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THE INFLUENCE OF THE VIEWING ANGLE ON NECK-LOAD DURING WORK WITH VIDEO DISPLAY UNITS

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Ergonomic measures have been found to reduce load-related trouble from the neck-and-shoulders during visual display unit (VDU) work. An important question is the height at which the screen should be placed to give the lowest possible load. Should it be placed at eye-level or below? The aim of the present study was to investigate whether there was any difference in external loading moments of force about the C7-T1 segment when the VDU-operators had a viewing angle of 20° below the horizontal plane as compared to 3° above the horizontal. Eight secretaries were videofilmed in the sagittal plane in the two work postures during simulated work. The loading moment was calculated from the film. It was significantly lower at viewing angle 3° above the horizontal than at 20° below the horizontal, both at the beginning (1.3 vs 2.2 nm) and at the end (1.4 vs 2.1 nm) of the film sequences ($p < 0.05$).

Key words: biomechanics, cervical spine, ergonomics, work posture.

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INTRODUCTION

Several investigations have shown that neck-and-shoulder trouble is common among persons who work in front of a computer screen (1–4). There is evidence that ergonomic measures reduce load-related disorders from the neck-and-shoulders (5–7). An important issue in ergonomic adaptation of computer workplaces is how the screen should be placed. A horizontal distance, i.e. the distance from the eye to the middle of the screen, of between 0.62 m and 0.76 m has been proposed (8–10). Regarding the height of the screen, the Swedish National Board of Occupational Safety and Health have recommended a viewing angle of 20° below the horizontal (−20°) (11). In a study in which the visual display unit (VDU) operators themselves chose their position, they chose a posture with the viewing angle 3° above the horizontal (+3°) (12). Another study comparing two different screen heights (viewing angles 8.5° below the horizontal and 3° above the horizontal) shows no difference in load moment between the postures (13). However, in that study the distance between the eye and the top edge of the screen was measured, and this gives a different viewing angle than if one measures from the eye to the middle of the screen, as in most other studies. Few studies have calculated the external load moment in the neck during VDU work.

The purpose of this study was to investigate how viewing angle affected the load on the neck in healthy subjects. The following question was analysed: is there any difference in load moment about the bilateral motion axis through the cervico-thoracic (C7-T1) motion segment in the neck when the viewing angle is changed from −20° to +3° in VDU work?

METHODS

Subjects

The study was scrutinized and approved by our ethical committee. All nine Medical Secretaries at a department of a large hospital in Stockholm, were voluntarily invited to take part in the study. Eight accepted. All were women. Median age was 46 years (lower and upper quartiles: 44 and 49 years, respectively), median height 1.64 m (lower and upper quartiles: 1.63 m and 1.70 m, respectively) and median weight 68 kg (lower and upper quartiles: 63 kg and 78 kg, respectively). The subjects were given verbal and written information before the study started. None had been sick-listed for symptoms from the neck and back which might have affected their posture during the experiment, and none had reduced visual acuity that had not been corrected with spectacles. Three of the eight secretaries had spectacles; one for myopia and two had progressive glasses for hypermetropia.

Working postures

Each subject was filmed in two sedentary work postures with different viewing angle at an experimental computer workstation. The order in which the two postures were investigated was randomized by lot for each person. The viewing angle was the angle between the horizontal plane and the line between the eye and the middle of the computer screen (Fig. 1) (11). The size of the CTX colour screen was 325 mm × 245 mm. In one of the work postures, the screen was placed at a level that gave an angle of −20° (11), and in the other posture at a height that gave an angle of +3° (12). To adjust to the right viewing angle, a stand with a moveable arm specially produced for this study was used (Fig. 1). This could be adjusted in height and angled to −20° or +3° . To obtain a suitable distance between eye and screen, the length of the moveable arm was 0.70 m (8–10). The screen was tilted to a position that each secretary felt comfortable working with.

For all subjects, the experimental workstation was individually adjusted as follows. An adjustable office chair without armrests was used. To ensure that the subjects' feet were placed firmly upon the floor, the chair was first adjusted to the correct height. The angle of the chair seat and the height of the back support were both adjusted to give a comfortable position for each subject (14). The height of the table with the keyboard was then adjusted so that the subject could support her forearms on the table and relax her shoulders as much as possible (15). The subjects were allowed time to "get sitting comfortably" and to change position if necessary.

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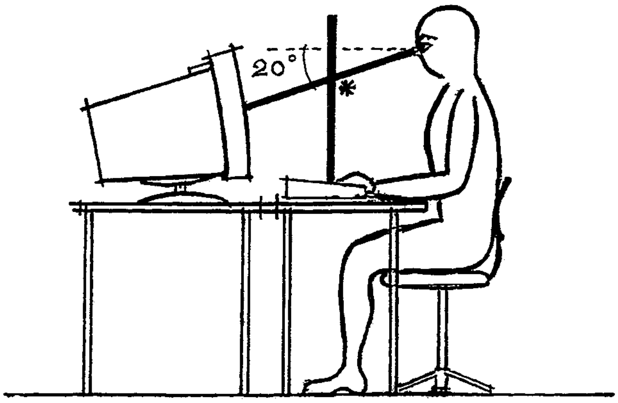

Fig. 1. To set the correct viewing angle, a stand with a movable arm was used. This is the black cross in the middle of the figure marked by the asterisk *. It could be adjusted in height and angled to 20° below the horizontal (−20°) and 3 degrees above the horizontal (+3°). The moveable arm was then aligned between the eye and the middle of the screen. The screen and the keyboard were placed on separate tables, which each could be individually adjusted in height.

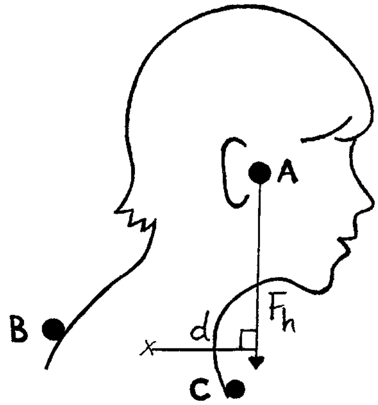

Fig. 2. Skin markers were used to indicate on each subject the centre of gravity for the head-and-neck at the tragus in front of the external auditory meatus (A). To be able to determine the position of the C7-T1 motion axis in the biomechanical calculations, skin markers were also attached over the spinous process at C7 (B) and at the jugular fossa (C). The external loading moments for the C7-T1 segment were calculated according to the formula: M = Fh × d. M is the outer loading moment in nm regarding C7-T1, Fh is the common gravitational force of the head-and-neck, i.e. 9.81 m/s^2 × 0.079 × body weight in kg, and d is the moment arm in metres, i.e. the perpendicular distance between the gravitational force of the head-and-neck and the C7-T1 motion arm.

The viewing angle was adjusted by placing the stand upon the table in front of the subjects. The keyboard was moved temporarily to one side. The subjects were encouraged to sit in a relaxed posture and to look directly forwards at the middle of the screen. The moveable arm was adjusted between the eye and the middle of the screen (see Fig. 1). The screen was placed on a separate table that could be raised or lowered to the height that gave the required viewing angle. The stand was then removed and the subjects positioned the keyboard in front of them as they wished. The subjects were allowed to angle their screen to a position that felt comfortable.

Task

For each trial, the subjects performed the same tasks as they did in their everyday work, i.e. word processing using keyboard and headphones. For a large part of the time, the subjects looked at the screen, and very seldom down at the keyboard. The mouse was used relatively infrequently.

Skin markers

Skin markers were used to indicate on each subject the centre of gravity of the head-and-neck at the tragus in front of the outer auditory meatus (16–18) (Fig. 2). To be able to determine the position of the C7-T1 segment bilateral movement axis for the biomechanical calculations, skin markers were also fixed over the spinous process at C7 and at the jugular fossa (17) (see Fig. 2).

Videofilming

A video camera (JVC Super-VHS) on a tripod was placed so that the subjects could be filmed perpendicularly to the sagittal plane. To permit biomechanical calculation from the videofilm, a 0.5 m long plumbline (graded in centimetres) was placed behind the subject in the focal plane. Each work posture was filmed for five minutes.

Analysis of the videofilms

The videofilms were analysed using a video recorder and TV screen. Each five-minute sequence was stopped and analysed at two points, one directly at the beginning (measurement 1) and one just before the film sequence ended (measurement 2). Transparent film was placed over the TV screen so that the skin markers and plumbline could be traced. The plumbline showed the direction of gravity on the film and made it possible to measure the external moment arm from the transparent film. To determine the true length of the external moment arm, an image factor was calculated by dividing the true length of the plumbline (0.5 m) by the length of the plumbline on the transparent film. The person who did the measurements from the transparent film did not know which viewing angle was being analysed.

Biomechanical calculations

The external moment arm (d) for the load moment with respect to the C7-T1 segment is the perpendicular distance between the gravity force induced by the weight of the head and neck and the motion axis (see Fig. 2). By multiplying the external moment arm from the film by the image factor, the true external moment arm (d) was determined. The bilateral motion axis for the C7-T1 segment was placed half-way between the skin marker for the spinous process and the skin marker for the jugular fossa (17, 19). The load moment (M) was calculated according to the formula M = Fh × d, where M is the outer loading moment in nm about the C7-T1 segment, Fh is the common centre of gravity of the head-and-neck, i.e. 9.81 m/s^2 × 0.79 × body weight in kilograms (16) and d is the moment arm in metres, i.e. the perpendicular distance between the gravity force induced by the weight of the head-and-neck and the bilateral motion axis of the C7-T1 segment. The low weight (0.066 kg) of the headphones and their placing were such that the load they induced could be disregarded. Their weight represented only between 0.7 and 1.4% of the weight of the subjects' head-and-neck.

Reliability

To establish how accurately a person could measure the moment arm, the measurements were repeated twice from each transparent film without the person being able to see the value from the first measurement (intra-assessor reliability). In the same way it was assessed how similar two persons could measure from the same transparent film (inter-assessor reliability).

Statistics

Since the material was not considered to be normally distributed, non-parametric statistics were used. To compare the loading moments in the two different work postures with different viewing angles, Wilcoxon's sign-ranks test was used. Inter- and intra-assessor reliability were calculated with Spearman's rank correlation test (rs).

RESULTS

At the beginning of the film sequences the load moments about the C7-T1 segment were higher for the −20° viewing angle (median: 2.21 nm, lower and upper quartiles: 1.54 and 2.42 nm, respectively) than for the +3° viewing angle (median: 1.32 nm, lower and upper quartiles: 0.50 and 1.75 nm, respectively) (see Fig. 3). The same was true for the load moments at the end of the film sequences, where the −20° viewing angle gave a higher value (median: 2.07 nm, lower and upper quartiles: 1.82 and 2.10 nm, respectively) than the +3° viewing angle (median: 1.36 nm, lower and upper quartiles: 0.58 and 1.92 nm, respectively). The differences were significant ($p < 0.05$). Thus the load on the neck-and-shoulders was significantly lower for the +3° viewing angle than for the −20° viewing angle. Concerning the individual results, the load was higher for the −20° viewing angle, for all subjects except one. This was true both at the beginning and at the end of the film sequences, and it was different subjects at the two instances. None of these two secretaries wore glasses. For the three subjects that wore glasses the load on the neck was always higher at the −20° viewing angle.

Repeated measurements from the transparent film of the same image gave very good intra-assessor reliability for both viewing angle, −20° and +3° (rs = 0.9, $p < 0.001$). The same applied to inter-assessor reliability for −20° and +3° (rs = 0.9, $p < 0.001$).

DISCUSSION

The purpose of the present study was to investigate whether a screen placing that gave a smaller downward view also gave a lower load upon the neck-and-shoulders. Viewing angle −20° was chosen since this is recommended by the Swedish National Board of Occupational Safety and Health (11) and viewing angle +3° was chosen because an earlier study showed that this was the posture VDU operators selected when they could themselves choose the placing of the screen (12). Another study comparing

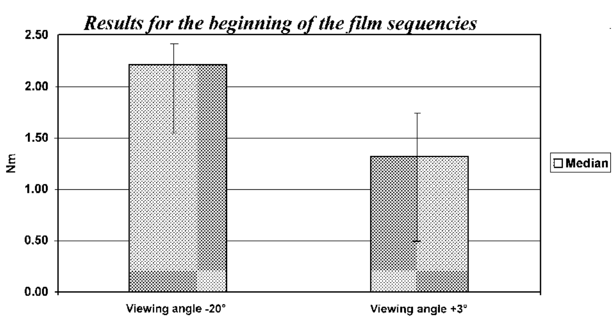

Fig. 3. Results for the eight subjects at the beginning of the film sequences. The median value for the loading moments for the viewing angle 20 degrees below the horizontal (−20°) and the viewing angle 3 degrees above the horizontal (+3°), respectively. The difference was significant with Wilcoxon's sign-ranks text ($p < 0.05$). The narrow vertical line shows the dispersion of values between the lower and the upper quartiles.

two different screen heights that resulted in median viewing angles of +3° and −8.5° gave no significant difference regarding load moments (13). In that study, the viewing angle was not adjusted individually for each subject, but all subjects sat at screens with given heights irrespective of their body height (distance between floor and middle of screen was 0.965 and 1.092 m, respectively). After the trials, the viewing angles resulting from the two different screen heights were established for each subject (13). An important part of the present study was to apply individual ergonomic adaptation. Each trial therefore started with the chair and table being adjusted for each subject before the viewing angles investigated were set. This resulted in a somewhat higher placing of the screen, average 1.02 and 1.35 m, respectively. The screen was thus somewhat higher for both viewing angles investigated but, more importantly, resulted in a larger difference in screen height: 0.33 m in the present study compared with 0.13 m in the study reported above (13). Since there are such large differences in body measurements between different individuals, it is an advantage in individual adaptation of the workplace that, as in the present study design, screen height can be adjusted separately from the height of the table upon which the keyboard and mouse are placed.

In the present study, the difference in load between the two different viewing angles (+3° and −20°) was significant in the comparison both at the beginning and at the end of each film sequence. It should be stressed that the values calculated for the load moments in this study apply only to the viewing angles investigated. An entirely different issue is how long a person usually works with the same viewing angle, how often one changes this angle and how the load develops over a longer period of work. Also the load on the shoulders were not calculated in the present study, only the neck load.

To obtain an optimal environment for VDU work, account must be taken of the individual's conditions both physical and mental. Important factors are, for example, work organisation, psychosocial factors and the ergonomic design of the workplace. In the present study we investigated only how load on the neck about the externally loaded moment in the C7-T1 segment was affected by the two different viewing angles. Regarding eye trouble and VDU work it has been shown that a more upward-directed look gives a larger eye aperture and a greater risk of dehydration and eye tiredness (20). Another study demonstrated a connection between working time at the screen and eye complaints (21). There is no indication that the fact that three of the eight subjects in the present study wore glasses have changed the conclusions, since the results for all these three secretaries followed the same pattern as for the majority of the subjects.

The difference in median load on the neck at the viewing angles compared was 0.9 nm at the beginning of the film sequence and 0.7 at the end. One may wonder whether this apparently small difference in load has any practical significance. But the load increased by 68% at the beginning and by 51% at the end of the film sequences when changing from viewing angle +3° to viewing angle −20° . This indicates that the reduction in moment between 0.7 and 0.9 nm is not without significance regarding work postures adopted during a large part of a working day.

In the present study the viewing angle of $-20°$ gave a greater external load moment upon the neck-and-shoulders. At viewing angle $+3°$, therefore, the subjects sat with the cervical neck more upright. Several authors have shown that increased forward inclination of the head increases the occurrence of neck-and-shoulder complaints (4, 9).

For this study, an instrument was specially made to enable us to adjust a certain viewing angle individually. Without such an instrument, it is probably fairly hard to follow ergonomic recommendations regarding fixed viewing angles, not least in view of the great individual differences regarding bodily measurements. To load the neck as little as possible during VDU work, each individual should adjust the height of screen to obtain a suitable viewing angle for the eyes and one at which it is easy to keep the neck straight. The study shows that a viewing angle of $+3°$ gave less load upon neck than one on $-20°$.

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