Ergonomic evaluation on wheel-scrolling motions for reducing the risk of musculoskeletal disorders

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Abstract: The objective of this study is to find characteristics of wheel scrolling motions and to control such characteristics to observe whether or not subjective symptoms associated with musculoskeletal disorders were reduced. Wheel scrolling motions were obtained by a high-speed video camera and changes in joint angles and subjective evaluations for muscular loads were monitored. Susceptible characteristics of musculoskeletal disorders were enumerated by analyzing dynamic changes in finger joint angles and two mouse prototypes to reduce such characteristics were produced for evaluation. As a result, muscular loads were higher when subjects performed scroll-up motions (SU) than scroll-down motions (SD). Unnecessary finger motions with potentially awkward posture were also found during SU motions. Muscular loads during SU motions seemed related to the awkward postures of the finger. All in all, it was revealed that such awkward posture lead to the muscular loads.

Keyword: scroll wheel, mouse, musculoskeletal disorders, repetitive motions, finger motions

1. Introduction

In recent years, the mouse has become the standard peripherals with evolution of the graphical user interfaces. However, intensive use of the mouse may cause heavy muscular loads, yielding the risk of musculoskeletal disorders. According to the Aptel et al [1], musculoskeletal disorders were the type of disease that related to the physical activity generated stress on the musculoskeletal system. Tendonitis and low back pains are common musculoskeletal disorders. Lee et al [2], Korte et al [3] and Chen et al [4] evaluated muscular loads by making mouse prototype to reduce the influence by the risk factors for continuous musculoskeletal disorders. Additionally, Aptel et al [1] indicated that the repetitive motion was one of the risk factor of musculoskeletal disorders as well as the sustained muscular loads. Since wheel-scrolling motions contain dominating repetitive motions during the use of the mouse, such repetition has been considered as the other risk factors for musculoskeletal disorders. Although a number of studies on scroll wheels (SW) have been conducted to obtain the improvement of the usability, there have been no studies thus far to deal with finger motions during SW operations. Hence, the present study focused on the index-finger motion during using SW. The objective of this study is to find characteristics of wheel scrolling motions and to control such characteristics to observe whether or not subjective symptoms associated with musculoskeletal disorders were reduced. Two mouse prototypes were produced for reducing such characteristics along with for subjective evaluation of muscular loads.

2. Preliminary Experiment

According to the survey, it was revealed that subjects had a certain level of muscular loads when performing scroll up motions (SU) than scroll down motions (SD).As a preliminary experiment, we obtained wheel-scrolling motions by a high speed camera and changes in joint angles of the index-finger were obtained. Figure 1 shows the joint location of the hand taken by a high-speed video camera during SW operations.

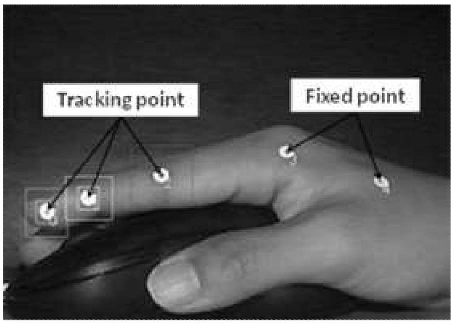


Fig.1 Measurement of index-finger joint angles

Figure 2 shows typical example of changes in finger joint angles during SU motion. In Figure 2, positive values in %MMA represent levels of joint extensions and negative values represent levels of joint flexion. White area in Figure 2 denotes the wheel rotating phase and shaded area denotes the rewinding phase. As shown in Figure 2, SW operations required more finger extensions than finger flexions. The MP joint was flexed after overextension at the middle of rewinding phase. Such distinctive finger motion patterns were not found in SD operations. Muscular loads for the extensor muscle has found to be the potential symptom for musculoskeletal disorders [2], we focused upon the maximum extension angles of the MP joint indicated on the basis of anatomical point of view. Such a large level of joint angles at the MP joint seemed prominent during SU operation than SD operation, suggesting that muscular loads caused by large changes in the MP joint angles were higher during SU operations. In conclusion of the preliminary experiment, two factors, i.e., overextension of the MP joint and the total levels of angular displacement of the MP joint were chosen as factors affecting muscular loads.

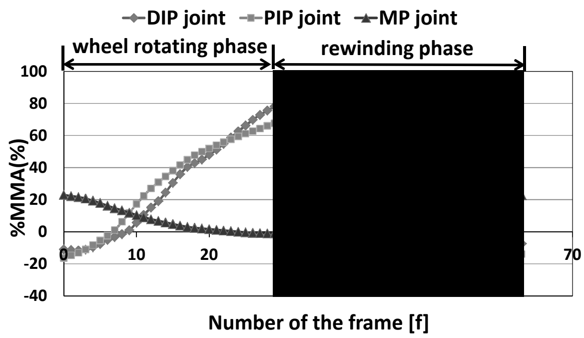


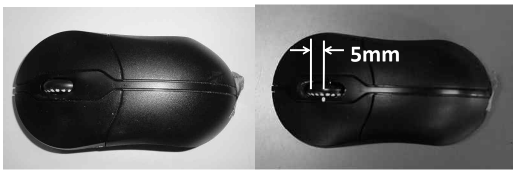
Fig.2 Transition of %MMA in SU

3. Prototype Mouse Experience

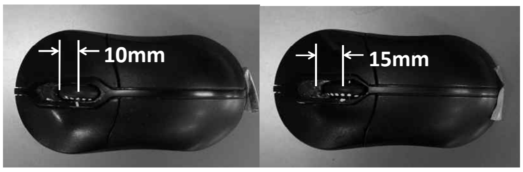
Two mouse prototypes were produced in order to empirically clarify the relationship between two characteristics and muscular loads. Prototype A was meant for reducing overextension of the MP joint and prototype B for reducing total level of angular displacement of the MP joint. Subjective muscular loads were also obtained by the experiment.

3-1.Mouse prototype A

Mouse prototype A was based on the mouse used in the preliminary study. A total of three prototype along with the standard mouse was made such that the location of the SW was shifted backward directing to the rear part of the mouse, shown in Figure 3.



(a) (b)



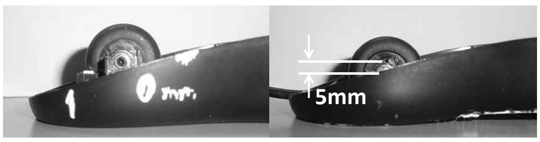
(c) (d)

Fig.3 Prototype mouse A

(a) standard mouse (b)A-5 (c)A-10 (d)A-15

3-2.Mouse prototype B

Mouse prototype B was based on the same mouse used in the preliminary study. The prototype was modified such that the location of the SW was lowered to the bottom of the mouse, shown in Figure 4.



(a) (b)

Fig.4 Prototype mouse B

(a) standard mouse (b)B-5

3-3.Experimental procedure

A total of 14 male subjects participated in the experiment. The subject placed his index finger at the top of the left button of the mouse. Then the subject moved the SW continually to the direction specified prior to the experiment. A high-speed camera was used to monitor the motion of the index finger during SW operation.

Experimental condition for testing prototype mouse A included four levels of mouse type (standard, A-5, A-10, and A-15) and two levels of rotating directions (SD, SU). Operation was finished after 10 scrolling motions and the subject reported his subjective muscular discomfort levels at his hand and forearm by using a 7-level evaluation form.Experimental condition for testing prototype mouse B included two levels of mouse type (standard, B-5) and two levels of rotating directions (SD, SU). As for prototype mouse B, only 5mm difference was given, thus number of SW motions was increased to 20, 50, and 100 scrolling motions for exhibiting extra muscular loads. The experiment, therefore, was splited into three sessions in separate days.

3-4.Results

3-4-1.Mouse prototype A

Figure 5 shows levels of overextensions of the MP joint, expressed as the percentage of the maximum movable angles (%MMA), by the mouse prototype. The %MMA was averaged in five scrolling motions. Figure 6 shows changes in subjective muscular discomfort levels by the mouse prototype. As shown in Figure 5, overextension levels of the MP joint was gradually decreased as the location of the SW moved backward. However, subjective muscular loads became higher when the location of the SW moved backward. This contradictory result implied that overextension did not necessarily reflect on the subjective muscular loads during SU motions.

3-4-2.Mouse prototype B

Figure 7 shows the maximum %MMA during SU operations by the mouse prototype. The %MMA was obtained by averaging five scrolling motions. Figure 8 shows changes in subjective muscular discomfort levels by the mouse prototype.It was revealed by figure 7 that the lowered SW location in 5mm reduced the maximum %MMA of the MP joint. Figure 8 shows that subjective muscular loads were lower when the subject used the mouse prototype B-5. These two results implied that the level of joint angle displacement may be associated with subjective muscular loads. It was also revealed that SW operation in a longer period of time showed significant decrement of discomfort levels by using mouse prototype B-5.

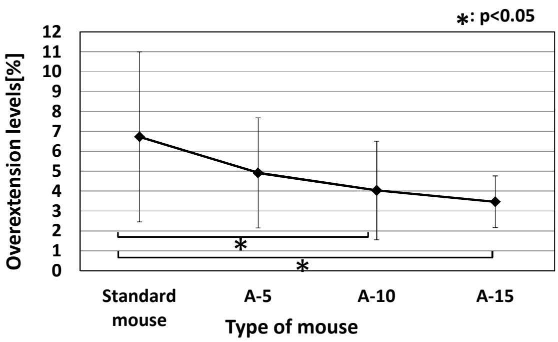


Fig.5 Overextension levels by mouse type

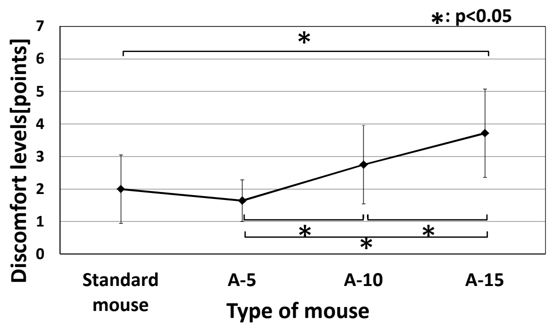


Fig.6 Discomfort levels by mouse type

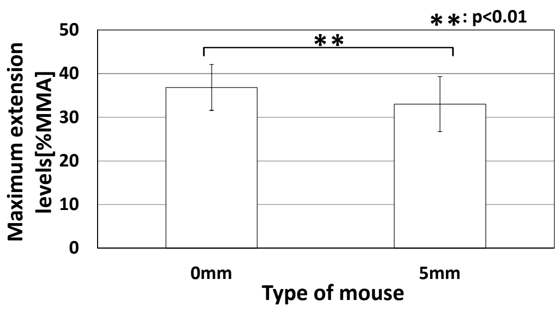


Fig.7 Maximum extension levels in SU motion by mouse type

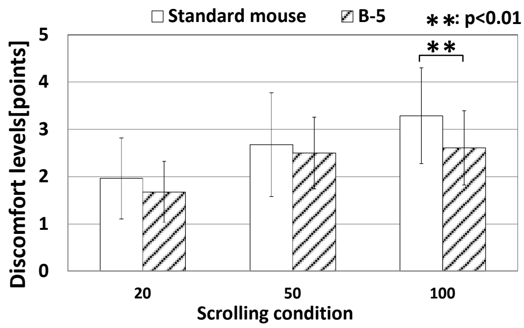


Fig.8 Discomfort levels by mouse type

4. Conclusion

In our study using prototype mice, a significant maximum extension angle at the MP joint at the index finger was in agreement with the increment of discomfort levels. Further quantitative research would offer indices in designing comfortable was of scroll wheels.

Acknowledgement

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