마우스 사용시 전완지지대의 인간공학적 평가

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Ergonomic Evaluation of a Forearm Supporter for a Mouse

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Abstract : Traditionally, keyboards have been one of the most frequently used input devices for information processing using computers. As most computers adopt the Microsoft Windows for their operating system, however, the usage of mouse has recently increased to a great extent. Moreover, the mouse has been used as the leading input device in such areas as industrial design and computer aided design. Excessive uses of mouse may cause a severe pain and fatigue on neck and upper limb due to the intensive and repetitive use of corresponding muscles, which renders a decline in efficiency and leads to musculoskeletal disorders. The main purpose of this study is to find the best working conditions to prevent musculoskeletal disorders when using mouse in a neutral posture. Utilizing electromyogram amplitude and Borg's scale, the role change and strength imposed on the muscles were measured and analyzed with and without the forearm support concerned. Also investigated were the effects of changes in elbow forearm supporter.

초록 : 최근 산업현장 전반에 걸쳐 작업관련성 근골격계질환의 발생이 증가하고 있으며 그 피해의 규모도 점점 확대되어 가고 있다. 뿐만 아니라, 과거에는 주로 중량물 취급 또는 단순반복적인 작업등에 의해서 발생하였지만 최근에는 대부분의 생산현장에서 컴퓨터를 이용한 자동화가 이루어지고 가정용 PC가 널리 보급됨에 따라 컴퓨터의 사용과 관련한 근골격계질환의 발생이 증가하고 있다. 많은 사람들이 컴퓨터의 사용과 관련한 불편함 및 통증을 호소하면서 각종 보조도구들이 개발 및 판매되고 있으나 대부분 그 효과가 입증되지 않은 상태로 사용되고 있어서 오히려 이러한 보조도구의 사용이 근골격계질환의 발생위험성을 더 높아지게 할 수도 있다.
본 연구에서는 마우스 사용시 보조도구로 이용되는 전완 지지대의 사용에 대하여 그 효과를 실험을 통하여 평가하였다. 본 실험에서는 Borg's scale과 근전도(Electromyography : EMG)를 이용하여 측정하였으며 분산분석(Analysis of Variance : ANOVA)을 통해 유의성을 검증하였다. 측정자료를 분석한 결과 전완지지대의 사용이 오히려 작업의 효율을 떨어뜨리고 작업자가 느끼는 불편함 및 통증의 정도와 근육의 활동량을 증가시킴을 알 수 있었다.

Key Words : musculoskeletal disorders (MSDs), visual display terminal (VDT) syndrome, forearm supporter; electromyogram (EMG), borg's Scale

1. Introduction

With the recent advances in information technology, personal computers have been popularized and become an essential part of our daily lives and their usefulness has widely been recognized. On the other hand, the wide spread and excessive uses of personal computers have caused many work related disorders, such as musculoskeletal disorders (MSDs) and visual display terminal (VDT) syndrome. Especially, work related MSDs (WMSDs) has recently been paid a particular attention from research community mainly due to its significant impacts on the computer workers' operational efficiency. WMSDs is a syndrome characterized by discomfort, impairment, disability, or persistent pains in joint, muscles, and other soft tissues[1]. It is also characterized by the symptoms of pain, numbness,

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and stiffness, and may eventually lead to weakness[2]. There has been a great deal of research efforts to examine the nature of WMSDs and investigate preventive measures under various working conditions[2-6].

Traditionally, keyboards have long been one of the most frequently used input devices for information processing using computers. Recently, however, the usage of mouse has significantly grown with the wide adoption of Microsoft Windows for operating systems. Furthermore, the mouse has been used as the primary input device in such tasks as data processing with spreadsheet programs and computer aided design. It has been reported, in a recent study by Andersen[7], that computer workers are exposed to an increased risk for neck and upper limb pains and even a higher risk for forearm and elbow pains when the weekly usage of mouse exceeds 20 to 25 hours. Using inadequate computer desks and playing mouse operation-intensive computer games, ordinary users are also exposed to high risks of MSDs. Many investigators[8-14] observed symptoms similar to carpal tunnel syndrome in experiments with computer users using mouse excessively, and coined the term 'mouse syndrome'[15]. It is also noted that MSDs may not only occur in industrial settings but also in daily lives. It will thus be meaningful to investigate preventive measures for tasks involving frequent uses of mouse. The main purpose of this study is to find the best working conditions to prevent MSDs when using mouse in neutral posture. Utilizing electromyogram (EMG) amplitude and Borg's scale, the role change and strength imposed on the muscles were measured and analyzed with and without the forearm support concerned. Also investigated were the effects of changes in hand position. This article is organized as follows: First, the method of experiment is described in the next section. Experimental results are then summarized and their statistical significance is tested with the base of analysis of variance (ANOVA). Conclusions and discussion follow in the last section.

2. Experimental Methods

Subjects and Equipment:

Without the history of illness or injury on the shoulder and upper limbs, 11 adult males participated in the experiments. Flexcomp version 1.51B from Thought Technology Ltd. was adopted to measure the EMG signal and to collect the data, and the forearm supporter used in the experiments is capable of altering height of supporter. And the forearm supporter and mouse in the experiment were in figure 1.

Experimental Design:

The experiments were conducted with two factors, the existence of forearm supporter and the elbow. Treatment levels for each factor are summarized in Table 1. The height of forearm supporter may change by 5cm. Treatment level N for height of forearm supporter represents the neutral posture of elbow, and N-5 and N+5 are the height of forearm supporter below and above the neutral posture by 5cm, respectively. Task completion time, Borg's scale, and surface EMG data were collected at each design point. Task contents and posture were strictly controlled by the experimenter, and the same computer and mouse were provided.

Procedure:

(1) Participants were asked to click an object appearing at an arbitrary position on the monitor, and were completed after 500 objects appeared one session.

(2) In each experimental design point, the pain in muscles and joints on the right shoulder and upper limbs were recorded using Borg's scale[16] for 10 subjective rating regions including trapezius, deltoid, biceps,

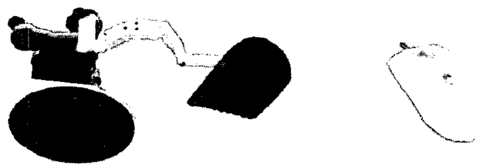

Fig. 1. Forearm supporter and mouse used in the experiment

Table 1. Experimental Factors and Treatment Levels

Factors		Without the Forearm Supporter	With the Forearm Supporter
Height of Forearm supporter	N-5	X11	X21
	N	X12	X22
	N+5	X13	X23

supinators, hand, shoulder joint, triceps brachii, elbow joint, extensor carpi radialis, and wrist, and task completion times were also recorded.

(3) Based on the previous studies and subjective ratings taken in Step (2), the surface EMG was measured by attaching electrode on four muscles, trapezius, deltoid, biceps, and extensor carpi radialis.

(4) Steps (1)~(3) were repeated for each experiment design point, and the experiments are randomly conducted.

3. Experimental Results and Analysis

Experimental results of task completion times, subjective ratings on Borg's scale, and surface EMG data were analyzed, and their statistical significance was tested using ANOVA.

Task Completion Times:

The ANOVA table is shown in Table 2, and it might be concluded that the main and interaction effects were insignificant at the significance level of 5%. It was observed that the task progress tended to be accelerated, as the participants got familiar with a specific task.

Subjective Ratings on Borg's Scale:

The experimental results of subjective ratings on Borg's scale are summarized in Table 3. The AVOVA indicated that the main and interaction effects on the Borg's scale of four individual muscles were insignificant. But the only exception was that main effect of the height of forearm supporter on the Borg's scale of deltoid was significant (Table 4). However, the main effects of forearm supporter and height showed a significant effect on the overall average rating score (Table 5). It was observed from Table 3 that tasks without the forearm supporter in a neutral posture rendered the lowest rating score in this experiment. Most participants had were experienced difficulties with the manipulation of mouse with the forearm supporter mainly because they are not familiar with the forearm supporter.

Table 2. ANOVA Table of Task Completion Times

Source	DF	SS	MS	F	P-value
Supporter	1	5546	5546	2.73	0.104
Height of Supporter	2	6763	3381	1.66	0.198
Interaction	2	11001	5501	2.71	0.075
Error	60	121895	2032		
Total	65	145205			

Table 3. Average of Borg's Scale Score for Individual Muscles

Muscles	Without the Forearm Supporter			With the Forearm Supporter		
	X11	X12	X13	X21	X22	X23
Trapezius	1.68	1.55	1.95	1.50	1.68	1.68
Deltoid	1.64	1.36	2.32	1.68	1.59	1.59
Biceps	1.36	1.23	1.55	1.00	1.14	1.14
Supinators	2.18	1.05	1.55	2.05	1.59	1.59
Hand	1.64	1.14	1.59	1.64	1.50	1.50
Shoulder Joint	1.68	1.64	2.05	1.91	1.82	1.82
Triceps Brachii	1.41	1.45	1.86	1.82	1.27	1.27
Elbow Joint	2.09	1.14	1.64	2.00	1.36	1.36
Extensor Carpi Radialis	2.55	1.32	2.27	2.36	1.77	1.77
Wrist	2.73	1.45	2.23	2.68	2.23	2.23
Total	2.36	1.64	2.64	3.00	2.36	3.3

Table 4. ANOVA Table of Borg's Scale Score for Deltoid

Source	DF	SS	MS	F	P-value
Supporter	1	0.06	0.06	0.05	0.817
Height of Supporter	2	7.64	3.82	3.42	0.039
Interaction	2	0.28	0.14	0.13	0.882
Error	60	66.95	1.12		
Total	65	74.94			

Table 5. ANOVA Table of Borg's Scale Score for Upper Limbs

Source	DF	SS	MS	F	P-value
Supporter	1	7.33	7.33	5.88	0.018
Height of Supporter	2	10.64	5.32	4.26	0.019
Interaction	2	0.03	0.02	0.01	0.988
Error	60	74.86	1.25		
Total	65	92.86			

Surface EMG Measurement:

The surface EMG for four muscles was measured after 30 minutes rest to obtain more accurate data.

The main and interaction effects were significant for the surface EMG of trapezius while none for biceps. Only the main effect of elbow height was significant for the surface EMG of extensor carpi radialis. Finally, the main effect of elbow height and the interaction effect were significant for the surface EMG of deltoid. The ANOVA tables are shown in Tables 6 through 9, and the statistical significance of factors on muscular activities is summarized in Table 10. The average of individual surface EMG data is presented in Table 11. Muscular activities of trapezius and extensor carpi radialis were minimized without the forearm supporter in a neutral posture. For deltoid, tasks with the forearm supporter in a neutral posture induced the least muscular activities. Muscular activities of biceps showed no differences over the experimental conditions.

Table 6. ANOVA Table of Surface EMG Data for Tapezius

Source	DF	SS	MS	F	P-value
Supporter	1	2852	2852	20.16	0.004
Height of Supporter	2	4871	2436	17.22	0.003
Interaction	2	3437	1718	12.15	0.008
Error	6	849	141		
Total	11	12009			

Table 7. ANOVA Table of Surface EMG Data for Deltoid

Source	DF	SS	MS	F	P-value
Supporter	1	49.5	49.5	1.74	0.235
Height of Supporter	2	486.3	243.2	8.56	0.017
Interaction	2	461.0	230.5	8.11	0.020
Error	6	170.5	28.4		
Total	11	1167.3			

Table 8. ANOVA Table of Surface EMG Data for Biceps

Source	DF	SS	MS	F	P-value
Supporter	1	10.30	10.30	4.01	0.092
Height of Supporter	2	0.19	0.09	0.04	0.964
Interaction	2	0.92	0.046	0.18	0.840
Error	6	15.43	2.57		
Total	11	26.84			

Table 9. ANOVA Table of Surface EMG Data for Extensor Carpi Radialis

Source	DF	SS	MS	F	P-value
Supporter	1	36095	36095	5.23	0.062
Height of Supporter	2	281162	140581	20.36	0.002
Interaction	2	48271	24136	3.50	0.099
Error	6	41430	6905		
Total	11	406958			

Table 10. Experimental Factors and Their Statistical Significance

	Trapezius	Deltoid	Biceps	Extensor Carpi Radialis
Forearm Supporter	Significant	Insignificant	Insignificant	Insignificant
Height of Supporter	Significant	Significant	Insignificant	Significant
Interaction	Significant	Significant	Insignificant	Insignificant

Table 11. Average of Surface EMG Data for Individual Muscles

		Without the Forearm Supporter	With the Forearm Supporter
Trapezius	N-5	21.655	24.347
	N	20.2695	31.6395
	N+5	27.9245	106.36
Deltoid	N-5	16.695	10.555
	N	16.82	13.64
	N+5	17.105	38.615
Biceps	N-5	9.23115	7.70575
	N	9.45735	8.0568
	N+5	9.8371	7.20385
Extensor Carpi Radialis	N-5	789.6045	744.0695
	N	310.191	575.3685
	N+5	713.4235	822.8475

4. Conclusions and Discussion

Though following conclusions might be confined to a specific model since the experiments were conducted with the forearm supporter concerned, but observed results were as follow: First, task completion times might be affected by psychological factors rather than the experimental design factors. Second, the subjective ratings on Borg's scale to examine the pain in four individual muscles on shoulders and upper limbs indicated that the elbow height affected the pain only in deltoid muscles and the existence of forearm supporter is insignificant for all muscles. However, the overall average of subjective rating scores is affected by both main effects to some extent. It was observed that the least pain is rendered when tasks are conducted without the forearm supporter in a neutral posture. Third, the analysis of surface EMG data revealed the statistical significance of factors on muscular activities. While muscular activities of deltoid and extensor carpi radialis were affected only by the elbow height, both main effects were significant for muscular activities of trapezius. In addition, interaction effects turned out to be significant for muscular activities of trapezius and deltoid. Examining the average of surface EMG data, it might be concluded that muscular activities of trapezius and extensor carpi radialis are least when conducting tasks without the forearm supporter in a neutral posture. On the other hand, tasks with the forearm supporter in a neutral posture induced the least muscular activities of deltoid. On the whole, the participants complained of difficulties in manipulating mouse with the forearm supporter. This was mainly because the forearm supporter hindered the movement of upper limbs to handle the mouse. Therefore, it would be desirable to develop a forearm supporter which helps the movement of upper limbs.

Most participants were unfamiliar with the forearm supporter, and thus subjective ratings and surface EMG measurements might have largely been influenced by involuntary muscular reflexes. To analyze and assess the muscular strength and pains more accurately, it might be necessary to train participants to familiarize with the forearm supporter. Finally, the location of extensor carpi radialis may be altered due to the wrist adduction and abduction when moving the mouse, which in turn changes the length and location of deltoid and biceps. This phenomenon might influence the surface EMG. measurement data. The experiments of this study were executed using only one mouse and forearm supporter. It is recommend that types of mouse and supporter would be important factors in further experiment.

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