The Relationship between the Active Cervical Range of Motion and Changes in Head and Neck Posture after Continuous VDT Work

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Abstract: This study investigated the relationship between the active cervical range of motion (ROM) and changes in the head and neck posture after continuous visual display terminal (VDT) work. Twenty VDT workers were recruited from laboratories. The active cervical ROM of the participants was measured and videotaped to capture the craniocervical and cervicothoracic angles using a single video camera before and after VDT work. Pearson correlation coefficients were used to quantify the linear relationship between active cervical ROM measurements and the changes in the craniocervical and cervicothoracic angles after continuous VDT work. Active neck extension ($r=-0.84$, $p<0.01$) was negatively correlated with the mean craniocervical angle, and active neck flexion ($r=-0.82$, $p<0.01$) and left lateral flexion ($r=-0.67$, $p<0.01$) were negatively correlated with the mean cervicothoracic angle.

Key words: Cervical range of motion, Forward head posture, Long-term VDT work

Introduction

Poor posture is a common finding in physical therapy evaluations of patients with musculoskeletal complaints. The upper spine has been of particular interest to physical therapists treating disorders of the cervical and thoracic spine, the shoulder, and the temporomandibular region¹⁾. Many studies have attempted to identify head and neck postures that would reduce the risk of developing musculoskeletal pain of the neck and trunk²⁾.

The effects of the head and neck posture depend on the characteristics of a task³⁾. Visual display terminal (VDT) work typically involves remaining for a long time in a fixed position⁴⁾. Sezto *et al.*⁵⁾ found that individuals increase their forward head posture during VDT work, which involves an excessive anterior position of the head in relation to the theoretical plumb line perpendicular to the body's center of gravity, and can be considered similar to a protracted position of the cervical spine in which the lower cervical vertebrae are flexed in a forward glide and the upper cervical vertebrae are extended⁶⁾. This

causes a shortening of the posterior cervical and suboccipital muscles, lengthening and weakness of the anterior neck muscles, weakness of the scapula retractor muscles, and increased stress on the ligaments. The imbalances created by this position decrease muscular efficiency, and extra muscular action is needed to hold the head and neck in a stable position⁷⁾. Fredriksson *et al.*³⁾ reported that neck and shoulder pain was associated with VDT work in both men and women.

The head and neck posture of an individual can influence soft-tissue relationships in the cervical region⁵⁾. Neck postural changes can lead to neck pain via associated changes in cervical movement patterns, so it is necessary to evaluate cervical spine kinematics in both normal subjects and in patients with neck pain⁸⁾. Reductions in the cervical range of motion (ROM) have implications for the safety and efficiency of functional activities and lead to a loss of corrective or protective reactions, which contribute to a loss of balance in the soft tissue extensibility around a joint^{9, 10)}. A study has also shown that a decreased cervical ROM is associated with poor sitting postures, such as forward head posture¹⁰⁾. ROM losses can occur from inactivity and structural changes of the

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tissues in the cervical spine, and result in an increase in connective-tissue density, shortening of collagen tissue, and muscle fibrosis¹¹).

Goniometer-based systems such as the CROM can reliably measure uniplanar cervical spine movement¹²) and the Spin T is a three-dimensional goniometer with demonstrated accuracy and reliability for measuring cervical spine mobility¹³). Norton and Ellison¹⁴) also obtained good reliability and validity for Metrecom measurements on inanimate objects with known dimensions¹⁴). The head and neck posture when performing computer work has been commonly evaluated in the sagittal plane based on two-dimensional posture or movement¹⁵).

The association between forward head posture and neck pain has not been clearly defined, but a mechanism for the development of neck pain from habitual postures has been demonstrated⁵). Studies of the effect of sustained forces have indicated that a single posture should not be sustained for longer than 1 h¹⁶). McGill and Brown¹⁷) have shown that 20 min in a position of sustained loading can induce creep in soft tissues, with recovery taking longer than 40 min. Sustained forces produce time-dependent deformation and adaptations in soft tissue¹⁷). Short-duration stretching produces temporary deformation of soft tissues, but 1 h of stretching might be sufficient for long-term soft-tissue adaptations¹⁶). Therefore, a long-term habitual posture can result in abnormal loading of ligaments and muscles that might ultimately contribute to a reduction in the cervical ROM and to the development of neck pain⁸). Yoo *et al.*¹⁸) suggested that it is necessary to frequently change the sitting posture when performing long-term VDT work.

Examining the active cervical ROM forms an important part of patient evaluations¹⁹) and has been studied in primary researches of work-related neck and upper-limb disorders^{3, 5, 20}). Therefore, primary studies need to investigate the association between cervical ROM and poor habitual posture. The purpose of this study was to elucidate the relationship between the active cervical ROM and changes in cervical posture after continuous long-term VDT work.

Methods

Subjects

Twenty VDT workers (6 males, 14 females) aged 26–32 yr were recruited from laboratories in the Biomedical Science and Engineering Center. The subjects used computers for 7.0 ± 3.5 h/d (mean $\pm$ SD) as full-time workers (Table 1). Subjects with conditions that might have affected the mobility of the cervical spine injury or with pain or neurologic deficits in the neck and upper extremities during the previous year were excluded

Table 1. Subjects demographic information

Variable	Description
Gender	6 males, 14 females
Age	28.6 ($\pm$ 4.2) yr
Height	1.67 ($\pm$ 0.05) m
Mass	64.3 ($\pm$ 5.6) kg
Hours of VDT work	7.0 ($\pm$ 3.5) h/d

Fig. 1. Cervical Range of Motion instrument (CROM).

ed from the study. The subjects were selected from 24 laboratories using consecutive sampling.

Instrumentation

Cervical range of motion instrument

All cervical ROM measurements were taken with a Cervical Range of Motion instrument (CROM) (Performance Attainment Associates, St. Paul, Minn) (Fig. 1). The CROM attaches to the subject's head and contains 2 gravity goniometers and 1 compass goniometer. Sagittal and frontal plane gravity goniometers measure flexion-extension and lateral flexion respectively. Rotation is measured by the compass goniometer in conjunction with a magnetic yoke. Intra-test reliability of the CROM instrument was 0.89 and inter-test reliability was 0.91. The cervical ROM measurements of participants were measured before typing work. The measurements were taken by an investigator. Each participant began this phase by sitting in a standard folding chair and being fitted with the CROM. Before the ROM measurements were taken, all participants were asked to self-correct their posture by demonstrating the most erect posture they could achieve. Subjects were asked to place the CROM device on their head like a pair of glasses^{9, 12}). The same procedure was completed for the opposite side, flexion, extension, and lateral flexion in a randomized order.

Video motion analysis system

Each subject was videotaped to capture the sagittal pro-

Fig. 2. Craniocervical angle (A) and cervicothoracic angle (B).

file of the upper body using a single video camera. The measured value of craniocervical and cervicothoracic angles was recorded by a digital camera and video motion analysis software SIMI[®] Twinner Pro (SIMI Reality Motion Systems GmbH, Unterschleissheim, Germany) was used to analyze the kinematic data. This system had a sampling rate of 30 Hz for digitalization. The lens aperture was set at F-stop 8, zoomed to 70 mm, and the camera placed so that the center of the lens was 3 m from the subject, with the subject in approximately the center of the lens so as to reduce lens error, and with the camera perpendicular to the ground, parallel to the facing plane of the subject, and approximately level with the subject's pelvis to minimize parallax error. Two plumb lines were suspended from the ceiling to provide a vertical and magnification reference.

Markers for the craniocervical and cervicothoracic angles were placed by the same investigator on the outer canthus of the eye, the tragus of the ear, the C7 spinous processes, and the midpoint of the greater trochanter. The craniocervical angle was defined as that between the line from tragus to the outer canthus of the eye and the line from the tragus to the C7 spinous process; cervicothoracic angle was defined as that between the line from the C7 spinous process to the tragus and the line from the C7 spinous process to the greater trochanter (Fig. 2)²¹. Yellow foam balls of 2.5 cm diameters were used as skin markers. This all procedures were always carried out by the same investigator in order to reduce the variability.

Procedures

All subjects performed VDT work for 1 h using the

same computer workstation, in which the LCD monitor was inclined backwards by 20°, the eye was 0.8 m from the monitor, and the top of the monitor was 20° below eye level. An adjustable-height table and a chair with no backrest were used to set the initial sitting posture so as to ensure that the hips and knees were flexed by 90°. A 5-min adjustment period was provided, during which subjects were instructed to select a workstation configuration (including the table height, keyboard position, and position and inclination of the document holder) that felt most comfortable and natural to them. The same configuration was maintained for the duration of the 1-h work period. The subjects performed selected VDT work in the Hansoft program of Korea¹⁸. Each 1-h period of VDT work was divided into three sections separated by 30 s of resting time.

The measured parameters were the mean craniocervical and cervicothoracic angles, with the angles differing between the initial cervical angle before the work and the cervical angle after continuous VDT work ($|\text{the mean craniocervical angle}| = \text{the craniocervical angle after the work} - \text{the initial craniocervical angle before the work}$). The craniocervical and cervicothoracic angles were captured during natural sitting posture at 5 min before and after the VDT work.

During data collection, the study participants were bare-foot with arms relaxed, their hands lightly clasped in front of the body, and feet positioned 20 cm apart. A double-blinded recording method was used to ensure that neither the researchers nor the participants were biased by the results.

Data analysis

Pearson correlation coefficients were used to quantify the linear relationship between active cervical ROM measurements and the changes in the craniocervical and cervicothoracic angles after 1 h of VDT work. An a priori alpha level of 0.01 was set to determine statistical significance. The relationships were also observed graphically to assure that correlations were not depressed by nonlinear associations.

Results

The CROM measurements were $50.3 \pm 10.91^\circ$ for flexion, $42.6 \pm 14.25^\circ$ for extension, $40.7 \pm 10.18^\circ$ for right lateral flexion, $39.1 \pm 11.32^\circ$ for left lateral flexion, $57.0 \pm 9.76^\circ$ for right rotation, and $58.3 \pm 10.47^\circ$ for left rotation, and the changes in the craniocervical and cervicothoracic angles were $20.1 \pm 11.60^\circ$ and $20.7 \pm 11.05^\circ$, respectively (Tables 2 and 3).

Active neck extension was negatively correlated ($r = -0.84$, $p < 0.01$) with the mean craniocervical angle, and

Table 2. Descriptive statistics for the active cervical range of motion

Cervical range of motion	mean $\pm$ SD
Flexion	50.3 $\pm$ 10.91
Extension	42.6 $\pm$ 14.25
Right lateral flexion	40.7 $\pm$ 10.18
Left lateral flexion	39.1 $\pm$ 11.32
Right rotation	57.0 $\pm$ 9.76
Left rotation	58.3 $\pm$ 10.47

Table 3. Descriptive statistics for the changes in the mean craniocervical and cervicothoracic angles

Changes in the mean cervical posture	mean $\pm$ SD
Craniocervical angle before the work	126.5 $\pm$ 7.72
Craniocervical angle after the work	146.6 $\pm$ 13.33
Change in craniocervical angle	20.1 $\pm$ 11.60
Cervicothoracic angle before the work	143.8 $\pm$ 8.72
Cervicothoracic angle after the work	123.1 $\pm$ 9.49
Change in cervicothoracic angle	20.7 $\pm$ 11.05

Table 4. Pearson correlation of active cervical ROM measurements and the change in the mean craniocervical angle and cervicothoracic angle

Active cervical ROM	Crano-cervical angle		Cervico-thoracic angle	
	Pearson correlation	<i>p</i>	Pearson correlation	<i>p</i>
Flexion	-0.59	0.006	-0.82	0.000
Extension	-0.84	0.000	-0.54	0.013
Right lateral flexion	-0.47	0.035	-0.51	0.022
Left lateral flexion	-0.48	0.030	-0.67	0.001
Right rotation	-0.54	0.015	-0.36	0.123
Left rotation	-0.48	0.032	-0.15	0.533

Correlation is significant at the 0.01 level (2-tailed).

active neck flexion ($r=-0.82$, $p<0.01$) and left lateral flexion ($r=-0.67$, $p<0.01$) were negatively correlated with the mean cervicothoracic angle (Table 4). Right lateral flexion and right and left rotations showed either a very weak correlation or were not correlated with the mean craniocervical and cervicothoracic angles ($p>0.01$) (Table 4).

Discussion

A previous study found that workers using VDTs had increased forward neck flexion compared to those with relaxed sitting postures²²⁻²⁴). Increased forward neck flexion may result in increased tension in posture-stabilizing muscles as well as increased compressive forces in the articulations of the cervical spine, resulting in a high-

er risk of work-related musculoskeletal disorders²⁵). Slumping over documents and staring all day at a VDT screen do great damage to muscles, exacerbating tension and tightness around neck and shoulders²³).

This study was designed to identify the relationship between the active cervical ROM and the changes in the mean craniocervical and cervicothoracic angles after VDT work. Our hypothesis was that these parameters are significantly correlated. This study showed that the active neck extension angle was negatively correlated with the mean craniocervical angle ($r=-0.84$, $p<0.01$) and that the active neck flexion angle was negatively correlated with the mean cervicothoracic angle ($r=-0.82$, $p<0.01$). This shows that, after long-term VDT work, subjects with a more limited ROM of neck extension would exhibit a change in the craniocervical angle and those with a more limited ROM of neck flexion exhibit a larger change in cervicothoracic angle. We also suggest that treatments for poor cervical posture should focus on recovering the normal ROM of neck flexion and extension. The significant correlations between the upper trapezius muscle activity and head-neck angles found in studies represent important evidence of a link between muscle activity and postural control^{5, 18, 26}). We propose that the change in craniocervical angle would be related with shortening of the scalenus muscles in deep muscles, because shortening of scalenus muscles can cause limited range of motion in neck extension. The change in cervicothoracic angle would be related to shortening of the levator scapular muscle in deep muscles, because shortening of the levator scapular muscle can cause limited range of motion of neck flexion.

Jull *et al.*²⁷) found that patients with neck pain put higher demands on their superficial neck muscles than do healthy people, to compensate for weakness of the deep muscles. The role of deep muscles for maintenance of cervical posture was verified in a computer model, which showed regions of local segmental instability if only the large superficial muscles of the neck were stimulated to produce movement, particularly in a ideal posture²⁸). Specific postural re-education exercise, initiated with the formation of a neutral lumbopelvic posture, should therefore be viewed at this time as a component of rehabilitation, providing a simple means for the patient to recruit the deep postural muscles of the cervical spine in a functional way regularly throughout the day²⁹). Postural patterns are maintained by a complex arrangement of input modified by habits. Poor postural patterns eventually result in chronic pain symptoms, which have been shown to be predictably caused by limited range of motion or shortening or lengthening of muscles. We suggest that an effective treatment program should include individually determined exercises based on postural muscle bal-

ance.

Only left lateral flexion in lateral flexion angles was negatively correlated with the change in cervicothoracic angle ($r=-0.67$, $p<0.01$). All subjects were right-handed. Generally, they spend the majority of their day sitting at desks testing or studying. These tasks usually involve right-handed mouse work. It is possible that the constant use of this work causes shortening of muscles such as the upper trapezius. Habitually shortened muscle length, with the individual not moving through a complete range of motion on a daily basis, might cause adaptive changes in muscle length with a habitual forward head posture^{25, 30}. The length/tension relationship of a muscle will adapt to the new resting length. Head posture will affect cervical range of motion in normal individuals as well as in individuals with neck pain²⁵.

There are several advantages to using a video camera to assess posture over a long period. In this study the intra- and intertest reliabilities were 0.90 and 0.84, respectively. However, these methods rely on the experimenter's judgment to identify a change in posture and the accuracy of taking angular measurements from a monitor. It is difficult to compare the results from most postural studies due to the lack of standardization of postural assessments and the difficulty of reproducing certain assessment tools in the clinical setting³¹. More detailed quantitative data would be needed to provide a more accurate measurement of posture changes. Also, this study involved a small sample and did not assess kinetic data. A better research design should have included measurement of cervical ROM as well as the craniocervical and craniothoracic angles — both before and after the VDT work. Further research is needed to understand the nature of motor control problems in deep muscles of patients with WRMD, and to assess synchronously obtained 3-D motion and electromyography data of the neck and shoulder from many VDT workers.

Conclusion

We found that the active neck extension angle was negatively correlated with the mean craniocervical angle and that the active neck flexion angle was negatively correlated with the mean cervicothoracic angle. We suggest that treatments for poor cervical posture should focus on recovering the normal ROMs of neck flexion and extension. Also, the cervical ROMs of neck extension and flexion could be useful data for predicting changes in the head and neck posture after long-term VDT work.

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