Quantitative Study of the Effect of Wrist Rests on Muscle Fatigue During Keyboard Operation (Postprint)

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Abstract

By investigating the surface electromyography (sEMG) signals of three muscles in the forearm and back during text input using a standard keyboard, this study explores the practical efficacy of wrist rests in alleviating muscle fatigue, providing an ergonomics-based theoretical foundation for improving wrist rest design and typing posture. The experiment tested surface muscle signals from forearm and back muscles in 10 subjects under conditions of no wrist rest and with three wrist rests of different materials. The obtained data were normalized, and statistical analysis software SPSS was used to analyze the normalized data (NsEMG). Results indicated that the upper trapezius (UT) in the back was the most fatigue-prone muscle during keyboard operation, and its fatigue was not related to wrist rest material usage. However, significant differences ($P < 0.05$) in normalized EMG values of the flexor digitorum superficialis (FDS) were observed when using a fabric wrist rest.

Full Text

A Quantitative Study on How Wrist Rests Affect Muscle Fatigue During Keyboard Operation

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Abstract: This study investigates the actual efficacy of wrist rests in alleviating muscle fatigue by examining surface electromyography (sEMG) signals from three forearm and back muscles during computer keyboard use, providing ergonomic theoretical support for improving wrist rest design and typing posture. The experiment measured surface EMG signals from forearm and back muscles of ten participants under four conditions: no wrist rest and three wrist rests of different materials. After standardizing the data (NsEMG), SPSS was used for statistical analysis. Results indicate that the upper trapezius (UT) is the most fatigue-prone muscle during keyboard operation, and its fatigue level is independent of wrist rest use. However, using a cloth wrist rest produced a significant difference in the flexor digitorum superficialis (FDS) normalized EMG values ($P < 0.05$).

Keywords: Surface electromyography, keyboard wrist rest, data normalization, muscle fatigue

1 Introduction

With the widespread adoption of computers, increased usage time has led to growing reports of muscle discomfort among users, which can progress to musculoskeletal disorders over time. The primary cause of these symptoms is static muscle loading—prolonged muscle tension while maintaining a static working posture. The root cause of static loading across different muscle groups is the sustained use of "unnatural" working postures, often maintained unconsciously for extended periods. These unnatural postures ultimately result in physiological fatigue and disorders. Consequently, modern computer workers (e.g., programmers, office staff) frequently experience musculoskeletal discomfort and have a high risk of developing related disorders [1]. As an essential computer input device, keyboard usage is closely linked to user health. Prolonged typing in non-ergonomic postures significantly increases the risk of forearm and shoulder disorders [2-3]. Therefore, research on keyboard comfort and occupational injury prevention is critically important.

Recent domestic and international research on keyboard comfort and fatigue has focused on two main areas: the impact of keyboard design on comfort and fatigue, and the relationship between forearm EMG signals and muscle load [4].

Domestic studies have emphasized keyboard design. Research [5] found that ergonomic keyboards can reduce muscle load and improve subjective comfort when examining different keyboards and typing speeds. Study [6] investigated the relationship between keyboard parameter design and work comfort, redesigning key layouts to create a new ergonomic office keyboard. Another work [7] analyzed fatigue factors associated with standard keyboard use, proposing specific recommendations for layout and exterior design to improve operational comfort. Additionally, research [8] improved keyboard operation panels in flat workstations to enhance user comfort and convenience.

Surface electromyography (sEMG) measurement uses physiological polygraph instruments to record bioelectrical signals generated during neuromuscular activity via electrodes. These signals, which correlate with muscle activity state and reflect muscle function, have important applications in ergonomic design/evaluation, muscle function testing, and sports medicine research.

Regarding keyboard-related muscle strain, study [9] used questionnaires and computer simulation to identify high rates of muscle strain during continuous keyboard input in military settings, leading to musculoskeletal system damage. Studies [10-11] found that using height-adjustable furniture to support forearms reduces muscle load, with forearm support on work surfaces decreasing muscle activity more effectively than chair armrests. Research [12-13] demonstrated that forearm support affects musculoskeletal discomfort in computer users, though combining wrist rests with forearm support showed minimal additional effect. Study [14] found that both forearm support and wrist rests can reduce sEMG signals, but affect different muscle groups, with forearm support influencing more muscles. Research [15] specifically examined aging female workers, analyzing how keyboard posture (angle) affects EMG signals. Study [16] revealed that different working postures produce varying muscle fatigue levels, with arm flexion angle influencing fatigue. Meanwhile, study [17] analyzed muscle loading from a biomechanical perspective, using torque analysis to examine muscle forces across postures and comparing results with EMG signals. Study [18] approached the issue from repetition reduction, finding that not all ergonomic keyboards effectively reduce muscle strain—only those that sufficiently decrease movement repetition prove valuable.

These studies primarily focus on forearm support, with some indicating that wrist rests can influence muscle fatigue, though specific factors affecting muscle activity remain underexplored. This paper investigates wrist rest material effects through experimental design.

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2 Methods

2.1 Participants

Ten right-handed participants (5 male, 5 female) with a mean age of 23.2 ± 0.8 years, height of 170.1 ± 4.5 cm, and weight of 60.9 ± 7.8 kg were recruited. All participants were proficient keyboard users with no history of arm or back musculoskeletal disorders and no prior wrist rest usage. Before the experiment, participants familiarized themselves with the Xunluo keyboard and experimental procedures under researcher guidance to ensure error-free performance during formal testing. All participation was voluntary.

2.2 Apparatus

The experiment used a BIOPAC MP150 16-channel physiological polygraph system (BIOPAC Systems, USA) with ACK software for data acquisition and analysis. Additional equipment included a Xunluo standard keyboard, an adjustable office chair, three wrist rests of different materials (wood, silicone, and cloth), and a hand dynamometer.

2.3 Experimental Setup and Procedure

Prior to testing, participants adjusted their chairs to a comfortable position and fixed the keyboard location. Each participant ensured their arms were in a comfortable position, which was maintained throughout the experiment.

Muscle Selection: Based on literature [16], three muscles were selected for EMG recording from the right arm: flexor digitorum superficialis (FDS), flexor carpi ulnaris (FCU), and upper trapezius (UT).

Electrode Placement: Participants contracted each muscle to locate its center point. The positive and negative electrodes were placed approximately 5 cm from the center point on either side, with the ground electrode positioned on the nearest bony landmark. After identifying the three locations, hair was removed using a depilatory, the skin was cleaned with medical alcohol to remove oils, and after drying, the surface was gently abraded to remove dead skin cells [19] before electrode attachment.

Maximum Voluntary Contraction (MVC): Before formal testing, participants performed three MVC trials for each muscle. Participants gripped the dynamometer with their right hand, gradually building to maximum force over 5 seconds, then slowly releasing. After 10 seconds of rest, the next trial began. The peak sEMG value from the three trials was recorded as the MVC value for data normalization.

Baseline Measurement: Following a 1-minute rest period, participants' resting sEMG signals were recorded for 1 minute to establish a baseline.

Typing Task: Participants performed text input on the Xunluo keyboard in a standardized posture, maintaining both high accuracy and maximum typing speed. Each participant completed four experimental conditions: (1) no wrist rest, (2) cloth wrist rest, (3) wood wrist rest, and (4) silicone wrist rest. Each condition lasted 10 minutes, with sEMG signals recorded from the three muscles (FDS, FCU, UT) at four time points (every 2 minutes, with 1-minute recording duration). Participants rested for 5 minutes between conditions [20]. All typed text was saved for accuracy and speed verification. Before each trial, participants rated comfort levels for body regions using a subjective scale (0 = no discomfort to 10 = extreme discomfort), with post-trial ratings also collected.

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3 Data Processing

Raw sEMG signals were processed using ACK software to obtain non-negative sEMG values. To improve accuracy, data were normalized using the formula:

$$\mathrm{NsEMG} = \frac{\mathrm{sEMG}_{\mathrm{observed}} - \mathrm{sEMG}_{\mathrm{rest}}}{\mathrm{sEMG}_{\mathrm{mvc}} - \mathrm{sEMG}_{\mathrm{rest}}}$$

where NsEMG represents normalized surface EMG. Normalized data effectively reflect participant muscle fatigue levels [21].

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4 Results

4.1 EMG Results

One-way ANOVA was performed on NsEMG values across conditions (no wrist rest, cloth, wood, silicone) using SPSS, with significance set at $P < 0.05$. Levene' s test confirmed homogeneity of variance (all $P > 0.05$). The F-test results were: FDS: $F(3,36) = 4.207$; FCU: $F(3,36) = 0.893$; UT: $F(3,36) = 0.202$. For FDS, P 0.05 rejected the null hypothesis, indicating significant differences across conditions. No significant differences were found for FCU or UT.

Table: Intergroup Differences in FDS Muscle

Comparison	Mean Difference (I-J)	Significance
1-2	7.00900*	0.001
2-1	-7.00900*	0.001
1-3	-4.45838*	0.070
3-1	4.45838*	0.070

Note: Conditions 1-4 represent no wrist rest, cloth wrist rest, wood wrist rest, and silicone wrist rest respectively. indicates $P < 0.05$.*

The table shows significant differences between no wrist rest and cloth wrist rest ($P = 0.001 < 0.05$), with higher NsEMG values in the no-rest condition, indicating greater FDS fatigue. No significant differences were found between no rest and wood ($P = 0.070 > 0.05$) or silicone ($P = 0.212 > 0.05$), suggesting not all wrist rests reduce FDS EMG values. A significant difference between cloth and silicone wrist rests ($P = 0.033 < 0.05$) indicates silicone is least effective for reducing FDS fatigue.

As shown in [Figure 1: see original paper], cloth wrist rest produced the lowest NsEMG values across all three muscles, indicating minimal fatigue. Without a wrist rest, FDS and FCU showed elevated EMG values, while UT values remained relatively high across conditions.

Comparisons between the mean plot and significance table confirm that cloth wrist rest reduces FDS NsEMG values without significantly affecting the other two muscles. Wood and silicone wrist rests showed no significant differences from the no-rest condition, though cloth differed significantly from silicone. During keyboard operation, UT is the most fatigue-prone muscle, with minimal variation across conditions. FCU shows noticeable differences between rest conditions, with wrist rests reducing fatigue to some degree. Different wrist rest materials also affect FDS fatigue levels.

4.2 Subjective Scale Results

SPSS analysis of subjective scale data revealed significant differences: right upper arm $F(3,36) = 4.134$, $P = 0.13$; right forearm $F(3,36) = 2.923$, $P = 0.47$; upper back $F(3,36) = 3.600$, $P = 0.23$. Participants reported greatest overall fatigue in the no-rest condition and least fatigue with cloth wrist rest, consistent with sEMG findings [Figure 2: see original paper].

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5 Discussion

Lower FCU EMG values with wrist rest use likely occur because unsupported wrists maintain an angled position during typing, deviating from a neutral posture and increasing EMG activity, consistent with literature [16] showing elbow angle affects fatigue and [11] demonstrating wrist height influences EMG values. Cloth material significantly reduced FDS EMG values compared to silicone, possibly because its softer composition maintains the arm in a more comfortable state. Alternatively, cloth' s compressibility may provide lower effective support height, which could be more appropriate for wrist positioning and thus reduce muscle fatigue.

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6 Conclusion

Based on continuous keyboard typing experiments and subjective scale results:

1. During keyboard text input, the upper trapezius (UT) is the most fatigue-prone muscle, and its fatigue is unaffected by wrist rest use.
2. Not all wrist rests reduce forearm fatigue. Cloth wrist rests significantly decrease muscle fatigue, while wood and silicone show minimal effect.
3. Wrist support height and material softness likely represent two key factors affecting forearm fatigue.

These findings recommend cloth wrist rests for prolonged keyboard users to reduce fatigue and lower musculoskeletal disorder risk. Future research should investigate optimal wrist support height and material properties.

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Note: Figure translations are in progress. See original paper for figures.