

Effect of visual display terminal height on the trapezius muscle hardness: quantitative evaluation by a newly developed muscle hardness meter

Muneyuki Horikawa*

Department of Bio-Medical Engineering, Tokai University School of High-Technology for Human Welfare, Nishino 317, Numazu-shi, Shizuoka 410-0395, Japan

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Abstract

The aim of this study was to determine trapezius muscle hardness in 9 healthy volunteers before and after word processing tasks with a video display terminal (VDT) at three different heights. When using a desktop personal computer (PC), no change was observed in muscle hardness even after a 30-min task if a subject was in the reference posture with a declination angle formed by the Reid's line directed toward the upper edge of the PC screen and the horizontal plane within 5–10°. However, an increase in muscle hardness was observed after a 15-min task in a posture of looking up at the screen (angle of elevation: 15–20°) and after a 30-min task in a posture of looking down at the screen (angle of declination: 15–20°). When the same tasks were performed with a notebook PC, muscle hardness increased after 15 min. Fifteen minutes of relaxation exercise reduced the muscle hardness caused by VDT work. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: VDT work; Screen height; Muscle hardness; Muscle hardness meter; Trapezius muscle

1. Introduction

When using a video display terminal (VDT) and keyboard for data entry, the screen height and keyboard position have a strong influence on the angles of the operator's neck, shoulders, elbows and trunk inclination (Villanueva et al., 1996; Straker et al., 1997). It was reported that long-term VDT work might be a significant risk factor in the development of musculoskeletal complaints because of constrained postures of the neck and shoulders (Chaffin, 1973; Hagberg, 1984; Onishi et al., 1982). On the other hand, there is a report (Aarås et al., 1997) that the trapezius load showed no significant differences when comparing data entry with sightline to the centre of the screen at an angle of 15–30° below the horizontal. There is also an epidemiological report (Aarås, 1994) that the incidence of sick leave due to musculoskeletal illness in the neck and shoulder region is lower in workers who take flexion of the head and neck for the predominant work position. Like the

above, there is a lot of discussion about a causal relationship between VDT work and musculoskeletal complaints and as well as the optimal gaze direction to the screen (Smith et al., 1981; Onishi et al., 1982; Arndt, 1983; Hermans and Spaepen, 1995; Fernström and Ericson, 1997; Jensen et al., 1998). However, there has been no study that quantitatively investigated muscular hardness as an important objective sign of musculoskeletal complaints such as shoulder stiffness and tension-type headache. There are many cases especially in Japan in which musculoskeletal complaints and muscle stiffness lead to tension-type (so-called muscle contraction) headache (Maeda, 1977). Sakai et al. (1995) reported the results of a study using a newly developed noninvasive muscle hardness meter for patients with tension-type headache. The study showed that the trapezius muscles were significantly harder in patients who had a feeling of severe or painful stiffness. Therefore, it is important to study the relationship between VDT work and muscle stiffness.

From a bioengineering point of view, a living body is a viscoelastic material; therefore, its hardness (elasticity) can be expressed by Young's modulus, which is

*Corresponding author. Fax: +81-559-68-1156.

E-mail address: horikawa@wing.ncc.u-tokai.ac.jp (M. Horikawa).

calculated by the ratio of stress (pressure) and strain (displacement). Therefore, in order to study musculoskeletal complaints it is important to measure subjective complaints of muscle stiffness as an objective, quantitative and rheological parameter of Young's modulus of muscular tissue.

In the present study, we used a muscle hardness meter developed by Horikawa et al. (1993) to objectively and quantitatively evaluate the effect of different screen heights on trapezius muscle hardness during VDT work.

2. Materials and methods

2.1. Materials

For the VDT, a desktop personal computer (PC) (PC-9801 with a 15-inch screen, NEC) and a notebook PC (LW40H with a 13-inch screen, NEC) were used. A height-adjustable table and chair well known for business office use were chosen.

2.2. Subjects

Nine healthy volunteers with no symptom of headache (5 males and 4 females, age range: 21–22 yr) participated in this study as subjects. All of them frequently use VDTs for word processing and are touch-typists. Volunteers were excluded if they were engaged in VDT work more than 3 h a day or had symptoms of neck or upper limb discomfort.

2.3. VDT task postures

The working environment such as illumination, room temperature, and other factors was adjusted in compliance with the guidelines of the industrial hygiene standard (Labor Standard Bureau, 1997) (see Fig. 1).

Exp. 1: As shown in Fig. 1, a subject sat facing the desktop PC. The angle of declination formed by the Reid's line and the horizontal plane when the subject looked down at the upper edge of the screen was adjusted within 5–10°. This posture was defined as the reference posture (Labor Standard Bureau, 1997).

The Reid's line is defined by a line connecting the margo infraorbitalis and the centre of the outer canal of the ipsilateral ear. The neck angle was defined as the angle formed by the horizontal plane and the Reid's line directed toward the upper edge of the screen. The viewing angle was defined as the angle formed by the horizontal plane and the line between the margo infraorbitalis and the centre of the screen.

Exp. 2: As shown in Fig. 2A, screen height was adjusted so that the angle of elevation was 15–20°. The subject was asked to perform the VDT task in the posture of looking up at the screen for 15 min.

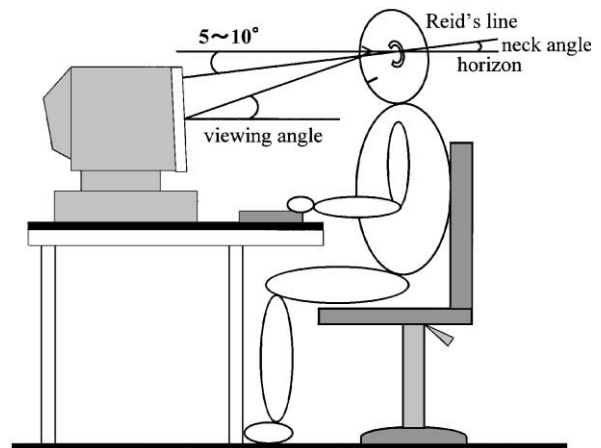


Fig. 1. Reference posture during VDT work while using a desktop PC and the parameters to define postures. Angle of declination looking down at the upper edge of the screen: within 5–10° below the horizontal plane. Viewing angle: 21–25° (downward). Viewing distance: more than 40 cm. Table space in front of the keyboard: enough to support hands or forearms. Armrests or something to support elbows were not used. Angle of elbow during key operation: almost 90°. Height of chair: adjustable to allow maintenance of adequate posture. Height adjusting lever: height can be adjusted in sitting position. Height of chair: adjustable to allow maintenance of adequate posture. The legs of the chair should be stable. The entire sole of the foot should contact the floor. Room temperature: 18–22°C. Illumination: 300 luxes.

Exp. 3: As shown in Fig. 2B, screen height was adjusted so that the angle of declination was 15–20°. The subject performed the task in the posture of looking down at the screen for 15 min.

Exp. 4: The subject performed the task for 30 min in the same posture as in Exp. 3.

Exp. 5: Using a notebook PC, the subject entered a source document placed beside the LCD screen for 15 min.

2.4. Procedure

Using a desktop PC in Exp. 1 through Exp. 4, the subject used a keyboard to input a source document in the above-mentioned postures and periods of time. In Exp. 5, the subject used the notebook PC to do the data entry tasks of Exp. 1–4.

In each posture, the hardness of the right and left trapezius muscles was measured before and after the VDT task.

In Exp. 1 through Exp. 4 a source document was fixed beside the screen with a special holder so that the document's height changed when the screen height was adjusted. All subjects performed only two experimental tasks a day. The second task was performed 2 h after the first task was finished. In addition, before beginning the

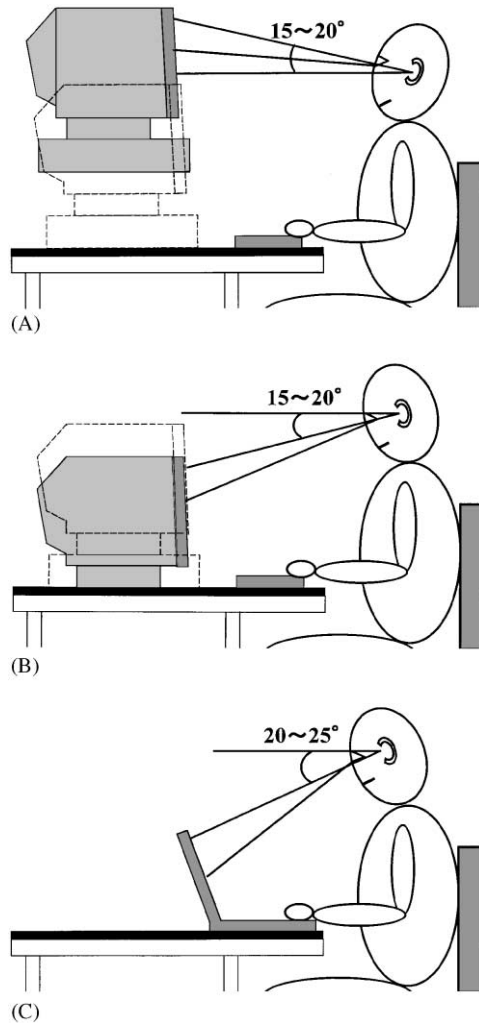


Fig. 2. Working postures of looking up at the CRT screen (A), looking down at the screen (B) during desktop PC use and the posture during notebook PC work (C). (A) CRT set higher (angle of elevation looking up at the upper edge of the CRT: 15–20°). Viewing angle: 3–6°(upward). (B) CRT set lower (angle of declination looking down at the upper edge of the CRT: 15–20°). Viewing angle: 29–32°(downward). (C) Notebook PC (angle of declination looking down at the upper edge of the LCD screen). Viewing angle: 36–40°(downward).

second task, muscle hardness was measured to ensure that it recovered the control value before the first task and that no effect remained from it.

In Exps. 2 and 4, a relaxation exercise such as clockwise or counterclockwise turning of the head around the trunk or up and down motion of both shoulders was done for 15 min after the VDT task. Muscle hardness was measured immediately after the relaxation exercise. When different tasks were assigned in succession, over 2 h of rest was allowed between tasks. During the rest the subjects did their routine daily activities without doing VDT work or intense exercise that yielded muscle pain.

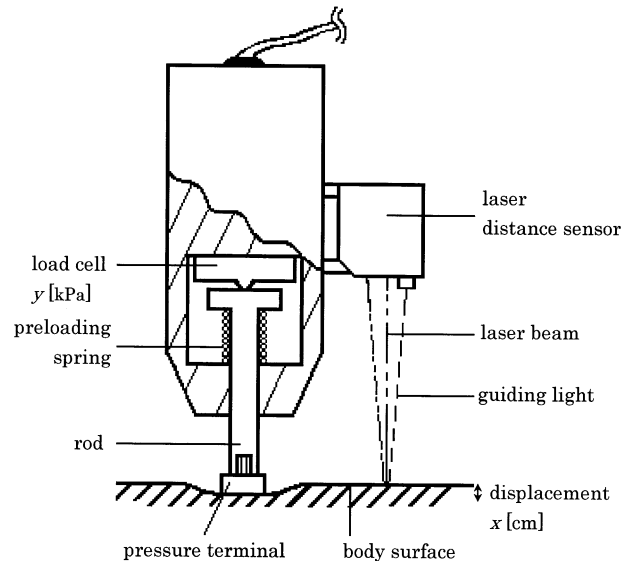


Fig. 3. Schematic diagram of the pressure-displacement transducer for the measurement of muscle hardness.

3. Muscle hardness measurement

In this study, the short-term phenomenon of trapezius muscle hardness was quantitatively measured with our newly developed noninvasive muscle hardness meter (Horikawa et al., 1993). Briefly, this meter is a pressure-displacement transducer that enables simultaneous measurement of pressure and displacement, as shown in Fig. 3. Hardness of the muscle was estimated by applying pressure to the muscle and measuring the amount of distortion which resulted. Pressure was measured by a circular pressure terminal with a surface area of 1 cm² connected to a load cell via a rod. Resulting displacement of the tissue was obtained from the distance the transducer approaches the body surface. This distance was measured in the trigonometric survey method by a laser distance sensor attached to the transducer, as shown in Fig. 3. The transducer was depressed vertically on the subject's measurement site. The skin where the centre of the transducer pressure terminal was applied was marked with a felt-tip pen, and a repeated measurement was performed at the same site before and after the stress of VDT task.

Displacement was plotted on the *x*-axis and pressure was plotted on the *y*-axis to yield a pressure-displacement curve as shown in Fig. 4. The slope of this curve (pressure/displacement) indicates hardness in kPa/cm. The initial slowly increasing slope of the curve represents the hardness of the soft subcutaneous tissue, so the slope of the portion where the curve straightens linearly as pressure and the resulting displacement are increased and was defined as hardness of the measurement site muscle. For details, refer to the literature (Horikawa et al., 1993).

The trapezius muscle was chosen as the measurement site and the middle point between the spinous process of the prominent vertebra and acromion was selected as the measurement point. This measurement point was almost the centre of the pars transversa of the trapezius muscle. The subject was asked to take the reference posture shown in Fig. 1. Under relaxed conditions, hardness was measured 3 times each for the right and left trapezius muscles and the mean values were obtained.

3.1. Statistical analysis

The paired *t*-test was used for statistical analysis of differences in muscle hardness before and after the task

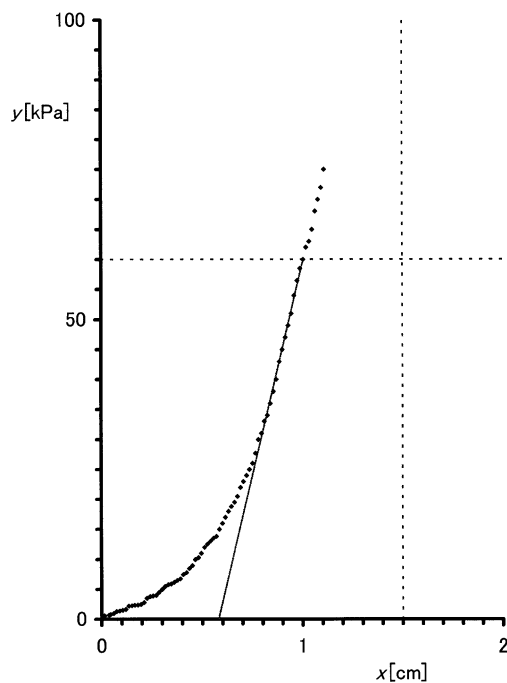


Fig. 4. Typical pressure-displacement curve measured on the trapezius muscle. Muscle hardness can be calculated from the slope of the straight part of the curve.

and after the relaxation exercise. The difference was considered statistically significant when *p* was less than 0.05.

4. Results

As shown in Table 1, even after a 30-min task in the reference posture in Exp. 1, no significant difference in muscle hardness was found. When screen height was set higher and the task was done in the posture of looking up at the screen for 15 min (Exp. 2), muscle hardness significantly increased from 91.4 to 102.1 kPa/cm ($p < 0.01$). But, after relaxation exercise the muscle hardness significantly decreased to 87.2 kPa/cm and the muscle became softer than before the task ($p < 0.01$).

When screen height was set lower, no significant difference was observed after a 15-min task (Exp. 3), but after a 30-min task (Exp. 4) muscle hardness increased from 90.7 to 98.0 kPa/cm ($p < 0.01$). Relaxation exercise restored the hardness to the level before the task.

In a 15-min task with a notebook PC (Exp. 5), muscle hardness increased from 85.1 to 94.9 kPa/cm and the muscle grew stiff ($p < 0.01$). In all experiments no subject complained of a stiff shoulder.

5. Discussion

The results of the studies investigating the relation between sitting posture and muscular activity in the neck and shoulders by means of surface electromyography indicated that the trapezius muscle electrical activity was significantly higher in the whole spine flexed posture than in the straight and vertical spine posture and that muscular activity levels were higher in the straight and vertical spine posture than in the slightly backward-inclined spine posture (Schüldt et al., 1986; Harms-Ringdahl et al., 1986). Static muscle work in the neck and the shoulders is sustained if the VDT task is

Table 1
Summary of muscle hardness before and after VDT work and after relaxation exercise in different experiments^a

	Before work (kPa/cm)		After work (kPa/cm)		After exercise (kPa/cm)
Exp. 1	92.2 ± 5.7		94.0 ± 12.7		—
		NS			
Exp. 2	91.4 ± 10.1		102.1 ± 13.5	$p < 0.01$	87.2 ± 11.6
		$p < 0.01$			
Exp. 3	86.0 ± 11.0		86.1 ± 11.0		—
		NS			
Exp. 4	90.7 ± 8.6		98.0 ± 11.1	$p < 0.01$	89.2 ± 11.8
		$p < 0.01$			
Exp. 5	85.1 ± 12.6		94.9 ± 10.4	$p < 0.01$	—
		$p < 0.01$			

^a Values: mean ± standard deviation ($n = 9$), NS: not significant.

continued in the same posture (Schüldt et al., 1986; Onishi et al., 1982). It is believed that static contraction increases intramuscular tissue pressure and causes ischemia in the trapezius muscle, yielding such pathological changes as stiffness, dullness and pain as well as an increase in muscle hardness (Larsson et al., 1993; Hagberg, 1984; Sadamoto et al., 1983). Neck angle changes easily in accordance with screen height. There is a strong correlation between neck posture and neck extensor muscle activity (Villanueva et al., 1996, 1997).

In the reference posture, the 30-min continuous VDT work did not cause an increase in trapezius muscle hardness. But, since it is well known that tasks longer than 30 min reduce work efficiency such as speed and accuracy, continuous work longer than 30 min should also be avoided (Mital, 1997).

When screen height was set higher and the task was performed for 15 min in the posture of looking up at the screen, trapezius muscles hardness clearly increased. This position seems to be partly an extension of the neck which increases the muscle load of the extensors (Harms-Ringdahl et al., 1986). Static contraction of the neck and the shoulder muscles including the trapezius muscle were sustained and muscle hardness increased due to the mechanism speculated by Larsson et al. (1993) and Hagberg (1984). However, it was confirmed that simple relaxation exercise caused the increased muscle hardness after the task to return to the hardness before the task. The importance of upper limb exercise during VDT work was confirmed.

According to previous reports, EMG activity of the trapezius and the neck extensor muscles increases as a more forward-bending posture is taken in response to lower screen height (Turville et al., 1998; Villanueva et al., 1977). It is suggested that static muscle contraction in the neck and shoulder muscles including the trapezius muscle might cause increased muscle hardness.

When the task was done with a notebook PC for 15 min, increase in muscle hardness was observed. Notebook PC LCD screens are usually fixed to the keyboard with a hinge. In the use of notebook PC, it can be considered that much stronger neck flexion and head tilt (Straker et al., 1997), narrower visual angle in comparison with a desktop PC screen, and a relatively poor clarity and poor quality of the notebook LCD screen may cause the operator to lean forward in order to see more clearly. It can be considered that this working posture gives stress to the neck and shoulders. Saito et al. (1997) clarified this from findings in EMG activity of the neck and upper arm. Since notebook PCs are rapidly becoming more widespread in home and education, some measures should be considered.

Increase in trapezius muscle activity due to the lifting of the shoulders to compensate for a slight slumping of the back was observed (Kleine et al., 1999); so not only screen height, but also trunk posture needs to be

studied. Hardness change in the trapezius muscle when using various input devices such as a mouse or a trackball together with a keyboard also needs to be examined.

6. Conclusion

Using a newly developed muscle hardness meter, quantitative examination of the relation between screen height and trapezius muscle hardness during desktop PC work revealed that when looking 15–20° upwards toward the upper part of the screen, trapezius muscle hardness increased after 15 min of data entry work. With a notebook PC, the 15-min work increased hardness of the trapezius muscle. When increased muscle hardness is sustained, it can cause muscle stiffness, dullness, and occasionally muscle pain. To avoid these musculoskeletal complaints in VDT works, it is recommended to take a posture looking slightly downward toward the upper part of the screen. When using a notebook PC, it seems better not to take a posture of excessive forward inclination of the head. Relaxation exercise is considered effective in order to make the increased muscle hardness return to the hardness level before VDT work.

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