Original article

Acute effects of badminton practice on the surface temperature of lower limbs Introduction

Alfredo Bravo-Sánchez[1], Javier Abián-Vicén[1], Almudena Torrijos Montalbán[2], Pablo Abián-Vicén[3]

[1]Facultad de Ciencias del Deporte. Universidad de Castilla-La Mancha. [2]Hospital Nacional de Parapléjicos. Toledo. [3]Facultad de Humanidades y Ciencias Sociales. Universidad Pontificia de Comillas. Cantabria.

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Summary

Introduction: The objective was to evaluate the effect of badminton training on the skin temperature of lower limbs and the possible asymmetries derived from the one-sidedness of the sport.
Material and method: 19 badminton players participated in the study (Age: 34.4±14.1 years, Height: 168.1±7.8 cm, Body mass: 66.2±13.9 kg). Each player was tested before and after performing a 2-hour standardized badminton workout. To record body temperature, a VARIOCAM® HR model thermographic camera was used. The images of the anterior and posterior parts of the lower limbs were divided into three zones (thigh, knee and leg).
Results: The mean temperature of the dominant lower limb was higher after training in the anterior knee (pre=31.52±0.91 ºC *vs* post=32.15±0.51 ºC, P=0.003) and in the anterior leg=32.10±0.75 ºC *vs* post=32.81±0.73 ºC, P<0.001). In the non-dominant lower limb an increase after training was recorded in the medial temperature in the anterior thigh area (pre=32.15±0.85 ºC *vs* post=32.50±0.52 ºC, P=0.018), in the anterior area of the knee (pre=31.55±0.91 ºC *vs* post=32.26±0.56 ºC, P<0.001), in the anterior area of the leg (pre=32.22±0.76 ºC *vs* post=32.80±0.74 ºC, P<0.001) posterior of the leg (pre=32.13±0.69 ºC *vs* post=32.50± 0.65 ºC, P=0.006). No differences were found in the surface temperature between the dominant and non-dominant lower limbs at any instant or in the analyzed area.
Conclusions: The results show that the anterior regions of the knee and leg in both lower limbs and the anterior region of the thigh and posterior leg in the non-dominant lower limb are those that show a greater increase in temperature after a training of badminton should be where they focus more attention in the recovery period and in the return to calm after training.

Key words:
Lower extremity. Thermography. Badminton.

Efectos agudos de la práctica del bádminton sobre la temperatura superficial de los miembros inferiores

Resumen

Introducción: El objetivo fue evaluar el efecto de un entrenamiento de bádminton sobre la temperatura superficial de los miembros inferiores y las posibles asimetrías derivadas de la unilateralidad del deporte.
Material y método: 19 jugadores de bádminton participaron en el estudio (Edad: 34,4±14,1 años, Estatura: 168,1±7,8 cm, Masa corporal: 66,2±13,9 kg). Cada jugador fue analizado antes y después de realizar un entrenamiento de bádminton estandarizado de 2 horas. Para registrar la temperatura corporal se utilizó una cámara termográfica VARIOCAM® modelo HR. Se tomaron las imágenes de la parte anterior y posterior de los miembros inferiores divididos en tres zonas (muslo, rodilla y pierna).
Resultados: La temperatura media del miembro inferior dominante fue mayor después del entrenamiento en la zona anterior de la rodilla (pre=31,52±0,91 ºC *vs* post=32,15±0,51 ºC; p=0,003) y en la zona anterior de la pierna (pre=32,10±0,75 ºC *vs* post=32,81±0,73 ºC; p<0,001). En el miembro inferior no dominante se registró un incremento después del entrenamiento en la temperatura media en la zona anterior del muslo (pre=32,15±0,85 ºC *vs* post=32,50±0,52 ºC; p=0,018), en la zona anterior de la rodilla (pre=31,55±0,91 ºC *vs* post=32,26±0,56 ºC; p=0,001), en la zona anterior de la pierna (pre=32,22±0,76 ºC *vs* post=32,80±0,74 ºC; p<0,001) y en la zona posterior de la pierna (pre=32,13±0,69 ºC *vs* post=32,50±0,65 ºC; p=0,006). No se encontraron diferencias en la temperatura superficial entre el miembro inferior dominante y no dominante en ningún instante ni zona analizada.
Conclusiones: Los resultados muestran que las regiones anteriores de la rodilla y de la pierna en ambos miembros inferiores y la región anterior del muslo y posterior de la pierna en el miembro inferior no dominante son las que muestran un mayor incremento de temperatura tras un entrenamiento de bádminton debiendo ser en ellas donde recaiga mayor atención en el periodo de recuperación y en la vuelta a la calma después del entrenamiento.

Palabras clave:
Extremidades inferiores. Termografía. Bádminton.

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Correspondence: Javier Abián-Vicén
E-mail: javier.abian@uclm.es

Introduction

Badminton is one of the most popular sports in the world with around 150 million players, according to the figures provided by the International Badminton Federation. It is characterised as a unilateral sport with short, continuous movements, jumping actions, changes of direction and rapid arm movements in a wide range of body postures, with the aim of returning the shuttlecock[1]. The unilateral nature of badminton, both in the lower and upper limbs, may result in changes in the muscle and tendon architecture which could be detrimental in the long term[2,3].

Badminton injuries constitute between 1% and 5% of all sports injuries[4-6]. The injury rate for badminton is between 2.9 and 5.0 per 1,000 playing hours[7], which is far lower than the incidence injury rates for contact sports, such as football[8], rugby[9] and basketball[10], with rates of more than 10 injuries per 1,000 playing hours. In contrast to other sports, the injury rate in badminton is greater during training than at matches[11], with minor injuries being the most common. Out of all the injuries, those caused by overuse are approximately three times higher than traumatic injuries, both at matches and during practice sessions[12]. Categorising the injury rate by location, the highest rates are for the lumbar spine, knee joint and shoulder joint on the dominant side[12].

Thermography is a non-invasive technique that makes it possible to visually represent the entire process, during and after exercise. This device permits a quantitative, accurate evaluation of the spatial distribution of the skin temperature, and the evolution time, permitting a data recording speed of up to 100 Hz[13]. Thermography is widely used for medical diagnostic analyses and is being increasingly used to record physical exercise-associated skin temperature changes[13], while it is valid for detecting possible sports injuries by showing alterations in the temperature of the tissues involved[14]. The type of thermal alteration will depend on the intensity of the biological phenomenon that is occurring and the size and depth of the tissue involved. For example, due to the low heat transfer capacity of fat, the mean temperature will be lower in individuals with high adiposity[15]. The most important uses of thermography in the area of sports are the prevention and monitoring of injuries; the detection of muscle imbalances; the quantification of the thermal response to the training load; the detection of delayed onset muscle soreness and the lactate threshold; and the evaluation of fitness and performance[16]. However, we have found no studies in the literature that address any of these aspects in relation to badminton.

Finally, considering the concept of anatomical proportionality, the thermal response between contralateral body parts is expected to be symmetrical in baseline conditions[16]. Thermal monitoring that compares bilateral body parts indicates that differences of up to 0.25-0.62 °C[17,18] are considered normal. However, differences that are above these values may indicate problems in the region of interest examined: a higher temperature, contrasted with the individual's usual thermal profile, may correspond to an inflammatory problem, while a temperature below the normal value may represent a degenerative problem[19,20]. It is important to be aware that thermography can be an indication of the existence of a thermal abnormality in the tissue characteristics, but it can never serve as an anatomic descriptor of the same[20]. To date, although studies have been conducted on potential muscle asymmetries in order to assess the physical condition of athletes in bilateral sports such as swimming[21], we have not found any investigation that focuses on unilateral sports such as badminton.

Therefore, the aim of this study is to evaluate the effect of badminton training on the surface temperature of the lower limbs and the possible asymmetries resulting from the unilateral nature of the sport.

Material and method

Material and method

An experimental study was conducted, with the voluntary participation of 19 amateur badminton players (Aged: 34.4 ± 14.1 years; Height: 168.1 ± 7.8 cm; Body mass: 66.2 ± 13.9 kg; Fat percentage: 14.1 ± 6.9%). All participants were licensed players with a minimum experience of 5 years in this sport, regularly training 2 $h*day^{-1}$ 3 $days*week^{-1}$. The laterality of the players was recorded in order to differentiate between the dominant lower limb and the non-dominant lower limb. Excluded from the sample were those players with an injury or any pain that would prevent them from doing their usual sports practice.

All players were informed in writing and orally of the objective and procedure of the investigation, through informed consent. All the players handed in their signed consent before the start of the study. The players were free to abandon the activity, with no need to give any kind of explanation and with no penalty imposed by their club for doing so. The study was approved by the Ethics Committee of the Virgen de la Salud Hospital, in accordance with the principles of the latest version of the declaration of Helsinki.

Experimental design

In this present investigation, an experimental study was conducted. All the players participating in the study were part of the same training group and were analysed on the same day and in the same practice conditions. Measurements were taken individually and at two different times: before and after standardised badminton training with a two hour duration (pre-training and post-training).

The training comprised four distinct parts: 1) 15 minute standardised warm-up including an aerobic part, followed by dynamic stretching of the upper and lower limbs and specific exercises with a shuttlecock on the court. 2) technical hitting sequences and defence and attack exercises of 2 against 1 on the badminton court, with a 40 minute duration (each player performed three 4 minute series, acting as a "feeder" for his/her fellow players when not performing the exercise). 3) individual badminton matches for 40 minutes. 4) cooling down session with games on the badminton court followed by stretching exercises with a total duration of 20 minutes.

Experimental protocol

Evaluation of the players

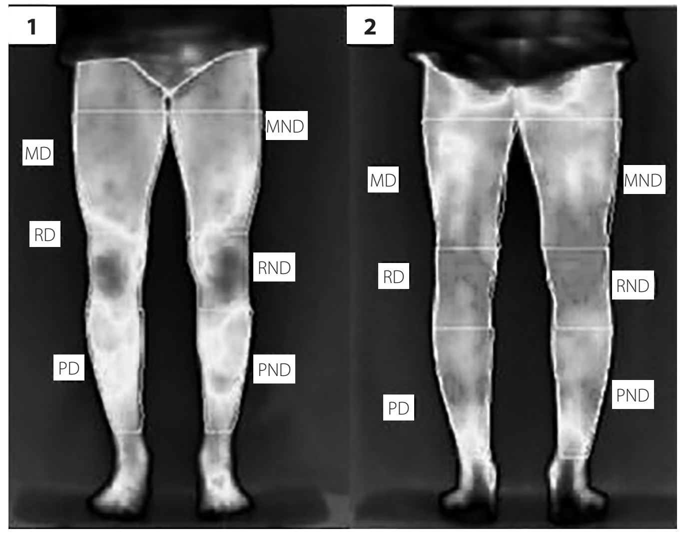
The body mass was measured through bioelectrical impedance with a Tanita TBF 300 (Tanita Corp., Tokyo, Japan), with an accuracy of 0.1 kg and a measurement frequency of 150 Hz. The participants, in their undergarments, stood on the metal strips on the scales. All the measurements were taken after standing for at least 10 minutes in order to minimise the potential errors of abrupt changes in fluid distribution. The laterality of the players was also recorded.

The variables relating to the infrared thermography were evaluated with a VarioCAM Hr® camera (Infratec GmbH, Dresden, Germany). The mean temperature range that can be recorded by the VarioCAM Hr® is between -40 °C and 1,200 °C with a measurement accuracy of 2%. The influence variables (physical activity or most recent physical treatment, shower or previous cream-gel-spray, intake of food, caffeine and medicine, consumption of tobacco or alcohol) were recorded in a questionnaire prior to the evaluation in order to ensure that there were no interference factors. The values for temperature (21 ºC), atmospheric pressure (954hPa) and humidity (49%) of the room, remained stable and within the ideal range for performing thermographic studies on humans[20,22]. The camera was positioned at a distance of three metres from the participant; this distance was selected as it was therefore possible to completely observe the lower limbs[23]. 4 images were taken during the evaluation (anterior and posterior lower limbs, for pre-training and post-training alike). For the analysis of the images, we used IRBIS3® software (Infratec GmbH, Dresden, Germany). For each dominant and non-dominant leg, 6 regions of interest were analysed, 3 in the posterior view and 3 in the anterior view, corresponding to the area of the thigh, knee and leg (Figure 1), recording the mean and maximum temperature for each area[24].

Statistical analysis

The statistical analysis was conducted using the SPSS v 22.0 software (SPSS Inc., Chicago, IL). The values are presented as mean values ± standard deviation. The Shapiro-Wilk test was used to check for the normal distribution of the dependent variables, which showed that all variables were parametrically distributed. A two-factor Anova was performed with repeated measurements in order to calculate the significant differences in the temperature-related variables; the first factor corresponded to the time at which the data were taken (pre-training or post-training), the second factor corresponded to the limb measured (dominant or non-dominant limb). Bonferroni was used as a post-hoc test. The magnitude of effect size was interpreted using the Cohen scale25: an effect size of less than 0.2 was considered to be small; an effect size of 0.5 was considered to be medium and an effect size was considered to be large when the result was greater than 0.8. The significance criterion was p <0.05 for all statistical tests.

Figure 1. Regions of interest.



1. Anterior region; 2 Posterior region. MD: dominant thigh; MND: non-dominant thigh; RD: dominant knee; RND: non-dominant knee; PD: dominant leg; PND: non-dominant leg.

Results

Anterior region

The data for the pre and post-training thermographic evaluation of the anterior region of the lower limbs are included in Table 1. In the anterior view of the lower limbs, the mean temperature of the non-dominant thigh region increased by 1.08±2.06% (p=0.018; d=0.50) after training. Also in the anterior region, an increase in the mean temperature was observed for the regions of the dominant knee by 1.96±2.73% (p=0.003; d=0.85), non-dominant knee by 2.19 ± 2.60% (p=0.001; d=0.94), dominant leg by 2.14±2.26% (p<0.001; d=0.96) non-dominant leg by 1.77±1.50% (p<0.001; d=0.77). All maximum temperatures increased in the post-training. No differences were found in the comparison between the dominant and non-dominant limbs.

Posterior region

The data for the pre and post-training thermographic evaluation of the posterior region of the lower limbs are included in Table 2. In the posterior region of the lower limbs, the mean temperature of the non-dominant leg region increased by 1.14±1.76% (p=0.006; d=0.55). Also in the posterior region, an increase in the maximum temperature was observed in the regions of the non-dominant thigh by 0.93±2.26% (p= 0.045; d=0.48), dominant knee by 0.96±2.47% (p=0.049; d=0.46), non-dominant knee by 1.31±2.53% (p=0.018; d=0.67), dominant leg by 1.42±1.78% (p=0.001; d=0.81) and non-dominant leg by 1.50±1.55% (p<0.001; d=0.83). No differences were found in the comparison between the dominant and non-dominant limbs.

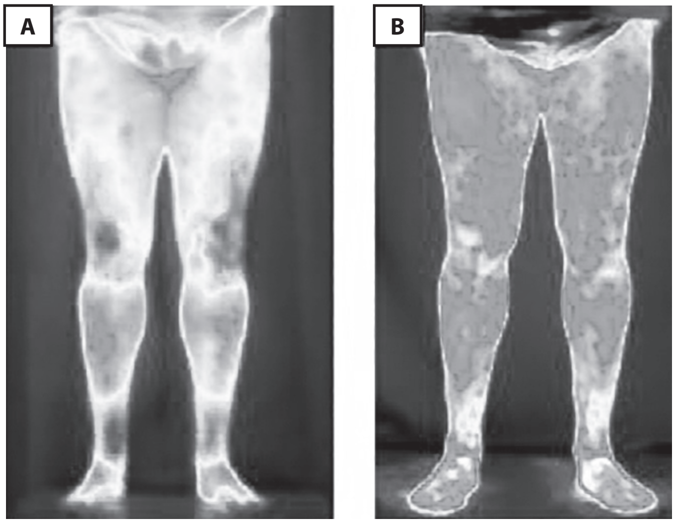
Table 1. Thermographic variables of the anterior region. Mean and standard deviation of all the thermographic variables of the anterior region of the lower limbs for pre and post-training conditions.

	Pre-training	Post-training	Δ (95% CI)
Mean temperature			
MD	32.24 ± 0.84	32.50 ± 0.53	0.27 ± 0.77 (0.04 to -0.57)
MND	32.15 ± 0.85	32.50 ± 0.52	0.35 ± 0.67 (-0.08 to -0.62)
Δ (95% CI)	0.09 ± 0.18 (0.17 to 0.00)	0.00 ± 0.27 (-0.13 to 0.13)	- 0.08 ± 0.21 (-0.18 to 0.02)
RD	31.52 ± 0.91	32.15 ± 0.51	0.63 ± 0.87 (-0.27 to -0.98)
RND	31.55 ± 0.91	32.26 ± 0.55	0.71 ± 0.84 (-0.38 to -1.04)
Δ (95% CI)	-0.03 ± (-0.15 to 0.09)	-0.11 ± 0.39 (-0.29 to 0.09)	- 0.08 ± 0.38 (-0.26 to 0.11)
PD	32.10 ± 0.75	32.81 ± 0.73	0.71 ± 0.75 (-0.41 to -0.91)
PND	32.22 ± 0.76	32.80 ± 0.74	0.59 ± 0.49 (-0.39 to -0.78)
Δ (95% CI)	-0.12 ± 0.35 (-0.29 to 0.05)	0.01 ± 0.28 (0.14 to -0.13)	0.13 ± 0.35 (0.30 to -0.04)
Maximum temperature			
MD	33.23 ± 0.82	33.79 ± 0.61	0.56 ± 0.84 (-0.23 to -0.89)
NDL	33.27 ± 0.85	33.74 ± 0.56	0.47 ± 0.70 (-0.20 to -0.75)
Δ (95% CI)	-0.04 ± 0.32 (-0.19 to 0.12)	0.05 ± 0.35 (0.22 to -0.12)	0.08 ± 0.42 (0.29 to -0.12)
RD	32.98 ± 0.78	33.65 ± 0.59	0.67 ± 0.89 (-0.32 to -1.02)
RND	33.05 ± 0.69	33.69 ± 0.59	0.64 ± 0.71 (-0.36 to -0.93)
Δ (95% CI)	-0.07 ± 0.36 (-0.24 to 0.10)	-0.04 ± 0.59 (-0.29 to 0.79)	0.02 ± 0.69 (0.36 to -0.31)
PD	33.35 ± 0.62	34.00 ± 0.68	0.66 ± 0.52 (-0.45 to -0.86)
PND	33.36 ± 0.68	34.03 ± 0.80	0.67 ± 0.42 (-0.50 to -0.84)
Δ (95% CI)	-0.01± 0.32 (-0.17 to 0.14)	-0.02 ± 0.37 (-0.20 to 0.16)	- 0.01 ± 0.32 (-0.17 to 0.14)

Table 2. Thermographic variables of the posterior region. Mean and standard deviation of all the thermographic variables of the posterior region of the lower limbs for pre and post-training conditions.

	Pre-training	Post-training	Δ (95% CI)
Mean temperature			
MD	32.14 ± 0.70	32.12 ± 0.64	0.27 ± 0.77 (-0.29 to 0.32)
NDL	32.10 ± 0.72	32.09 ± 0.60	0.00 ± 0.78 (-0.31 to 0.31)
Δ (95% CI)	0.04 ± 0.16 (0.12 to -0.03)	0.03 ± 0.23 (0.14 to -0.08)	-0.01 ± 0.22 (-0.12 to 0.09)
RD	32.52 ± 0.75	32.52 ± 0.60	0.00 ± 0.87 (-0.35 to 0.35)
RND	32.43 ± 0.84	32.51 ± 0.55	0.08 ± 0.86 (0.26 to - 0.42)
Δ (95% CI)	0.09 ± 0.23 (0.21 to -0.02)	0.01 ± 0.23 (0.12 to -0.10)	-0.08 ± 0.24 (-0.20 to 0-04)
PD	32.18 ± 0.71	32.44 ± 0.73	0.27±0.71 (0.26 to -0.42)
PND	32.13 ± 0.69	32.50 ± 0.65	0.37±0.58 (-0.14 to -0.60)
Δ (95% CI)	0.05 ± 0.17 (0.13 to -0.03)	-0.06 ± 0.25 (-0.18 to 0.06)	-0.11 ± 0.22 (- 0.21 to 0.00)
Maximum temperature			
MD	33.16 ± 0.73	33.41 ± 0.54	0.25±0.77 (0.06 to -0.56)
NDL	33.07 ± 0.70	33.38 ± 0.59	0.32±0.77 (-0.01 to -0.62)
Δ (95% CI)	0.10 ± 0.26 (0.22 to -0.03)	0.03 ± 0.32 (0.18 to -0.12)	- 0.06 ± 0.26 (-0.19 to 0.06)
RD	33.50 ± 0.75	33.83 ± 0.67	0.33±0.84 (0.00 to -0.67)
RND	33.46 ± 0.78	33.91 ± 0.55	0.45±0.86 (0.26 to -0.42)
Δ (95% CI)	0.04 ± 0.29 (-0.12 to -0.84)	- 0.08 ± 0.43 (-0.29 to 0.13)	-0.12 ± 0.41 (-0.31 to 0.08)
PD	32.98 ± 0.53	33.47 ± 0.67	0.48±0.60 (0.14 to -0.55)
PND	32.91 ± 0.64	33.42 ± 0.59	0.50±0.52 (-0.30 to -0.71)
Δ (95% CI)	0.07 ± 0.31 (0.22 to -0.07)	0.05 ± 0.36 (0.22 to -0.12)	-0.02 ± 0.35 (-0.19 to 0.15)

Figure 2. Pre-training and post-training thermography. Anterior view.



A. Anterior view pre-training; B. anterior view post-training.

Discussion

The aim of this study was to evaluate the effect of badminton training on the surface temperature of the lower limbs and possible asymmetries resulting from the unilateral nature of the sport. This is the first study with badminton players to evaluate the acute effects of practising this sport on the skin temperature of the lower limbs, which is a good gauge of the muscle activity performed[26]. The principal findings of this study were that the mean temperature of the anterior view increased in the regions of the non-dominant thigh, dominant knee, non-dominant knee, dominant leg and non-dominant leg, increases were also recorded for all the maximum temperatures. On the other hand, for the posterior view, the mean temperature increased for the region of the non-dominant leg and the maximum temperatures increased for the regions of the non-dominant thigh, dominant knee, non-dominant knee, dominant leg and non-dominant leg. Based on these results, badminton involves greater activity in the anterior region of the lower limbs in relation to the posterior region, in both extremities.

The mean temperature of the anterior region increased in the post-training measurement in relation to the pre-training measurement. Physical exercise is associated with important haemodynamic changes involving multiple regulatory processes[27]. Given the fact that exercise generates heat in the body and invokes skin thermoregulatory processes, this leads to alterations in the skin temperature[26]. During this compensatory mechanism, the skin blood flow may vary widely in order to provide heat dissipation or conservation, giving rise to marked variations in body temperature. Moreover, the areas responsible for removing the heat will depend on the type of exercise and its level of intensity[28]. In the case of badminton, an explosive, intermittent sport, the expected results are a continuous increase in body temperature, particularly in the area of the lower limbs, due to the increased physiological demand of movements such as lunging which account for 15% of the total actions made during a match[29]. We have found no studies that report the thermal behaviour of the upper limbs following unilateral physical activity, although there are studies that describe the thermal profile of the upper limbs in pre-competitive situations[24] or post-training of cyclic sports such as swimming[21]. Other investigations affirm that the temperature of the upper limbs drops when the activity performed involves a greater use of the lower limbs, such as for cycling[28].

Badminton is characterised by the execution of sporadic movements of moderate and high intensity, related to repetitive actions of short duration but of a highly explosive nature[1]. In our study, the highest temperature increase occurred in the anterior area of the dominant and non-dominant knees (Figure 2). This is due to the increase in physiological stress in the area, primarily caused by the movements and the continuous semi-flexed position of the joint during the pause periods in order to keep the centre of gravity low and improve the speed of reaction[29]. Moreover, a significant increase in the mean temperature can also be observed in the region of the non-dominant leg in the posterior view. This temperature increase may be related to the unilateral eccentric movements made with the non-dominant limb when landing after the jump smash[30]. All these regions of the anterior part, except the dominant thigh, increased their mean temperature, which could be caused by the existence of a predominance of cutaneous vasodilator mechanisms that operate with a sympathetic impulse in this area during exercise and even after the gradual decrease in the core temperature following exercise, thereby causing the surface temperature to remain high after exercise[27]. Similar results were found in students performing repetitive jumps[31].

It should be mentioned in our study that no significant differences were found between the dominant and non-dominant sides, this is indicative of the absence of possible injuries in the regions examined, having regard to the studies that cite excessive thermal asymmetry between limbs as a key factor in the detection of injuries[18-20]. Therefore, this finding could indicate that, despite the unilateral nature of the movements, this is not sufficient to cause a greater physiological load on the dominant limb in relation to the non-dominant one, as far as thermal values are concerned. The literature indicates that a difference of 0.5ºC or more between the dominant and non-dominant sides could be a sign of injury[19,20], offering the case of the basketball player in the study by Sampedro *et al*.[24] as an example. At the time of measurement, he was suffering from Achilles tendinopathy, showing a difference of more than 2 ºC between the affected limb and the healthy one. By contrast, without describing it as pathological, the study of other athletes did show certain asymmetries in muscle groups as a result of practice[32]. It is therefore necessary to continue this line of investigation in order to improve the quantification of the training and competition loads on the different groups of muscles and make recovery strategies more effective.

Practical applications

To provide a tool that could improve the diagnosis of injuries in badminton players and, therefore, help structure the training and competition loads in order to keep them from excessive physiological stress and the overloads resulting from practising this sport. We would strongly recommend considering methodologies to evaluate muscle condition in order to provide guidance for recovery strategies. Despite the fact that the physiological aspects studied show a certain aptness between both limbs, the findings underlined the need to focus attention on the anterior region of both legs, particularly on the region of the knee. The results of this study appear to suggest that there is a greater physiological stress on the anterior region of both knees, which could be related to the characteristics of the game itself. This study can be used to help players and their team select the appropriate strategy to promote correct recovery after matches and training sessions.

Conclusion

In summary, the players taking part in the training experienced an increase in the mean temperature in the regions of the non-dominant thigh, dominant knee, non-dominant knee, dominant leg and non-dominant leg in the anterior view, and non-dominant leg in the posterior view in relation to the baseline condition at the pre-training measurement. We would therefore recommend focussing the recovery strategies on the anterior regions of both legs, particularly in the area of the knees, which experience the greatest temperature increase in the post-training.

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