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A sEMG-based Method for Assessing the Design of Computer Mice

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Abstract—**Computer users who experience repetitive wrist movements and awkward hand positions are prone to developing upper extremity disorders. Manufacturers have designed various ergonomic mice in response to complaints of pain and discomfort related to computer mouse use. The objective of this work was to validate the use of surface electromyography (sEMG) in assessing the design of non-keyboard input devices (computer mice). While holding the computer mouse in different grasp positions sEMG of the forearm and hand were recorded during a set of static tasks. The sEMG signal provided information regarding the level of muscle activity and the varied combinations of muscular effort needed to position the hand in a specified posture. A significant decrease in the level of sEMG activity was observed for the pronator muscles when subjects were tested using ergonomic computer mice. The sEMG-based method was validated to be sensitive to the impact of subtle differences in shape/design on the amplitude of the surface EMG data. We also proved a significant effect of hand size and grasp position on the level of muscle activity associated with different mice.**

Keywords— **EMG, ergonomics, musculoskeletal disorder, non-keyboard input devices, surface electromyography**

I. INTRODUCTION

In the information age, the rise of the Internet and society's growing dependence on the computer has brought about an epidemic of musculoskeletal disorders of the hand/wrist region [1]. Approximately 80% of computer users, whose job involves repetitive wrist movements and awkward hand positions, exhibit musculoskeletal dysfunction [2, 3]. Manufacturers have developed new ergonomic designs to improve the user's interaction with the computer. Ergonomic mice are designed to eliminate awkward posture, fit the contour of the hand, facilitate controlling/positioning of the mouse and decrease stress on muscles. Different designs and different hand sizes may require different postures and thus require different levels of muscle activity. The use of surface electromyography (sEMG) enables one to assess the designs objectively by measuring the amount of muscle activity needed for the hand to conform to the surface of the mouse. The advantage of sEMG over kinematics is that it provides physiological information. For instance, sEMG can detect activation of the pronator teres signifying pronation which is relevant because this movement causes compression of the median nerve and compromises blood flow. Additionally, sEMG provides information on muscle recruitment, timing patterns, muscle co-activation, fatigue and reflects the force produced by the muscle [5]. sEMG can also be used in a clinical setting as a diagnostic tool and help quantify neuromuscular dysfunctions.

Three factors that have not been controlled for in previous studies of computer mouse use are that all subjects: have their forearm supported, hold the mouse a specified posture and have their workstations setup identical to one another. As a result of these confounding factors it is difficult to differentiate whether the observed EMG patterns are due to varied hand postures, poor mouse design, or general mouse use.

The objective of this paper was to validate the use of sEMG to assess the design of computer mice.

II. METHODOLOGY

A. Subjects

Twenty-one healthy subjects were recruited in this study. Age ranged from 20 to 38 years with a mean and standard deviation of 26.3 +/- 5.8 years. Ten of the subjects were female. Subjects were recruited in order to cover a range of hand sizes from the 5th percentile of the female population to the 95th percentile of the male population [4].

B. Surface EMG equipment setup

Muscle selection in this study was based on several criteria. The first criterion was that the muscle of interest had to be detectable by surface electrodes. Secondly, the recorded activity was reproducible in any environment and eventually could be applied to a field investigation. EMG signals were recorded from the following muscles of the forearm and the hand: Extensor Carpi Ulnaris (ECU), Extensor Digitorum (ED), Pronator Quadratus (PQ), Pronator Teres (PT), Flexor Digitorum Superficialis (FDS), First Dorsal Interosseus (FDI), and Second Dorsal Interosseus (SDI) muscles. These muscles were chosen because they are the dominant muscles that control the hand to assume the three tested positions. Fig. 1 shows the position of the electrodes on the forearm and hand of one subject. A single and double differential electrode is

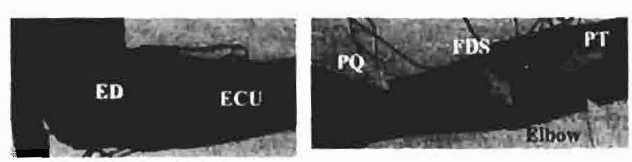

Fig. 1. Electrode placement on the forearm.

implemented based on the muscle of interest zone [5] (Fig.2). When measuring activity of the wrist/finger extensor muscles that are in close proximity with one another it is ideal to use double differential electrodes. The double differential also called three-bar electrode is preferred for localized areas because it removes neighboring muscle signals from the signal of interest [5].

Fig. 2. Single and double differential electrodes

Single differential electrodes are used when high selectivity is not a main concern (bicep, quadriceps, calf, etc.). The sEMG signals were detected with a Bagnoli- 8-channel system (Delsys Inc.). In order to provide an output range of 0.1-1 V (peak to peak) the sEMG signals were amplified with a gain of 1000 or 10,000. The sEMG signal was then filtered at a bandwidth of 20 to 450 Hz and sampled at 1024 Hz using a 12-bit Analog to Digital conversion board. The modified signal was then stored in computer memory.

C. Restraining Device

The amplitude of the sEMG signals recorded from the muscles of the forearm and hand are sensitive to the shoulder, forearm and hand position. Changes in the subject's posture may result in modifications of the sEMG signals that could potentially mask differences associated with using different computer mice [7, 5]. By constraining the subject's posture with a custom made device, we ruled out an important confounding factor and therefore, can link sEMG patterns to different computer mouse designs.

D. Computer Mice

The study was performed using the following four computer mice: Logitech Mouse, Logitech Mouse Man, Microsoft IntelliMouse and Microsoft IntelliMouse Pro. The Logitech Mouse and Microsoft IntelliMouse were chosen because they are commonly found at college computer terminals and are standard in desktop computer packages. The criterion for choosing the Microsoft IntelliMouse Pro was its ergonomic feature. Logitech was the first to provide slanted mice to reduce the flat, hands-down posture (forearm pronation) typical with mouse use. As a result we decided to test the Logitech Mouse Man.

E. Grasp Positions

In order to compare computer mouse designs it was necessary to specify hand positions that were the same across tests performed with different computer mice. Three static positions of the hand, corresponding to three different ways of holding the computer mouse, were tested: 1) rest [Fig. 3]; 2) side grip [Fig. 4]; 3) grab position [Fig.5].

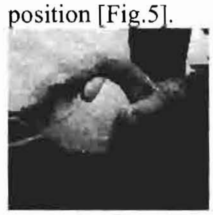

Fig.3. Rest

Fig.4. Side Grip

Fig. 5. Grab

F. Protocol

Before initiating the tests, the subjects were requested to become familiar with all the hand positions while holding each computer mouse. We introduced a pre-test accommodation maneuver in order to make the tests resemble the actual use of computer mice. These movements also allowed the subject to conform the hand to the computer mouse surface immediately before the test. The subject grabbed the mouse in one of the three positions described and made medial to lateral wrist movements on the plastic arm of the restraining device. Then after 15 s the subject stopped in the neutral position; the middle finger was aligned with the midline of the forearm. The hand rested in this designated position for approximately 10 s. All tests were performed sequentially on each computer mouse. The computer mice were tested in a random order.

G. Analysis

Once the recordings were performed, the root mean square (RMS) values of the surface EMG signals were estimated for all eight muscles [5]. Time intervals of 5 s were selected from the static tests by choosing sections where sEMG data had stable and constant amplitude.

The Friedman ANOVA statistical test [6] was used to test for differences in the RMS values associated with different computer mice. A post-hoc study, the Minimum Significant Difference (MSD) [6] was conducted to determine which mouse/mice significantly differ from one another.

III. RESULTS

Among the three tests used in this study, the Rest test appeared to be most effective in identifying significant differences ($p<0.05$) among the four computer mice. The Side Grip test appeared mildly sensitive to the different shapes of the mouse. The Grab test did not show noticeable differences among the computer mice. Hand sizes also had an effect on sEMG patterns across different mice. Subjects in the medium hand size group had the greatest number of muscle sites that were significantly different ($p<0.05$) among the computer mice. This was observed for the Rest position as well as for the Side Grip position, while low sensitivity was shown for all the hand size groups for the tasks associated with the Grab position.

Examples of RMS values obtained in the Rest position from two subjects are presented in fig. 6. Panels A and B show bar-plots of the RMS values for each muscle for the four computer mice tested in this study. The bars are grouped so as to facilitate the comparison of the muscular activity associated with different muscles: Extensor Carpi Ulnaris (ECU), Extensor Digitorum (ED), Pronator Quadratus (PQ), Pronator Teres (PT), Flexor Digitorum Superficialis (FDS), First Dorsal Interosseous (FDI), and Second Dorsal Interosseous (SDI). The order of the presentation of the muscles was chosen so as to locate muscles with similar function adjacent to each other. For each muscle, four bars represent the RMS value associated with Microsoft IntelliMouse, Logitech Mouse, Microsoft IntelliMouse Pro, and Logitech MouseMan (from left to right). Similar plots were obtained for each test. A qualitative analysis of these plots showed that lower levels of EMG activity were generally associated with the Microsoft IntelliMouse Pro and Logitech MouseMan ("new" designs) compared to the Microsoft IntelliMouse and Logitech Mouse ("old" designs). Friedman ANOVA test was used to determine whether the differences observed in fig. 6a and 6b and the other nineteen subjects were statistically significant. The statistical difference between contour designs for the whole sample of subjects was less than 0.05 for the PQ, PT, FDS and FDI muscles.

We further analyzed the data from the rest and side grip tests of the medium hand size group in order to quantify the percentage decrease in activity in those muscles that demonstrated significant differences between "old" and "new" designs. For the Rest test, the percentage decrease in EMG RMS values was equal to 69 % for the Pronator Quadratus muscle, 67 % for the Pronator Teres muscle, 48 % for the Flexor Digitorum Superficialis muscle, and 32 % for the Second Dorsal Interosseus muscle. For the Side Grip test, decreases in EMG RMS values were shown to be 28 % for the Extensor Digitorum muscle, 19 % for the Pronator Quadratus muscle, 38 % for the Pronator Teres muscle, and 23 % for the Flexor Digitorum Superficialis muscle.

IV. Discussion

In this paper, a sEMG-based method was developed to assess the effect of shape and design of computer mice on muscular activity patterns of the forearm in a controlled posture. The significant differences in sEMG data presented in the results section suggests that the "new" design computer mice were associated with a dramatic reduction in muscle activity level when compared with the "old" design computer mice. In particular, the Microsoft IntelliMouse Pro contour is designed in a manner that tilts the subject's palm reducing pronation and compression of the median nerve. Similar trends were observed for the Logitech MouseMan.

Wrist extension was another movement that was monitored because of its association with musculoskeletal disorders of the upper extremity [8]. Two muscles of interest that provide information regarding wrist posture were the Extensor Digitorum and the Extensor Carpi Ulnaris. The Extensor Digitorum muscle was the only one of the set, which was not sensitive to the design of the computer mice for all tasks. The Extensor Carpi Ulnaris, however, showed significant differences ($p < 0.1$) in sEMG patterns across the different designs of computer mice. This implies that the design of the computer mice required similar amount of wrist extension, but some required more ulnar deviation than others. The physiological impacts of these sustained postures are: ulnar deviation may result in damage to the ulnar nerve and wrist extension causes the extensor retinaculum to compress the tendons of the flexor muscles to the hand and the median nerve as they pass into the carpal tunnel.

In addition to shape and design of the mouse, the size of the contact surface relative to the subject's hand had an effect on the sEMG patterns of the forearm. Participants whose hand size was large relative to the contact surface of the mice needed a negligible amount of muscle effort to conform to different designs. Similarly, for individuals whose hand was smaller than the surface of the mouse no significant effect on sEMG RMS values was observed

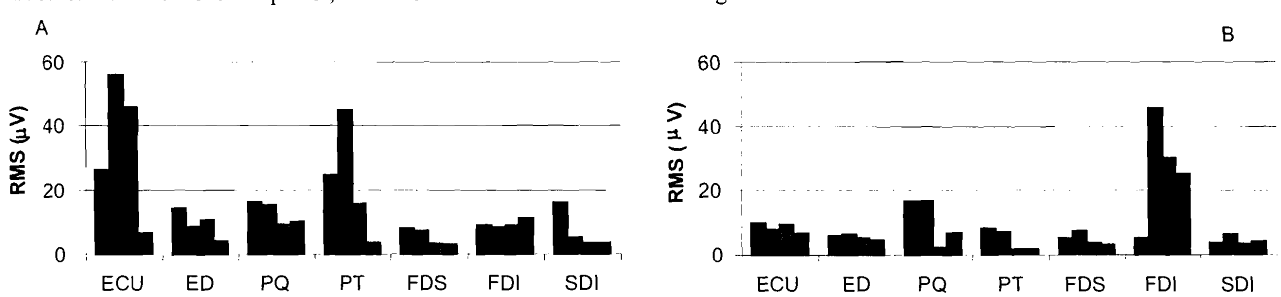

Fig. 6 RMS values of the seven muscles for the four mice tested for two subjects A and B. on the same mouse. Extensor Carpi Ulnaris (ECU), Extensor Digitorum (ED), Pronator Quadratus (PQ), Pronator Teres (PT), Flexor Digitorum Superficialis (FDS), First Dorsal Interosseus (FDI), and Second Dorsal Interosseus (SDI) muscles.

because the hand "sits" on top. Further analysis of the muscles from medium sized hands, using the Minimum Significance Difference Test, suggested subjects used varied combinations of muscular effort to place the hand in similar positions on the computer mouse. These findings suggest a computer mouse must be chosen according to the size of the hand of the subject as emphasized by recommendations of the Occupational Safety and Health Administration [1].

A key attribute of the proposed method was its ability to assess whether the computer mouse provided a comfortable resting surface for the hand. A mouse design that provided a resting surface would be associated with a decrease in muscle activity level. The three designated grasp positions represent the different degrees of contact between hand and surface of mouse that may occur during mouse use. An increase in the amount of contact corresponded to our method's increased sensitivity to the impact that subtle changes in the mouse design had on muscular activity. The positions tested may not be "natural" but they enable us to compare data across subjects. Further studies are necessary to determine whether or not the findings from these static tasks are representative of those that would be observed during dynamic computer mouse use.

The dramatic differences in EMG RMS values observed when comparing computer mice suggest a possible influence of the device's design on the incidence of disorders of the upper extremities. However, no direct relationship between EMG patterns and disorders of the upper extremities may be claimed at this time. Field investigations would need to be performed in order to address this issue.

V. Conclusion

The proposed method was able to detect distinct muscle patterns associated with different computer mice designs during static tests. Additionally, the grasp position and the subject's hand size had an effect on the level of muscle activity. The sEMG-based method has a potential role in the clinical setting as a supplement for qualitative observational methods and self-reports and in ergonomics as an assessment tool of other non-keyboard input devices.

Acknowledgment

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