-15 IFT variables. Thus, we hypothesized that (a) Tsk would decrease immediately after the 30-15 IFT in the lower limbs compared with the baseline level based on previous research on sailing and volleyball athletes (Cerezci Duygu et al., 2019; Chudecka & Lubkowska, 2012); (b) Tsk asymmetries between the dominant and nondominant sides would be found in the lower limb after the 30-15 IFT (Vardasca, 2008; Vardasca et al., 2012); and (c) negative associations between Tsk asymmetries and the 30-15 IFT variables would exist (Hadžić et al., 2019).

Method

This was an observational cross-sectional study that was carried out at single time points during the 2022-2023 pre-season. Participants were divided into two groups to evaluate acute thermal responses after the 30-15 IFT. After the 10-minute acclimatization period, the athletes underwent pretest thermographic measurements, and approximately 30 minutes later, they underwent a 30-15 IFT. Finally, immediately after the 30-15 IFT, the athletes underwent posttest thermal imaging. The experimental design of the study is shown in Figure 1.

Figure 1. Schematic representation of the experimental design of the study



Participants were instructed to adhere to specific pre-test guidelines. They were asked to avoid strenuous exercise during the 24 hours prior to testing. In addition, the consumption of energy drinks or and supplements was prohibited in the 48 hours before the test. Participants were also required to refrain from caffeine and alcohol intake for at least 3 hours before testing and to abstain from eating within the 2 hours preceding the test (Valladares-Rodríguez, 2017).

Participants

A priori analysis was conducted on G*Power (version 3.1.9., University of Kiel, Germany), which provided an estimated sample of 19 with a power (1-β) of 80% and an α error of 5% with an effect size of 0.4 for pair comparisons (test: mean, differences between two dependent means) (Faul et al., 2009). Twenty-one male professional soccer players (age: 22.6 ± 2.8 years; professional experience: 5.4 ± 1.6 years; height: 174.4 ± 4.8 cm; and body mass: 73.3 ± 3.2 kg) voluntarily participated in the study. The inclusion criteria were as follows: 1) had a training duration of six times a week with an average duration of 80 minutes and played at least one official game per week and 2) had not suffered a lower limb injury in the last 6 months. The exclusion criteria consisted of 1) no intensive training 72 hours prior to the study, 2) no physiotherapy (massage, electrotherapy, ultrasound, heat treatment, etc.) to obtain the most reliable images of Tsk, and 3) not being a goalkeeper. Participants completed a written informed consent form after receiving a full description of all procedures. This study was approved by the University Ethical Commission with reference number 2023-134 and was conducted in accordance with the ethical principles of the Declaration of Helsinki.

Procedure

30-15 Intermittent Fitness Test

The 30-15 IFT consists of 30 sec. commutes interrupted by 15 sec. passive recovery phases. The speed is set at 8 km/h for the first 30 sec. of operation and then increased by 0.5 km/h in each 30 sec. stage. Players must run back and forth between two lines 40 m apart at a pace determined by a pre-recorded beep. The prerecorded beep allows players to adjust their running speed as they enter a 3 m zone in the middle and at each end of the field. During the 15-second recovery period, players will run in a forward direction toward the nearest line. Players are instructed to complete as many stages as possible. The test ends when the players can no longer maintain the required running speed or when they are unable to reach a 3 m zone in time for the sound signal three times in succession (Buchheit, 2010). All athletes performed a standardized 10-minute warm-up consisting of 5 minutes of light running and 5 minutes of joint mobility and dynamic stretching (Hermosilla-Palma et al., 2024). All tests were conducted under the conditions of a natural grass soccer pitch. During the changes of direction, participants were not restricted to the dominant or non-dominant leg; however, they were clearly instructed to use both legs when executing turns in order to prevent excessive loading on a single leg.

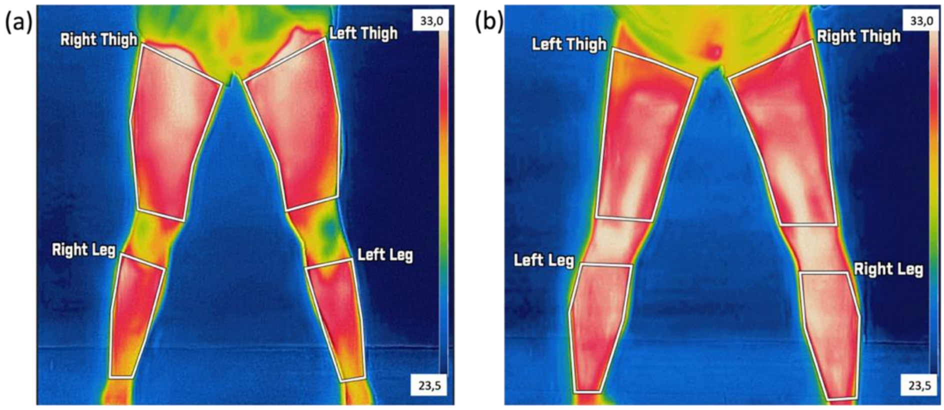
Thermal skin temperature asymmetry

Thermal image sequences of the lower limbs (thighs and legs) were acquired using an infrared thermal camera (FLIR One Pro, FLIR Systems Inc., USA) with a measurement range of -20 °C to 400 °C (accuracy of ±3 °C or ±5%, thermal sensitivity of 150 mK, and spectrum range of 8–14 µm) and a frame rate of 8.6 Hz with a thermal resolution of 160x120 pixels. Compared with conventional thermal cameras, this smartphone-attached infrared camera has proven to be more reliable for assessing muscle asymmetry in the lower extremities (Alfieri et al., 2020).

All thermographic images were taken 30 min before and immediately after the 30-15 IFT in an acclimatized room with a temperature of 23±1.5 °C and a relative humidity of 51±8.5%. The 10-minute acclimatization period applied in this study was selected based on previous thermography research in sports settings, which recommend at least 8–10 minutes to stabilize skin blood flow before imaging (Moreira et al., 2017; Alfieri et al., 2020). Furthermore, restrictions on smoking, alcohol, caffeine intake, and strenuous exercise prior to testing were implemented to minimize potential confounding influences on skin temperature responses, following methodological practices commonly reported in the literature. In addition, we adhered to the Delphi consensus recommendations for thermographic imaging in sports and exercise medicine (Moreira et al., 2017), which emphasize the importance of standardizing environmental conditions, acclimatization time, and participant preparation to ensure reliable and valid measurements. The thermographic imaging in sports and exercise medicine (TISEM) checklist was also used to verify that all factors that could influence thermographic measurements were considered (Moreira et al., 2017). The distance between the participant and the camera was standardized to 1.5 m (Alfieri et al., 2020) with the tripod positioned perpendicular to the participant approximately 60 cm above the floor (at knee height). The pictures were taken in underwear. The same applicants carried out all the image processing for the IRT data.

The manual ROI approach and procedures for Tsk data collection applied in this study were standardized across all participants and time points, following protocols previously used in athlete populations (Buoite-Stella et al., 2025; da Silva et al., 2022). The analysis was conducted using FLIR Ignite Sync software (FLIR Systems, USA), from which both mean and maximum Tsk values were extracted. ROIs were manually described according to established anatomical landmarks: for the thigh, 5 cm above the upper border of the patella and at the groin line; and for the leg, 5 cm below the lower border of the patella and 10 cm above the malleolus. The mean Tsk values were considered in the evaluation of four different ROIs: the anterior thigh, anterior leg, posterior thigh and posterior leg. Figure 2 shows representative anterior and posterior thermal images of the thigh and leg.

Figure 2. Anterior (a) and posterior (b) limb thermal reports using the FLIR Ignite Sync software



Two outcome variables were derived from the thermographic measurements. First, variation was defined as the within-limb change in skin temperature for each ROI and calculated as:

ΔTsk ROI = Tsk (post) – Tsk (pre)

This variable represents the acute thermal response of the muscle region to exercise, indicating how much the local skin temperature deviates from baseline after the 30-15 IFT.

Second, asymmetry was defined as the absolute bilateral difference in Tsk between the dominant and non-dominant limbs for each ROI, expressed as:

Asymmetry ROI = | Tsk (dominant) – Tsk (non-dominant) |

This variable quantifies the degree of bilateral thermal imbalance, independent of direction, and may reflect neuromuscular asymmetries, differential mechanical loading, or localized physiological stress.

Data analysis

All the data were analyzed using SPSS 27 (IBM, USA) for statistical analysis. The data are presented as descriptive statistics (mean ± SD), and the Shapiro–Wilk test was applied to confirm the normality of the distribution of the data. To determine significant differences between each ROI before and after the 30-15 IFT, paired samples t tests were performed. For significant paired differences, Cohen's *d* effect size (ES) was calculated using the following classification (Hopkins et al., 2009): trivial (<0.2), small (0.20–0.59), moderate (0.60–1.19), large (1.20–1.99), and very large (≥2.0). The Pearson correlation coefficient was also calculated for the correlation between the 30-15 IFT values and Tsk asymmetries for each ROI. The magnitude of correlation between variables was assessed with the following thresholds: <0.1, trivial; 0.1–0.3, small; 0.3–0.5, moderate; 0.5–0.7, large; 0.7–0.9, very large; and > 0.9, nearly perfect (Hopkins et al., 2009). The significance level was set at $p<0.05$.

Results

The descriptive characteristics of the participants and 30-15 IFT metrics, including running time, peak velocity, and true velocity (VIFT), of the soccer players are shown in Table 1.

Table 1. Characteristics and 30-15 IFT performance of the participants

Age (years)	Height (cm)	Body mass (kg)	30-15 IFT		
			Running time (sec)	Peak velocity (km/h)	VIFT (km/h)
22.6 ± 2.8	174.4 ± 4.8	73.3 ± 3.2	1115.9 ± 109.1	20.3 ± 1.2	20.0 ± 1.2

Tsk variation for the dominant and nondominant limbs

The pre- and post-test differences in the Tsk values of the dominant and nondominant limbs are shown in Table 2. Compared to the baseline values of the soccer players, Tsk in the anterior-posterior thigh and leg regions significantly decreased by 0.98 °C, 1.50 °C, 0.50 °C and 0.50 °C for the dominant limb and by 1.25 °C, 1.66 °C, 0.80 °C and 0.57 °C for the nondominant limb immediately after the 30-15 IFT.

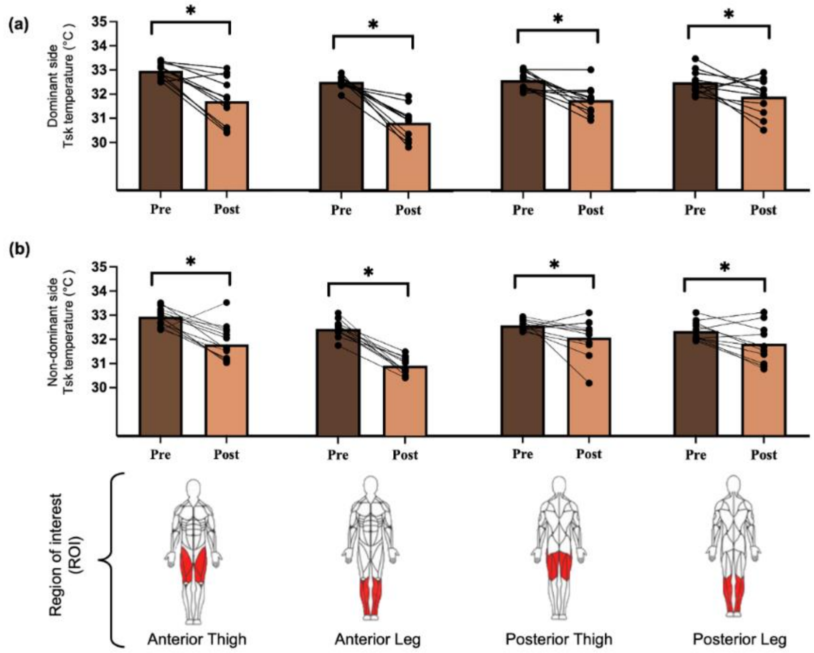
Table 2. Differences in the Tsk (ΔTsk) of the dominant and nondominant limbs for each ROI

ROI (Dominant limb)		Tsk (°C) (Mean ± *SD*)	ΔTsk	*SD*	*t*	*p*	Effect size
Anterior Thigh	Pre Post	32.9 ± 0.4 31.8 ± 0.6	0.98	0.82	5.45	<0.001*	Very large
Anterior Leg	Pre Post	32.4 ± 0.3 30.9 ± 0.6	1.50	0.46	14.90	<0.001*	Very large
Posterior Thigh	Pre Post	32.6 ± 0.2 32.1 ± 0.8	0.50	0.85	2.69	0.014*	Moderate
Posterior Leg	Pre Post	32.2 ± 0.4 31.6 ± 0.7	0.50	0.59	3.91	0.001*	Moderate
ROI (Non-dominant limb)							
Anterior Thigh	Pre Post	32.8 ± 0.4 31.6 ± 0.6	1.25	0.84	6.85	<0.001*	Very large
Anterior Leg	Pre Post	32.5 ± 0.2 30.8 ± 0.7	1.66	0.73	10.36	<0.001*	Very large
Posterior Thigh	Pre Post	32.5 ± 0.4 31.7 ± 0.6	0.80	0.65	5.64	<0.001*	Large
Posterior Leg	Pre Post	32.4 ± 0.5 31.8 ± 0.7	0.57	0.81	3.26	0.004*	Moderate

* p<0.05

Differences in the Tsk values of the dominant and nondominant limbs of professional soccer players after 30-15 IFT are shown in Figure 3. Accordingly, when acute thermal responses immediately after the endurance test are examined, Tsk decreases significantly in all anterior-posterior leg and anterior-posterior thigh regions compared to baseline levels.

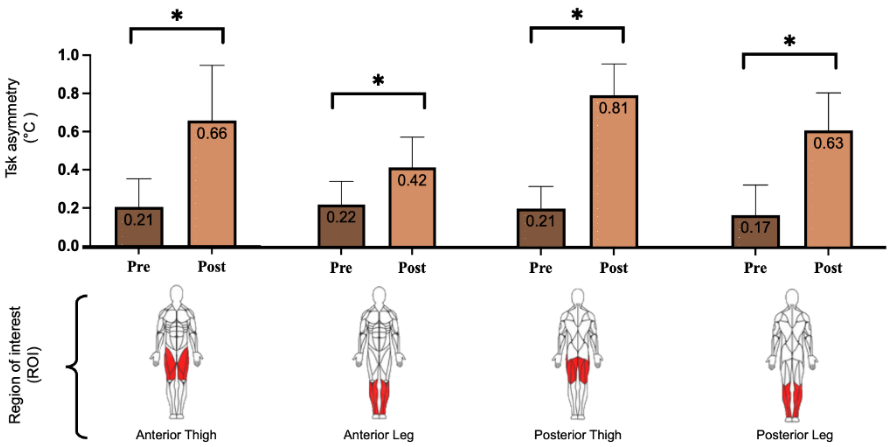
Figure 3. Tsk differences between pre- and posttest in dominant (a) and nondominant (b) limb for each ROI (*p<0.05)



Tsk asymmetries between the dominant and nondominant limbs

The Tsk asymmetries (|ΔTsk|) before and after the 30-15 IFT for each ROI are shown in Figure 4. Although the soccer players showed low asymmetries (between 0.17 and 0.22 °C) in all ROIs before the test (baseline level), these asymmetries differed significantly after the 30-15 IFT. The asymmetries in the anterior thigh (0.66 °C) and posterior leg (0.63 °C) were similar, with the lowest and greatest asymmetry occurring in the anterior leg (0.42 °C) and posterior thigh (0.81 °C), respectively.

Figure 4. Tsk asymmetry in each ROI (*p<0.05)



Tsk asymmetry and 30-15 IFT results

The correlation values between the Tsk asymmetries of each ROI and the pre- and posttest 30-15 IFT measurements are given in Table 3. According to the pre-test Tsk asymmetry, a significant negative correlation was found between posterior leg Tsk asymmetry and only the 30-15 IFT metrics (running time, peak velocity and VIFT). On the other hand, although the Tsk asymmetries increased in post-test, no significant correlations were found between the other 30-15 IFT metrics.

Table 3. Correlations between pre- and post-test Tsk asymmetries and 30-15 IFT results

Region of Interest		Running time		Peak velocity		VIFT	
		pre	post	pre	post	pre	post
Anterior Thigh	Pearson's r	.229	-.174	.228	-.177	-.190	-.135
	p value	.317	.451	.321	.443	.410	.560
Anterior Leg	Pearson's r	.067	-.116	.068	-.116	-.008	-.117
	p value	.774	.615	.769	.616	.973	.613
Posterior Thigh	Pearson's r	-.036	-.245	-.035	-.242	-.015	-.258
	p value	.877	.285	.880	.290	.949	.258
Posterior Leg	Pearson's r	-.475	-.028	-.472	-.032	-.486	-.026
	p value	.030*	.903	.031*	.891	.025*	.910

* *p*<0.05

Discussion

This study aimed to (a) assess Tsk responses before and after the 30-15 IFT in professional soccer players, (b) analyze Tsk asymmetries before and after the 30-15 IFT, and (c) determine the correlation between Tsk asymmetries and the 30-15 IFT. In recent years, IRT applications have increased tremendously in the field of sports sciences, and determining the thermal profile of an athlete in different sports can help prevent injuries by helping coaches plan training sessions to reduce thermal asymmetries that could be harmful to the athlete (Marins et al., 2013).

According to our results, the first hypothesis confirmed that compared to the baseline values, Tsk significantly decreased in the anterior thigh (0.98-1.25 °C), anterior leg (1.50-1.66 °C), posterior thigh (0.50-0.80 °C) and posterior leg (0.50-0.57 °C) immediately after the 30-15 IFT for the dominant and nondominant limbs. The fact that Tsk values after the 30-15 IFT are lower than baseline levels is an indication that the vasoconstriction mechanism may continue in the first stage of recovery, depending on the duration and intensity of exercise. Studies in the literature (Merla et al., 2010; Tanda, 2018) have shown that although Tsk tends to increase rapidly after exercise, it appears to return to baseline after approximately 5-10 minutes as the temperature decreases during graded exercise. This finding is similar to the results of the Tsk measurements taken immediately afterwards in our study. The asymmetries detected immediately after the 30-15 IFT may represent early indicators of localized overload, while the persistence of asymmetries up to 48 h after soccer game, as reported by Fernandes et al. (2025), highlights their potential role as markers of muscle damage and incomplete recovery. Our results showed that there were no significant differences between the dominant and non-dominant sides of any of the ROIs according to the pretest measurements. However, our second hypothesis also confirmed that after the 30-15 IFT, there were significant contralateral asymmetries in all ROIs for both the anterior (thigh: 0.66 °C; leg: 0.42 °C) and posterior (thigh: 0.81 °C; leg: 0.63 °C) regions. The Tsk of the thighs was also measured by Coh and Sirok (Čoh & Širok, 2007) both before and after different intensities of physical activity, and they found that the change in Tsk increased with increasing physical intensity. When comparing bilateral body parts using thermal monitoring, variations between 0.25 °C and 0.62 °C (Vardasca, 2008; Vardasca et al., 2012) are regarded as acceptable. Variations in these values, however, might suggest that ROIs with a higher or lower temperature—compared to the individual's typical thermal profile—may have some inflammatory (hyperthermia) or degenerative (hypothermia) issues (Hildebrandt et al., 2012). According to studies in the literature (Neves et al., 2015; Romão et al., 2021), the behavior of Tsk can vary depending on the type of exercise, intensity, duration, muscle mass and subcutaneous fat layer.

On the other hand, there was a negative correlation between baseline Tsk asymmetries and the 30-15 IFT. However, this was only confirmed in the posterior leg region with running time (r= -0.475; p=0.30), peak velocity (r= -0.472; p=0.31), and VIFT (r= -0.486; p=0.25), and no correlation was found for other ROIs. This can be interpreted as a lower mechanical stress in the calf region positively affecting endurance performance, especially before shuttle-run tests such as the 30-15 IFT, which involves many deceleration and acceleration activities during changes in direction. Additionally, a previous study showed a negative correlation between an increase in Tsk and a decrease in the amount of power required to exercise the quadriceps and that exercising quadriceps power could be predicted by Tsk (Hadžić et al., 2019). This information reinforces more research in this field with different training exercises or tests. Furthermore, similar to Maior et al. (2017), we also found only limited associations between thermographic indices and performance variables, reinforcing the view that thermography provides complementary insights rather than overlapping with biochemical markers such as CK. Taken together, these results highlight the potential of thermography as a rapid, non-invasive monitoring tool that can be applied immediately after training or testing sessions to support decision-making in athlete load management. When interpreting the present findings, it is important to consider the potential influence of the standardized warm-up protocol. Previous research has shown that warm-up procedures can elevate skin temperature and modify peripheral blood flow, thereby influencing acute thermographic responses (Hermosilla-Palma et al., 2024). In addition, the nature of the 30-15 Intermittent Fitness Test, which requires a large number of changes of direction, should also be acknowledged as a contributing factor. Repeated decelerations and accelerations during such maneuvers may lead to localized increases in mechanical load, potentially amplifying asymmetrical skin temperature responses between limbs.

Limitations and future directions

This study has several limitations, including the fact that the measurements were taken at a single point in time. Therefore, additional measurements over time might reveal information about how changes in muscular imbalances impact variations in temperature. The sample size was not large enough to provide separate data not only for the Tsk profiles but also for the player positions. Another limitation arises from the absence of data collected immediately after exhaustive performance tests, since professional athletes required shower, therapy, and rest, which restricted recovery assessments to 15–30 minutes post-exercise Tsk. Other limitations of this study include the lack of thermography software using artificial intelligence technology and conventional cameras with better thermal resolution and sensitivity.

To overcome these limitations and to gain a deeper understanding of the relationship between thermal asymmetries and performance or fatigue mechanisms, it may be possible to diversify the tests used and perform longitudinal protocols.

Practical Applications

Thermal imaging can be used to assess muscular asymmetries following specific endurance tests or conditioning training, and this information can provide valuable information for better training and load adjustments while avoiding fatigue and injury risk.

Conclusions

This study is important in terms of investigating whether the results obtained before and after the performance test are related to muscular imbalance. In conclusion, IRT can be useful for the assessment of lower limb Tsk asymmetries considering the difference between post fatigue and baseline values, and it is also used as a noninvasive monitoring tool related to muscular asymmetries when cumulative fatigue is induced by field-based endurance tests. It can also be said that athletes with lower baseline Tsk asymmetries in the posterior leg region may have better 30-15 IFT performance. From a practical point of view, the present study contributes to the scientific knowledge on the use of IRT for the assessment of fatigue monitoring based on sport-specific fitness tests in noncyclic sports.

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