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TECHNICAL REPORT

Infrared Thermography Protocol on Reducing the Incidence of Soccer Injuries

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Context: Infrared thermography has been used to detect skeletal muscle overload and fatigue in athletes, but its use in injury prevention in professional soccer has not been studied to date. ***Objectives:*** To establish a novel injury prevention program based on infrared thermography and to determine its influence on the injury incidence in professional soccer players in the preseason. ***Design:*** A cross-sectional, prospective study design was used to compare a conventional injury prevention program (CPP) applied over the first preseason and an infrared thermography injury prevention program (IRTPP) carried out in the following preseason. ***Setting:*** Soccer training ground. ***Participants:*** Twenty-four players belonging to a first division soccer team from Spain. ***Main Outcome Measures:*** Injury incidences of each player were recorded according to the Orchard Sports Injury Classification System (version 10.0) convention to determine the injury classification, location, and type. ***Results:*** The incidence of injuries decreased from 15 injuries in the CPP preseason (0.63 [0.77] injuries per player) to 6 injuries in the second preseason when the IRTPP was applied (0.25 [0.53] injuries per player). The days of absence due to injuries also decreased from the CPP preseason (156 d, 10.4 [11.0] d per injury) to the IRTPP preseason (14 d, 2.3 [2.8] d per injury). The injury severity also decreased from the first preseason to the second preseason, and fewer musculoskeletal injuries in the thigh, hip, and groin were reported. ***Conclusions:*** The implementation of an IRTPP can reduce the presence of injuries by identifying players potentially at risk and as a result, reducing the injury severity and days lost as a consequence.

Keywords: general sports trauma, imagery, prevention, football, preseason injuries, Spanish *LaLiga*

Injuries are an inherent part of high-level sports performance, with soccer having one of the highest injury incidences.[1] Specifically, epidemiological studies in soccer have observed a prevalence of injuries about 15% per season, affecting 65% to 95% of all players.[1,2] Injury rate in soccer has been defined as the number of injuries per 1000 hours of exposure (training or competition), with a greater number of injuries occurring during competitions (8.7–65.9 lesions per 1000 h) with respect to those in training (1.37–5.8 lesions per 1000 h).[1]

The high player load and high match frequency are important mechanisms underlying injuries in professional soccer. Such a relationship between the amount of training and competition and the incidence of injury, illness, and soreness has been seen in other team-based sports.[3] During the preseason, when most teams engage in greater training volume and intensity,[3] players are exposed to an increased risk of noncontact injuries, accounting for 17% of all injuries.[2]

Noncontact injuries account for 59% of all lower-extremity injuries,[1] and this number appears to be increasing. This suggests that injury prevention programs could be applied systematically to professional soccer players in such a way that takes into account the training and match loads during in-season play for each player.[3] Multifaceted injury prevention programs are useful to reduce the risk of injuries in team sports; a number of techniques have been recently used to assess the tissue changes and to predict the risk of injuries and state of underperformance in team sports.[4] In addition, factors such as the communication between technical and medical staff have been shown as a critical part of the success of different programs and methodologies to reduce the injury incidence.[5] Although there is sufficient information on how different methodologies are useful to reduce the injury risk,[6] it has been suggested that these programs or methodologies are not always applied successfully and could possibly be improved.

Among the injury prevention programs, infrared thermography has been used as a valid,[7] accurate,[8] and reliable[7,9] technique to use on a daily basis to detect skeletal muscle overload and fatigue in athletes.[10] Infrared thermography, a noninvasive and fast technique, applied to the skin temperature provides a detailed temperature map of the human body in which each pixel of the image corresponds to a given temperature.[11] When athletes train or compete in matches, they are exposed to physical stress, which causes changes in blood flow profusion influencing skin temperature. Hence, a thermal asymmetry might represent a potential risk of injury related to training/competition overload.[12]

Although there has been an increasing interest in thermography research recently,[10] these investigations are either case studies or represent small sample sizes. The application of such a protocol in a professional soccer team has not been studied before. Considering the high incidence of injuries in preseason, the purpose of this study was to establish a novel injury prevention program based on infrared thermography and to determine its influence on the injury incidence in professional soccer players in the preseason. It was hypothesized that the use of infrared thermography protocol will reduce the injury incidence and severity in professional soccer players.

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Materials and Methods

Participants

A total of 33 male professional soccer players volunteered to participate in this study. The players belonged to a first division soccer team from Spain, which played in the national league competition (*LaLiga*) and the national cup competition (*Copa del Rey*) over 2 seasons. The injury incidence among the players was recorded during the preseason. Only players who had not suffered an injury in the 2 months prior to either preseason were included in the study giving a total of 24 players (mean [SD]; age: 27.4 [4.0] y, playing experience as a professional: 6.2 [4.6] y). Prior to the commencement of research, all subjects were informed of the protocols and the purposes of the data collection and signed an informed consent to participate in the study. Subjects were also informed about their right to withdraw from the investigation at any time. The study was conducted according to the Ethical Principles for Medical Research Involving Human Subjects (Declaration of Helsinki) and approved by the Universidad Politécnica de Madrid Research Ethical Committee.

Study Design

A cross-sectional and prospective study design was used to compare 2 injury prevention programs applied over 2 consecutive preseasons: a conventional injury prevention program (CPP) applied over the first preseason (48 d) and an infrared thermography injury prevention program (IRTPP) carried out during the second preseason (40 d) with all the injury incidences of each player recorded.

Procedure

Following the Union of European Football Associations Medical Committee criteria, injury definition, injury severity, training, and match exposure were determined. Following the same consensus statement, each injury was coded according to a modified version of the Orchard Sports Injury Classification System (version 10.0; https://www.johnorchard.com/osics-downloads.html) to determine the injury classification, location, and type.

Preseason Training Program

Both the technical staff and the medical staff were the same during both training preseasons. Training, recovery methodologies, and microcycle structure (morphocycle) were the same between both periods. The training ground used during the 2 preseasons was the same, except for the training performed in foreign countries. In this case, the field conditions were similar and optimal for soccer training at all times: natural grass always cut at the same length (2 cm). During the first preseason, 53 training sessions were held (77 h of training in total), and 8 friendly matches were played (each lasting 90 min); during the second preseason, 44 training sessions were held (60 h of training in total), and 9 friendly matches were played.

Thermographic Analysis

During the second preseason, an infrared thermography digital camera (ThermaCAM™ SC660; FLIR Systems AB, Danderyd, Sweden) was used to record all the thermograms (accuracy = ±1°C and thermal sensitivity < 30 mK at 30°C). Considering the requirements for the skin profile assessment, the thermograms were recorded in a room where the temperature was set to 20°C (2°C), the humidity was at 39.8% (7.8%), and the atmospheric pressure was maintained at 0.96 (0.04) atm to avoid the influence of ambient temperature on skin temperature.[13] The ambient temperature and relative humidity in the assessment room, influencing factors on skin temperature,[12,13] were measured by means of the BAR988HG station (Oregon Scientific, Portland, OR).

Thermographic assessment was carried out before every training session at the same daily time (9 AM). Players followed the same routine before and during the infrared thermography assessment and were instructed to avoid behaviors that might influence the assessment of their thermal images,[11] such as smoking, drinking alcohol, taking medicines or therapeutic treatments, or applying cosmetics to the areas to be examined. Each subject adapted to the surrounding conditions for a period of 15 minutes[13] by exposing the recording area and wearing only undergarments.

The thermograms were recorded in standing position; the distance between the exposed body part and the camera was 2.5 to 3 m, depending on the player's height. Two images were captured (front and rear views of the lower limbs and the abdominal and lower back areas) for each subject thorough the assessment. The same researcher and infrared thermography specialist took all the measurements. Surface thermal images in JPG format of the size 640 × 480 pixels were captured, and skin temperature was extracted, for 25 regions of interest (ROIs; Figure 1) by means of ThermaCAM™ Researcher™ software (version 2.9; FLIR Systems AB). Individual reports with the skin temperature from each ROI and the level of asymmetries between contralateral ROI were daily edited and distributed to the technical and medical staff.

Injury Prevention Programs

Every member of the technical and medical staff of the club was instructed by a multiprofessional team (consisting of a doctor, strength and conditioning coach, and a physiotherapist) on how to implement both the prevention programs (the CPP during the first preseason and the IRTPP during the second preseason). These instructions were given at the beginning of the respective preseason

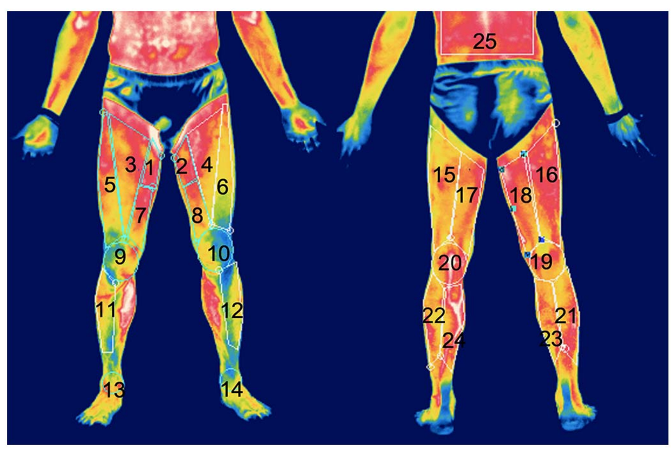

Figure 1 — Thermograms indicating the region of interest analyzed. 1: Right hip adductors, 2: left hip adductors, 3: right rectus femoris, 4: left rectus femoris, 5: right vastus lateralis, 6: left vastus lateralis, 7: right vastus medialis, 8: left vastus medialis, 9: right knee, 10: left knee, 11: right tibialis anterior, 12: left tibialis anterior, 13: right ankle, 14: left ankle, 15: left posterolateral thigh, 16: right posterolateral thigh, 17: left posteromedial thigh, 18: right posteromedial thigh, 19: right popliteus, 20: left popliteus, 21: right lateral gastrocnemius, 22: left lateral gastrocnemius, 23: right medial gastrocnemius, 24: left medial gastrocnemius, 25: lumbar region.

periods, and the club's staff were constantly in contact with the professional team in case there were any doubts or questions that needed to be clarified.

The CPP was applied only when the player reported pain (considered to be a value of 4 or more on the visual analog scale), discomfort, or fatigue in a particular body area. The following procedures regarding the CPP were made:

1. The technical staff advised to the player and minor adjustments to his training regime were made.
2. After training, physiotherapy treatment (joint and soft tissue mobilization and passive stretching) and cold water or ice (10°C–12°C for 10 min) were applied to the affected areas.

In the second preseason, every player's thermograms were taken immediately before each morning training session, and the temperature of each ROI was determined. The IRTPP was applied when a bilateral asymmetry in skin temperature was detected based on the following scale: normal (0.00–0.29°C), follow-up (0.30–0.49°C), prevention (0.50–0.99°C), warning (1.00–1.49°C), and severe asymmetry (≥1.50°C). Hence, the prevention protocol was applied when a bilateral temperature difference ≥0.5°C was found. The following procedures regarding the IRTPP were made:

1. The player and the technical staff were informed immediately after the thermography assessment of the infrared thermography qualitative results (ie, hotspots and subjective asymmetries) in order to modify the training session, taking into account the body area affected.[14]
2. Ice or cold-water immersion (10–12°C for 10 min) was applied to the affected ROI immediately after training.
3. Physiotherapy treatment, based on joint and soft tissue mobilization and passive stretching, was applied to the affected ROI after the training session.

A quantitative individual and collective report was provided to the technical and medical staff after the morning training session, and this included the evolution of the skin temperature of the considered ROIs.

Statistical Analysis

Quantitative variables were presented as mean (SD). In order to determine normality, the Shapiro–Wilk test was applied. Comparison between 2 dependent samples was performed using paired Student *t* test for parametric data. For nonparametric data, both the Friedman and Wilcoxon tests were performed.

Injury incidence (frequency, location, type, and mechanism) and days of absence due to injury were processed by contingency tables of means; comparisons were established by chi-squared test of means (χ^2). In addition, association between 2 variables was performed by Cramer *V* (V_{Cramer}) for nominal variables and by Somers *D* (d_{Somers}) for ordinal variables.

The statistical significance was set at $\alpha = .05$ for all tests. Statistical analyses were performed on SPSS (version 20.0; IBM Corp, Armonk, NY).

Results

The incidence of injuries decreased ($t_{46} = 1.964$, $P < .05$) from 15 injuries in the CPP season (0.63 [0.77] injuries per player) to 6 injuries in the IRTPP season (0.25 [0.53] injuries per player). Over the 2 preseasons, there were a total of 170 days of absence due to injuries (8.1 [10.0] d per injury), being higher ($t_{46} = 2.406$, $P < .05$) following the CPP (10.4 [11.0] d per injury) than with the IRTPP (2.3 [2.8] d per injury) (Figure 2). In addition, days of players' absence, when considering the injury severity, decreased from CPP respect to IRTPP: mild (11 vs 6), minor (8 vs 0), moderate (95 vs 8), and serious (42 vs 0).

On comparing the injury location (based upon the ROIs) over both preseasons (Figure 3), the thigh (47.6%), the hip–groin region (14.3%), and the ankle (14.3%) were the most affected regions. No statistical differences ($\chi^2_6 = 10.710$, $P = .10$) nor association ($d_{Somers} = 0.137$, $P = .52$) between programs and injury location were found. However, following the IRTPP, there was a reduction in thigh injuries ($t_{47} = 2.269$, $P < .05$). There was also an absence of knee and hip–groin injuries (Figure 2).

Musculoskeletal injuries were the most common type of injuries (61.9%), followed by tendon (19.0%) and joint (9.5%) injuries (Figure 4). Although no significant differences ($\chi^2_4 = 3.567$, $P = .47$) nor association ($d_{Somers} = -0.260$, $P = .22$) were found between programs and injury type, there was a significant decrease in the number of skeletal muscle injuries following the IRTPP when compared with the CPP ($t_{46} = 2.356$, $P < .05$) (Figure 4).

No significant differences ($\chi^2_5 = 3.436$, $P = .33$) nor significant association between injury severity and programs ($d_{Somers} = -0.341$, $P = .06$) were found. Injury mechanism (overload and trauma) frequency were similar between CPP and IRTPP (86.7% [n = 13] vs 83.3% [n = 18] and 13.3% [n = 1] vs 16.7% [n = 3], respectively), and no significant differences ($\chi^2_1 = 0.039$, $P = .84$) nor association ($d_{Somers} = -0.042$, $P = .85$) between injury mechanism and programs were found.

It is important to note that there were no significant differences in the anthropometries of the players who participated in the 2 preseasons (height: 182 [4] [CPP] vs 182 [4] cm [IRTPP], weight: 76.3 [4.2] [CPP] vs 75.8 [4.1] kg [IRTPP], and body mass index: 23.0 [1.2] [CPP] vs 22.9 [1.5] kg·m^{-2} [IRTPP]). The training load (70.1 [16.1] [CPP] vs 66.8 [2.3] min·session^{-1} [IRTPP]) and total load (75.7 [17.4] [CPP] vs 72.9 [2.5] min·session^{-1} [IRTPP]; 1815 vs 1750 min) were also similar between the 2 seasons. However, the friendly matches load was statistically lower for CPP (132 min) respect to IRTPP (148 min) (5.5 [1.3] vs 6.1 [0.43] min·session^{-1},

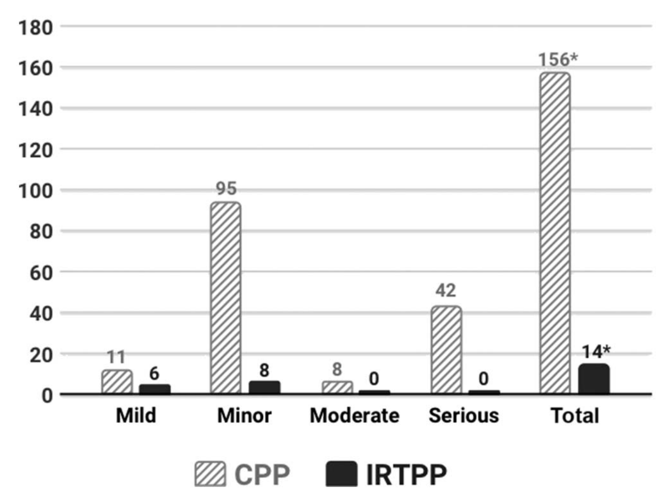

Figure 2 — Days lost due to injury in the 2 preseasons. CPP corresponded to the first preseason when the conventional injury prevention program was applied, and IRTPP corresponded to the second preseason when the infrared thermography injury prevention program was applied. *Statistically significant difference between the 2 seasons with $P < .05$.

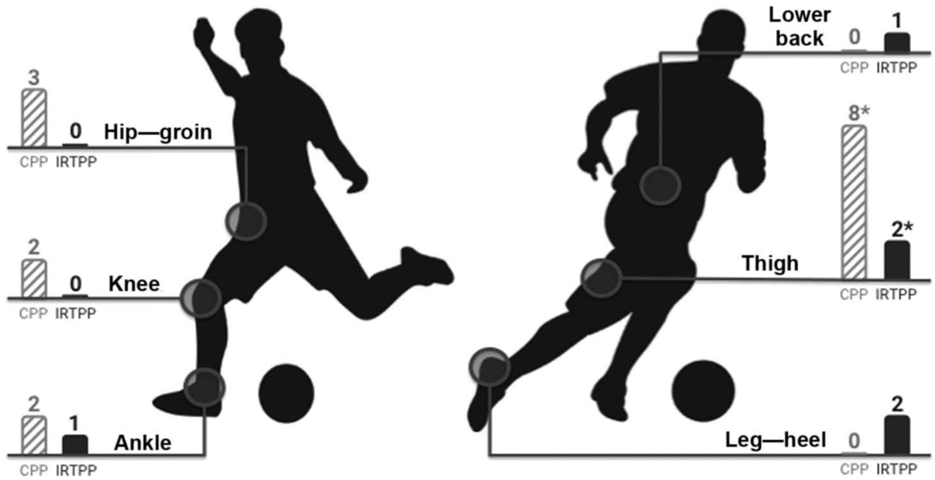

Figure 3 — Injury location across the 2 preseasons. CPP corresponded to the first preseason when the conventional injury prevention program was applied, and IRTPP corresponded to the second preseason when the infrared thermography injury prevention program was applied. *Statistically significant difference between the 2 seasons with $P < .05$. (Figure designed from a Freepik illustration.)

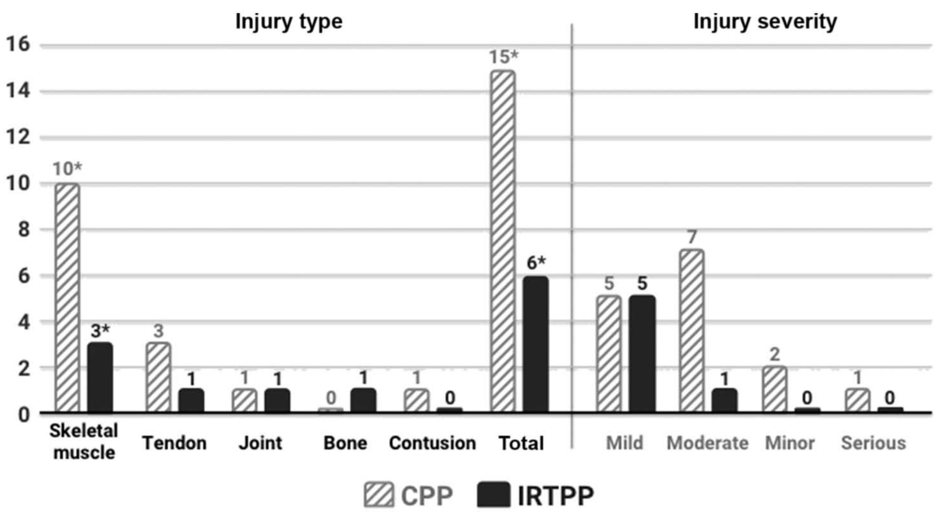

Figure 4 — Number of injuries based on their type and severity across the 2 preseasons. CPP corresponded to the first preseason when the conventional injury prevention program was applied, and IRTPP corresponded to the second preseason when the infrared thermography injury prevention program was applied. *Statistically significant difference between the 2 seasons with $P < .05$.

$t_{27} = -2.442$, $P < .05$). Although a greater number of injuries occurred in training (11 vs 5 in the CPP and IRTPP seasons, respectively) than during matches (4 vs 1 in the CPP and IRTPP seasons, respectively), no significant differences ($\chi^2_1 = 0.236$, $P = .63$) and no associations ($V_{Cramer} = 0.106$, $P = .63$) were found in the distribution of injury incidence for training and competition between prevention programs. The injury rate average was 5.9 injuries per 1000 hours of exposure (CPP: 8.3 [14.1] vs IRTPP: 3.4 [7.6]), for training was 4.9 injuries per 1000 hours (CPP: 6.5 [9.4] vs IRTPP: 3.1 [8.0]), and for competition 17.9 injuries per 1000 hours (CPP: 30.3 [86.5] vs IRTPP: 6.8 [34.0]). The relative risk of sustaining an injury in training in CPP was 2.2 times higher than in IRTPP (95% confidence interval, 0.66–7.30) with the probability of sustaining an injury in training following the CPP and IRTPP being 0.85 and 0.26, respectively. In competition, the relative risk of sustaining an injury was 4 times higher in CPP than with the IRTPP (95% confidence interval, 0.90–11.46), and the probability of sustaining an injury in competition was 0.19 for the CPP and 0.04 for the IRTPP.

Discussion

In this preliminary study, a protocol of infrared thermography for professional soccer was developed and applied, and a comparison of injury incidence in preseason was carried out over 2 consecutive preseasons with the same team of professional soccer players playing in the first division of the Spanish *LaLiga*. The fundamental difference between the 2 preseasons was the implementation of an injury prevention program based on infrared thermography, in which reports were prepared and provided the team's coaching and medical staff with additional information about changes in the skin temperatures of different body areas for each player over time. The results show a significant reduction in the injury incidence and the days missed due to injury in the season where the novel infrared thermography injury prevention program was implemented. There was also a significant reduction in the probability of injury between the 2 preseasons, possibly owing to a greater availability of the players during preseason training sessions and matches. These results are in line with a recent pilot study in Brazilian soccer[10] that indicated that infrared thermography, if used properly, could constitute a valuable source of information for a team's technical and medical staff.

First, the decrease in injury incidence and days of absence during the second preseason could be due to appropriate decisions made by the staff regarding players' health,[15] which were aided by the individual thermography reports of injury risk. The injury incidences during the training (7.0 injuries per 1000 h of exposure) and matches (37.5 injuries per 1000 h) in the first preseason were similar to those reported previously in literature.[2] However, these injuries were significantly higher than that seen during the second preseason (3.8 injuries per 1000 h of exposure in training and 6.0 injuries per 1000 h of exposure in matches). Over the 2 seasons, the player characteristics and training load were similar but a fewer number of matches were played in the first preseason. Although a greater number of matches played implies a greater injury risk,[1] this was not found to be true in this study, possibly indicating that the infrared thermography program was useful in helping the coaching and medical staff to make better decisions, thereby reducing the relative risk of injury and the days of absence.

Second, by comparing the type and location of the injury over the 2 preseasons, there was a reduction in the total number of musculoskeletal injuries, specifically, in the thigh, and an absence of injuries at the hip, groin, and knee. In soccer players, the thigh, the knee, the hip, and the groin are the regions that are the most susceptible with the highest number of primary and secondary injuries,[1,2] which are responsible for absences for the players. The infrared thermography prevention program appears to be effective in reducing the injury incidence in these regions, ensuring that players are fit to participate in the maximum number of training sessions and for selection in matches. In this regard, the results in this study are consistent with previous studies that have analyzed injury classification in soccer.[1,2]

Third, observing the distribution of injuries according to their severity, data from the second preseason showed that the injuries were exclusively mild or moderate in nature, compared with the first preseason where minor and serious injuries were also noted. When high levels of asymmetry were obtained in the thermograms of a particular player, the player was subjected to an individualized training program in order to reduce the asymmetry. These days were also counted as those lost due to injury, but the results of the study indicate that they could have served to avoid a major injury, as evident from the lower number of days lost based on injury severity. This is especially important while interpreting the data on the days of absence. The more severe the injury, the greater number of days lost by the player. Hence, the preliminary study indicates that using information from infrared thermograms not only could reduce the number of training sessions and possible matches lost due to injury, but could also probably reduce the cost of medical fees and insurance premiums.[10]

Fourth, similar results were obtained over the 2 preseasons when considering the data on the mechanism of injury, the results were in line with those previously published in literature.[1,2] This data are critical to specify the applicability of infrared thermography in the field of injury prevention. The technique is ineffective, for example, in preventing injuries that result from trauma and direct contact, such as the case of contusions. However, overuse and noncontact injuries can be targeted. According to some authors,[16,17] noncontact injuries are mainly due to insufficient recovery from the demands required for the given activity.

Although the results of the study seem to be promising in terms of applying thermography to reduce the risk of injuries in a professional setting, one must treat the results of this study with precaution, given its preliminary nature. One of the limitations of this study was that it was carried out only during a single preseason due to the decision of the coaching staff. Applying infrared thermography throughout the season rather than just the preseason and applying it over various seasons can be used to corroborate and consolidate these initial results. Further research can be carried out to look at the application of this technology in players of either sex, of different age groups, or even to other sports. Finally, it could be strongly recommendable to study the relation of skin temperature with other parameters used to control the internal and external load of an athlete, such as global positioning systems, nutrition, and rest outcomes.

Conclusions

Infrared thermography provided the team's coaching and medical staff with quantitative information about bilateral differences in skin temperatures that appeared to provide useful information for the purpose of injury prevention. Using such a methodology, instead of relying on subjective information from the player, ensured that the injury incidence and the days missed due to injury in the season were both reduced. This technique, if carried out by a qualified technician, could possibly become a source of objective information to help make informed injury prevention decisions. Injury reduction is one of the most important concerns to all members of a professional soccer team. Strength and conditioning coaches can use this information to determine how the workload intensity and volume of training and matches affect the bilateral temperature differences in players throughout the season. Doctors and physiotherapists can also make decisions to adapt the treatment specifically to each athlete and to follow the progress of the athlete's physical condition in order to prevent possible injury. In the case of an injured athlete, they can consider the changes in the thermal profile that could be useful in the injury recovery process.

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