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PHYSIOLOGY OF ATHLETES: INVESTIGATION OF THERMOREGULATION WITH DIFFERENT SPORTSWEAR USING THERMOGRAPHY

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SUMMARY: Sports equipment is crucial in achieving athletic performance by providing comfort, flexibility, and support during physically demanding activities. Its functionality not only enhances athletes' performance but also helps maintain body temperature and comfort, allowing athletes to fully dedicate themselves to sporting challenges. This research focuses on sportswear, specifically football jerseys, emphasizing the importance of comfort. By analysing the thermal properties of footboall jerseys, the study aims to better understand the effects of clothing on thermal comfort during different phases of activity. Using an infrared thermographic camera and recording images of the participants before and after intense activity, zones of sweating and temperature changes are identified. The results of the study provide guidelines for the behaviour of athletes in sportswear made of three different materials. The results should also serve to improve the development of sportswear to better meet the needs of athletes and increase their comfort and performance.

Key words: *sportswear, material, physiology, comfort, activity, infrared thermographic camera*

INTRODUCTION

By definition, sportswear is manufactured and designed to provide a product that meets the performance requirements of athletes. It must be functional, comfortable and safe. The performance of sportswear can often make the difference between a win and a second place in competitive sports. The leading companies in the market today enjoy a competitive advantage thanks to their size and financial ability to innovate through performance and technology. Professional athletes often serve as the faces of these companies in a mutually beneficial partnership *(Hayes et al., 2016)*. An athlete should be able to use sportswear to protect themselves from a variety of environmental factors such as rain, snow, wind and sun. In addition, sportswear needs to be able to disperse perspiration and body heat while maintaining a balance with the heat generated by the wearer *(Salopek Čubrić, 2021)*. For any athletic performance to be optimal, a variety of things must be taken into account. Three key factors determine whether a sport is successful or not: (i) the skill of the athlete, (ii) the facilities and equipment, and (iii) engineered clothing *(Chowdhury et al., 2012)*.

When sports activities take place, human body sweats. When the body comes into contact with textiles, sweat is transferred from the skin to the material and the sportswear becomes wet. The fiber's characteristics and the surface properties of the material determine how much the textile fabric can be wetted. Through capillary action or absorption, the liquid is further transmitted through a flat construction. The type of fibre, yarn construction, textile fabric structure, finishing, moisture and temperature conditions and other factors all affect absorbency *(Gorji et al., 2016)*.

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Therefore, choosing the right sportswear material is crucial to improving performance.

Thermoregulation is the process by which the body maintains its internal temperature within a narrow range despite changes in external conditions. During intense exercise, the metabolism speeds up and generates heat. To avoid overheating, the body activates the mechanism of sweating, dilates the blood vessels and breathes faster. Sweating cools the body as the evaporating sweat absorbs heat, cools the skin and blood vessels and thus regulates the internal temperature. It was confirmed that professional athletes adapt to sweating more efficiently by starting to sweat earlier and to sweat more intensively than the non-trained individuals. It is also important to point out that athletes sweat more but lose fewer electrolytes, thus balancing their fluid levels during exercise. Sweating affects an athlete's overall performance. It is therefore up to scientists, including those involved in the development of materials and sportswear, to find solutions that ensure a higher level of comfort during sport.

The vast amount of literature published in the last two decades has focused on the use of thermography in the observation of health-related problems in athletes *(Menezes et al., 2018, Priego Quesada et al., 2015, Ludwig et al., 2016, Quesada et al., 2019)*. Research in the field has further been extended to include the influences of gender on temperature changes in moderate and cold thermal environments *(Salopek Čubrić and Čubrić, 2021)*. However, with the significant increase in interest in improving sports outcomes and awareness of the importance of sports for health and well-being, studies have focused on investigating the influence of textiles. Therefore, in recent years there has been a growing interest in defining different approaches to explore the possibilities of using thermography in the study of different textiles and sportswear.

The results of the extensive research published *(Fournet, 2013)* have confirmed that the use of thermography is extremely important in selecting the optimal material for sportswear and adapting the garment design to the requirements of each sport. The previously published work related to different types and levels of training indicated temperature differences between the observed body zones, which raises the question of the importance of the careful selection of sportswear tailored to the specifics of the training session *(Salopek Čubrić et al., 2021, 2022)*.

The aim of this paper is to gain insight into the physiological response of the human body when dressed in different football jerseys and performing intense exercise. To this end, thermography is used to examine the temperature changes in different areas of the body.

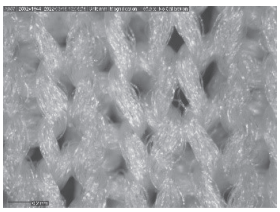
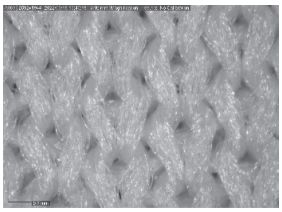
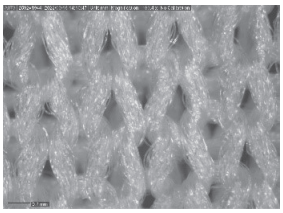
METHODOLOGY

Selected materials

This study focuses on analysing the changes in body temperature in athletes wearing suitable football jerseys. Special attention is given to two important influencing factors. The first factor examines the influence of intense physical activity on temperature changes in athletes, investigating how the body reacts after being exposed to such activity. The second influencing factor is the properties of the different knitted fabrics used in the manufacture of jerseys, taking into account their role in regulating body temperature.

Three representative T-shirts produced for a professional football players were selected for the investigation, labelled as FT1, FT2, and FT3. These T-shirts are integral parts of the football jersey. All T-shirts are of size M and in white colour. The materials used for the production of jerseys are produced as knitted structures and differ in the mass per unit area that ranges 145-155 g/m2. The comparison of the main characteristics of materials used for the production of the football T-shirts, including the material composition, mass per unit area, yarn fineness, material thickness, vertical and horizontal stitch density (i.e. the density of the main units forming the structure of the material), and microscopic images are provided in Table 1.

Table 1. Characteristics of materials used for the production of T-shirts
Tablica 1. Karakteristike materijala korištenih za izradu majica

Material ID	FT1	FT2	FT3
Microscopic image			
Material composition	100% polyester	100% polyester	100% polyester
Mass per unit area,g/m^2	155	151	145
Yarn fineness, tex	12	10	10
Thickness, mm	0.618	0.491	0.556
Stitch density (horizontal/ vertical), stitches · cm^{-1}	18/20	18/19	20/18

Measurement

A TESTO 872 infrared thermographic camera was used to assess the temperature change of the upper body covered by the football jersey. With the practical functions offered by the camera, it is possible to generate objectively comparable infrared images without errors. More detailed specifications of the camera can be found in Table 2.

Table 2. Infrared thermographic camera specifications
Tablica 2. Specifikacije infracrvene termografske kamere

Field of view	42° x 30°
Focus	Fixed focus
Minimum focus distance	<0.5 m
Geometric resolution (IFOV)	2.3 mrad
Image refresh rate	9 Hz
Infrared resolution	320 x 240 pixel
SuperResolution (IFOV)	1.3 mrad
SuperResolution (Pixel)	640 x 480 pixels
Thermal sensitivity	<0.05 °C (50 mK)
Spectral range	7,5 to 14 µm

Three healthy active athletes participated in the experiment as part of the thermographic measurements. Their average age was 28 ± 3 years, with a height of 177 ± 3 cm and a weight of 81 ± 3 kg, resulting in an average BMI of 25.85 ± 3 kg/m^2. All tests were performed in accordance with the principles of the WMA Declaration of Helsinki and approved by the Ethics Committee of the University of Zagreb Faculty of Textile Technology.

Participants were given precise guidelines, including a series of recommendations to follow the day before the actual experiment. These guidelines included avoiding hot drinks, alcohol and spicy foods, refraining from smoking, avoiding intense physical activity immediately before the test, refraining from using cosmetics that could interfere with infrared radiation, and ensuring adequate rest to stabilise body temperature. The participants were also informed in advance about the aims and procedure of the experiment and agreed to participate by signing the consent form.

The participants were provided with suitable football T-shirts (FT1, FT2, and FT3) to study body temperature changes during intense physical activity. The T-shirts were selected in size M, considering the participants' body sizes. This is crucial in the context of using the infrared thermographic camera because properly sized clothing ensures optimal contact with the body surface, enabling precise thermal measurements. The appropriate T-shirt size is essential for accurate infrared thermography, as ill-fitting clothing can create gaps or uneven contact, leading to inaccurate temperature measurements and affecting the overall reliability of the obtained thermal data.

A graphical representation of the protocol can be found in Figure 1. The experiment began with an acclimatization phase in which the participants were placed in a controlled, closed room for 10 minutes, in which the air temperature was

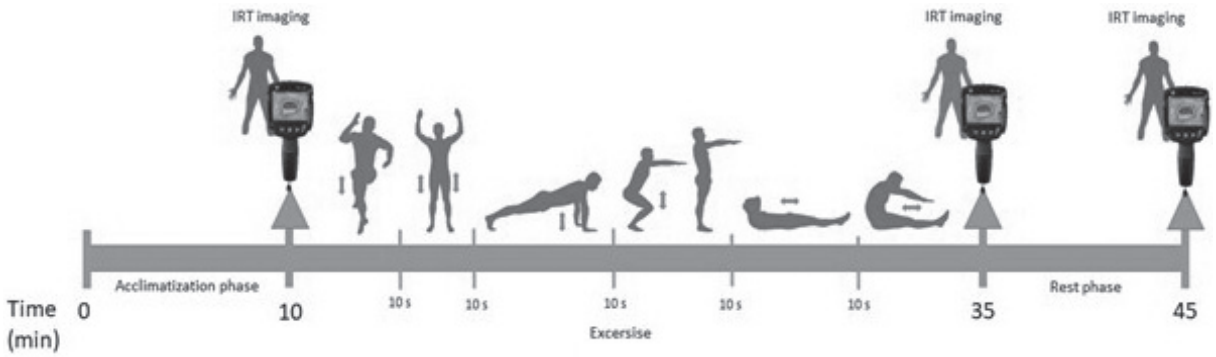


Figure 1. Experimental protocol
Slika 1. Eksperimentalni protokol

maintained at 22 ± 2 °C and the humidity at 60 ± 2%, according to ISO 139. After acclimatization, the participants were imaged with an infrared thermographic (IRT) camera to record the baseline temperature before the start of physical activity. The camera was placed at a constant distance of 2 meters from the subjects.

The physical activity consisted of 21 short exercises, including sit-ups, push-ups, and squats in various forms, with a 30-second rest between each exercise. The total duration of the exercise was 25 minutes. At the end of the physical activity, the participants underwent another thermographic examination to detect temperature changes on the body surface covered by the football T-shirt and to localize sweaty areas. This was followed by a rest phase. Ten minutes after the end of the activity, the participants were recorded again to investigate how the bodies reacted after the rest. This procedure allows a detailed analysis of the temperature changes during the different activity phases and contributes to a better understanding of the relationship between physical activity, rest, and thermal comfort. The experimental protocol was applied uniformly to all three types of football T-shirts during the three-day study.

All experimental conditions remained the same each day and the protocol was always conducted at the same time, in the morning hours. This consistency ensured the precision of the measurements and ruled out possible deviations that could affect the research results.

Data processing

The Testo IRSoft software, which is compatible with the TESTO 872 thermographic camera, was used to determine the temperature of the participants before, immediately after and 10 minutes after exercise. The thermograms precisely marked zones divided into 6 anterior, 6 posterior and 2 lateral body zones, as shown in Figure 2. The use of Testo IRSoft software enabled a detailed analysis of the thermal properties of the participants' selected sportswear. Each thermogram provides a clear visualization of the temperature distribution on the body surface, while the precise marking of zones on the T-shirts allows specific monitoring of thermal changes in the designated areas of interest. The appropriate software allows the emissivity to be determined, which is set at 0.98, as the emissivity of the skin is between 0.97 and 0.99. Therefore, most authors use a factor of 0.98 as the default emissivity of the skin in their studies. In addition, the temperature and humidity of the room air are entered into the software to ensure that the results are as accurate as possible.

During the thermographic measurements, each participant was recorded five times in each phase of the experiment. The results presented are derived from the average values of all five thermograms for each participant in a particular measurement phase and from the average temperature values of all three participants. This procedure was completed for each among the three selected T-shirts.

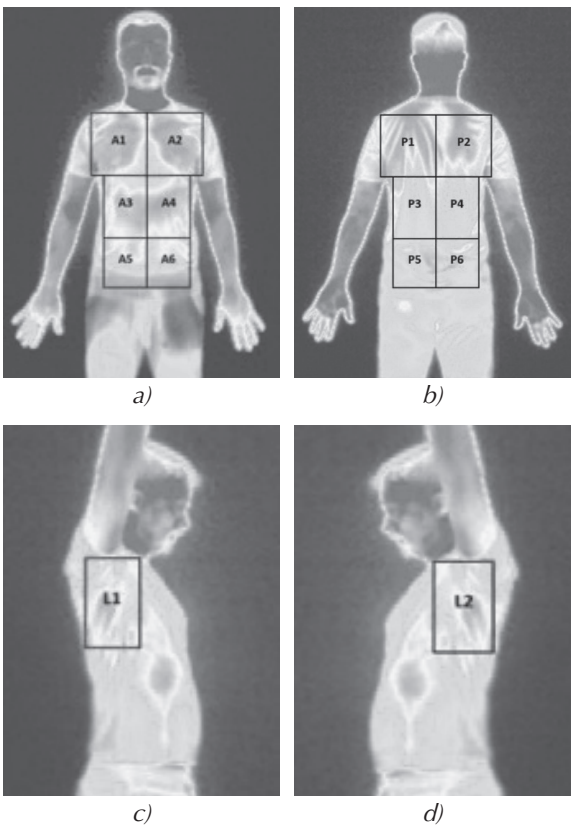


Figure 2. Division of the body into zones: a) Anterior (A1-A6); b) Posterior (P1-P6); c) Right lateral side of the body (L1); d) Left lateral side of the body (L2)

Slika 2. Podjela tijela na zone: a) prednja (A1-A6); b) stražnja (P1-P6); c) desna bočna strana tijela (L1); d) lijeva bočna strana tijela (L2)

RESULTS AND DISCUSSION

Figures 3, 4 and 5 show the results of the thermographic temperature measurement on the surface of the football T-shirts in the various training phases. The bar charts show the average temperatures of three participants in specific body zones before, immediately after and 10 minutes after exercise. Figure 3 shows the results for the zones identified on the FT1 football T-shirt for the anterior, posterior and lateral parts of the body. In the graph for the anterior part of the body (Figure 3a), the temperature before exercise was between 25.5 and 29.6 °C. The highest temperature was measured on the chest, in zones A1 and A2. After exercise, a significant drop in temperature was observed in all zones. This decrease in temperature can be associated with intense physical exertion, which leads to increased sweating. Sweating is the body's natural mechanism for regulating temperature: when the body gets hot, the sweat glands produce sweat to cool the skin through evaporation. This process removes heat from the body, resulting in a decrease in skin surface temperature and overall body temperature. Ten minutes after exercise, an increase in temperature can be observed compared to the temperature immediately after exercise. This increase in temperature can be attributed to the cooling process of the body, namely the evaporation of sweat that has accumulated on the surface of the T-shirt immediately after the activity. The evaporation of sweat from the surface of the skin creates a cooling sensation, but also leads to heat loss. As the body tries to reach thermal equilibrium, it may gradually warm up after 10 minutes. This warming process may be due to less heat loss from sweat evaporation from the skin surface and increased blood circulation, which transports heat from inside the body to the skin.

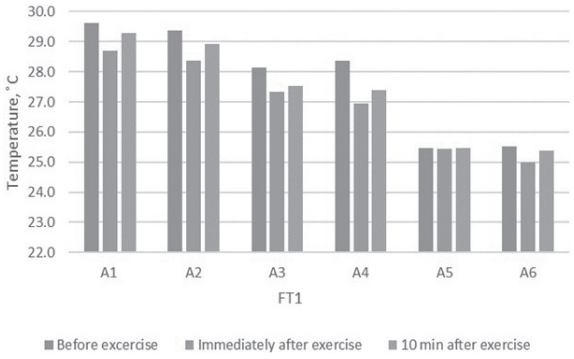
On the posterior part of the body (Fig. 3b), the same trend can be observed as on the anterior part of the body, with a decrease in temperature in all zones after exercise. However, a more pronounced decrease in temperature is observed on the back, which is related to greater sweating in this area, leading to heat loss through sweating. Ten minutes after the end of the exercise, the same trend is observed as on the anterior part of the body, namely an increase in temperature. This could also be due to the evaporation of sweat and the gradual adjustment of the body to thermal equilibrium. Another interesting observation is that the temperatures in the first two zones (P1 and P2) are significantly higher compared to the other zones on the posterior part of the body. These zones are located on the upper part of the back, which indicates that this part of the body is much warmer than the lower back. This could be due to the fact that the T-shirt on the upper back is close to the body, while on the lower back there is more space between the skin and the T-shirt. This creates a complex thermal dynamic where heat is held closer to the body in the joints and areas of higher pressure, such as the upper back, resulting in higher temperatures in these zones. This provides a more detailed explanation of how

different clothing features and personal anatomy affect the body's thermoregulation during exercise.

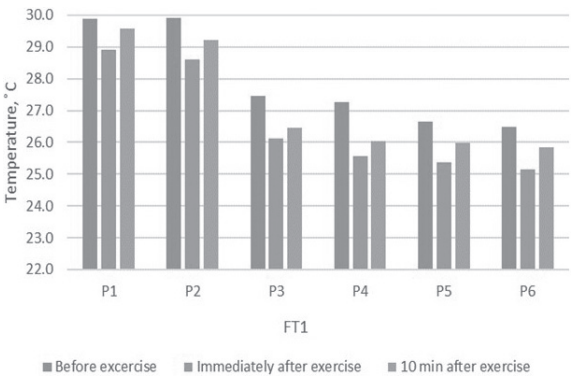
The graph of the lateral body parts (Figure 3c) in two zones (L1 and L2) located in the armpit area also shows a decrease in temperature after exercise of about 1 °C. It is known that athletes often sweat intensively in these areas. These results therefore indicate increased sweat production and a gradual removal of sweat from the surface of the T-shirt 10 minutes after exercise , as well as the body's gradual return to pre-activity temperature. This complex dynamic process illustrates how different areas of the body respond to physical activity and subsequent recovery, and provides a more detailed insight into the thermal dynamics of the selected sportswear.

Sweating in the armpit area is often intense due to the high number of sweat glands in that region. When the body heats up during physical activity, the sweat glands are activated to cool the body. At the end of the activity, the sweat remains on the surface of the T-shirt, which leads to an initial decrease in temperature. As the body cools down and the sweat evaporates, the temperature gradually returns to normal. It is important to note that the thermal changes in the armpits are not only important for regulating body temperature during physical activity, but also for the comfort of the athlete. Excess moisture and heat in these areas can lead to discomfort and skin irritation. Therefore, choosing appropriate sportswear is crucial for maintaining optimal performance and comfort during exercise.

When analysing the results for the football T-shirt FT2, shown in Figure 4a, significant differences were observed in the temperature changes compared to the FT1 during the different phases of physical activity and rest. The football T-shirt FT2 with a surface mass of 151 g/m^2 and a thickness of 0.491 mm shows a similar initial temperature range before exercise in all zones,



a)



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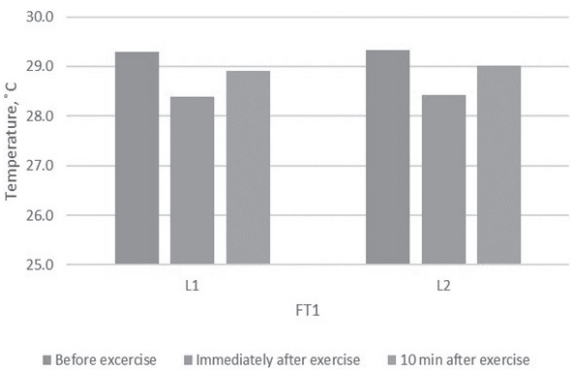


c)

Figure 3. Average temperatures when wearing football T-shirt FT1: a) Anterior; b) Posterior; c) Lateral body parts

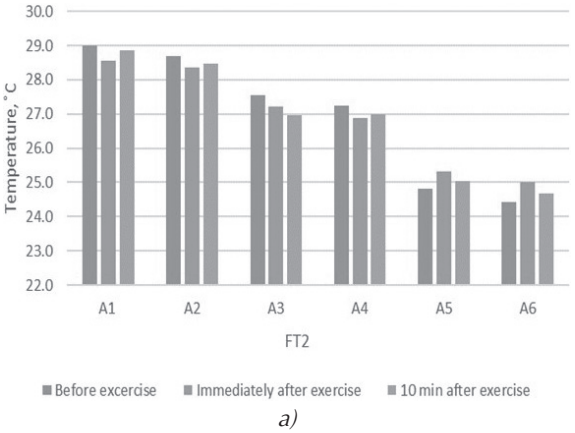
Slika 3. Prosječne temperature pri nošenju nogometne majice FT1: a) prednja; b) stražnja; c) bočni dijelovi tijela

between 24.4 and 29.0 °C. Immediately after exercise, FT2 shows a decrease in temperature in most zones (A1 to A4). However, there is an increase in zones A5 and A6, indicating increased blood flow and metabolic activity in these areas. These two zones, located on the lower back where the T-shirt is not tight to the body, ensure that any sweat does not stick to the T-shirt and provide limited cooling compared to other zones. An interesting change occurs 10 minutes after exercise when the temperature on the anterior part of the body decreases in zones A3, A5 and A6, with minimal differences compared to the temperature immediately after exercise. This faster temperature drop in these zones could be related to the lower surface mass and thickness of the material compared to FT1. The FT2 material has a lower heat storage capacity, which allows for faster cooling after the end of physical activity. This underlines the importance of material parameters in regulating the thermal dynamics of sportswear and highlights the need to adapt materials to the specific requirements of physical activity and comfort.

On the posterior part of the body, when analysing the results for football T-shirt FT2 (Figure 4b), it was found that immediately after exercise, the temperature decreased in all zones, suggesting increased sweating on the back of the body during activity. Ten minutes after the end of the exercise, a further decrease in temperature was observed in zones P4 and P6, which even fell below the initial level. In zone P4, a temperature decrease of 1.2 °C was observed compared to the baseline level, while in zone P6 it was 0.6 °C. This phenomenon may be due to the intense sweating on the lateral body parts during exercise, which leads to heat loss through sweat evaporation. As sweating increases, the body tries to maintain its temperature through this cooling mechanism. As the body cools down and the sweat evaporates, the temperature on the body's surface gradually decreases. What is particularly interesting is that this temperature decrease continues even after the end of the exercise, indicating that the cooling process continues even after the activity.

In the lateral zones L1 and L2, shown in Figure 4c, a very similar trend to the FT1 football T-shirt can be observed. At the end of the exercise, there is a decrease in temperature in the armpit area due to increased sweating. Ten minutes later, the temperature begins to rise as sweat evaporates from the surface of the T-shirt, gradually warming the body and equilibrating with the pre-exercise baseline temperature. Intense underarm sweating during exercise leads to an initial drop in temperature, while sweat evaporation after activity leads to a gradual return to normal temperatures. This process of thermoregulation allows the body to maintain an optimal temperature and comfort during and after physical activity, which is crucial for athletic performance and recovery.

Figure 5 shows the results for the football T-shirt FT3. Most of the results obtained are similar or identical to the results of the two previous T-shirts. However, there is a significant difference in the behaviour of zone A6 (Fig. 5a), where no temperature change was recorded immediately after exercise or even after 10 minutes of rest. The temperature remained constant at 25.1 °C. Zone A5 was the only one to show an increase in temperature immediately after exercise, followed by a decrease in temperature 10 minutes after exercise. It is important to note that the FT3 football T-shirt has the lowest surface mass (141 g/m2) and thickness of 0.556 mm compared to the other T-shirts. These material properties can influence the thermal dynamics during exercise and recovery. Considering that no sweating was recorded in zone A6, it is important to investigate other possible factors that contributed to maintaining a constant temperature in this area. One possible factor is that the T-shirt in this zone is not as close to the body as in other zones. This could lead to less thermal conductivity between the body and the T-shirt, helping to maintain a constant temperature. In addition, it is possible that the material in this area of the T-shirt is less breathable or that there are changes in the knit structure that do not allow efficient evaporation of sweat from the surface. These factors can affect thermoregulation in this area and cause the temperature to remain constant after exercise.



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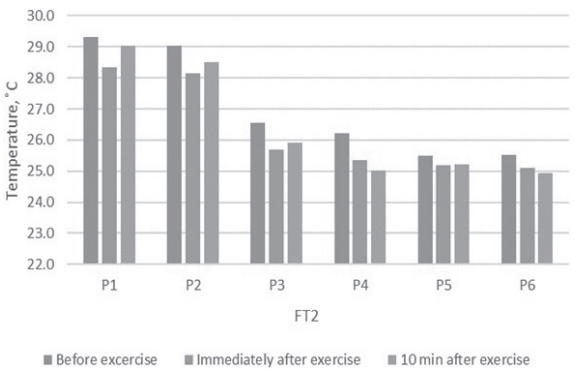

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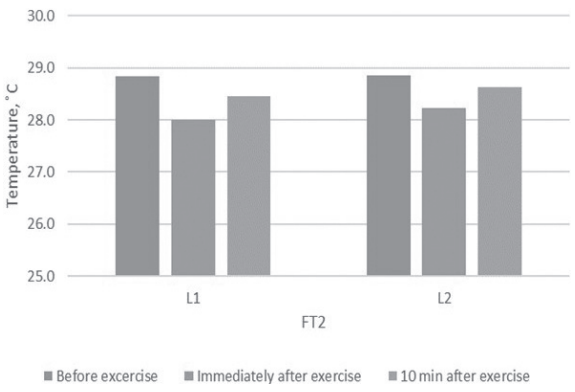
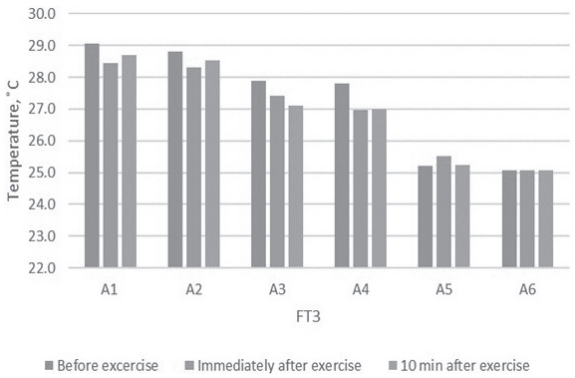


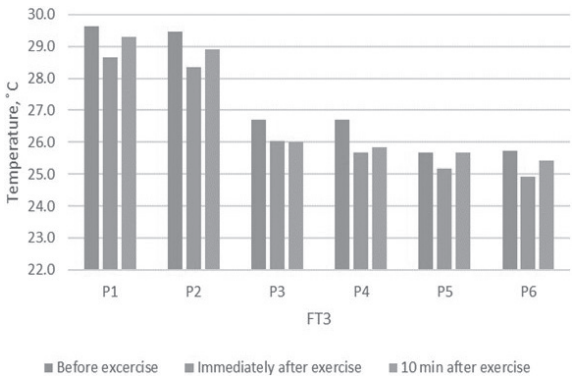
c)

Figure 4. Average temperatures when wearing football T-shirt FT2: a) Anterior; b) Posterior; c) Lateral body parts

Slika 4. Prosječne temperature pri nošenju nogometne majice FT2: a) prednja; b) stražnja; c) bočni dijelovi tijela



a)



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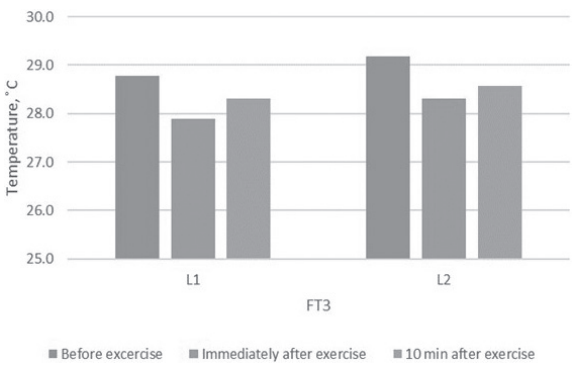

c)

Figure 5. Average temperatures when wearing football T-shirt FT3: a) Anterior; b) Posterior; c) Lateral body parts

Slika 5. Prosječne temperature pri nošenju nogometne majice FT3: a) prednja; b) stražnja; c) bočni dijelovi tijela

When analysing the results for the posterior part of the body (Fig. 5b), the same trend can be observed as for FT1. There is a drop in temperature immediately after exercise, followed by an increase in temperature 10 minutes after exercise. The lateral sides also follow the same trend as the two previous football T-shirts. As for the armpit area, which shows consistent results for all three football T-shirts, it can be concluded that this area is particularly sensitive to thermal changes during physical activity and recovery. Intense sweating in this area during exercise leads to an initial drop in temperature, while evaporation of sweat after activity leads to a gradual return to normal temperatures. This area can be crucial for thermoregulation and comfort during sports activities and therefore requires special attention in the development of sportswear to ensure an optimal sports experience for athletes.

The results in terms of the absolute temperature differences between the measured body temperatures before exercise and the body temperatures immediately after exercise are shown in Figures 6 - 8. The results are shown by zones for the anterior, posterior and lateral side of the body for all three tested football T-shirts.

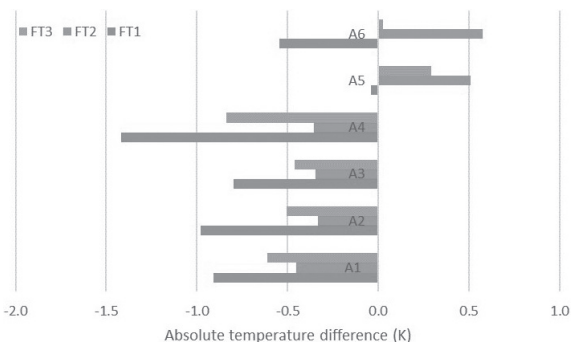

Figure 6. Absolute temperature difference for anterior body zones A1-A6

Slika 6. Apsolutna temperaturna razlika za prednje tjelesne zone A1-A6

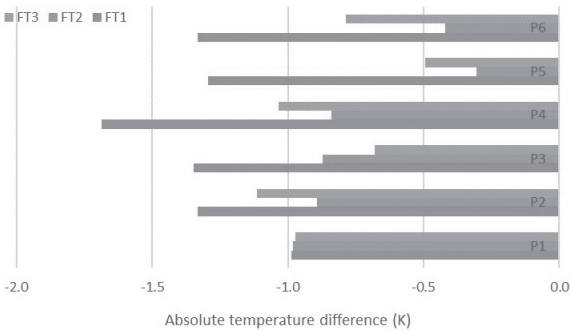

Figure 7. Absolute temperature difference for posterior body zones P1-P6

Slika 7. Apsolutna temperaturna razlika za stražnje tjelesne zone P1-P6

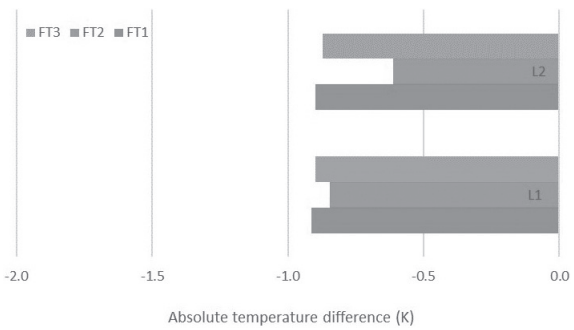

Figure 8. Absolute temperature difference for lateral body zones L1 and L2

Slika 8. Apsolutna temperaturna razlika za bočne zone tijela L1 i L2

Analysing the results obtained using infrared thermography, it can be concluded that the football T-shirt FT1 shows the largest temperature drop, which implies that the athlete sweated the most in this football jersey, but also that the T-shirt effectively removed the sweat from the surface of the T-shirt and the body. On the other hand, the lower temperature drop in the FT2 and FT3 football T-shirts may indicate a lower amount of sweating or a lower efficiency of moisture removal from the body surface. However, it is important

to consider other factors such as comfort, dryness sensation and drying speed of the material, as these elements also play an important role in the performance of sportswear. Although a higher temperature drop may be a sign of better ventilation, other aspects must also be considered in the overall assessment to make a definitive statement about the performance and comfort of sportswear.

The results of the t-test are determined with $\alpha = 0.05$ and are listed in Table 3. The test compares the temperature differences by body zones before and immediately after training for all three football T-shirts tested. According to the p-value given, the differences are not considered statistically significant. As can be seen from the table, a significant difference ($p < 0.05$) was only defined for zone A4 on the anterior and zone A5 on the posterior.

Table 3. Results of the t-test

Tablica 3. Rezultati t-testa

p-value			
Zones	**FT1**	**FT2**	FT3
Anterior body zones			
A1	0.2786	0.6712	0.5092
A2	0.2848	0.7381	0.4992
A3	0.3042	0.7916	0.6313
A4	0.0458	0.7592	0.3832
A5	0.8544	0.4899	0.6703
A6	0.0477	0.4847	0.9750
Posterior body zones			
P1	0.3338	0.0946	0.2348
P2	0.2629	0.2160	0.0986
P3	0.2325	0.0949	0.4393
P4	0.1240	0.0901	0.2519
P5	0.0497	0.7065	0.1001
P6	0.1368	0.6131	0.0581
Lateral body zones			
L1	0.3442	0.2219	0.2137
L2	0.3120	0.3148	0.3774

CONCLUSION

In this study, thermographic temperature measurements carried out on various football T-shirts during different phases of training provided information on the body's thermoregulatory responses. For the anterior part of the body, a significant drop in temperature was observed for all T-shirts after training, which can be attributed to increased sweating and subsequent evaporative cooling. The observed increase in temperature 10 minutes after exercise indicates ongoing thermal adaptations, including evaporation of sweat and improvement in blood circulation. Notably, different temperature distributions were observed in different zones, reflecting the intricate interplay of garment design, body anatomy and physiological responses. Similar trends were observed for the posterior part of the body, with pronounced temperature drops immediately after exercise, especially in the zones of intense sweating. Consistent temperature fluctuations were observed in the lateral body zones, underlining the importance of thermoregulation under the armpits during physical activity.

A comparative analysis of the three football T-shirt prototypes revealed differences in temperature dynamics, which are influenced by material properties such as mass per unit area and thickness. While the T-shirt with the highest mass per unit area (155 g/m^2) showed the greatest temperature drop, which indicates effective moisture removal, the T-shirts with the masses per unit area of 151 and 145 g/m^2 showed different thermal behaviour, which suggests a different efficiency of sweat management.

The application of infrared thermography in the development and evaluation of sportswear opens up new opportunities for improving the performance, comfort and safety of athletes. Future advances in infrared thermography technology will likely further expand its applications in sports, providing even greater insight into the optimal design and functionality of sportswear.

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FIZIOLOGIJA SPORTAŠA: ISPITIVANJE TERMOREGULACIJE U RAZLIČITOJ SPORTSKOJ ODJEĆI PRIMJENOM TERMOGRAFIJE

SAŽETAK: Sportska oprema ključna je u postizanju sportske izvedbe pružajući udobnost, fleksibilnost i potporu tijekom fizički zahtjevnih aktivnosti. Njezina funkcionalnost ne samo da poboljšava sportske rezultate već i pomaže u održavanju tjelesne temperature i udobnosti, omogućujući sportašima da se potpuno posvete sportskim izazovima. Ovo istraživanje usredotočuje se na sportsku odjeću, posebno na nogometne dresove, ističući važnost udobnosti. Analizirajući termalna svojstva nogometnih dresova, studija ima za cilj bolje razumjeti učinke odjeće na termalnu udobnost tijekom različitih faza aktivnosti. Koristeći infracrvenu termografsku kameru i snimajući slike sudionika prije i nakon intenzivne aktivnosti, identificiraju se zone znojenja i promjene temperature. Rezultati studije pružaju smjernice za ponašanje sportaša u sportskoj odjeći izrađenoj od tri različita materijala. Rezultati bi također trebali poslužiti za poboljšanje razvoja sportske odjeće kako bi se bolje zadovoljile potrebe sportaša i povećala njihova udobnost i izvedba.

Ključne riječi: *sportska odjeća, materijali, fiziologija, udobnost, aktivnost, infracrvena termografska kamera*

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