Muscle functional connectivity during text entry using personal computers and smart-phones

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The aim of this study was to assess the muscle functional connectivity obtained from surface electromyogram (SEMG) during unilateral and bilateral texting on a smart-phone as well as standard text entry on a personal computer. Fourteen healthy adults participated in the study. The SEMG signals from the left and right proximal: cervical erector spinae, upper trapezius, lower trapezius and distal muscles: extensor carpi radialis, extensor digitorum, flexor digitorum superficialis and, abductor pollicis brevis were recorded. The normalized mutual information (NMI) was computed between muscle pairs as an index indicating functional connectivity. The NMI was lower for text entry using a PC compared with either bilateral or unilateral texting on a smart-phone (P<0.001). Furthermore, the NMI values were higher for proximal muscles compared with distal homonymous muscle pairs (P<0.05). The changes in functional connectivity during bilateral or unilateral texting may not be favourable in the long run.

Practitioner Summary: This study presents a new method assessing the functional connectivity among muscles during text entry. This approach may help to identify risks of developing work-related musculoskeletal disorders due to extensive use of handheld devices.

Keywords: Mutual information, Muscle activity, Multi-touch phone

1. Introduction
Musculoskeletal disorders are often reported among computer users (Waersted et al 2010). These disorders have tremendous personal and social impact leading to reduced quality of life as well as the risk of loss of work and social isolation (Schneider et al. 2010). Altered muscle coordination has been suggested to play an important role in the development of work-related musculoskeletal disorders (WMSD), see e.g. (Madeleine 2010, Samani et al. 2009). Especially, the modern IT era still poses the question of the link between the use of electronic devices and their relationship to WMSD (Waersted et al. 2010).

Previous studies have found an association between computer work and acute musculoskeletal pain (Andersen et al. 2008, Mikkelsen et al. 2012). For chronic musculoskeletal, such association is still a matter of debate. A causal relationship between computer work duration and chronic musculoskeletal complaints has been in the neck-shoulder region and upper extremities (Gerr et al. 2006, IJmker et al. 2007). On the other hand, more recent studies have challenged such relationship (Andersen et al. 2011, Waersted et al. 2010). Despite a possible lack of relationship between computer work and chronic musculoskeletal pain, many computer users report recurrent episodes of pain (Madeleine et al. 2013). This puzzling issue is nowadays reinforced by the extensive use of another type of handheld devices, i.e. smart-phones and the development of musculoskeletal symptoms (Berolo et al. 2011). The use of smart-phones and their influence on the muscular activity of the shoulder region has recently started to attract interest (Gustafsson et al. 2010, Gustafsson et al. 2011, Jonsson et al. 2011). To date, there is no information about the changes in muscle coordination when using smart-phones with respect to computer work. Muscle coordination can be studied by computing the normalized mutual information among muscle pairs and be used as an index of functional connectivity. Changes in muscle functional connectivity may be precursor of development of muscle discomfort and fatigue as such changes have been reported in response to e.g. eccentric exercise and long-lasting muscle contractions (Fedorowich et al. 2013, Johansen et al. 2013, Kawczynski et al. 2015, Madeleine et al. 2011). Particularly, increased functional connectivity between subdivisions of trapezius has been reported in presence of muscle soreness (Madeleine et al. 2011).
In this study, we investigated the functional connectivity among homonymous muscle pair surface electromyographic (SEMG) signals while performing unilateral and bilateral texting on a smart-phone compared with standard text entry on a personal computer (PC).

2. Methods

Fourteen healthy adults aged 23.4±3.2 years, 166.9±12.8 cm and 61.3±10.9 kg from universities in the Hong Kong vicinity volunteered to participate in the study. All volunteers were required to text on a smart phone and a PC. The study was conducted in accordance with the declaration of Helsinki, and was approved by the local ethics committee. The participants signed an informed written consent prior to the experiment. Text entry was thus performed 3 times for 10 minutes with 5 minutes pause in between. Text entry consisted of (i) bilateral texting with both thumbs; (ii) unilateral texting with the right thumb on a smart-phone (iPhone 4s) and (iii) bimanual texting on a PC. The tasks were performed in a randomized balanced order. The same children’s story in English was used for the 3 texting tasks.

The SEMG activities of left and right proximal muscles were recorded using SEMG electrodes (Ag/Ag Cl) during texting tasks. The recorded muscles were the cervical erector spinae (CES), upper trapezius (UT), lower trapezius (LT) and distal muscles: extensor carpi radialis (ECR), extensor digitorum (ED), flexor digitorum superficialis (FDS) and abductor pollicis brevis (APB). The SEMG signals were amplified, band-
pass filtered ([10–500 Hz]), sampled at 1.5 kHz using a 16-bit A/D converter (NoraxonTeleMyo system, Noraxon Inc., USA), and stored on disk. Then, the EMG signals were digitally band-pass filtered (Butterworth, 4th order, [10–500 Hz]). The normalized mutual information (NMI) values between each left and right muscle pairs were computed over 1-s epochs. The muscle pairs were left and right: APB, FDS, ED, ECR, LT, UT and, CES. NMI is a measure of muscle pair functional connectivity. The NMI varies between 0 (no functional connectivity) and 1 (complete functional connectivity) within the muscle pair (Madeleine et al. 2011). The computed NMIs were averaged for each texting tasks. A two-way repeated analysis of variance with task types and muscle pairs as independent factors was applied.

3. Results
The type of texting task played a significant role on the NMI values ($F_{2,26}=18.8$, $P<0.001$). The NMIs were lower for text entry with a PC compared with respectively unilateral and bilateral texting on a smart-phone ($P<0.001$ for both). The muscle pairs also played a significant role on the NMI values ($F_{6,76}=50.0$, $P<0.001$). The NMIs were in general lower for distal muscle pairs compared with proximal muscle pairs ($P<0.05$, Fig. 1).

Finally, there was a significant task types x muscles pairs interactions ($F_{12,156}=8.8$, $P<0.001$). The post-hoc analysis showed that for the left and right LT and CES, the NMIs were lower for text entry with a PC compared with respectively unilateral and bilateral texting on a smart-phone ($P<0.001$ for both, Fig. 1).

4. Discussion
The present study revealed the type of task used while performing text entry affected the functional connectivity of homonymous muscles. The functional connectivity was lower for text entry using a PC compared with either bilateral or unilateral texting on a smart-phone. Moreover, we reported for the first time difference in functional connectivity among proximal and distal homonymous muscle pairs (higher NMI values for proximal muscles).

Despite a lack of clear relationship between computer use and chronic musculoskeletal pain, recurrent episodes of pain are reported among computer users working with text entry for more than 20 hours per week (Madeleine et al. 2013). A preliminary study in a Canadian university has reported association between musculoskeletal symptoms and extensive use of handheld devices (Berolo et al. 2011). This association has been suggested to be linked with altered hand kinematics and increased SEMG activity (Gustafsson et al. 2010, Gustafsson et al. 2011). However, these studies did not assess possible changes in muscle coordination of the upper extremity. The NMI furnishes an index of shared neural information among muscles (Madeleine et al. 2011). As such, NMI has been shown to change in presence of muscle fatigue and muscle soreness (Fedorowich et al. 2013, Johansen et al. 2013, Kawczynski et al. 2015, Madeleine et al. 2011). To our knowledge, such analysis had never been conducted earlier during texting work. The increase in NMI during bilateral or unilateral texting on a smart-phone may not put the musculoskeletal system in a favourable situation since increase in NMI are reported in relation to muscle fatigue and soreness (Johansen et al. 2013, Kawczynski et al. 2015, Madeleine et al. 2011). The computation of NMI provided also novel knowledge concerning the dynamic changes among co-acting homonymous muscles delineating functional connectivity between left and right muscles. This opens further possibilities for delineating unilateral and bilateral pain. In conclusion, NMI as an index of functional connectivity among muscles may be a valuable tool for the assessment of the effects of intensive use of smart-phones and its possible relation to musculoskeletal complaints among users of handheld devices. Further studies investigating the changes in NMI in users of handheld devices with and without musculoskeletal complaints are warranted.

References


