ISB2011 Brussels

PHYSIOLOGICAL CHANGES MEASURED DURING OFFICE AND INDUSTRIAL REPETITIVE HAND MOVEMENTS

[1] Ukadike C Ugbolue, and [1] Alexander C Nicol
[1]Bioengineering Unit, University of Strathclyde, Wolfson Building, 106 Rottenrow, Glasgow, G4 0NW, UK
email: u.c.ugbolue@strath.ac.uk; a.c.nicol@strath.ac.uk, web: www.strath.ac.uk/bioeng/

SUMMARY

Work related upper limb disorders (WRULDs) have existed since pre-historical times. Exposure of the hand to prolonged repetitive activities over long periods of time could contribute to WRULDs if precautionary measures are not observed [1]. To elucidate some of the underlying mechanisms associated with the development of (WRULDs), biomechanical studies designed to assess office related and industrial related occupations are essential. This study reports the physiological changes that occur to the hand during the performance of repetitive activities associated with office and industrial work.

INTRODUCTION

Hand movement is complex and comprises finger joint movements together with synergistic wrist motions [2-4]. Within the work setting, WRULDs rank highly in the UK, second only to back complaints. WRULDs cover a broad spectrum of physical and physiological responses that affect the nerves, tendons, muscles, soft tissues of the hand, upper limb and neck.

Although the human skeleton and soft tissues were not designed to meet constantly repetitive movements, static and awkward postures, high force exertion, vibration and extreme cold working environments; the muscles, tendons and bones have been known to adapt to almost any habitual posture and activity leaving the nervous system with no such adaptability. Thus, depending on the level of repetition and vulnerability of the soft tissues and nerves, physiological reactions in the upper limb characterised by symptoms could eventually manifest as signs of local swelling, temperature rise, crepitus or restricted movement [5, 6].

Though a substantial amount of research has been investigated from a biomechanical perspective, imaging and morphological perspective, rehabilitational perspective and neurological perspective, little is still known about the physiological changes the hand undergoes during and after the performance of a repetitive activity. It is therefore important to perform an investigation with physiological relevance that can provide useful information about hand motion representative of a set of activities within an occupational setting. The aim of this study was two-fold: (a) to report the changes in temperature at the hand as a result of the repetitive task, and (b) to determine the amount of local swelling occurring at the hand and wrist over the duration of the repetitive activity.

METHODS

Ethical approval from the University of Strathclyde was attained before the commencement of the experiments. Nine asymptomatic subjects aged between 23 and 33 years participated in the study. Two sets of repetitive activity experiments were performed namely: office activity experiment and an industrial activity experiment. All participants started the experiments with their hands placed in a neutral position (0º flexion-extension and 0º radio-ulnar deviation). A custom-made Lycra® flexible electrogoniometric glove (FEG) was worn by each participant during the performance of the experiment.

The office activity experiment covered three main areas: data entry, mouse clicking and dragging, and mouse scrolling. These tasks were chosen because they are considered the main activities involved during the operation of software. The duration of the office activity experiment was 30 minutes. A bilateral comparative study of the hands whilst not wearing a splint (FEG-only) and wearing a splint (FEG-Splint) was performed. The sequence of experiments (i.e FEG-only and FEG-Splint) was randomized. The industrial activity experiment was designed to imitate some of the hand movements carried out in industry. The movements were narrowed down to flexion and extension of the wrist and finger, repetitive grasp-release, and pinching. Each industrial repetitive task lasted for a period of 5 minutes and bilateral hand assessments were performed.

Hand temperature and hand volumetric measurements were obtained prior to the performance of both activity experiments. Hand temperature was measured using thermocouples connected to a Pico Technology Thermometer (Model: TC-08, Pico Technology, UK). The thermocouples were placed on the palmar side of the index finger and wrist. Precautionary measures were observed to ensure the index finger and wrist were within the neurological testing standards i.e. between 31°C and 33°C [7, 8]. A hand volumetric tank was used to ascertain the level of swelling caused to the hand after the performance of the repetitive activity. Prior to obtaining the hand volumetric measurements, the hand volumetric tank was immersed into a thermostatically controlled water bath set to between 41°C and 44°C. This ensured the temperature in the hand volumetric tank ranged between 31°C and 33°C.

Descriptive statistics were incorporated. ANOVA was used to determine significance between the left and right hands with respect to each activity experiment. Significance was set to p = 0.05. Power was set to 0.8 to determine sample size.

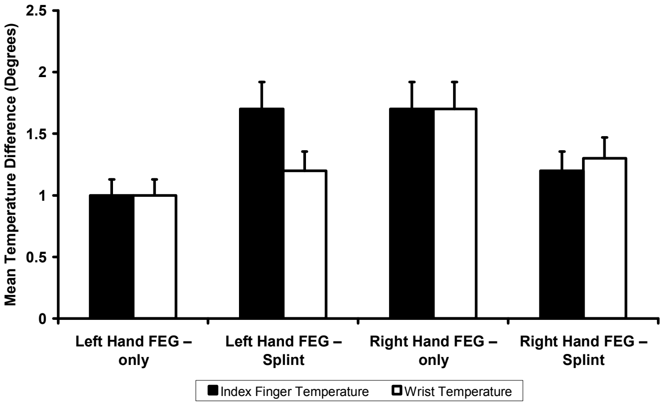

Figure 1: Average temperature difference for the left and right hands during FEG-only and FEG-Splint office activity experiments

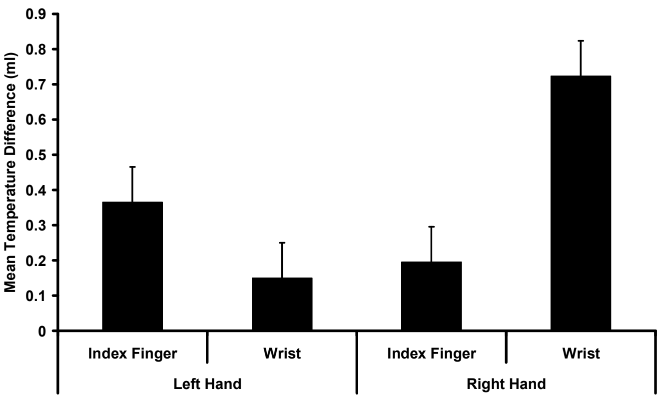

Figure 2: Left and right hand mean temperature difference at the index finger and wrist during the industrial activity experiment

RESULTS AND DISCUSSION

Both hands from all participants produced differences in hand volumetric measurements for the FEG-only and FEG-Splint experiments. For the FEG-only office activity experiment only seven out of nine participants produced hand volume increments. Also for the left and right hand FEG-Splint experiment seven out of nine subjects showed an increase in hand volume. Both results from the FEG-only and FEG-Splint experiments showed hand volume increments of over 2 ml. There were no statistical differences between the hand volume increments for the left and right hands ($p > 0.05$). Also with respect to the FEG-only and FEG-Splint experiments, there were no statistical differences between the initial and final hand volumes for the left and right hands ($p > 0.05$). Between experiment types both hands showed no statistical differences between the FEG-only and FEG-Splint experiments ($p > 0.05$). With respect to the FEG-only and FEG-Splint experiments seven out of nine subjects showed signs of hand temperature influencing the hand volumetric measurement. All subjects that showed a decrease in hand volume subsequently showed a decrease in final temperature and vice versa. On average differences between the initial and final temperatures were no larger than 2°C (Figure 1). The ambient temperature (mean ± SD) was 19 ± 1°C. The index finger and wrist temperature difference was no higher than ± 2° for each of the individual experiments.

For the industrial activity experiment, there was a low correlation between hand temperature and hand volumetric measurement for both left ($R^2 = 0.543$) and right ($R^2 = 0.622$) hands. Although there was a large variability across participants with respect to the rate of increase or decrease in temperature and hand volume, all participants that showed an increase in hand volume subsequently produced an increase in final temperature. Both the left ($p = 0.472$) and right ($p = 0.102$) hands showed no statistical differences between temperatures measured at the index finger and wrist. Also between both hands no statistical differences were observed with respect to the index finger temperature difference ($p = 0.817$) and wrist temperature difference ($p = 0.448$). Specifically, the left hand (mean ± SD) index finger temperature difference and wrist temperature difference were 0.366 ± 0.78°C and 0.15 ± 1.15°C while the right hand (mean ± SD) index finger temperature difference and wrist temperature difference were 0.196 ± 1.69°C and 0.723 ± 1.44°C (Figure 2).

CONCLUSIONS

The results from the hand temperature and hand volumetric measurements obtained from both sets of experiments indicate that these physiological changes are reliable outcome measures useful to evaluate the levels of swelling and temperature changes at the hand. More research is necessary and should be geared towards the development of more sensitive outcome measures useful for diagnosing WRULDs.

REFERENCES

1. Arndt P, *RSI Explained*, Hudson Publishing Services, Hawthorn, 1986.
2. Metcalf CD, et al., *IEEE Trans Biomed Eng*. 55(3): 1199-210, 2008.
3. Su FC, et al., *Clin Biomech (Bristol, Avon)*, 20(5): 491-1, 2005.
4. Li ZM et al., *Clin Biomech (Bristol, Avon)*, 20(2): 177-83, 2005.
5. MacLoughlin PVA, *"RSI" and the Work Related Upper Limb Disorders*, Peterborough Press, 1998.
6. Putz-Anderson V, *Editor cumulative trauma disorders: A manual…*, Taylor & Francis, London, 1988.
7. Denys EH, *Muscle Nerve*, 14(9): 795-811, 1991.
8. Dumitru D, *Nerve conduction studies*, Hanley & Belfus, 140-3, 1995.