Thermal and functional symmetry between dominant and non-dominant limbs in under-20 soccer players

Simetría térmica y funcional entre los miembros dominante y no dominante en futbolistas sub-20

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Abstract

Introduction: Soccer involves high-intensity actions that place substantial neuromuscular and physiological demands on the lower limbs, potentially leading to functional and thermal asymmetries between the dominant and non-dominant sides. The unilateral countermovement jump (UCMJ) and infrared thermography have been widely used to assess neuromuscular performance and physiological responses; however, evidence combining these methods in young soccer players remains limited.
Objective: To compare unilateral countermovement jump performance and skin temperature between the dominant and non-dominant limbs of under-20 soccer players.
Methods: This cross-sectional study included 27 male under-20 soccer players aged 18–20 years. Unilateral countermovement jump performance was assessed using a contact mat, while skin temperature was evaluated through infrared thermography under controlled environmental conditions. Mean and maximum skin temperatures of the anterior and posterior regions of the lower limbs were analyzed. Comparisons between dominant and non-dominant limbs were performed using paired statistical tests, with significance set at $p < 0.05$.
Results: No significant differences were observed between limbs in unilateral jump performance (20.30 ± 3.55 vs. 20.37 ± 3.78 cm; p = 0.841; Cohen's dz = −0.04; 95% CI: −0.79 to 0.65), with a mean asymmetry of −0.49%. Similarly, no significant differences were found for anterior (p = 0.242; dz = 0.23; asymmetry = 0.11%) or posterior skin temperature (p = 0.497; dz = 0.13; asymmetry = 0.08%). The magnitude of differences across all variables was trivial. Conclusion: Under-20 soccer players did not exhibit meaningful functional or thermal asymmetries between limbs. The trivial effect sizes and minimal asymmetry values (<1%) suggest a well-balanced neuromuscular and physiological profile in young athletes.

Keywords

Soccer; infrared thermography; unilateral countermovement functional symmetry.

Resumen

Introducción: El fútbol implica acciones de alta intensidad que imponen elevadas demandas neuromusculares y fisiológicas sobre los miembros inferiores, lo que puede conducir a asimetrías funcionales y térmicas entre los lados dominante y no dominante. El salto con contramovimiento unilateral (SCMU) y la termografía infrarroja se han utilizado ampliamente para evaluar el rendimiento neuromuscular y las respuestas fisiológicas; sin embargo, la evidencia que combina ambos métodos en jugadores jóvenes de fútbol sigue siendo limitada. Objetivo: Comparar el rendimiento en el salto con contramovimiento unilateral y la temperatura de la piel entre los miembros dominante y no dominante en futbolistas sub-20.
Métodos: Este estudio transversal incluyó 27 jugadores de fútbol masculinos de la categoría sub-20, con edades comprendidas entre 18 y 20 años. El rendimiento en el salto con contramovimiento unilateral se evaluó mediante una plataforma de contacto, mientras que la temperatura de la piel se analizó mediante termografía infrarroja bajo condiciones ambientales controladas. Se analizaron los valores medios y máximos de temperatura cutánea en las regiones anterior y posterior de los miembros inferiores. Las comparaciones entre los miembros dominante y no dominante se realizaron mediante pruebas estadísticas pareadas, estableciéndose un nivel de significación de $p < 0,05$.
Resultados: No se observaron diferencias significativas entre los miembros en el rendimiento del salto unilateral (20.30 ± 3.55 vs. 20.37 ± 3.78 cm; p = 0.841; Cohen's dz = −0.04; IC 95%: −0.79 a 0.65), con una asimetría media de −0.49%. De manera similar, no se encontraron diferencias significativas en la temperatura cutánea anterior (p = 0.242; dz = 0.23; asimetría = 0.11%) ni posterior (p = 0.497; dz = 0.13; asimetría = 0.08%). La magnitud de las diferencias en todas las variables fue trivial.
Conclusión: Los futbolistas sub-20 no presentaron asimetrías funcionales ni térmicas relevantes entre los miembros. Los tamaños del efecto triviales y los valores mínimos de asimetría (<1%) sugieren un perfil neuromuscular y fisiológico equilibrado en atletas jóvenes.

Palabras clave

Fútbol; termografía infrarroja; salto con contramovimiento unilateral.

Introduction

Team sports, such as soccer, involve high-intensity actions including jumping, sprinting, accelerations, decelerations and rapid changes of direction that impose substantial physiological demands on athletes (Falces-Prieto et al., 2022; Gualtieri et al., 2023; Zheng et al., 2025). These actions are largely characterized by high mechanical loads and pronounced eccentric muscle contractions (Abade et al., 2025), which can trigger inflammatory responses (Bengtsson et al., 2013; Lundberg & Weckström, 2017; Mohr et al., 2016; Peake et al., 2017), and lead to specific neuromuscular adaptations in the lower limbs. Over time, these adaptations may contribute to the development of bilateral asymmetries through repeated unilateral loading and neuromuscular specialization (Hildebrandt et al., 2010; Maloney, 2019; Rahnama et al., 2005; Zahálka et al., 2013).

Given the potential emergence of functional asymmetries due to the repetitive and asymmetric nature of soccer-specific actions, vertical jump tests have been widely used to assess lower-limb neuromuscular function (Stella et al., 2022; Menzel et al., 2013; Svynos et al., 2024). Among the different jump modalities, the unilateral countermovement jump (UCMJ) allows for the isolated assessment of each limb, enabling the identification of inter-limb differences in force production, motor control, and stretch–shortening cycle utilization (Teixeira et al., 2020). Compared to bilateral tests, the UCMJ is considered more sensitive for detecting inter-limb differences, as it isolates the contribution of each limb and reduces compensatory strategies that may mask asymmetries during bilateral movements.

Although soccer performance depends on coordinated bilateral actions, in many movements one limb is primarily responsible for force generation (e.g., kicking or propulsion), while the contralateral limb provides stabilization (Lees et al., 2010; Li & Qian, 2025; Paravlic et al., 2024). Therefore, unilateral assessments may be more sensitive in detecting asymmetries that are not evident in bilateral tests, contributing to more precise monitoring of functional performance.

In parallel, infrared thermography (IRT) has been used as a non-invasive tool to monitor physiological responses to training and to detect thermal asymmetries between body regions (Santana et al., 2022; Fernandes et al., 2012). Variations in skin temperature may reflect underlying inflammatory processes, localized muscle overload, or altered neuromuscular activation patterns, making it a valuable complementary approach for assessing athletes' functional status (Santana et al., 2022; Fernandes et al., 2012). Under normal physiological conditions, thermal symmetry between contralateral regions is expected; thus, deviations from this pattern may indicate asymmetric adaptations with potential implications for injury risk and load management. In general, temperature differences between contralateral regions below 0.5°C are considered within normal physiological limits, whereas asymmetries greater than 0.5–1.0°C may indicate abnormal physiological responses, such as localized inflammation or tissue overload.

Although inter-limb asymmetries have been widely investigated, their prevalence in soccer players has been reported to range from 20% to 60%, depending on the population and assessment method. Asymmetry thresholds above 10–15% have been associated with increased injury risk and reduced performance. However, most studies have focused on adult or elite populations, and limited evidence is available regarding young soccer players, particularly when combining neuromuscular performance and physiological markers such as skin temperature. Inter-limb asymmetry is typically considered relevant when differences exceed 10–15%, as such magnitudes have been associated with impaired performance, reduced force production efficiency, and an increased risk of musculoskeletal injury. From a functional perspective, asymmetries may compromise movement coordination and load distribution, while clinically they have been linked to higher injury incidence and delayed recovery.

Despite the growing use of unilateral performance tests and IRT in sports science, studies simultaneously examining functional and thermal asymmetries in young soccer players remain scarce. This population presents unique characteristics related to ongoing maturation and exposure to structured training loads, which may influence the development of inter-limb asymmetries. Therefore, considering the limited evidence combining functional and thermal assessments in young soccer players, the present study aimed to compare unilateral countermovement jump performance and skin temperature between the dominant and non-dominant limbs in under-20 soccer players.

Method

Sample

This study followed a cross-sectional comparative design, aimed at analyzing differences between dominant and non-dominant lower limbs. The total sample consisted of 27 male athletes aged between 18 and 20 years, selected by convenience from an under-20 soccer team. This sampling approach was adopted due to the specific accessibility of a homogeneous group of athletes with similar training routines and competitive levels, which allowed for controlled comparisons between dominant and non-dominant limbs. Although convenience sampling may limit generalizability, it is commonly used in sports science studies involving team-based populations. Only athletes without a recent history of musculoskeletal injuries to the lower limbs, pelvis, or spine, and without limb length discrepancies greater than 2 cm, were included in the study. Athletes who did not complete all stages of data collection or who sustained injuries during the study period were excluded.

The study was conducted in accordance with the ethical guidelines for research involving human subjects established by the National Health Council (2012) and was approved by the Research Ethics Committee of the University Hospital of the Federal University of Maranhão (CAAE: 57676922.9.0000.5086; Approval No. 8.281.672). All participants were informed about the study procedures and objectives and provided written informed consent. Although no a priori sample size calculation was performed, this study should be interpreted as exploratory, providing preliminary evidence on functional and thermal symmetry in young soccer players.

Procedures

Participants were instructed not to use diuretics, antipyretics, or dietary supplements during the two weeks prior to data collection to avoid interference with fluid and thermal homeostasis. Before the assessments, all participants were familiarized with the infrared thermography protocol and attended two sessions aimed at learning and standardizing the movement used in the jump performance test. Basic anthropometric measurements (body mass, height, and body mass index calculation) were performed, followed by infrared thermography and jump performance assessments, in accordance with previously standardized procedures.

Instruments

Anthropometric Assessment

Anthropometric measurements included body mass, height, and calculation of body mass index (BMI). Body mass and height were measured using a scale with an attached stadiometer (WELMY W300), with a precision of 0.05 kg and 0.5 cm, respectively. BMI was calculated as the ratio of body mass (kg) to height squared (m^2).

Jump Performance Assessment

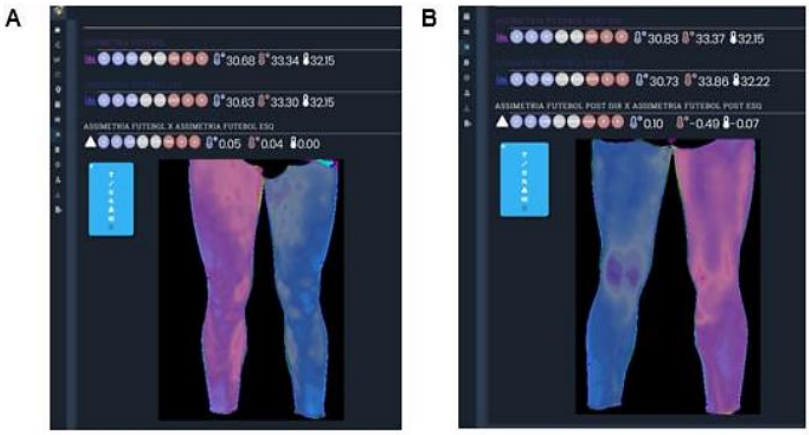
Jump performance was assessed using a contact mat (Jump Test System, Hidrofit, Brazil), which measured jump height in centimeters (cm). For this study, only the UCMJ was used. The test was performed with one lower limb at a time. From a standing position, the athlete executed a countermovement followed by rapid extension of the joints of the assessed limb, while the contralateral limb remained without contact with the mat throughout the movement. A 10-second interval was allowed between trials. Each athlete performed five trials with each lower limb. The highest and lowest values were excluded, and the mean of the three intermediate trials was used for analysis. Inter-limb asymmetry was calculated using the following formula: Asymmetry (%) = ((dominant − non-dominant) / dominant) × 100.

Infrared Thermography

Participants were instructed to avoid vigorous physical activity during the 24 hours preceding data collection, as well as the consumption of alcohol and caffeine and the application of creams or lotions on the skin during the six hours prior to assessment, in order to minimize interference with skin temperature. Thermographic images were obtained in a climate-controlled room without natural light, illuminated only by fluorescent lamps and with no directed airflow. Ambient temperature was maintained between 22–23°C, and relative humidity between 50–60%, monitored using a digital psychrometer (INCOTERM, Brazil). Prior to image acquisition, athletes remained at rest for 10 minutes to allow thermal

equilibrium. Images were captured using a FLIR T650sc camera (FLIR Systems Inc., Sweden), with a resolution of 640 × 480 pixels, positioned at a distance of 2.5 m and configured with an emissivity of 0.98. Image analysis was performed using Apollo Omni® software (Brazil), considering mean and maximum temperature values of the regions of interest (ROIs). The ROIs corresponded to the right and left lower limbs, on the anterior and posterior aspects, delimited by a line above the medial malleolus and the inguinal line, as illustrated in Figure 1.

Figure 1. Thermograms of the thigh and leg regions. (A) Anterior region; (B) Posterior region.



Statistical Analysis

Data were analyzed using descriptive and inferential statistics. Numerical variables were expressed as mean and standard deviation. Data normality was assessed using the Shapiro–Wilk test. To compare asymmetries between lower limbs, paired Student's t-tests were applied. In addition to p-values, effect sizes (Cohen's dz) and 95% confidence intervals (CI) were calculated. Inter-limb asymmetry was also computed as ((dominant − non-dominant) / dominant) × 100 to provide a measure of practical relevance.

Results

Table 1 presents the descriptive characteristics of the sample. The athletes had a mean age of 19.19 ± 0.79 years. Mean height was 1.80 ± 0.08 m, and mean body mass was 72.84 ± 10.50 kg. The mean body mass index (BMI) was 22.37 ± 1.78 kg/m^2.

Table 1. Descriptive characteristics of the under-20 athlete's sample.

Variable	Mean ± standard deviation
Age (years)	19.19 ± 0.79
Height (m)	1.80 ± 0.08
Body mass (kg)	72.84 ± 10.50
BMI (kg/m^2)	22.37 ± 1.78

Note: BMI: body mass index.

Table 2 presents the mean and maximum skin temperature values of the lower limbs. The right and left anterior regions showed mean temperatures of 31.56 ± 0.91°C and 31.51 ± 0.91°C, respectively, and maximum temperatures of 33.40 ± 0.75°C and 33.33 ± 0.79°C. In the posterior region, mean temperatures were 31.54 ± 0.70°C (right) and 31.49 ± 0.75°C (left), while maximum temperatures were 33.10 ± 0.70°C and 33.00 ± 0.69°C, respectively.

Table 2. Descriptive skin temperature values in the anterior and posterior regions of the lower limbs.

Variables	Mean ± standard deviation (°C)
Mean anterior temperature – right	31.56 ± 0.91
Maximum anterior temperature – right	33.40 ± 0.75
Mean anterior temperature – left	31.51 ± 0.91
Maximum anterior temperature – left	33.33 ± 0.79
Mean posterior temperature – right	31.54 ± 0.70
Maximum posterior temperature – right	33.10 ± 0.70
Mean posterior temperature – left	31.49 ± 0.75
Maximum posterior temperature – left	33.00 ± 0.69

Figure 2 presents the comparison of unilateral jump performance between the dominant and non-dominant limbs. No significant differences were observed between limbs (20.30 ± 3.55 cm vs. 20.37 ± 3.78 cm; mean difference = −0.07 cm; 95% CI: −0.79 to 0.65; p = 0.841; Cohen's dz = −0.04). The mean inter-limb asymmetry was −0.49%, indicating a trivial magnitude of difference and negligible practical asymmetry between limbs.

Figure 2. Comparison of unilateral jump performance between the dominant and non-dominant limbs.

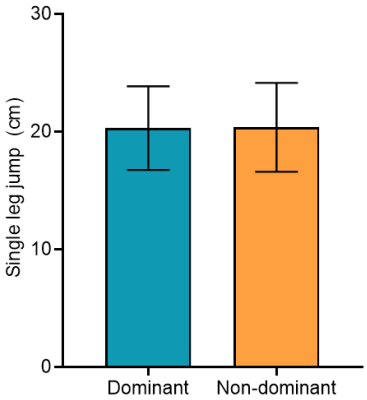
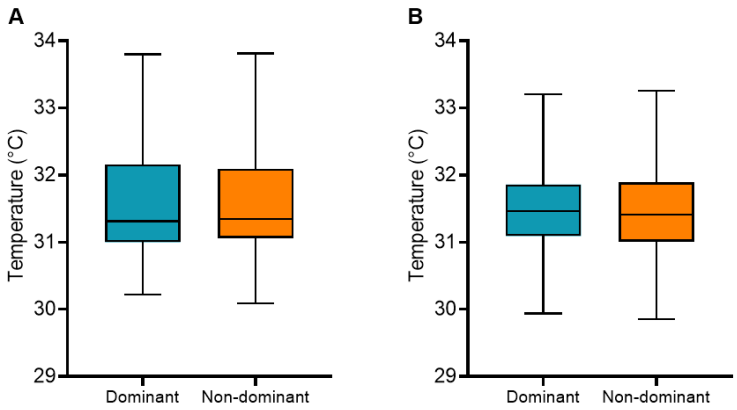


Figure 3 presents the comparison of skin temperatures between the dominant and non-dominant limbs in the anterior (Figure 3A) and posterior (Figure 3B) regions. No significant differences were observed between limbs in the anterior region (31.55 ± 0.92°C vs. 31.52 ± 0.91°C; mean difference = 0.04°C; 95% CI: −0.03 to 0.10; p = 0.242; Cohen's dz = 0.23), with a mean asymmetry of 0.11%, indicating a negligible thermal difference between limbs. Similarly, no significant differences were observed in the posterior region (31.52 ± 0.72°C vs. 31.50 ± 0.73°C; mean difference = 0.03°C; 95% CI: −0.05 to 0.10; p = 0.497; Cohen's dz = 0.13), with a mean asymmetry of 0.08%, also indicating a negligible thermal difference between limbs. Overall, the magnitude of differences across all variables was trivial, and inter-limb asymmetry values remained below 1%, reinforcing the absence of meaningful functional or thermal asymmetries in this sample.

Figure 3. Comparison of skin temperatures between the dominant and non-dominant limbs. (A) Anterior region. (B) Posterior region.



Discussion

The present study aimed to compare unilateral countermovement jump performance and skin temperature between the dominant and non-dominant limbs of under-20 soccer players.

The main findings indicated no significant differences between sides in either neuromuscular performance or skin temperature variables. Importantly, the inclusion of effect sizes and inter-limb asymmetry indices revealed that these differences were trivial in magnitude (<1%), reinforcing that the absence of statistical significance was accompanied by negligible practical differences.

The absence of differences in UCMJ performance between the dominant and non-dominant limbs is consistent with previous findings in young athletes. Evidence from the literature indicates that the UCMJ shows high sensitivity for identifying functional asymmetries when present, particularly in contexts of injury, accumulated fatigue, or pronounced unilateral specialization (Parera et al., 2021). However, in young athletes, such asymmetries tend to be less pronounced, which may be attributed to their stage of neuromuscular development and relatively shorter exposure to chronic asymmetric loading (Kalata et al., 2025; Mala et al., 2023). This interpretation is further supported by the trivial effect size and minimal asymmetry observed in the present study, suggesting that neuromuscular performance between limbs was highly balanced.

In under-20 soccer, although certain technical actions—such as kicking—are predominantly performed with the dominant limb, most motor actions involve high-intensity bilateral demands, including accelerations, decelerations, jumps, and changes of direction. This pattern of demands may contribute to a relatively balanced development between the lower limbs, thereby reducing the manifestation of functional asymmetries detectable in unilateral tests (Villanueva et al., 2025; Vaisman et al., 2017). Thus, the results observed in this study suggest that symmetry in the UCMJ may represent an expected-and potentially desirable-functional profile in young athletes, particularly in the absence of a recent injury history.

Similar findings were observed in the thermographic analysis, as no significant differences in skin temperature were identified between the dominant and non-dominant limbs. Additionally, the very small effect sizes and asymmetry values reinforce that thermal differences between limbs were not only statistically non-significant but also physiologically negligible. This result is consistent with previous studies, which also reported no association between thermal asymmetry and strength imbalances in soccer players (Teixeira et al., 2020). The literature suggests that skin temperature is strongly influenced by central and peripheral thermoregulatory mechanisms, such as vasomotor control and cutaneous blood flow, which do not necessarily directly reflect underlying mechanical or neuromuscular differences between limbs (Cuevas et al., 2015).

Additionally, experimental studies indicate that even eccentric stimuli capable of inducing muscle damage do not always result in asymmetric thermal responses, particularly in young and physically trained individuals, who tend to exhibit greater adaptive capacity and more efficient recovery responses (Santana et al., 2022). In this context, the absence of thermal differences in the present study may indicate a stable physiological condition, with no signs of localized overload or asymmetric inflammation in the lower limbs.

On the other hand, evidence from professional athletes demonstrates that infrared thermography can be a useful tool for identifying thermal alterations associated with overload, accumulated fatigue, and an increased risk of injury. A study published in 2020 reported a reduction in the incidence of muscle injuries following the implementation of preventive programs based on thermographic monitoring in elite players (Carmona et al., 2020). The discrepancies between these findings and the results of the present study may be attributed to differences in competitive level, training load (volume and intensity), injury history, and timing of data collection within the training cycle. Professional athletes, who are exposed to higher and more repetitive loads, tend to exhibit more asymmetric physiological responses throughout the season (Beato et al., 2021; Gholizadeh et al., 2022; Miguel et al., 2022).

Thus, the findings of the present study suggest that both the UCMJ and infrared thermography may exhibit greater practical and clinical sensitivity when applied longitudinally, monitoring variations in

training load, periods of competitive congestion, or specific phases of the season, rather than through isolated assessments. In young athletes, single-point evaluations may not be sufficient to detect subtle alterations, particularly when the group is in good musculoskeletal health. From a practical perspective, these findings suggest that the absence of detectable asymmetries in young athletes should not be interpreted as a limitation of the assessment methods, but rather as a reflection of a balanced and well-adapted functional profile.

Despite the relevance of the findings, some limitations should be acknowledged. The relatively small sample size may have limited the detection of asymmetries of small magnitude. Additionally, the cross-sectional design precludes the analysis of the evolution of asymmetries over time and their relationship with training load or injury occurrence. The inclusion of other neuromuscular performance measures, such as isokinetic strength, kinetic variables, or electromyographic assessments, could provide a more comprehensive understanding of athletes' functional status. Furthermore, although infrared thermography is a promising tool, its interpretation strongly depends on environmental standardization and control of individual factors, which may reduce its sensitivity, particularly in cross-sectional designs.

From a practical perspective, these findings suggest that the absence of asymmetries in young athletes reflects a well-balanced neuromuscular and physiological profile. Therefore, routine monitoring of asymmetry may be more relevant in contexts involving injury, fatigue, or high training loads, rather than in isolated assessments of healthy youth players. The trivial magnitude of inter-limb differences observed in this study further supports this interpretation.

Conclusions

The results of this study indicate that under-20 soccer players do not present meaningful differences between the dominant and non-dominant limbs in unilateral countermovement jump performance or lower-limb skin temperature. The trivial effect sizes and minimal inter-limb asymmetry values (<1%) observed reinforce a profile of functional and thermal symmetry in this population. These findings suggest a well-balanced neuromuscular and physiological status in young athletes, particularly in the absence of injury or excessive training load.

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