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Original article

Changes in Musculoskeletal Discomfort and Postural Alignment According to the Height of the Worktable When VDT Activities were Performed by Patients in a Wheelchair with C6 and T6 Spinal Cord Injuries

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Abstract

Purpose: This purpose of the study was to identify the effects of computer worktable heights on musculoskeletal changes in the neck and upper extremities and postural alignment in patients with C6 and T6 level spinal cord injuries. ***Materials and Methods:*** The participants in the present study were patients diagnosed with AIS A. The level of the worktable was set 5 cm below the elbow, at elbow level, and 5 cm above elbow level. Subjective musculoskeletal discomfort (Borg-RPE) was measured at the end of the experiment. To compare the side posture for the wheelchair axle, patients with C6 and the T6 injuries were selected to measure the angle of the centerline for the axle, the tip of the chin, and the postural change for the tragus of the ear. ***Results:*** First, in the patient with C6 injuries, the Borg-RPE scores decreased when the worktable height was 5 cm above the elbow, whereas, in the patient with T6 injuries, the Borg-RPE scores decreased when the worktable height was decreased. Second, in the patient with C6 injuries, the chin tip and tragus of the ear were close to the center of the wheelchair when the height of the worktable was 5 cm above the elbow in the lateral position. In the patient with T6 injuries, there was no difference in lateral posture according to the height of the worktable. ***Conclusion:*** To reduce musculoskeletal system discomfort in patients during video display terminal (VDT) work, it is necessary to set the worktable height higher than the elbow standard for patients with C6 injuries and lower than elbow height for patients with T6 injuries. In the case of posture change, in the patient with C6 injuries, the higher the worktable height, the more the neck and head changed from forward flexion to a neutral posture.

Keyword: ***Borg-Scale, Muscle activity, Spinal cord injury, Visual display terminal, Worktable height***

Introduction

Spinal cord injury has become one of the leading causes of disability in the world, occurring every year in one out of 1,000 people [1]. The level of most spinal cord injuries is the thoracic spine in 42.7% of the patients, followed by the cervical spine in 38.5%, and the lumbar spine in 17.8%. Approximately one-third of the patients with spinal cord injuries also have tetraplegia, wherein approximately 50% of the patients have complete injuries [2-4]. In the case of complete motor paralysis, trunk muscle weakness and paralysis below the injured area result in a straight neck, thoracic and lumbar kyphosis, and the pelvis in a posteriorly tilted position when sitting in a wheelchair [5-7]. Most of the activities of patients with spinal cord injuries involve the repeated use of the upper limb in a seated position in a wheelchair for a long time, resulting in an increase in the load on the upper limb, and eventually, musculoskeletal pain [8-9]. Accordingly, the musculoskeletal pain rate due to spinal cord injury was reported to reach 70% when performing daily activities, leading to a negative perception of the patient's quality of life and independence [10].

In the international classification of health, participation is defined as "participation in life situations" for spinal cord injury [11]. However, in the case of spinal cord injuries, there are restrictions on self-care, mobility, family life, interpersonal activities, communication, and participation in community activities [1-13]. In addition, most patients with spinal cord injuries experience psychological frustration after the injury, among which, frustration due to motor dysfunction, frustration with difficulties in daily life, and frustration in the interruption of communication with society are reported to be the biggest [14]. About 84% of the patients with spinal cord injuries are male, with an average age of 32.4 years. Most spinal cord injuries occur in active adolescents and older people [15-16]. Therefore, the adaptation to daily life and rehabilitation from spinal cord injury are the most important practical problems experienced after an injury. At the same time, the difficulties experienced during this process and the desire for rehabilitation have great significance for individuals [17-19]. For this reason, initial rehabilitation planning is the most important, and client-centered rehabilitation treatment is required from the time of the injury [20-21].

For people with disabilities, the use of a video display terminal (VDT) becomes a vehicle for daily activities and leisure activities, including work performance and social communication [22-23]. However, the increased use of VDT causes VDT-related syndrome in the users [24-25]. For patients with spinal cord injuries, the risk of musculoskeletal problems resulting from the use of VDTs would be higher than in normal people due to the difficulty in diminishing the static load or controlling their respective postures, wherein patients with spinal injuries would have different postures in which they feel comfortable [26-28]. Patients with spinal cord injuries vary in function depending upon the degree of motor impairment, and more people use wheelchairs due to the loss of higher trunk control in cervical and upper thoracic injuries than in lower thoracic and lumbar injuries [29-30]. In addition, among the factors that cause VDT-related symptoms, the height of the workbench is a variable that causes musculoskeletal problems in patients with spinal cord injuries using a wheelchair [31-32]. Most ergonomic studies on VDT have been conducted with normal subjects and may not be suitable for patients using wheelchairs [26-33].

Therefore, it is necessary to study the working environment and correct posture for the height of the VDT worktable for patients with cervical and upper thoracic spinal cord injuries. The purpose of this study was to determine the effect of computer worktable heights on neck and upper limb musculoskeletal discomfort and postural angles in patients with C6 and T6 spinal cord injuries.

Material and Method

The participants in the study were one patient with a C6 spinal cord injury and one with a T6 spinal cord injury. Both were diagnosed with AIS A. The level of the worktable was set 5 cm below the elbow, at elbow level, and 5 cm above elbow level. The participants performed the experiment sitting in the wheelchair used by the patient.

The computer used for the study had a 21-inch monitor with adjustable levels, where the top of the monitor was set at the patient's eye level. The distance from the monitor to the eyes of the patient was set at 70 cm [34]. Standard keyboards were used for the experiment. The keyboards were placed on each patient with a default keyboard slope angle of 3° [35]. For the patient with a C6 injury, a bend-type typing device was used [22]. The participants were asked to type for two minutes. A metronome was used to eliminate the effects resulting from the different typing speeds of the participants. The participants were asked to use their left hand to enter "A," "S," "D," and "F" keys, while their right hand was supposed to type the "J," "K," and "L" keys simultaneously. The sequence of letters in the typing task of each patient was determined randomly. Five minutes of rest was allowed for each patient upon the completion of each typing task in the given posture. The participants were instructed not to put their wrists and forearms on the worktable to eliminate the effects of supporting the lower arms during the given typing task [36].

The Borg-RPE (rating of perceived exertion) scale was employed to measure musculoskeletal discomfort in the neck and upper limbs. The Borg-RPE scale spanned the range from "no pain at all" to "maximal pain." The scores ranged from 6 to 20 points, with lower scores indicating less discomfort [32-37]. The scores were obtained from self-reported checklists distributed to each patient upon completion of the experiment. To compare the lateral posture of the wheelchair axis, each change in the subject's wheelchair axis centerline and chin tip, wheelchair axis centerline, and ear tragus was measured (**Figure 1**).

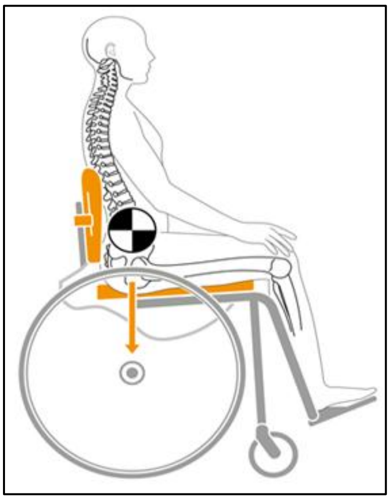

Figure 1: Axle and COG

Statistical Analysis

The subject's musculoskeletal discomfort was expressed as a Borg-RPE score. The lateral posture angle was measured in the second of three experiments. The angle was measured in a picture taken at one minute of typing. ImageJ 1.52 version (National Institutes of Health, USA) was used for the angular measurements.

Results

The subjects were male and the general characteristics of age, height, weight, eye height in sitting position, elbow height in sitting position, onset, ASI A, and the level of injury are summarized in Table-1.

Table 1: General characteristics of the participants

	C6 subject	T6 subject
Age (years)	26	60
Height (cm)	172	169
Weight (kg)	72.5	70
Eye height in sitting position (cm)	131	114
Elbow height in sitting position (cm)	74	65
Onset	20/08/2016	14/08/2018
ASIA	A	A
Level of injury	C6	T6

On the Borg-RPE scale, the patient with a C6 injury scored 19 points when the worktable was 5 cm below elbow height, 15 points at elbow height, and 13 points when it was 5 cm above elbow height. The patient with a T6 injury scored 6 points when the worktable was 5 cm below elbow height, 13 points at elbow height, and 20 points when it was 5 cm above elbow height (Table-2).

Table 2: Borg-RPE scales

		C6 subject	T6 subject
-5	cm	19	6
0	cm	15	13
+5	cm	13	20

Table-3 shows the angle of posture according to the height of the worktable (**Figures 2,3**).

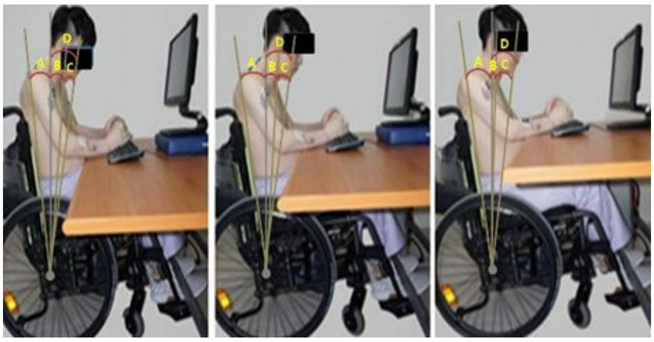

Figure 2: Comparison of C6 subject's lateral posture according to the heigh of the worktable

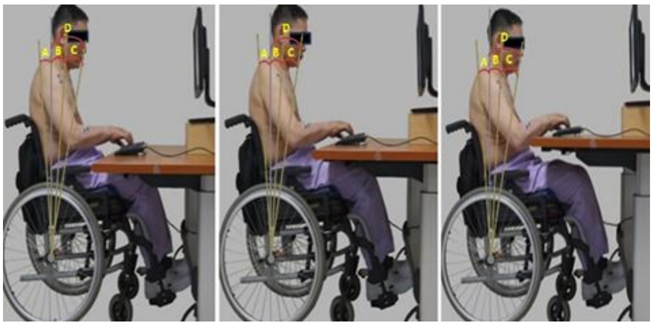

Figure 3: Comparison of T6 subject's lateral posture according to the heigh of the worktable

Discussion

In the present study, we investigated the effects of varied keyboard positions and worktable heights on musculoskeletal discomfort and postural changes in patients with spinal cord injuries who were asked to perform a typing task on a VDT, with the goal of identifying the proper keyboard position. Based on this, we wanted to present a VDT worktable suitable for patients with cervical and upper thoracic spinal injuries.

In the patient with a C6 injury, the Borg-RPE scale scores decreased as the worktable height increased, and in the patient with a T6 injury, the Borg-RPE scale scores decreased as the worktable height decreased. Our results were similar to the findings of

Table-3: Angle of side posture

Subject	Worktable height		Angle to centerline							
			A		B		C		D	
C6	-5	cm	6.90	°	4.65	°	3.01	°	7.66	°
	0	cm	7.44	°	4.23	°	3.13	°	7.36	°
	+5	cm	8.57	°	1.35	°	4.40	°	5.57	°
T6	-5	cm	3.59	°	5.44	°	5.39	°	10.83	°
	0	cm	3.98	°	4.51	°	5.55	°	10.06	°
	+5	cm	4.50	°	4.26	°	6.00	°	10.26	°

A: Wheelchair centerline and scapular superior angle
B: Wheelchair centerline and ear tragus angle
C: Ear tragus and chin tip angle
D: Wheelchair centerline and chin tip angle

A previous study involving patients with upper thoracic spinal cord injuries who were using wheelchairs. That study sought to identify subjective preferences and the degree of fatigue when working on a VDT with various worktable heights, similar to our objective. Their subjects preferred the desk height level of 5 cm below the elbow [26-32]. The height of the worktable affects the position of the shoulder joint and scapula, and the height of the worktable causes muscle fatigue in the deltoid and upper trapezius muscles by abducting the shoulder joint and elevating the scapula. Maintaining repeated VDT tasks in these positions for long periods increases musculoskeletal discomfort in the user.

However, in the patient with a C6 injury in this study, the Borg-RPE scale scores decreased as the height of the worktable increased. In the case of a complete C6-7 injury, it is difficult to balance in a sitting position due to the loss of finger function and flexion of the wrist joint and the loss of motor function of the torso and lower limbs below the injury level [3-22]. In particular, patients with cervical spine injuries are more affected by the external environment due to lower trunk control than patients with thoracic spine injuries [30-38].

The wheelchair centerline and ear tragus angle, and wheelchair centerline and chin tip angle were compared in patients with C6 and T6 injuries. In the case of the patient with a C6 injury, the chin tip and tragus of the ear were close to the center of the wheelchair when the height of the worktable was 5 cm above the elbow in the lateral position. In the patient with a T6 injury, there was no significant difference in the posture of the neck and head according to the height of the worktable. This is because when working at a low-height desk, the shoulders and trunk are tilted forward, and muscle activity increases while discomfort and pain occur [39]. Therefore, in the case of cervical spine injuries in which the control power of the trunk and upper limbs decreases, the safety of the trunk increases as the worktable height increases, so that the subject's neck and head change from anterior flexion to neutral, and the sensitivity to musculoskeletal discomfort is considered to decrease. These results are different from the previous ergonomic VDT working posture, adjusting the proper worktable height for the cervical cord injured is recommended.

The workstation height is recommended to be within 25° of shoulder joint flexion, 15 - 20° of shoulder joint abduction, and 90° of elbow flexion in ergonomic terms, and 90° to 120° of elbow flexion is recommended by the Occupational Safety and Health Administration (OSHA) [40-41]. However, the criteria for the height of these worktables vary from study to study. In this study, the effects on Borg-RPE values and the posture of patients with C6 and T6 injuries were confirmed based on the height of the worktable suggested in previous studies.

In particular, in the case of cervical spine injuries, internet use was found to have a significant relationship with quality of life, emotional state, physical state, functional area, economic life, and self-respect [42]. However, limb paralysis caused by cervical spine injury is more serious than paralysis caused by thoracic spine injury [43], and when using VDT, cervical spine injury caused by limb paralysis requires the use of auxiliary tools and changes in the work environment. However, most of the research on computer work environments has been based on normal people and those with thoracic spine injuries, and most cervical spine injury studies are case studies. However, given that the assistive technology approach is widely applied to patients with cervical spine injuries, this study is important in that objective experiments were conducted on VDT worktable heights for cervical spine injuries.

The study had several limitations. First, the typing task was a simplified short-run task, which was very different from actual work performed using a VDT. Second, when analyzing the center of gravity relative to the axis of the wheelchair, only simple angles were presented. Third, psychological features according to the degree of spinal cord injury were not considered. Therefore, future research should consider the accuracy and psychological aspects of work performance.

Conclusions

In the patient with a C6 injury, the higher the working table height, the lower the musculoskeletal discomfort in the neck and upper extremities, and in the patient with a T6 injury, the lower the working table height, the less the musculoskeletal discomfort. When comparing the lateral posture of the wheelchair axis, in the patient with a C6 injury, the higher the worktable height, the closer the ear tragus and chin tip came to the centerline of the wheelchair. In the patient with a T6 injury, the posture of the neck and head was not significantly affected by the change in the height of the worktable. Thus, in the patient with a C6 injury, for the lateral posture, the higher the position of the worktable, the more the neck and head changed from a forward bending posture to a neutral position.

Declarations

No ethics approval and consent to participate

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Competing contributions

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Abbreviations

COG: Center of gravity

SCI: Spinal cord injury

VDT: Visual display terminal

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Author contributions

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