

Thermography in ergonomic assessment: the case of wood processing industry workers

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Background. Workers in the wood processing industry perform activities that demand great physical and ergonomic demands, which favors the emergence of inflammatory processes, favoring the occurrence of heat regions in the body, thus making it possible to assess the inflammatory level by means of gradients of temperature. This study aimed to evaluate the use of thermography as an ergonomic analysis tool in the identification of regions with musculoskeletal overload in workers in a wood processing industry.

Methods. The study was conducted with nine workers in the central-west region of Brazil. The evaluations of obtaining the thermographic images were carried out before the beginning of the workday, on Monday (day I) and on Friday (day II), in order to verify the regions of overload in the accumulation of days worked. The thermal images were collected in an acclimatized room with controlled conditions, where the participants remained with the upper part of the body bare for acclimatization, in which the lumbar and scapular regions were evaluated. The images were obtained using the FLUKE Thermal Imager, model TI 400, with analysis using the SmartView software to demarcate the body regions of interest.

Results. The mean temperature values obtained on day I did not differ significantly from the mean values obtained on day II. Qualitative analysis showed thermal patterns with high temperature at the same points on both evaluated days. In general, although the thermographic analysis performed in this study cannot provide definitive results, they helped to provide evidence for a more accurate diagnosis in the evaluated workers.

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Abstract

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Keywords. Thermal patterns, Occupational diseases, Wood splitting

Introduction

The evolution of pain to the chronic state, mainly in the spinal region, occurs in activities that require physical strength, being one of the main causes of temporary or permanent incapacity for the development of work in Brazil. Thus, it may be responsible for leading workers to resort to the social security system, requesting disability retirement (Treede et al., 2019; Grant et al., 2019; Sündermann, Flink & Linton, 2020).

It is known that pain symptoms arising from injury trigger inflammatory processes that can simultaneously promote the occurrence of heat regions in the body as a result of increased metabolism. Thus, it is possible to assess the inflammatory level through temperature gradients (Brioschi et al., 2007; Machado et al., 2009).

In medicine, the evaluation of physiological responses associated with skin temperature, in order to identify regions of the body with lesions, may be performed using thermography (Gold, Cherniack & Buchholz, 2004; Santos et al., 2014; Chandler, 2015; Côte & Hernandez, 2016). This is a non-invasive method used to record gradients and body thermal patterns, through thermographic images, which help in the early recognition of the beginning of an inflammatory process, which has not yet presented classic signs and symptoms, acting in a preventive way (Magalhaes, Vardasca & Mendes, 2018; Gefen et al., 2019; Jimenez-Pavon et al., 2019).

Several factors influence variations in body temperature, which may be directly associated with the metabolic process and activities of the synaptic nervous system on organs. In this way, the thermal analysis makes it possible to observe the physiological changes that can occur in the human body from temperature variation (Côte & Hernandez, 2016; Tan & Knight, 2018; Geneva et al., 2019).

Thermography has also been applied in studies aimed at identifying the variation in skin temperature in muscle groups of workers throughout the development of their work activities (Oliveira et al., 2018; Uchôa et al., 2018; Moreira-Marconi et al., 2019), standing out as a technique that can be used to evaluate ergonomic factors at work.

In tropical forest regions in Brazil, the activities of the wood sector are commonly carried out in inappropriate thermal conditions, due to the hot and humid climate, demanding high energy expenditure and physical effort from the worker. These workers often operate and handle machines and equipment that produce high levels of noise and vibration, in addition to adopting

postures that can be harmful to the body, given the constant lifting, handling and transport of loads weighing above the tolerable limits (Vasconcelos et al., 2019; Lima et al., 2019, 2022; Schettino et al., 2021).

Considering that the activities of the wood processing industry in tropical forest regions in Brazil are highly dependent on human labor for their accomplishment, thermography, in these cases, can be an allied technique in the ergonomic evaluation of workers subjected to conditions that favor the emergence of musculoskeletal diseases. Its study becomes interesting, as it can contribute to the establishment of preventive actions to protect workers' health.

In this context, this research was based on the hypothesis that the accumulation of working days associated with the short recovery time between one workday and another, can contribute to muscle overload in work activities, such as those performed by workers in a wood processing industry, which demand great physical demands. It is possible that this work model provides inflammatory processes in body regions that are highly requested during the execution of activities, in this way, a significant increase in the body temperature of these places can occur.

Therefore, it is believed that the body temperature of the most requested regions is higher at the end of the work week (Friday), when the worker comes from a period of accumulation of days developing his activities associated with a short rest interval (± 12 h). Unlike the beginning of the working week (Monday), when the rest period is longer (>48 h), because on Saturday and Sunday the worker does not carry out work activities, with more time for possible muscle recovery and, consequently, reduction of inflammatory processes.

In the case of workers in the wood processing industry, the scapular and lumbar body regions tend to be the most requested due to the characteristic of the work performed. Thus, we evaluated the influence of the accumulation of working days on the increase in body temperature of the scapular and lumbar regions of workers in a wood processing industry located in tropical forest regions, through the application of thermography as an ergonomic tool.

Materials & Methods

The study was carried out with workers from a wood processing industry from a tropical forest, located in the state of Mato Grosso, in the central-west region of Brazil. The evaluated industry performed the splitting of logs, coming from areas of native forest regulated by sustainable forest management, into sawn wood, using specific techniques and machines for this purpose. The activities performed by the workers evaluated in this industry are described in Table 1.

Table 1 was here.

Nine workers from the wood processing industry participated in the research, selected, first, according to their acceptance to participate in the study and, then, considering the exclusion criteria for participation (individuals away from work for more than 30 days, performing the function less than a year, using medication, diagnosed with an injury or frequent consumers of alcoholic beverages). Table 2 shows the anthropometric characteristics of the evaluated workers.

Table 2 was here.

Thermographic assessment

To obtain the thermographic images, the workers were previously instructed not to consume alcoholic beverages and caffeine, not to use any type of body moisturizer and not to practice vigorous physical exercises for a minimum period of 24 hours prior to the assessment (Moreira et al., 2017). The collection of thermographic images was performed on two different days, in the morning (between 6:30 am and 8:30 am), as described below:

Day I – assessment carried out before the start of the workday on Monday: condition that considered the day on which the worker returns to work, after a rest period during the weekend (> 48 hours).

Day II – evaluation carried out before the beginning of the workday on Friday: condition that considered the accumulation of days worked between Monday and Thursday, associated with a shorter rest time (corresponding to the end of the workday from Thursday to fair and start of the day on Friday, <12 hours).

The evaluations were carried out on these two days, with the aim of verifying whether the accumulation of days worked (day II) would provide a higher thermal temperature pattern in relation to the images obtained on Monday (day I), where the worker remained for a period of time greater at rest from their duties. For the analysis, the posterior position of the workers' trunk was selected, specifically, the body regions of the lumbar and scapular, defined, based on the mode of operation of the activities, as they are requested at all times and are more conducive to the development of injuries.

Figure 1 shows the lumbar and scapular regions, selected for thermographic analysis, identified in the study as Body Regions of Interest (BRI).

Figure 1 was here.

For the collection of thermographic images, carried out in a room equipped with a cooling air conditioner, the participants remained with the upper part of the body bare (anterior and posterior regions of the hands, forearms and arms, abdominal, thoracic, cervical and lumbar regions), for acclimatization for a period of 15 minutes with temperature conditions ranging from 22°C to 23°C, relative air humidity around 50% and air speed below 0.2 m s (Marins et al., 2014b; Fernández-Cuevas et al., 2015; Costa et al., 2018).

They were positioned away from any source of infrared radiation or airflow, the camera was turned on 30 minutes before the test to allow the sensor to stabilize, according to the manufacturer's guidelines and, later, the images were captured perpendicularly to the Body Regions of Interest (BRI).

To obtain the thermal images, a Thermal Imager (FLUKE, model TI 400) was used with a resolution of 320 × 240 pixels, an accuracy of ± 2 °C and an object temperature range from -25

°C to +105 °C. The thermographic images obtained were analyzed using the SmartView software (version 3.1), through the demarcation of the BRI (lumbar and scapular). The emissivity value adopted for human skin was 0.98 and the reflected temperature was set at 22°C in the thermal camera.

Thus, for the quantitative analysis of the thermographic images, the average temperature values of the selected BRI were considered and, for the qualitative (visual) analysis, the heat points visible in the thermogram.

Statistical procedures

In order to verify whether the accumulation of working days would provide a higher thermal temperature pattern in relation to the images obtained after a longer period of rest, quantitative and qualitative evaluations were carried out.

The temperature data of the BRI were submitted to the Shapiro-Wilk normality test, and when considered with normal distribution, the paired Student's t test was applied to compare the average temperature of the BRI of the workers obtained on day I (image obtained after a longer period of rest) versus day II (image obtained after the accumulation of days worked from Monday to Friday).

Ethical principles

This research was approved by the Ethics Council of the Federal University of Espírito Santo (CAAE: 57864716.0.0000.5060/ approved on August 28, 2017), meeting the criteria established by Resolution No. 196/1996 of the Research Ethics Committee of the Ministry of Health from Brazil. Thus, we received the written consent of the participating workers by signing the Free and Informed Consent Form (Brazil, 1996).

Results

The analysis with the average and maximum values measured by the evaluation of thermographic images in the BRI (lumbar and scapular) of the workers is shown in Table 3. Table 3 was here.

The mean temperature values of the BRI (lumbar and scapular) of the workers evaluated on day I did not differ significantly in relation to day II, that is, there was no difference between the mean temperature values of the BRI evaluated due to a longer period of rest (day I) and the accumulation of days worked (day II).

Regarding the qualitative analysis of thermographic images, high temperature values are noted, regardless of the day evaluated, located in the region corresponding to the spine, as shown in Figure 2.

Figure 2 was here.

Discussion

The research aimed to evaluate the influence of the accumulation of working days on the increase in body temperature of the scapular and lumbar region of workers in the wood processing industry.

In the thermographic evaluation, it was found that there was no significant difference between the average temperature values obtained from workers between day I and day II in the BRI evaluated. The results suggest rejecting the hypothesis initially raised, that the skin temperature of the evaluated body regions were higher at the end of the work week (Friday) in relation to the beginning of the work week (Monday). Which was based on the idea that the worker could present a greater muscular overload resulting from the accumulation of days worked with a short rest interval (± 12 h).

Therefore, the period equivalent to a weekend of rest (>48 hours) may not be enough to evidence a possible muscle recovery, or that this thermal pattern may be the result of a musculoskeletal overload already predominant in the body regions evaluated in the workers.

In a study carried out in Taiwan with 57 healthy individuals aged between 24 and 80 years, an average temperature of 30.4 ± 0.7 °C in the lumbar region and 30.8 ± 0.7 °C in the scapular region was observed (Niu et al., 2001). The respective values are, on average, between 1.5 and 2 °C lower than those found in this study.

In the study, carried out with a population of young Brazilian men with a mean age of 21.3 ± 2.19 years, an average temperature of $31.56^\circ\text{C} \pm 1.0$ was found in the lumbar region and 32.14 ± 0.9 °C in the upper region of the trunk, values close to those reported in the workers in this study, but still lower (Marins et al., 2014a).

These studies reinforce the need to associate the use of thermography as an ergonomic analysis technique, as the data show evidence of a trend towards a higher temperature in the BRI (lumbar and scapular) of the evaluated workers.

In addition, there is the fact that the evaluated workers perform extremely stressful activities. Among which stand out, the constant and repetitive lifting of heavy loads, such as sawn wood planks, long working hours lasting up to 10 hours, in some situations, in addition to the inadequate conditions of the environment and work station, which do not take into account the ergonomic principles recommended for the preservation of the worker's health.

Several factors combine that can cause musculoskeletal overload. Symptoms can be influenced by work techniques and organization, individual characteristics and psychosocial factors (Cremasco et al., 2019; Tuček & Vaněček, 2020). In situations in which workers are subjected to working hours that demand a biomechanical model of atypical postures, repetitive movements and handling loads with high physical effort, they can cause the development of musculoskeletal disorders, since this type of work rhythm exceeds the psychophysiological capacities of individuals (Soranso et al., 2021).

Such evidence is extremely widespread in the literature, which indicates that the probable causes of prevalence of musculoskeletal disorders in sawmill workers are verified due to repetitiveness at work, handling heavy loads and uncomfortable posture, which may be the

possible factors causing the development of symptoms of musculoskeletal discomfort (Adhikari & Sahu, 2018; Ajayeoba, 2019; Adetifa et al., 2020; Das, 2020; Jamaludin et al., 2022).

Occupations with static postures and repetitive work are related to complaints of pain in the neck and shoulders, while problems in the lower back are often associated with heavy physical work with lifting loads (Park et al., 2018; Tang et al., 2021; Sarker et al., 2021).

The finding verified in the visual analysis of the images tends to be normal, since the lumbar and scapular are extremely vulnerable bone structures of the human organism (Iida & Guimarães, 2016), as they are used at all times by the human being, reducing their sustaining capacity over the years.

However, it can be seen that there was a prevalence of the thermal pattern among the images obtained from the workers on the two days evaluated. In other words, the places with the highest occurrence of maximum temperature in the evaluated BRI were the same on the first and second day of evaluation, with the occupation tending to be higher in workers with older ages.

Although the thermographic analysis performed in this study cannot provide definitive results, they helped to provide evidence for a more accurate diagnosis in the evaluated workers.

Considering that this was an initial work aimed at the ergonomic evaluation of workers in the wood processing industry, and there is not much information on how to apply thermography in the evaluation of workers under these conditions, it is suggested, for future works similar to this study, the development of evaluation methods that allow analyzing the distribution of temperature within the body regions of interest.

In addition, it is noteworthy that even with no significant differences in the assessments used in this study, thermography proved to be a viable tool in the detection of thermal patterns, and it is possible to adopt its application as a monitoring tool in the preventive detection of possible health problems of the workers. In activities in the wood processing industry, such as those evaluated in this study, its applicability is highlighted by the great physical demand required of workers during the execution of the work, being a practical method and easy to apply.

Conclusions

The accumulation of days worked associated with a shorter time for musculoskeletal recovery, did not provide thermal patterns with significant differences in relation to the evaluation of workers after a longer period of rest.

The qualitative analysis showed a greater amplitude of occupation of thermal patterns with high temperature in the body region of interest of the workers in both situations evaluated.

In general, the results indicate the need for an accurate examination, in order to verify whether the development of wood processing operations contributes to musculoskeletal overload in workers.

The research showed that the use of thermography associated with other assessment methods can contribute to improving the use of this technique in the ergonomic analysis of work, through the creation of early and preventive assessment methodologies in monitoring the health and

safety of workers who work activities of great muscular demand, as is the case of those evaluated in this study.

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Table 1 (on next page)

Description of operations performed by workers in the wood processing industry.

Operations	Description of the operation
Primary split	It refers to the process of reducing whole logs, through longitudinal cuts into smaller parts that can be boards, boards or pieces of rectangular or square section. The wood logs are moved by the log carriage to the main sawing machine, called a single vertical band saw. This operation normally involves three workers, one being responsible for operating the band saw and the other two for fixing the log in the log carrier, removing and disposing of the boards generated in the processing on a ramp that supplies the secondary split.
Secondary split	Corresponds to the activity performed after the primary split, with the purpose of reducing the size or defining the final dimensioning of the wooden pieces.
Secondary stripping	Made with the use of circular saws, it aims to regularize the final length of the wooden pieces, according to the standard for sale. This task is normally carried out by two workers, one being responsible for the operation of the circular saw and the other for removing the pieces of wood and placing them close to the site, where later the manual stacking/packing is carried out by other workers.
Manual stacking	It consists of the formation of piles of sawn wood, whose pieces of each pile have the same dimension. To carry out this task, two workers manually load the pieces, holding each one at one end, and deposit them in the place where the piles are being formed.

Table 2 (on next page)

Average values of anthropometric variables of workers in the wood processing industry evaluated.

*Body mass index obtained by the formula: $BMI = \text{Weight}/\text{Height}^2$. ** Values in parentheses refer to the minimum and maximum values of each variable.

	Age (years)	Body mass (kg)	Height (m)	BMI (kg m²)*
Average	39 (21 - 58)**	65.4 (60 - 76)	1.73 (1.67 – 1.84)	21.8 (20.7 – 24.8)

1

Table 3(on next page)

Average and maximum skin temperature values of the Body Regions of Interest (BRI) of workers (n=09) evaluated on day I and day II.

The averages showed no significant statistical difference ($p<0.001$).

BRI		Temperature °C	
		Day I	Day II
Scapular	Average	32,70	32,40
	Standard deviation	±1,08	±0,90
	Maximum	34,2	33,9
Lumbar	Average	32,20	32,00
	Standard deviation	±0,70	±0,90
	Maximum	34,3	34,3

1

Figure 1

Body Regions of Interest (BRI), lumbar and scapular, selected in the posterior position of each evaluated worker

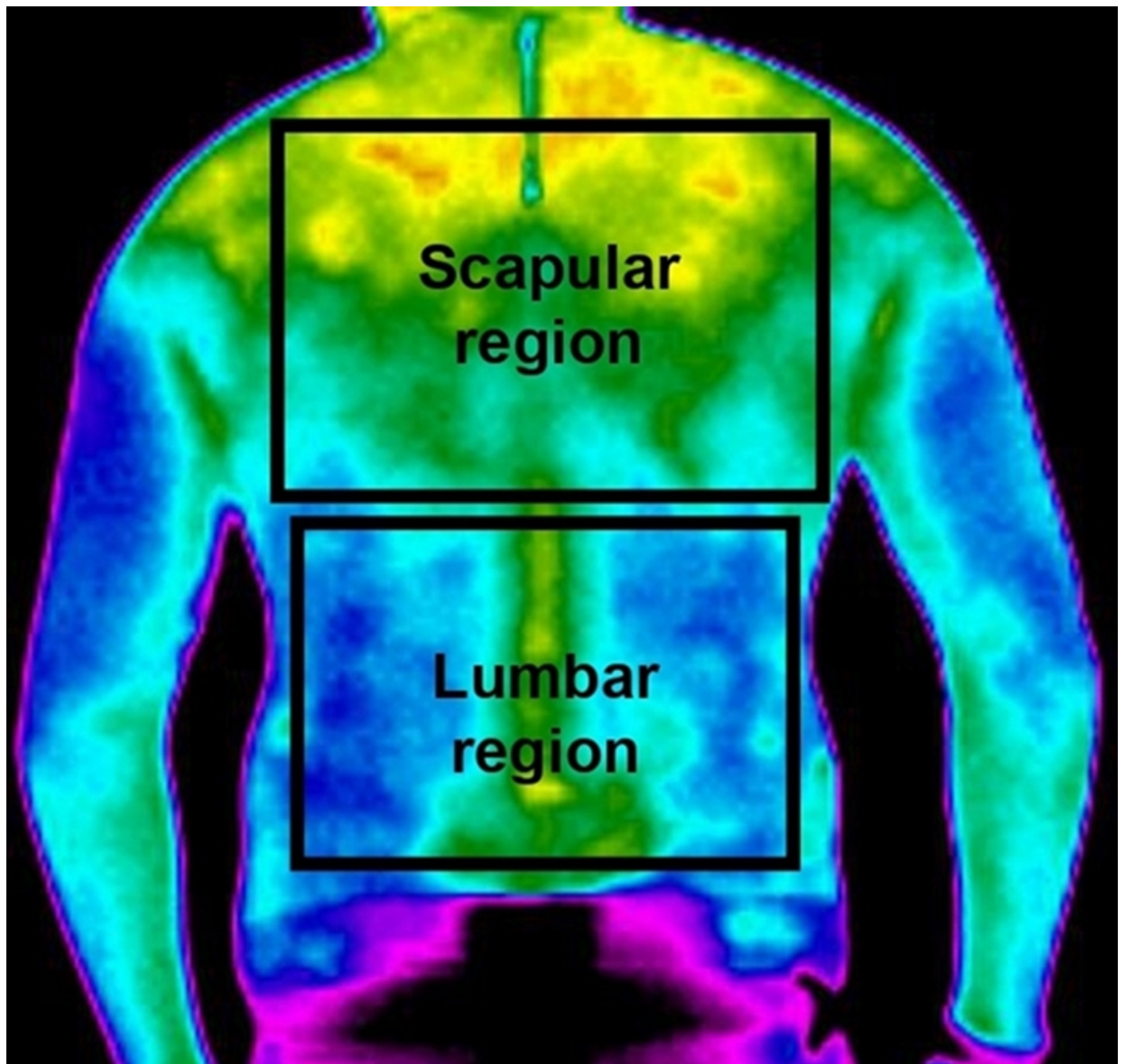


Figure 2

Comparison of thermal image of workers evaluated on day I (Monday, after a longer period of rest <48 hours) and day II (rest of approximately 12 hours associated with the accumulation of days worked)

