Thermal behavior of the skin on the wrist and finger extensor muscles during a typing task

Comportamento térmico da região cutânea dos extensores de punho e dedos durante uma tarefa de digitação

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ABSTRACT | Background: Occupational diseases are the second leading cause of sick leave in Brazil, among which musculoskeletal disorders are very common especially among workers whose job includes typing tasks. Thermography analyzes the temperature distribution on the skin surface and is used for diagnosis and prevention of musculoskeletal disorders. Objective: To investigate the thermal behavior of the skin on the wrist and finger extensor muscle area before, during and after a typing task. Methods: Twenty-four workers whose job involves typing were allocated to two groups—with or without elbow, forearm or injury—and performed a 10-minute typing task. Four thermography images were captured from the forearms and fingers at baseline, 0–2, 3–5 and 8–10 minutes and the minimum, maximum and mean temperature was calculated. The data were subjected to factorial ANOVA with software SPSS v 20.0. The significance level was set to 5%. Results: Minimum (mean difference–d=1.7), maximum (d=0.8) and mean (d=0.39) temperature was lowest on the elbow of participants with forearm injury; maximum temperature was lower on the right compared to the left side (d=0.39). Temperature did not vary as a function of time. Conclusion: There was difference in skin temperature between individuals with or without forearm injury and between the right and left sides, but not as a function of time. In future studies tasks should be longer and/or have set typing speed and goals. Keywords | ergonomics; occupational health; thermography.

RESUMO | Introdução: As doenças ocupacionais são a segunda causa de afastamento do trabalho no Brasil. Entre as alterações em tecidos mais comuns, estão as doenças ocupacionais nas afecções musculosqueléticas relacionadas ao trabalho, as quais têm acometido principalmente profissionais que trabalham com digitação. A termografia é uma técnica que avalia a distribuição da temperatura na superfície da pele, utilizada no diagnóstico e na prevenção de distúrbios musculosqueléticos. Objetivo: Verificar o comportamento térmico da região cutânea dos extensores de punho e dedos antes, ao longo e depois de uma tarefa de digitação. Métodos: Participaram 24 sujeitos digitadores profissionais divididos em dois grupos, com e sem lesão em antebraço e/ou mão, os quais realizaram uma tarefa de digitação por 10 minutos. Quatro capturas termográficas foram realizadas — repouso, 0–2 min, 3–5 min e 8–10 min — da região de antebraço e dedos, e obtiveram-se dados mínimos, Máximos e médios de temperatura. Os dados foram analisados no software Statistical Package for the Social Sciences (SPSS) versão 20.0 por meio da análise de variância (ANOVA) fatorial, com nível de significância de 5%. Resultados: Observaram-se menores temperaturas mínimas (diferença média [d]=1,7), máximas (d=0,8) e médias (d=1,2) em cotovelo de indivíduos que possuem lesão e menores temperaturas máximas (d=0,39) do lado direito. Não houve diferença entre as temperaturas ao longo do tempo. Conclusão: Existe diferença entre as temperaturas cutâneas de indivíduos com e sem lesão no cotovelo e entre lados direito e esquerdo. Não se obteve diferença na temperatura ao longo do tempo. Para pesquisas futuras, sugerem-se maiores intervalos de tempo e/ou o estabelecimento de velocidade e meta de digitação. Palavras-chave| ergonomia; saúde do trabalhador; termografia.
INTRODUCTION

As a result of the ongoing technological development, thermography is increasingly used for diagnosis of musculoskeletal disorders (MSD)\(^1\). This method detects variations in the skin temperature, and the acquired images may serve to ground inferences on the onset of an inflammatory process or still asymptomatic disease or presenting with symptoms other than the typical (pain, swelling and paresthesia). Thus, thermography has preventive application\(^2\)\(^-\)\(^5\) and enables early\(^6\) diagnosis through a painless\(^2\), noninvasive\(^7\), non-radioactive, rapid, low-cost and safe technique with a broad scope of applications and no restrictions\(^3\).

Chronic conditions may lead to disuse of the involved musculoskeletal structures, with consequent decrease of the blood flow (vasoconstriction) and local temperature\(^4\). In turn, acute injury and inflammation increase the skin temperature (vasodilation)\(^3\)\(^-\)\(^7\). In the state of rest, the skin temperature is about 33ºC, with some variability; the deeper a tissue, the higher its temperature, for instance, the intramuscular temperature is about 35ºC\(^8\)\(^-\)\(^10\). When combined to other diagnostic methods, such as imaging, physical and functional tests and clinical examination, thermography contributes to efficient diagnosis by detecting changes in tissues such as synovial membranes, tendons and bones, eventually also malignant tumors\(^11\).

Occupational diseases are the second leading cause of sick leave in Brazil\(^12\). Work-related MSD are frequently reported by typists, assembly line workers, telemarketers, bank employees, secretaries and journalists. Among these populations of workers, wrist, hand and finger joints are the most frequently involved\(^13\). Symptoms include fatigue, pain, paresthesia, feeling of heaviness, weakness, tremors, numbness, tingling and cold hands\(^14\). Most affected workers are aged 30 to 40, \textit{i.e.}, are at the peak of their productivity and experience\(^15\), and female\(^16\). Main reasons include repeated movements, physical effort, vibration, accelerated pace of work, environmental aspects, awkward posture and movements over long periods of time without the necessary rest breaks\(^17\). Such type injury occurs when the tissue recovery is not fast enough\(^17\), has insidious nature and multifactorial etiology\(^18\).

Thermography has been tested among workers with work-related MSD, especially those whose jobs involves typing\(^19\)\(^-\)\(^22\). However, there is wide variability in the reported results, work environments and data analysis. In most such studies assessments lasted 10 minutes and exclusively focused on the back of the hand\(^19\)\(^-\)\(^21\). Reported results included no changes or reduced temperature during and after typing tasks\(^19\)\(^-\)\(^22\).

Considering the relationship between the skin temperature and MSD among typists and the variation in analysis and findings among previous studies, the aim of the present one was to investigate and compare the thermal behavior of the skin on the wrist and finger extensor muscle area during a typing task among individuals with or without forearm injury.

METHODS

STUDY DESIGN

The present is a cross-sectional, comparative, observational and quantitative study and was approved by the research ethics committee of Centro Universitário da Serra Gaúcha, ruling no. 3,096,019.

SAMPLING

Through random sampling we selected 24 office workers in Caxias do Sul, Rio Grande do Sul, Brazil, aged 20 to 40 and whose job involved typing. The participants were allocated to two groups:
- Without injury (\(n=12\));
- With injury (\(n=12\)).

Eligibility criteria for the group of participants with injury (GI) were: typing at work at least 5 hours/day, with complaints of tendinitis involving the wrist/finger extensor muscles, lateral epicondylitis or carpal tunnel syndrome confirmed on diagnostic imaging or the Phalen or Cozen and Mills’ physical therapy tests\(^23\). Two participants had abnormal findings on ultrasound, four on magnetic resonance imaging, three on electromyography, one on the Phalen test and two on Cozen and Mills’ test. Inclusion criteria for the control group (CG) were typing at work at least 5 hours/day, without
any pain or other complaints. No participant could have
history of upper extremity fracture, Raynaud’s syndrome,
diabetes, high blood pressure, abnormal temperature or
take blood pressure medications.

The sample size was calculated with software
G*Power 3.1.9.2 from data obtained from the liter-
ature. On these grounds, the following criteria were:
effect size 0.25, error probability of 5%, statistical power
0.8, correlation between measurements 0.5 and sphe-
ricity of 1 for F tests (analysis of variance–ANOVA).
Thus, the sample had to comprise 24 participants, 12
per group.

PROCEDURES

Data collection was performed by two investigators
on sessions held at Integrated Health Center, Centro
Universitário da Serra Gaúcha, scheduled according to the
participants’ availability. The participants were requested
to avoid vigorous-intensity exercise, using keyboards, elec-
trical tools, caffeine, alcohol and smoking 60 minutes before
assessments. The temperature of the test room (3 × 6 m²)
was set to 23°C; typing equipment (computer, mouse and
keyboard) was provided.

After the participants signed an informed consent
form they were subjected to clinical interview including
data on their work routine. Next, a 2-cm piece of adhesive
tape was placed below the lateral epicondyle to be used
later for data analysis. The tests were performed with the
participants sitting at the desk, with arms and hands in a
relaxed position for 20 minutes (Figure 1A) at a distance
from keyboard and screen as recommended in ergonomics
standards (height adjustable chair, desk at the level or
below the elbow)²¹.

Thermography images were captured with FLIR
C2® camera, 4800 pixels (80x60), precision -10–150c,
±2% sensitiveness, 100mk, emissivity 0.98 and multi-
spectral mode (640 x 480 pixels); baseline images were
acquired with the participants’ hands resting on the
desk. Next, the participants were requested to type a
nontechnical text for 10 minutes. Along this period, we
captured four images:
• at rest;
• 0–2 minutes (beginning);
• 3-5 minutes (middle);
• 8–10 minutes (end).

The images were captured at a 1-meter distance from
above to include the elbow, forearm, wrist and hand. For this
purpose, the participants were requested stopped typing
shortly to immediately resume the task. The test ended
after 10 minutes.

DATA ANALYSIS

The captured imagens at each time-point were analyzed
with software FLIR Tools®; areas for analysis were the
skin on ventral side of the wrist and finger extensor area
(Figure 2A) and the first to fifth fingers (Figure 2B) bilat-
erally (Figure 2C). The 2-cm piece of adhesive tape placed
below the lateral epicondyle served as reference to define
the region of interest (ROI) i.e. an equal sized square.
To establish the finger ROI, we draw a line from each up
to the styloid process of the radius and ulna. Square and
lines were used to calculate resultant, minimum, maximum
and mean values.

STATISTICAL ANALYSIS

Statistical analysis was performed with software
Statistical Package for the Social Sciences (SPSS) version
20.0. Normality and homogeneity were investigated with
the Shapiro-Wilk and Levene’s test. Temperature data were
compared by means of factorial ANOVA according to the
following factors:

Figure 1. Position of the upper arms on the desk during the
capture of thermography images (A) usual image, (B) ther-
mography image.

Figure 2. Thermography analysis (A) of elbow, (B) fingers.
• group (two levels: with or without injury);
• time (four levels: rest, 0; 0–2 minutes, 3–5 minutes, 8–10 minutes);
• side (two levels: right and left).

The results were subjected to descriptive statistics (mean, standard deviation, mean difference \([d]\), F ratio (ANOVA), p-value (significance) and effect size (eta\(^2\)). Whenever ANOVA detected significant difference analysis continued with the Bonferroni correction. The significance level was set to p-value<0.05.

**RESULTS**

The sample comprised 24 participants whose job required typing, allocated to two groups:
• without injury—CG (n=12);
• with elbow, forearm, and hand injury—IG (n=12).

The participants’ characteristics are described in Table 1.

Factor group was associated with significant difference in temperature (\(F=4.897; p=<0.001; \text{eta}^2=0.352\)). The participants with injury (Figure 3) exhibited lower elbow minimum (CG=29.0±0.2; IG=27.2±0.2; \(d=1.7; p=<0.001\)), maximum (CG=32.5±0.1; IG=31.6±0.1; \(d=0.8; p=<0.001\)) and mean (CG=31.4±0.1; IG=30.2±0.1; \(d=1.2; p=<0.001\)) temperature. We did not find significant difference in the minimum, maximum or mean temperature of any of the five fingers (fifth: \(p=0.457, p=0.763, p=0.834\); fourth: \(p=0.674, p=0.588, p=0.683\); third: \(p=0.614, p=0.299, p=0.486\); second: \(p=0.444, p=0.208, p=0.459\); first: \(p=0.410, p=0.235, p=0.294\)) between the groups (Figure 3).

Relative to factor side, mean temperature was lower on the right compared to the left in both groups (\(F=1.969; p=0.014; \text{eta}^2=0.182\)). Post hoc analysis revealed that the maximum temperature was lower on the right elbow (\(R=31.9±0.1; L=32.3±0.1; d=0.39; p=0.040\)) while there was no difference in minimum (\(R=28.2±0.2; L=28.1±0.2; d=0.11; p=0.734\)) or mean (\(R=30.7±0.1; L=30.9±0.1; d=0.18; p=0.388\)) temperature. Maximum, minimum or mean temperature did not differ between any of the five fingers (fifth: \(p=0.448, p=0.697, p=0.411\); fourth: \(p=0.757, p=0.793, p=0.620\); third: \(p=0.990, p=0.904, p=0.753\); Table 1. Sample characteristics. Caxias do Sul, Brazil, 2019 (n=24).

| Characteristics          | Mean Control group | Injury group |
|--------------------------|--------------------|--------------|
| Age–years                | 28                 | 31           |
| Temperature at baseline–ºC| 36.80              | 36.63        |
| Body weight–kg           | 68.73              | 72.66        |
| Height–m                 | 1.67               | 1.65         |
| Years in the job         | 8                  | 8            |
| Daily typing hours       | 7                  | 7            |
| Numbers of words typed during task | 330              | 310          |
second: p=0.833, p=0.704, p=0.589; first: p=0.891, p=0.494, p=0.566).

In turn, we did not find significant differences between time-points (F=1.306; p=0.79; eta²=0.127) in the maximum, minimum or mean temperature of neither elbow (Figure 4) nor fingers (p=1.0, Figure 5). While there was no difference between both hands, we did detect difference between fingers (p<0.05).

We neither found significant difference in any of the analyzed variables considering the interaction between the three factors (F=0.772; p=0.930; eta²=0.075) also on the post hoc test for specific comparisons (p>0.05).

**DISCUSSION**

Our aim in the present study was to investigate the thermal behavior of the skin on the wrist and finger extensor muscle area during a short typing task among individuals with or without forearm injury. The former exhibited lower (<1ºC) minimum, mean and maximum temperature on the elbow. Temperature was lower on the right compared to the left side. In turn, there was no difference in the elbow or finger temperature before and after the requested task.

Chronic conditions lead to disuse of the involved musculoskeletal structures, with consequent decrease of the blood flow (vasoconstriction) and local temperature⁴. In turn, acute injury increases the skin temperature⁷. Since in the present study the skin temperature was lower on the elbow of the participants in GI, we may infer theirs was a chronic condition, i.e., without active inflammation. One further reason for the difference in temperature between the analyzed groups might derive from the action of the sympathetic nervous system¹⁹ resulting in a shift of the blood flow from the skin to the muscles, with consequent cooling of the former among the participants in GI. Among chronic patients who perform low-intensity tasks, such as typing, a vicious circle develops involving the sympathetic neural arc which decreases the skin temperature and leads the blood flow deeper into the muscles. This phenomenon accounts for lower temperature in GI. Gold et al.¹⁹ did not find difference among individuals with MSD and cold or not hands at baseline. Nevertheless, the same group²¹ reported lower temperature among individuals with injury compared to controls, but not when tested at rooms at 18 (p=0.09) or 21ºC (p=0.26). Also, Ring and Ammer²⁴ found that the skin temperature was lower among individuals with chronic injury.

The skin temperature was lower on the right compared to the left side in both groups, which probably reflects their hand dominance. Reste et al. reported that a tested mouse...
Thermal behavior of the wrist and finger extensor area during a typing task could have caused skin cooling, since the energy metabolism is lower in the active by comparison to the contralateral side and thus results in less heat. All the participants were right-handed and possibly used the mouse in a way that reduced the blood flow to the analyzed area, which they compensated for through the involvement of other parts of the upper extremities.

In the present study we did not find difference in the temperature of either forearm or fingers as a function of time, thus differently from the results obtained by Gold et al.\textsuperscript{19} also with a 10-minute typing task and three groups (injury and cold hands, injury without cold hands, controls). After the end of the task, the skin temperature was lower among the individuals with cold hands, while it exhibited oscillation among controls, with both increase and reduction. In turn, the temperature did not change among the participants without cold hands, probably due to heat dissipation by convection and the action of the sympathetic nervous system shifting the blood flow to the muscles\textsuperscript{4,19}. Yet in other studies the same group\textsuperscript{20,21} did not find any difference in the hand temperature.

We believe that the typing speed might influence the blood flow volume at the end of the task and that this accounts for the fact we did not find any change in the temperature of the analyzed sites. According to Gold et al.\textsuperscript{21} thermoregulation is impaired among individuals with MSD and cold hands. In their study neither the participants with nor those without injury felt symptoms of repetitive strain injury/work-related MSD during the allocated task. The reason is that their usual working hours were much longer than the test duration (10 minutes) which consequently did not suffice to trigger symptoms. These authors\textsuperscript{22} further observe that the forearm and arm temperature increases when the typing speed is above 50 words per minute. Reste et al.\textsuperscript{22} analyzed temperature dynamics among four individuals along a 3-hour task involving three mouse setups (horizontal computer mouse without mouse pad, horizontal computer mouse with mouse pad and padded wrist support, and vertical computer mouse with mouse pad). The skin temperature decreased in all the cases, but difference was lowest with the vertical mouse.

The main limitations of the present study derive from the task duration, typing speed and the fact we did not impose any demands as is usual in the daily work routine. Then, although we selected a nontechnical text to type, its topic was unfamiliar to the participants and thus the

Figure 5. Minimum, mean and maximum finger temperature during the typing task. Caxias do Sul, Brazil, 2019 (n=24).
task was harder compared to their routine. There is also the fact the participants had to use unfamiliar equipment, while productivity increases when workers are well acquainted with their tools. Finally, measurements were performed on the skin only, therefore the results cannot be extended to the muscles proper, which temperature is higher compared to the skin\(^8-10\). Nevertheless, we succeeded in gathering evidence for difference in the skin temperature between workers with or without wrist and finger extensor muscle injury. On these grounds, thermography may be useful to assess individuals with disorders involving the skin on the wrist and finger extensor muscle area.

For future studies we suggest increasing the duration of typing tasks or setting definite goals to analyze the typing speed too and with the same keyboards to which subjects are used.

**CONCLUSION**

The minimum, mean and maximum skin temperature was lower on elbow among individuals with forearm/hand injury compared to injury-free controls. Temperature was lower on the right compared to the left elbow in both groups and did not differ during and after the end of the typing task.
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