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Skin temperature and muscle blood volume changes in the hand after typing

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ABSTRACT

Several studies have measured altered hand skin temperature in response to typing. It is unknown whether this measure is indicative of an underlying change in muscle perfusion or merely reflective of skin capillary shunting. The objective of this pilot study was to examine the correlation between mean skin temperature (THand), and relative blood volume (RBV) in the first dorsal interosseous muscle as measured through near infrared spectroscopy in the hand after a 9-min typing task in ($n = 10$) healthy subjects. Additionally, the effect of typing speed on the physiological measures was determined. THand relative to baseline and RBV were moderately correlated during 10 min post-typing (Pearson correlation coefficient [PCC] = 0.75, $p = 0.01$ at 0–2 min after typing; PCC = 0.52, $p = 0.12$ at 3–5 min after typing; PCC = 0.77, $p = 0.01$ at 8–10 min after typing). A typing speed of greater than 50 words per minute affected both RBV and THand, with both measures normalizing more quickly among faster typists, indicating a possible metabolic influence on both measures. Skin temperature after typing does appear to reflect underlying muscle perfusion in the hand.

Relevance to industry: Reduced blood flow has been implicated in musculoskeletal disorder (MSD) pathophysiology. The current study examined two objective non-invasive measures after a low-intensity task in healthy subjects. Further studies should examine the post-task pattern in symptomatic individuals to determine the suitability of using these physiologic measures to indicate the presence of MSDs.

1. Introduction

Skin temperature is largely determined by cutaneous blood flow. Several studies have measured altered objective skin temperature in the hands of office workers in response to typing (Gold et al., 2004; Sharma et al., 1997), but it is unknown whether this changed surface temperature reflects a change in blood volume in the underlying muscle or a shunting to skin capillaries only. Relative blood volume (RBV) as detected through near infrared spectroscopy (NIRS) in the forearm has been examined under conditions of low-level isometric exercise (Murthy et al., 1997; van Beekvelt et al., 2002), and less frequently in conjunction with typical tasks of office work (Heiden et al., 2005; Crenshaw et al., 2006; Crenshaw et al., 2007). We are unaware of any prior study where RBV has been measured in the hands of computer users.

Altered blood flow may play a role in the pathophysiology of upper extremity musculoskeletal disorders (Larsson et al., 1998; Larsson et al., 1999; Pritchard et al., 1999; Coury et al., 1999; Brunnekreef et al., 2006; Zeisig et al., 2006; Village and Trask, 2007). Proposed mechanisms include compression of the brachial artery, increased intramuscular pressure or inadequate blood flow regulation (see Visser and van Dieen, 2006 for review).

The main purpose of this study was to determine if mean skin temperature in the dorsal hand (THand) was correlated with RBV in the first dorsal interosseous (FDI) muscle as measured through NIRS during a 10-min period following a brief typing task. An additional objective was to examine the effect of typing speed on THand and RBV.

2. Methods

2.1. Subjects

Office workers ($n = 11$) without symptoms of upper extremity musculoskeletal disorders (UEMSDs) were recruited at the University of Connecticut Health Center through an open solicitation broadcast email message to health center and university employees. They were first screened by telephone to determine eligibility, principally an absence of an UEMSD. During the first

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visit, each subject was further evaluated through administration of an upper extremity examination to confirm the absence of signs or symptoms of UEMSDs. One subject was eliminated from the study due to UEMSD signs found on examination. All subjects used a keyboard for four or more hours/day at least five days/week for at least five years; nine of the ten eligible participants were female (mean age = 38.2 ± 9.6 years).

2.2. Equipment and data capture

A near infrared spectrometer (USB4000-VIS-NIR, OceanOptics Inc., Dunedin, FL) was used in conjunction with OOIBase32 Spectrometer Operating Software (OceanOptics Inc., Dunedin, FL) to capture the absorbance measurements. A custom NIRS probe with optodes at 11 mm apart (depth ~5.5 mm) measured relative absorbancy of oxy- and deoxy-hemoglobin in the FDI muscle. The probe was adhered to the FDI with double-sided electrode washers (E432 In Vivo Metric, Healdsburg, CA). The NIRS sampling rate was set at 0.1 Hz. Since total hemoglobin, represented as the sum of absorbency of de-oxygenated and oxygenated hemoglobin, is proportional to muscle blood volume, RBV from baseline was determined by the UCL6 algorithm (Matcher et al., 1995) encoded into software.

In advance of the pilot study, four subjects were exposed to experimental conditions in order to validate the NIRS-derived measurements. After acclimating to a temperature controlled room at 22 °C for 20 min, the NIRS probe was adhered to the FDI. A baseline reading was captured for 2 min. Next, a blood pressure cuff was applied to the upper arm and inflated to capture a minimum value for the RBV in the FDI. After recovery from the blood flow occlusion, a cooling pad (2.5 °C) was applied to the distal phalanges of digits 2–5 for 5 min. After recovery from the prior condition, a heating pad (63 °C) was applied to the same location for 5 min. The RBV in the FDI during the cooling of the digits exhibited a gradually reduced value in comparison to the ambient temperature RBV. Yet, the minimum RBV due to cooling was greater than the occlusion RBV. The RBV in the FDI during the heating of the digits gradually increased over and above the ambient temperature RBV. Hence, RBV as measured during this validation testing proved to be at a reasonable level in relationship to the minimum value and appropriate to the experimental conditions.

An infrared camera (A40 M, FLIR Instruments, Billerica, MA) measured skin temperature in the dorsal hand. The data was captured to a laptop through ThermaCAM Researcher (FLIR Instruments, Billerica, MA) software. For the purpose of the present analysis, the thermography sampling rate for data analysis was set at 7 Hz.

3. Study protocol

Subjects rested their hands on a 3/4 inch acrylic slab on a desktop for 1 min before typing for 9 min (Fig. 1). Hands were returned to the desktop for 10 min after typing. Adhesive paper markers were positioned underneath their fingers to insure that subjects placed their hands in the same location before and after typing. Thermographic images were taken of the hands for 1 min prior to typing, and at three intervals post-typing (0–2 min post-typing [T1], 3–5 min post-typing [T2], and 8–10 min post-typing [T3]). The camera was situated 1 m above the subjects' hands. Mean relative temperature changes in the dorsum (defined as an area encompassing the head of the ulna and radius and the metacarpal phalangeal joints) from baseline and mean RBV in the FDI from baseline were calculated for each post-typing period. Three trials at an ambient temperature of 22° ± 1 °C were run for each of the ten subjects, yielding 30 observations in total. Ten of the 30 trials were removed from analysis, due to operator error or loose NIRS probe. For subjects with replicate observations, preliminary analyses demonstrated no statistical difference in response between replicates within subjects. Therefore, univariate analyses are based upon data averaged within subjects for those with multiple observations.

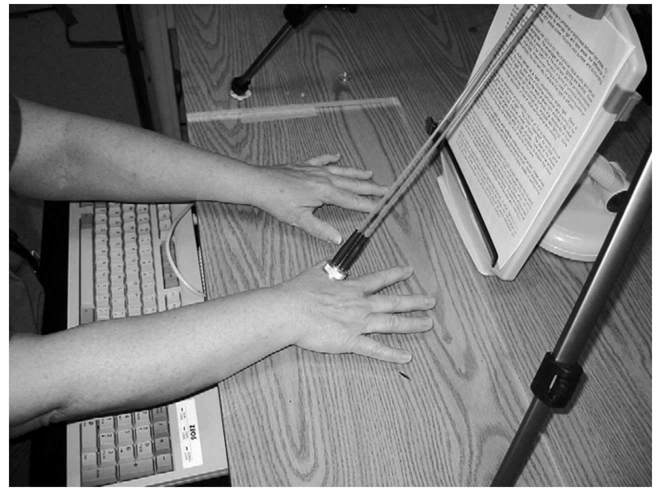

Fig. 1. Experimental setup showing NIRS probe at the first dorsal interosseous and acrylic slab on the desk surface.

The univariate relationship between RBV and temperature change was analyzed separately for the three post-typing time periods using Pearson's correlation coefficient. Mixed effects models were used to comprehensively assess the effect of words per minute (wpm) typed on RBV and temperature change over the three post-typing time periods relative to baseline; multiple observations per subject were accounted for in the covariance structure, and subject was included as a random effect. Excel (Microsoft Corporation, Redmond, WA), Stata (StataCorp LP, College Station, TX) and SAS (SAS Institute, Inc., Cary, NC) software were used in data analysis.

4. Results

4.1. Correlation between RBV and THand

The Pearson correlation coefficient between RBV and THand was determined as 0.75 ($p = 0.01$) at T1, 0.52 ($p = 0.12$) at T2, and 0.77 ($p = 0.01$) at T3. Although the two physiologic measures were reasonably well correlated both immediately and 8–10 min after typing, the response in both parameters was highly variable between subjects (Fig. 2).

4.2. Effect of typing speed on RBV and THand

The mean typing speed of these healthy subjects was 49.9 (SD = 8.2) wpm, with a range of 33.5–63.2 wpm. When stratifying at the mean typing speed, it was evident that overall change in both temperature and RBV after typing was more strongly affected when typing speed was greater than 50 wpm (Table 1). The overall slope of muscle RBV (relative to baseline) through the post-typing time periods increased at higher typing speeds, while typing at or below 50 wpm had minimal effect on RBV. For dorsal hand temperature change, those typing more than 50 wpm showed a faster overall post-typing temperature decrease toward baseline than for those typing at slower speeds (Table 1).

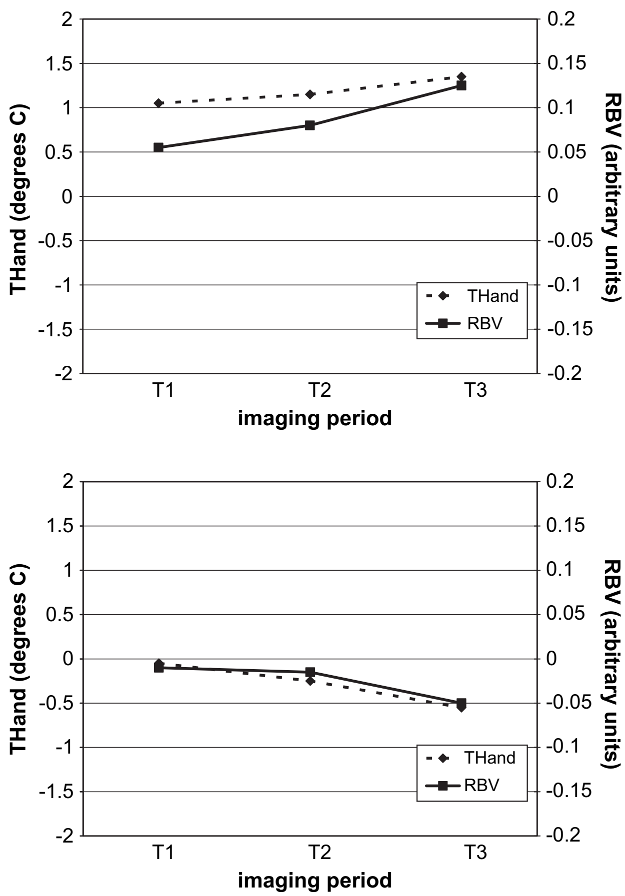

Fig. 2. Relative mean dorsal hand temperature (THand) and relative blood volume (RBV) after typing for 9 min in 2 of the 10 eligible subjects (see text for explanation of T1, T2, T3). NOTE: both measure relative to mean pre-typing (baseline) values.

5. Discussion

Moderate correlation between RBV in the first dorsal interosseus (as approximated through NIRS) and THand was found during the 10 min following a short typing task in a group of asymptomatic office workers. Additionally, post-typing RBV and THand appeared to be influenced by typing speed, normalizing more rapidly among subjects typing more than 50 words per minute.

Localized muscle metabolism may be measured through NIRS (Hamaoka et al., 1996; Boushel and Piantadosi, 2000), but that is beyond the scope of this paper. If repetition (wpm) is accepted as a surrogate for force (as there was no direct measure of the latter in this experiment), the results are suggestive of a metabolic component influencing both RBV and THand. Typing force in the wrist and forearm extensors has been estimated as 6.5–14% MVC (Fernstrom et al., 1994; Gerard et al., 1999; Simoneau and Marklin, 2001), with typing speeds in the latter experiment comparable to those in the current study. If increased RBV corresponds to increased blood flow, this would explain the greater decrease in THand since inflow of blood to the skin is effective in removing heat.

The literature is sparse in regards to muscle perfusion following computer work. Røe and Knardahl (2002) measured trapezius blood flow through percutaneous laser Doppler flowmetry (LDF) during and between a series of 3 min mousing trials. Speed of mouse movement did not affect blood flow during the 1 min recovery period between trials. It is likely that the shorter duration of exertion (3 min vs. 9 min) may have accounted for the lack of effect. It is also most likely that measures of blood flow in shoulder muscles indicate something quite different from intensity of hand activity. This is because the level of muscle activation in the trapezius is relatively low in keyboard tasks, whereas EMG signals in the digital musculature reflects a much higher level of activiation (Erdelyil et al., 1988; Dennerlein et al., 1998).

Reduced blood flow has been implicated in the pathophysiology of musculoskeletal disorders (Mackinnon and Dellon, 1988; Benjamin and Ralphs, 1994; Mackinnon and Novak, 1994; Larsson et al., 1998; Larsson et al., 1999; Pritchard et al., 1999; Brunnekreef et al., 2006). It is recommended that comparable studies be executed with symptomatic subjects. The present pilot study shows the feasibility of applying minimally invasive devices to measure perfusion in the hand after manual tasks. Given the acceptability and reproducibility of both measures, a next step would be the exploration of recovery patterns in injured or symptomatic subjects.

Table 1
Rate of change in relative blood volume (RBV) and relative skin temperature (THand) through three time periods (see text) after 9-min of typing, stratified by words per min (wpm).

	wpm $\leq$ 50 (8 Visits)	wpm $>$ 50 (12 Visits)
RBV	Slope = 0.0004, $p = 0.57$	Slope = 0.02, $p < 0.0001$
THand	Slope = −0.1, $p = 0.12$	Slope = −0.2, $p = 0.007$

6. Conclusions

THand and RBV in the FDI appear to be moderately correlated after a typing task of 9 min in asymptomatic office workers. This suggests that skin temperature may be indicative of underlying muscle perfusion. Typing speed appears to affect both measures, with faster typists showing overall increase in RBV and a faster overall decrease in THand than slower typists during a 10-min post-typing period. These physiologic changes may be indicative of a metabolic component, which should be taken into account in any NIRS or skin temperature measurement following dynamic exercise. Further research is necessary to confirm the study findings.

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