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Thermal profile classification of the back of sportive and sedentary healthy individuals☆

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ABSTRACT

Background: Infrared thermography (IRT) is a non-harmful, risk-free imaging technique and it has application for healthy and pathological population.
Objective: The aim of this study is to evaluate the thermographic profiles of the back of sport practitioners from different disciplines and compare it with those of sedentary healthy individuals.
Method: The back of 160 healthy subjects were evaluated, and participants were grouped considering their sport practice: team sport (TS), individual sport (IS), weight training (WT), inactive (I). Three regions of interest were identified to analyze the cervical, thoracic and lumbar temperatures of the back.
Results: The Multivariate analysis of variance (MANOVA) resulted significant showing statistical differences for the cervical ($p < 0.001$), dorsal ($p = 0.0011$), and lumbar areas ($p = 0.0366$). The Tukey post-hoc test for pairwise comparison showed statistically significant differences between groups. For the cervical area significance was found between the IN and WT group ($p = 0.002$), the IN and IS group ($p < 0.001$), IN and TS group ($p = 0.020$). The dorsal area resulted significant between the IN and WT group ($p = 0.007$), the IN and IS group ($p < 0.001$), IN and TS group. The lumbar area showed significant differences only between the IN and WT group and the IN and IS group ($p = 0.043$).
Conclusion: This study demonstrated that inactive individuals manifest a statistically significant higher temperature in the cervical, dorsal and lumbar area of the back compared to sportive individuals.

1. Introduction

The implementation of new technologies that provide data for the analysis of the musculoskeletal system has allowed a wider understanding of human physiology both in static and dynamic conditions (Kanko et al., 2021). The current interest of the scientific community is growing in the directions of those technologies that do not expose the individual to harmful radiations (Roggio et al., 2021). It is possible to examine the human body during its movements with tools like inertial sensors, infrared cameras, stereophotogrammetry and marker-less motion analysis systems (Roggio et al., 2021). For the static analysis of the musculoskeletal system the non-harmful technologies comprehend rasterstereography, infrared cameras, wearable devices (Rosá and rio, 2014) and mobile application for posture assessment (Trovato et al., 2022), 3D ultrasound imaging system (Lai et al., 2021), digital palpation device (Sohirad et al., 2017), moiré topography (Porto et al., 2010) and infrared thermography (IRT) (Kwok et al., 2017).

The interest of the scientific community for IRT as a complementary

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tool for the evaluation of the human body, and especially for the musculoskeletal system, is growing in the last decade (Li et al., 2020; Barbosa et al., 2020; Shakhih et al., 2021; da Silva et al., 2022). This technique is easy to perform and it is non-harmful, highly reproducible (Zaproudina et al., 2008), non-invasive and it does not require the contact with the patient. The IRT cameras use an advanced type of radiation thermometer that detects the heat radiations of a body in an electromagnetic spectrum invisible for the human eyes (Costa et al., 2016). The surface temperature identified is related to the blood flow and muscle metabolism which increase the convection of heat to different areas of the body (del Estal et al., 2017).

The standard operating procedure to perform accurate and reliable thermographic measurements is the one proposed in 2017 by Moreira et al. (2017) who redacted the Thermographic Imaging in Sports and Exercise Medicine checklist (TISEM) with all the variables to take into account when performing studies with infrared thermography, to minimize the risk of bias. With IRT it is possible to evaluate different of pathologies, selecting correct regions of interest (ROI) on the skin to analyze, from musculoskeletal diseases, such as rheumatoid arthritis (Pauk et al., 2019), to breast cancer (Mambou et al., 2018), psychophysiology and emotions (Cardone et al., 2017). Sport science is an interesting field of research where the IRT finds its application due to its versatility and the possibility of in-field use. Interestingly, IRT was employed with encouraging results as an indirect marker of muscle damage after an acute protocol of plyometric jumps in physically active men (Alburquerque Santana et al., 2022), as well as in the evaluation of professional athletes during competitions to achieve a better understanding of the thermoregulatory system during the performance (Aylwin et al., 2021). To date, there are only a few studies that classified the thermal profiles of athletes in static conditions (del Estal et al., 2017), (Bouzas Marins et al., 2014). However, it is important to study the thermal profiles of different athletes from various disciplines to achieve a better understanding of the adaptation of the thermoregulatory system to the sport. Collecting baseline data on the thermal profiles of the back of sport practitioners can help physician and trainers in adapting their approach to the players and to enhance their health status maintenance. As it was demonstrated by Côrte et al. (Côrte et al., 2019) and Gomez-Carmona et al. (Gomez-Carmona et al., 2020) IRT has the potential to be a useful prevention tool for the reduction of the injury rate during a competitive season in professional athletes. Thus, the aim of this study is to assess and classify the thermographic profiles of the back of sport practitioners from different disciplines and compare it with those of sedentary healthy individuals to understand how the sport impacts the thermal response of the back.

2. Materials and methods

A sample composed of 160 voluntary healthy young adults was recruited, 75 males and 85 females. Prior to testing, all participants were informed about the study procedure, risks, and benefits and provided written, informed consent to participate in the study and to use their data. All subjects participating gave their informed consent before participation. The study was approved by the local ethics committee of the Research Center on Motor Activities (CRAM), University of Catania (Protocol Number: Protocol n.: CRAM-020-2021, 20/12/2021), and it was conducted in accordance with the Declaration of Helsinki.

A researcher collected baseline information from each participant, including age (years), gender, height (cm), body weight (kg) and sport practiced prior to the thermal imaging acquisition. Furthermore, information related to their health status and sport background were also collected. Only healthy young adults were included and they were excluded if they presented physical acute (inflammation) or chronical conditions (chronic low back pain, scoliosis …). Inactive group (I) was composed by young adults that didn't took part in any physical and sporting activity in the last year. The sport group was composed by participants that practiced in weight training (WT), individual sport (IS), team sport (TS) for at least 5 years. Furthermore, sportive participants were considered eligible for the study only if they reported an average of 3 sessions of training per week. The sports included in the TS group were soccer, volleyball and basketball with 31 participants, in the IS group were swimming, track and field, ballet with 40 participants, the WT group had 69 participants and the IN group comprehended 20 participants.

2.1. Instruments

All the thermographic measurements were taken with the FLIR E54 (Wilsonville, OR, USA) camera with a detector resolution of 320 × 240 pixels and thermal sensitivity <0.04 °C. The camera was placed onto a tripod, distant 1.5 m from the individual in a room with a temperature of 23° ± 2 °C and humidity of 50%; camera emissivity level was set at 0.98. Three ROI were identified using the Flir thermal studio pro® software: cervical, dorsal and lumbar area. The ROI were delimited considering the vertebrae of the spine and excluding the upper limbs. The cervical ROI was delimited with a rectangle starting from the third cervical vertebra to the seventh one. The dorsal ROI of the body was delimited with a polygon from the first to the twelfth thoracic vertebra. The lumbar area was delimited with a polygon from the first to the fifth lumbar vertebra. The identification of the ROI is presented in Fig. 1.

All the participants had an acclimatization time of 20 min prior testing and the thermographic measurements were taken at morning, with no physical activity performed in the previous 24 h. Considering the influencing intrinsic and extrinsic factors for the measurement of the skin temperatures (T_{sk}) with IRT (Fernández-Cuevas, 2015) we applied the following exclusion criteria: presence of ointment on the skins

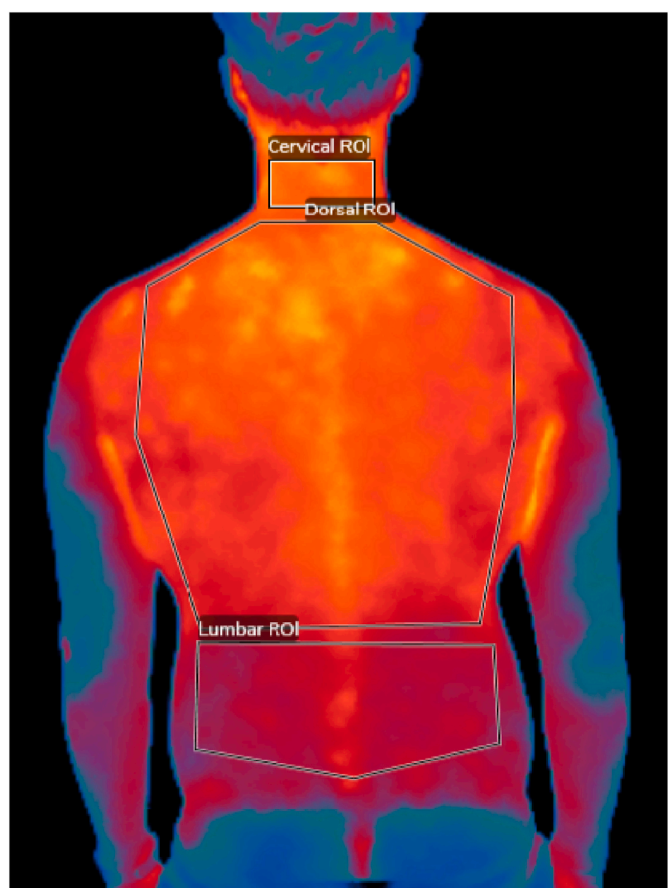

Fig. 1. Identification of the cervical, dorsal and lumbar ROI with Flir Thermal Studio Pro.

surface of the selected ROI, assumption of anti-inflammatories, analgesic, contraceptive and anesthetic drugs 48h prior the measurements and caffeine consumption 3 h prior testing. The thermographic values taken under consideration were the averages skin temperature (T_{sk}) of the 3 ROI selected.

2.2. Data analysis

Descriptive analysis was employed to report the anthropometric differences between the groups and the genders. Inferential statistics comprised the Levene's test to verify the homogeneity of the variance, the Mahalanobis distance verified the presence of multivariate outliers, the multivariate analysis of the variance (MANOVA) with the post hoc Tukey test was applied to detect significant differences between groups. Significance was accepted at $p < 0.05$. All the statistical analysis were performed with R Project for Statistical Computing (Vienna, Austria).

3. Results

The mean age of the sample was 26.6 (5.31) years, male mean height 176.2 (7.97) cm, female mean height 163.4 (6.04) cm, male mean weight 74.4 (11.9) kg, female mean weight 58.4 (8.74) kg, and male body mass index of 23.4 (2.75), mean female body mass index 22.1 (3.36).

The MANOVA analysis resulted significant showing statistical differences for the cervical ROI ($p < 0.001$), dorsal ROI ($p = 0.0011$), and lumbar ROI ($p = 0.0366$). The group with the higher temperature in the three ROI examined was the IN group, and the statistical analysis confirmed that there were significant differences between this group and the TS, IS, and WT group (Fig. 2).

Table 1 shows the average temperature of group per each ROI and two-way MANOVA results.

The highest temperature among sport practitioners was found in the TS group for the cervical, dorsal and lumbar ROI, but no statistically significant differences were found with other sport group. Fig. 3 and 4 show the thermographic profile of the back of a participant from each group. The Tukey post hoc test for pairwise comparison showed statistically significant differences between groups; the results are presented in Table 2.

Table 1
Description of the average T_{sk} and MANOVA analysis of the four groups.

ROI	GROUPS	MEAN	SD	p-value*
Cervical	Weight Training	33.77	0.9	0.0036
	Individual Sport	33.58	0.85	
	Team Sport	33.87	0.78	
	Inactive	34.57	0.65	
Dorsal	Weight Training	33.02	0.96	0.0011
	Individual Sport	32.85	0.84	
	Team Sport	33.06	0.81	
	Inactive	33.82	0.9	
Lumbar	Weight Training	32.4	1.17	0.0365
	Individual Sport	32.27	1.09	
	Team Sport	32.55	1.02	
	Inactive	33.13	1.25	

ROI: region of interest; *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$.

4. Discussion

The main finding of this study was that sedentary people present a statistically significant higher temperature of the three ROI of the back examined compared to team sport players, individual players and weight training practitioners. We found that the temperature followed the same pattern through the three ROI in all groups with the cervical ROI being the warmer one and the lumbar ROI the coldest one; moreover, we did not find any significant differences between male and female in all groups.

Schlager et al. found a good correlation between blood flow and skin temperature, and it is possible to examine it with IRT In healthy and pathological individuals (Schlager et al., 2010). It is a well known topic in literature that physical inactivity is correlated, as a risk factor, to many different pathologies, from the metabolic to the musculoskeletal ones (Chastin et al., 2015; Hawker, 2019). Physical inactivity is connected to a higher general prevalence of low back pain (Baradaran Mahdavi et al., 2021) and it is also correlated with neck pain (Auvinen et al., 2007). It was found by Wu et al. (2009) that a decrement in temperature was correlated with better pain score reported by subjects with back pain using the numeric pain rating scale. In our sample the highest temperature in the three ROI examined was recorded in the sedentary group; this could be explained by the negative effects that physical inactivity has on the musculoskeletal system, especially in neck

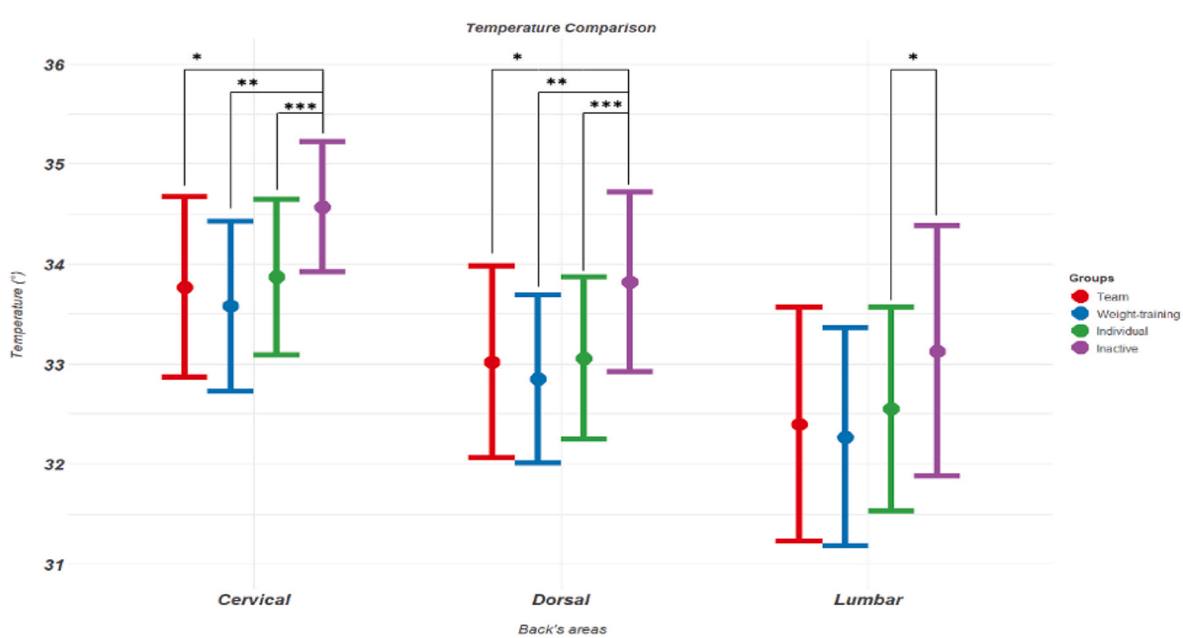

Fig. 2. Box plot of the thermal differences between groups. *: $p < 0.5$; **: $p < 0.01$; ***$p < 0.001$.

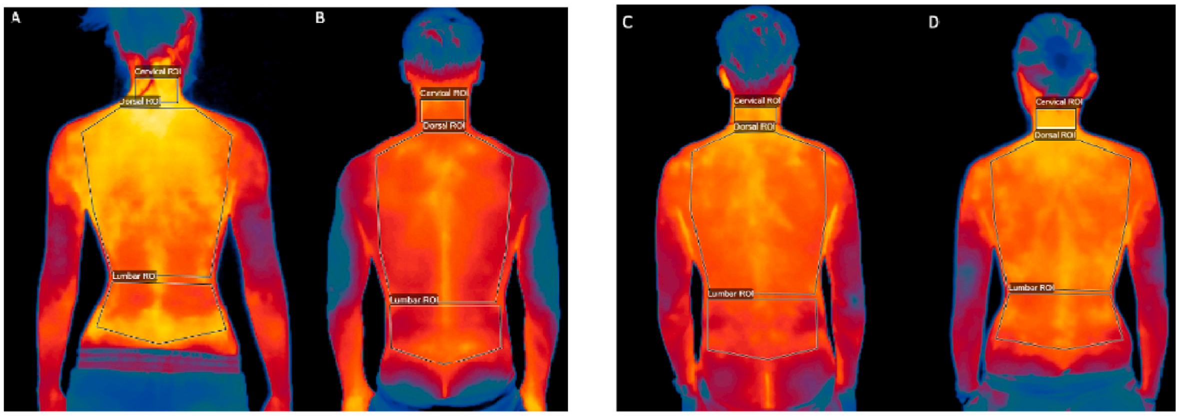

Fig. 3. Thermographic profile of a subject region of interest (ROI) respectively of the IN (A), IS group (B), TS (C), and WT group (D).

Table 2
Statistical differences between group with Tukey post hoc test.

	GROUPS					
ROI	IS-WT	TS-WT	IN-WT	TS-IS	IN-IS	IN-TS
CERVICAL	p = 0.696	p = 0.949	p = 0.002**	p = 0.487	p < 0.001***	p = 0.020*
DORSAL	p = 0.687	p = 0.998	p = 0.007**	p = 0.856	p < 0.001***	p = 0.013*
LUMBAR	p = 0.927	p = 0.991	p = 0.096	p = 0.857	p = 0.043*	p = 0.242

ROI: region of interest; IS: individual sport; WT: weight training; TS: team sport; IN: inactive.
For the cervical ROI significance was found between the IN and WT group ($p = 0.002$), the IN and IS group ($p < 0.001$), IN and TS group ($p = 0.020$). The dorsal ROI resulted significant between the IN and WT group ($p = 0.007$), the IN and IS group ($p < 0.001$), IN and TS group ($p = 0.013$). The lumbar ROI showed significant differences only between the IN and IS group ($p = 0.043$).

pain (Scarabottolo et al., 2017) and low back pain (Citko et al., 2018). The average temperature of three ROI of the back in all groups followed the same pattern with a higher temperature for the cervical ROI, in line with another study analyzing the back of healthy individuals (McCoy et al., 2011). Currently, the available literature does not provide data for the definition of the average temperature of the back in sportive individuals to consider as baseline for thermal comparison with sedentary people or specific populations, e.g., chronic pathologies. Furthermore, the studies that investigated this issue, focused only the lower limbs (de Carvalho et al., 2021; Rodrigues Jú et al., 2021; Escamilla-Galindo et al., 2017). However, the IRT is currently being adopted as a supportive method in the evaluation of different musculoskeletal pathologies (Schiavon et al., 2021; Morales-Cervantes et al., 2018; Deng et al., 2018). In 2020 Lubowska et al. (Lubkowska et al., 2020) compared children with scoliosis aged between 7 and 16 years with healthy matched control. The authors found that children with scoliosis presented thermal asymmetries especially in the thighs, upper back and chest. Although this study analyzed also the back of healthy individuals, as a control group, it is difficult to compare these thermographic data with ours, due to the huge difference in the age of the samples investigated; moreover, the cervical ROI in the Lubowska et al. study was not evaluated. Alfieri et al. (2019) evaluated the temperature and pain tolerance in patients with chronic low back pain by comparing the differences with a healthy sample. The average temperature of the 19 healthy individuals considered as control group was 29.7 C° which is quite different from our results as we found an average of 33.84 C° in our sedentary group. This noticeable difference could be explained by the difference in the IRT camera used. We employed the FLIR E54 camera which has a better resolution and a greater accuracy than the one used by those authors (±2 C° instead of ±1 C°). Furthermore, our sample is considerably younger than theirs (26.6 ± 5.31 instead of 47.8 ± 13.9), and mainly composed by sportive individuals. The baseline and the higher temperature may be the reflection of a more active muscle tissue. We also found that team sport players had an average higher temperature of the three ROI evaluated in comparison to other sportive individuals; however, the differences were not statistically significant.

This study presents some limitations. Firstly, although our sample was composed of participants practicing different sports at least 3 times per week, they were not professional athletes, so our findings could differ from other studies analyzing professional athletes. Secondly, we evaluated a sample of healthy individuals only that not reported neck or back pain and we could not correlate the detection of a certain Ts_k to neck or low back pain presence or intensity. Thirdly, there was a lack of thermographic data of the back in literature to compare our data of healthy young adults. Future studies should evaluate the thermal profiles of the back of professional athletes, sport by sport, and its connection with the frequency and intensity of neck and back pain.

5. Conclusion

For the first time in literature, we evaluated the thermographic profile of healthy young adults practicing different sport disciplines comparing it with those of healthy sedentary people. We found that inactive individuals manifest a statistically significant higher temperature in the cervical, dorsal and lumbar area of the back. These thermographic data on healthy young adults could be useful for clinicians and sport trainers as a reference to compare their data with a healthy sportive and sedentary control.

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Data availability statement

The raw/processed data required to reproduce the above findings cannot be shared at this time as the data also forms part of an ongoing study.

Authors' contribution

Bruno Trovato: conceptualization, methodology, investigation, data curation, writing – original draft. **Federico Roggio:** conceptualization, methodology, formal analysis, data curation. **Luca Petrigna:** conceptualization, methodology, investigation, writing – original draft. **Martina Sortino:** conceptualization, methodology, investigation, data curation. **Lucia Rapisarda:** writing – review and editing. **Giuseppe Musumeci:** conceptualization, methodology, investigation, data curation, writing review and editing, resources, supervision, project administration, funding acquisition. All authors read and approved the final manuscript.

Declaration of competing interest

The authors declare no conflict of interests.

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References

Alburquerque Santana, P.V., et al., 2022. Relationship between infrared thermography and muscle damage markers in physically active men after plyometric exercise. J. Therm. Biol. 104, 103187.
Alfieri, F.M., et al., 2019. Superficial temperature and pain tolerance in patients with chronic low back pain. J. Bodyw. Mov. Ther. 23 (3), 583–587.
Auvinen, J., et al., 2007. Neck and shoulder pains in relation to physical activity and sedentary activities in adolescence. Spine (Phila Pa 32 (9), 1038–1044, 1976.
Aylwin, P.E., et al., 2021. The use of infrared thermography for the dynamic measurement of skin temperature of moving athletes during competition; methodological issues. Physiol. Meas. 42 (8).
Baradaran Mahdavi, S., et al., 2021. Association between sedentary behavior and low back pain; A systematic review and meta-analysis. Health Promot. Perspect. 11 (4), 393–410.
Barbosa, J.S., et al., 2020. Infrared thermography assessment of patients with temporomandibular disorders. Dentomaxillofacial Radiol. 49 (4), 20190392.
Bouzas Marins, J.C., et al., 2014. Thermographic profile of soccer players' lower limbs. Rev. Andal. Med. Deporte 7 (1), 1–6.
Cardone, D., Merla, A., 2017. New frontiers for applications of thermal infrared imaging devices: computational psychopshysiology in the neurosciences. Sensors 17 (5).
Chastin, S.F., et al., 2015. Meta-analysis of the relationship between breaks in sedentary behavior and cardiometabolic health. Obesity 23 (9), 1800–1810.
Citko, A., et al., 2018. Sedentary lifestyle and nonspecific low back pain in medical personnel in north-east Poland. BioMed Res. Int., 1965807, 2018.
Côrte, A.C., et al., 2019. Infrared thermography study as a complementary method of screening and prevention of muscle injuries: pilot study. BMJ Open Sport Exerc. Med. 5 (1), e000431.
Costa, C.M., et al., 2016. Daily oscillations of skin temperature in military personnel using thermography. J. Roy. Army Med. Corps 162 (5), 335–342.
da Silva, H.K.V., et al., 2022. Evaluation of the female pelvic floor with infrared thermography: a cross sectional study. Braz. J. Phys. Ther. 26 (1), 100390.
de Carvalho, G., et al., 2021. Correlation between skin temperature in the lower limbs and biochemical marker, performance data, and clinical recovery scales. PLoS One 16 (3), e0248653.
del Estal, A., et al., 2017. Thermal asymmetries in striking combat sports athletes measured by infrared thermography. Sci. Sports 32 (2), e61–e67.
Deng, F., et al., 2018. Infrared thermal imaging and Doppler vessel pressurization ultrasonography to detect lower extremity deep vein thrombosis: diagnostic accuracy study. Clin. Res. J 12 (3), 1118–1124.
Escamilla-Galindo, V.L., et al., 2017. Skin temperature response to unilateral training measured with infrared thermography. J. Exerc. Rehabil. 13 (5), 526–534.
Fernández-Cuevas, I., et al., 2015. Classification of factors influencing the use of infrared thermography in humans: a review. Infrared Phys. Technol. 71, 28–55.
Gómez-Carmona, P., et al., 2020. Infrared thermography protocol on reducing the incidence of soccer injuries. J. Sport Rehabil. 29 (8), 1222–1227.
Hawker, G.A., 2019. Osteoarthritis is a serious disease. Clin. Exp. Rheumatol. 37 (5), 3–6. Suppl 120.
Kanko, R.M., et al., 2021. Concurrent assessment of gait kinematics using marker-based and markerless motion capture. J. Biomech. 127, 110665.
Kwok, G., et al., 2017. Postural screening for adolescent idiopathic scoliosis with infrared thermography. Sci. Rep. 7 (1), 14431.
Lai, K.K., et al., 2021. Validation of scolioscan air-portable radiation-free three-dimensional ultrasound imaging assessment system for scoliosis. Sensors 21 (8).
Li, X., et al., 2020. Infrared thermography in the diagnosis of musculoskeletal injuries: a protocol for a systematic review and meta-analysis. Medicine (Baltim.) 99 (49), e23529.
Lubkowska, A., Gajewska, E., 2020. Temperature distribution of selected body surfaces in scoliosis based on static infrared thermography. Int. J. Environ. Res. Publ. Health 17 (23).
Mambou, S.J., et al., 2018. Breast cancer detection using infrared thermal imaging and a deep learning model. Sensors 18 (9).
McCoy, M., et al., 2011. Intra-examiner and inter-examiner reproducibility of paraspinal thermography. PLoS One 6 (2), e16535.
Morales-Cervantes, A., et al., 2018. An automated method for the evaluation of breast cancer using infrared thermography. Excli J. 17, 989–998.
Moreira, D.G., et al., 2017. Thermographic imaging in sports and exercise medicine: a Delphi study and consensus statement on the measurement of human skin temperature. J. Therm. Biol. 69, 155–162.
Pauk, J., Wasilewska, A., Ihnatouski, M., 2019. Infrared thermography sensor for disease activity detection in rheumatoid arthritis patients. Sensors 19 (16).
Porto, F., et al., 2010. Moiré topography: characteristics and clinical application. Gait Posture 32 (3), 422–424.
Rodrigues Júnior, J.L., et al., 2021. Correlation between strength and skin temperature asymmetries in the lower limbs of Brazilian elite soccer players before and after a competitive season. J. Therm. Biol. 99, 102919.
Roggio, F., et al., 2021. Technological advancements in the analysis of human motion and posture management through digital devices. World J. Orthoped. 12 (7), 467–484.
Rosário, J.L.P.d., 2014. Biomechanical assessment of human posture: a literature review. J. Bodyw. Mov. Ther. 18 (3), 368–373.
Scarabottolo, C.C., et al., 2017. Back and neck pain prevalence and their association with physical inactivity domains in adolescents. Eur. Spine J. 26 (9), 2274–2280.
Schiavon, G., et al., 2021. Infrared thermography for the evaluation of inflammatory and degenerative joint diseases: a systematic review. Cartilage 13 (2_Suppl. l), 1790s–1801s.
Schlager, O., et al., 2010. Correlation of infrared thermography and skin perfusion in Raynaud patients and in healthy controls. Microvasc. Res. 80 (1), 54–57.
Shakhih, M.F.M., et al., 2021. Non-obstructive monitoring of muscle fatigue for low intensity dynamic exercise with infrared thermography technique. Med. Biol. Eng. Comput. 59 (7–8), 1447–1459.
Sohirad, S., et al., 2017. Feasibility of using a hand-held device to characterize tendon tissue biomechanics. PLoS One 12 (9), e0184463.
Trovato, B., et al., 2022. Postural evaluation in young healthy adults through a digital and reproducible method. J. Funct. Morphol. Kinesiol. 7 https://doi.org/10.3390/jfmk7040098.
Wu, C.-L., et al., 2009. The application of infrared thermography in the assessment of patients with coccygodynia before and after manual therapy combined with diathermy. J. Manipulative Physiol. Therapeut. 32 (4), 287–293.
Zaproudina, N., et al., 2008. Reproducibility of infrared thermography measurements in healthy individuals. Physiol. Meas. 29 (4), 515–524.