http://dx.doi.org/10.21611/qirt.2008.03_16_17
QIRT2008 9th International Conference on Quantitative InfraRed Thermography
July 2-5, 2008, Krakow - Poland

Thermal monitoring of hand stress during keyboard typing

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Abstract

Repetitive tasks such as keyboard typing increase hand and forearm temperature after a certain time due to muscular activity. This activity can be objectively quantified by the measurement of temperature changes over time. In this study changes in both hands were recorded while one hand was typing on a standard keyboard and the other one remained static. The temperatures of hands and forearms were recorded using thermal imaging. The infrared camera was positioned in a vertical static position recording an image once a minute over a period of 15 minutes. The thermograms of the 12 healthy volunteers participating in this study were analysed with the software package CTHERM. Results show that after 5 minutes the temperature of the typing forearm increased by 0.5℃ compared to the other one. The hands over the same period of time show a difference of only 0.1℃. After 15 minutes the difference between both forearms was 1.2℃ but between both hands only 0.4℃. In order to better assess thermal effects of keyboard stress on hands an additional vascular stress test immediately after the mechanical stress may produce increased discrimination. This investigation also shows that other factors such as handedness, age and Body Mass Index affect temperature changes caused by mechanical stress.

1. Introduction

Keyboard typing is a common task today, it involves repeated movements and some typists are working for long periods of time. These repetitive movements generate heat which can be recorded by thermal imaging: an objective, non-invasive and completely safe measurement method [1].

Extended exposure can provoke irritation in the muscles of the forearms and/or swelling and inflammation in the soft tissues and nerves of the fingers. Some authors mention that the tendons in hands and forearms also produce some swelling which can be painful [2]. In extreme cases continued and long exposure to repeated mechanical stress can cause a form of repetitive strain injury (RSI).

It is the aim of this study to investigate temperature changes in both hands and forearms in healthy volunteers without RSI in order to produce baseline data for normal temperature fluctuations while typing. This baseline information may then be used for the quantification of RSI status in sufferers and may also potentially be useful for the early detection of the onset of the condition.

The main objective of this study is therefore to investigate the amount of dorsal hand and forearm temperature changes in healthy subjects after 5 and 15 minutes of all-finger typing at constant speed. Dynamic Infrared Thermal Imaging (DITI) is used with 1 thermal image being recorded every minute. Handedness, age and Body Mass Index (BMI) of the participating 12 volunteers are recorded in order to assess the influence of these variables.

From [3] it is known that the mean temperature distribution at a steady state (30ºC environment temperature, low humidity and 0.5 m.s-1 air speed) on the hand is 32.9 ºC and on the forearm 33.6ºC. After 5 minutes keyboard typing at a speed of 30 to 50 words per minute Sharma et al. [4] observed a difference in temperature increase between patients suffering from chronic forearm pain and healthy volunteers. They suggest thermography as an efficient, reproducible and non-invasive method to quantify and evaluate temperature changes and to use it as a diagnostic procedure for hand and arm physiologic/pathologic manifestations.

A later study [5] on cold fingertips after keyboard typing involved 15 healthy females at a room temperature of 24ºC and demonstrated that after 15 minutes typing there was an average 1ºC increase in the temperature of the forearms while the fingertips cooled down by 0.15ºC due to vasoconstriction of blood vessels as a result of the repetitive stress caused by typing.

An examination of skin temperature in dorsal hands of office workers [6] shows that the healthy subjects used as controls have a temperature increase of 0.7ºC after 9 minutes typing non-technical text.

A recent study by the authors on the thermal symmetry of the hands and forearms in healthy subjects [7] defines thermal symmetry as a mean and standard deviation temperature difference of less than 0.2ºC. In this definition the areas of interest (AOI) which are identical in shape, size and as near identical in position as possible are mirrored across the body's longitudinal main axis. This tool is also used in this study.

In summary, as a result of the above studies this study expects to show a significant increase in the temperature of forearms and a mild increase on the dorsal hand as a result of typing. In addition this study also produces interim values at 1 minute intervals in order to assess any dynamic processes that may be present. In contrast to previous studies this work uses a standard protocol for image capture and patient preparation as outlined in the following section.

2. Materials and Methods

This investigation involved:

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- A FLIR A40 calibrated thermal camera, to record the images.
- A PC workstation with CTHERM, MS Excel and SPSS software packages installed, to process and analyse the thermal images.
- A standard keyboard, to be used as provocation tool.
- A table with the wooden board on top to improve the contrast of the background.
- A chair, for seating the volunteer.
- 12 healthy male volunteers (Nine with ages between 18 and 29, 3 of them left handed, 3 overweight. Three with ages between 30 and 39, 1 left handed and 2 overweight).

All the volunteers were students and healthy with an EURO-QOL score of zero. All volunteers were informed of the following procedure which involved two visits on two different days. During the first visit the right hand was typing while the left remained still (Fig. 1). During the second visit the left hand was typing and the right stayed still. The volunteers were requested to avoid heavy meals, alcohol, smoking and exercise 2 hours before the experiment. Arms and hands were free of clothes and jewellery, the examination room was regulated to a constant temperature of 22ºC and a humidity level of less than 50% was maintained. A thermal acclimatisation period of 10 minutes was enforced before each examination. The subjects were seated in a chair in a comfortable position, a table with a wooden board over it was used to improve the thermal contrast between the keyboard and the background.

The thermal camera was placed on a stand perpendicular to the target at a distance of 1m (Fig. 2). A 24º lens was used on the camera. The hands were placed in predefined positions as shown in Fig. 3.

Free style typing at constant speed (3 to 4 characters/second) was performed by the volunteers with the investigator supervising. It was decided not to provide a standard text for typing or to record the typed text in order to remove any psychological stress factors from the experiment.

During the 15 minutes examination a thermal image was taken before provocation and then one every minute.

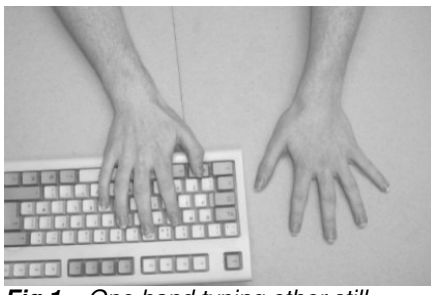

Fig.1 *– One hand typing other still*

Fig. 2 *– Position of the camera*

For data analysis 4 regions of interest (ROI) were defined in each thermal image (Fig. 3), 2 symmetrical squares completely enclosing the hands with 5600 pixels each and 2 symmetrical rectangles inside the forearm areas with 2140 pixels each. Fixed oversized Region of Interest (ROI) were used for the hands and undersized ROIs for the forearms in order to allow the calculation of values while the arms/hands were in motion. Mean temperatures and standard deviation were computed for each ROI (background pixels were discarded) and averaged for analysis and combined for all subjects, for handedness, for age group and for BMI class. All results were then analysed using the SPSS software package.

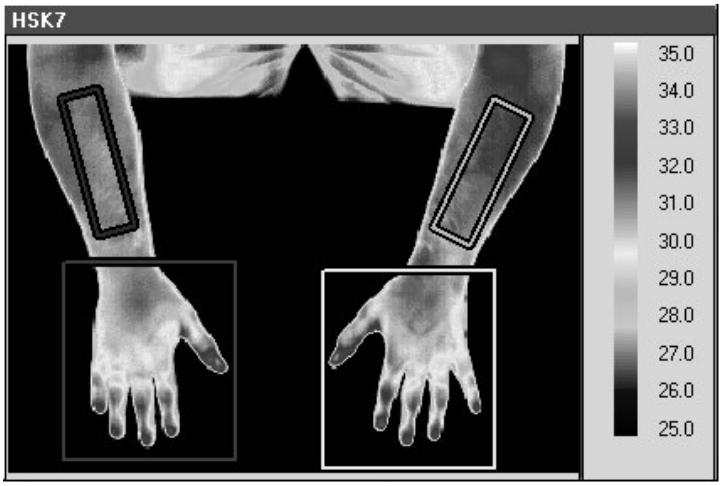

Fig. 3 *– Areas of Interest defined for data analysis*

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3. Results

The overall results demonstrated a temperature increase on the typing extremity. After 5 minutes typing the average mean temperature increase in the right hands when typing was 0.6ºC and in the forearms 0.8 ºC. When the left hand was typing average mean temperature increase in the hands was 0.5ºC and 0.4ºC in the forearms.

At the end of the 15 minute examination period the average mean temperature increase obtained was 0.9ºC in right hand and 1.7ºC on right forearm when the right hand was typing. When the left hand was typing the respective increases were 0.7ºC and 1ºC. Fig. 4 shows the full set of results for the right hand typing and Fig. 5 for the left hand together with the temperatures of the non-exercising hand.

Interestingly, the temperature of the exercising hand increases only during the first 10 minutes, after this it stays constant while the temperature of the forearms continues to climb.

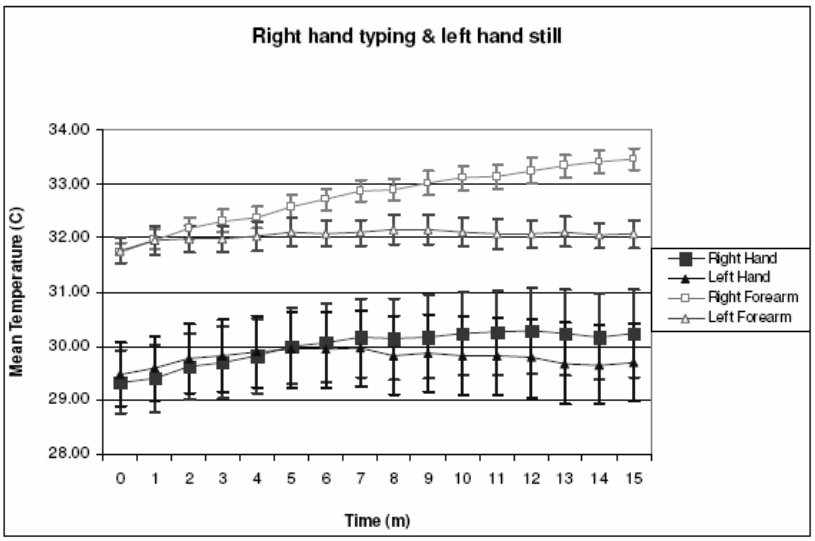

Fig. 4 *– Average mean temperature for right hand typing and left hand still.*

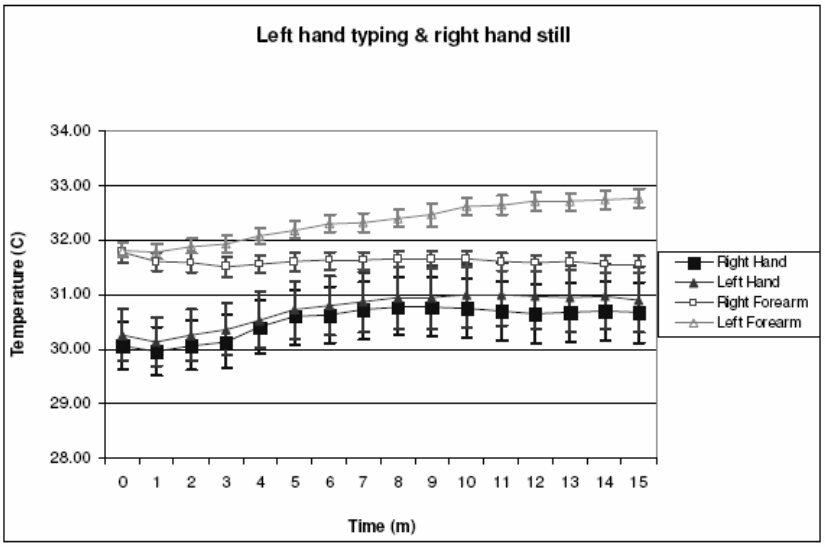

Fig. 5 *– Average mean temperature for left hand typing and right hand still*

A paired sample Student's t-test shows evidence of a strong correlation between the values obtained from the regions of interest (ROI) in the respective exercising hands. Between the right and the left hand the correlation is 0.977 with $p<0.01$. Between forearms the correlation is 0.984 with $p<0.01$. On the below table can be observed that there was an increase of right hand exercised of 0.6ºC after 5 minutes and 0.9ºC on the end of the 15 minutes. On the exercised right forearm that values were 0.7ºC after 5 minutes and 1.7ºC at end of the 15 minutes. On exercising the left limbs the obtained temperature increasing values after 5 minutes was 0.5ºC on hand and 0.4ºC on forearm. At the end of the 15 minutes 0.7 º C on hand and 1ºC on forearm.

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Table 1 *– Average mean temperature and standard deviation of 12 volunteers exercise*

	Right Typing & Left Still								Right Still & Left Typing							
	R Hand		L Hand		R Forearm		L forearm		R Hand		L Hand		R Forearm		L forearm	
T	mT	SD	mT	SD	mT	SD	mT	SD	mT	SD	mT	SD	mT	SD	mT	SD
0	29.34	2.02	29.48	2.04	31.73	0.83	31.77	0.66	30.07	1.54	30.26	1.58	31.78	0.63	31.81	0.47
5	30.00	2.44	29.94	2.43	32.58	0.87	32.11	0.70	30.60	1.76	30.72	1.85	31.61	0.55	32.19	0.55
15	30.24	2.80	29.70	2.51	33.46	0.89	32.07	0.71	30.68	1.91	30.91	2.10	31.57	0.52	32.78	0.60

Handedness appears to have an influence on the results as shown in Figs. 6 and 7. Left handed volunteers had warmer left arms when this side exercised and right handed volunteers showed the same effect in the right arm. This could be the result of the muscles of the respective side being stronger and thus producing more heat or requiring increased blood supply.

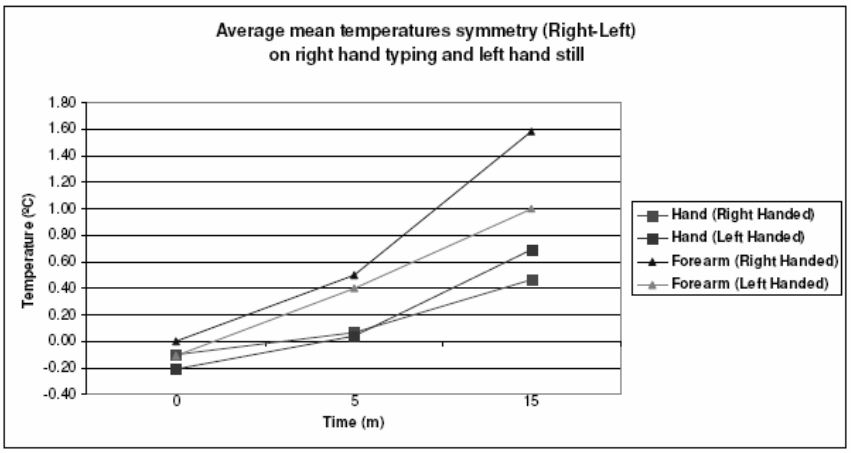

Fig. 6 *– Thermal Symmetry (Right ROI – Left ROI) according to handedness.*

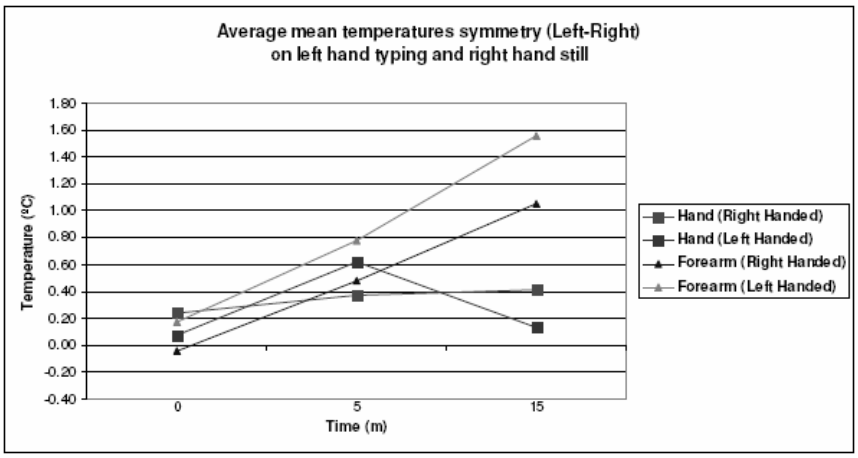

Fig. 7 *– Thermal Symmetry (Left ROI – Right ROI) according to handedness.*

In order to investigate the effect of age on the temperature increases in the typing arm, a comparison was made between the average mean temperatures of the two age group of 18-29 years and 30-39 years. As shown in Figs. 8 and 9 the difference over time on thermal symmetry was higher in the younger group, i.e. their typing arm became warmer with respect to the non-typing arm than that of their older peers.

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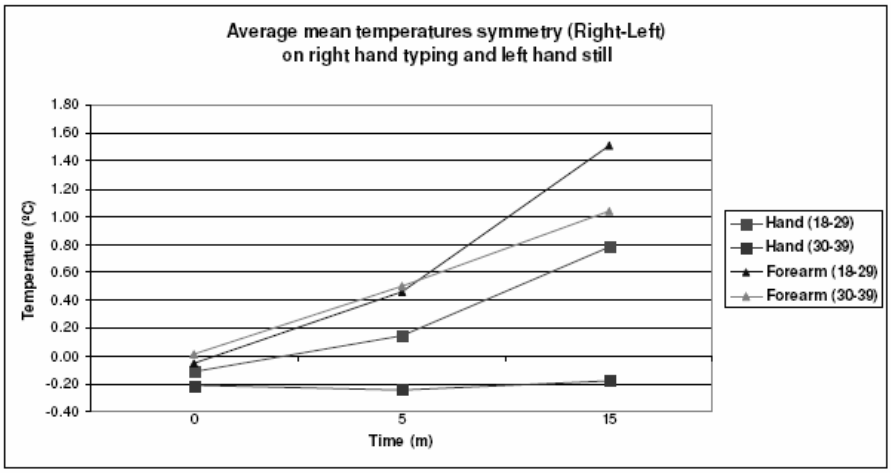

Fig. 8 *– Thermal Symmetry (Right ROI – Left ROI) according to age group.*

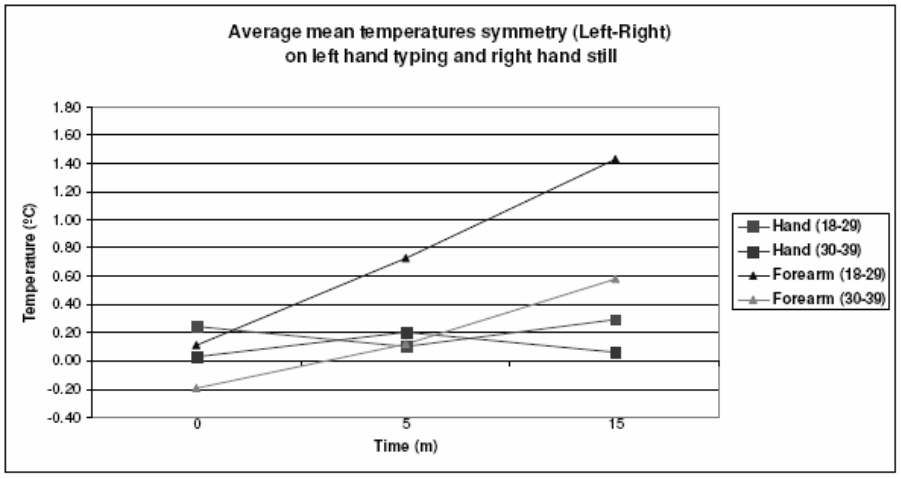

Fig. 9 *– Thermal Symmetry (Left ROI – Right ROI) according to age group.*

When investigating the effect of Body Mass Index on thermal symmetry it was found that subjects belonging to the 'normal' BMI class (18.5kg to 25kg) produced warmer exercised arms than those subjects in the 'overweight' class (25kg-30kg) as shown in Figs. 11 and 12.

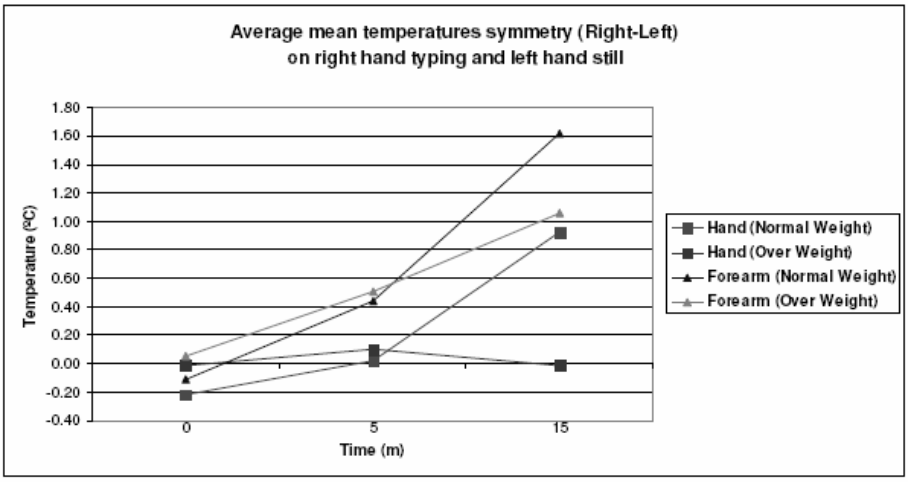

Fig. 10 *– Thermal Symmetry (Right ROI – Left ROI) according to BMI class.*

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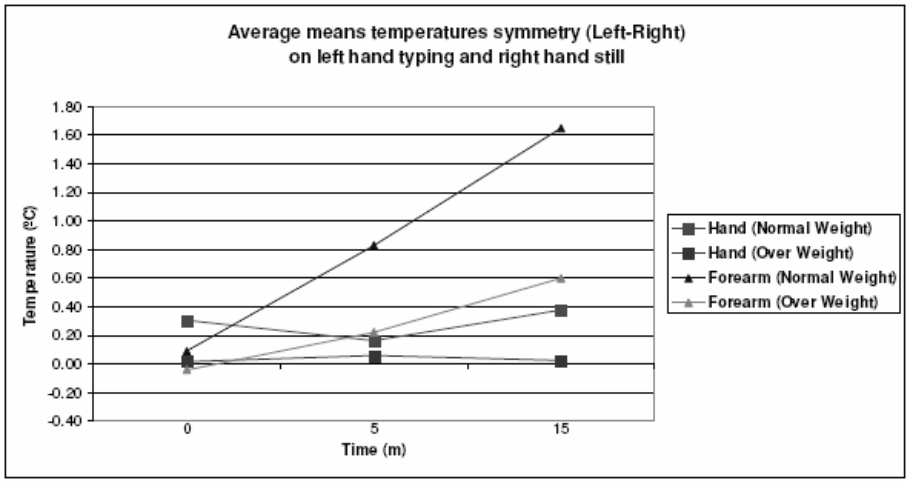

Fig. 11 *– Thermal Symmetry (Left ROI – Right ROI) according to BMI class.*

4. Discussion

This study agrees with previous studies [4, 5, and 6] on the temperature increase of hand and forearm after provocation by keyboard typing. It also confirms that the increase is higher on the forearm than in the hands as it is the muscles in the forearm that contract to facilitate typing and thus force the higher heat increase on this region. It was verified that there are significant differences and changes in thermal symmetry of hand ROIs when one side was exposed to exercise while the other remained still. For the hands some aspects of the stabilisation of temperatures after 10 minutes could be related to the vasoconstriction in the fingertips caused by the contact with the keyboard reported by [5]. During this investigation minor discomfort was expressed by some volunteers close to the end of the 15 minute typing period. This is the reason why the typing Fig. 10 – Thermal Symmetry (Right ROI – Left ROI) according to BMI class. Fig. 11 – Thermal Symmetry (Left ROI – Right ROI) according to BMI class. period was not longer. It is likely that an extended period of typing may have lead to the production of lactic acid in the muscles which is known to decrease muscle temperature [8].

5. Conclusion

Dynamic Infrared Thermography can be used to record temperature changes caused by exercise activity during a certain period of exposure and using a standard protocol [9]. This investigation revealed an average mean temperature change of 0.5ºC on the hand and 0.6ºC after 5 minutes exposure to standard computer keyboard typing, and after 15 minutes 0.7ºC on the hands and 1.4ºC on the forearm. Another achievement of this study is the identification that factors such as handedness, age and BMI affect temperature changes on this kind stress exercise. This investigation also revealed that for physiological assessments the values found for the hands can be inconclusive, an additional vascular provocation test [10] may be advised.

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