Effect of two Notebook stands on work posture and productivity

The aim of this study was to investigate the effect of using a notebook stand on the physical load when working with a notebook in a home environment. Sixteen subjects evaluated working with a notebook by performing three different tasks using two notebook stands and without using a notebook stand. Body posture, productivity, perceived fatigue and comfort/discomfort and personal preference were measured. We found that subjects have significantly less neck flexion when using a notebook stand compared to using only a notebook. They also rated significantly less subjective fatigue in the neck when using a notebook stand. From this study, we can conclude that the neck posture is objectively more neutral and subjectively less fatiguing.

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More and more people replace working on a desktop computer at home with working on a notebook computer. In May 2005 notebooks outsold desktop computers for the first time in the United States (Singer, 2005).

The mobility of a notebook comes with some constraints compared to a desktop computer. Two of these constraints deal with the display. First, the display has a fixed and too low height according to the ergonomics guidelines for VDU tasks, which says that the top of the display is at, or slightly below eye-level (Voskamp P. et al., 2008; Grandjean et al., 1984; Miller et al., 1983). Secondly, the distance between the display and the keyboard is fixed. Both the fixed height and the fixed distance between keyboard and display can cause unfavorable working postures, such as too much neck flexion (Sommerich et al., 2002; Straker et al., 1997) which may result in local discomfort and loss of productivity (Berkhout et al., 2004). It is recommended in ISO 11226 not to have more than 25° of static neck flexion for a working day (Voskamp P. et al., 2008).

The effect of display height in VDU tasks using a desktop or notebook computer has been the subject of a number of studies. Straker et al. (2008) reviewed 24 of these studies and concluded that there was a relatively linear increase in head and neck flexion

(relative to the vertical), overall, when the display moves lower than eye height. Berkhout et al. (2004) found that a lower display height of a notebook compared to a notebook used with a notebook stand was related to a higher torque in the neck (C7-Th1). Not surprisingly, muscle activity in the neck extensor muscles was found to increase with lower display heights in VDT work (Straker et al., 2008b; Seghers et al., 2003).

In order to address the problem of the low display height, notebook stands have been developed in several designs. The purpose of notebook stands is to increase the display height of the notebook and to uncouple the fixation of both eyes and hands on the same device by providing a separate keyboard and mouse.

Therefore, this study concerns the evaluation of the effect of using a notebook stand on working posture, productivity and subjective fatigue. The central question in the study was whether the use of a notebook stand affects the physical load (body posture, productivity and subjective fatigue) in a home environment.

In order to answer this question, a laboratory study was conducted in which working on two different notebook stands was compared to working without a notebook stand. A home situation was simulated by the tasks (email, text editing and web-surfing) that the subjects had to perform as well as the typical furniture height (dining table) they used.

Method

Design

A cross-over study design was used where each subject performed a set of tasks using three different notebook setups, two with a notebook stand and one without a stand. The order of use was balanced across the subjects, as much as possible.

Subjects

Sixteen healthy students (8 males and 8 females) participated in the study. The mean age of the subjects was 20 years (range 17–22). They were all experienced PC users with an average of 3.2 hours of computer usage per day. The subjects all had the ability to touch type, at a speed of at least 150 keystrokes/minute. Mean height of the female subjects was 1.72m (range 1.63–1.60m) and the mean weight 66kg (56–80kg), for the male subjects it was 1.83m (1.74–1.93 m) and 72kg (63 – 78kg). None of the subjects self-reported that they had any current musculoskeletal complaints in the hands, arms, neck or shoulder. All subjects signed an informed consent prior to the experiment.

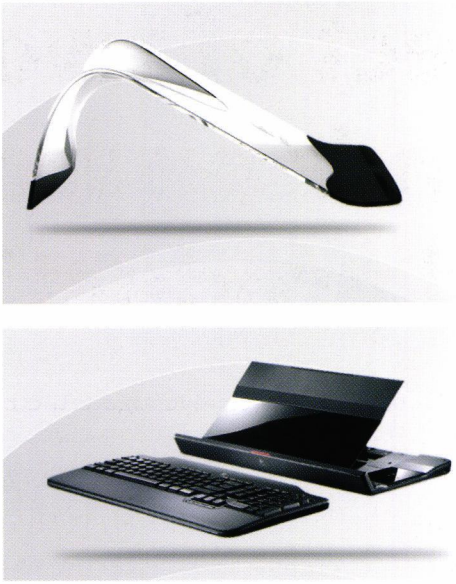


Figure 1. The two notebook stands, left the Logitech Alto Express (inclination 26°) and right the Logitech Alto Cordless (inclination 42°).

Task

The subjects performed three tasks of 8 minutes in each notebook setup. The tasks were display based and emulated emailing, surfing internet and reading.

The emailing task consisted of a text-entry in Microsoft Word (split screen: with the text in the upper half and the entry window in the lower half of the screen). After typing each complete sentence, the front style of the first word was changed to bold.

The surfing internet task consisted of three parts a custom built mouse game (1 minute), followed by reading a text (6 minute) in Microsoft Word and finishing with the same mouse game (1 minute). In the mouse game randomly positioned squares appear that must be clicked, 60 squares in total and two extra squares for each miss. The text was divided in paragraphs of the same length, each paragraph was presented one page. After reading a paragraph subjects changed the front style of three words to bold and scrolled down to the next paragraph.

The reading task consisted of reading a text from the display for 8 minutes.

Workplace

The subjects performed their task sitting on an adjustable office chair at a table with a fixed height of 74 cm to simulate a typical dining table height.

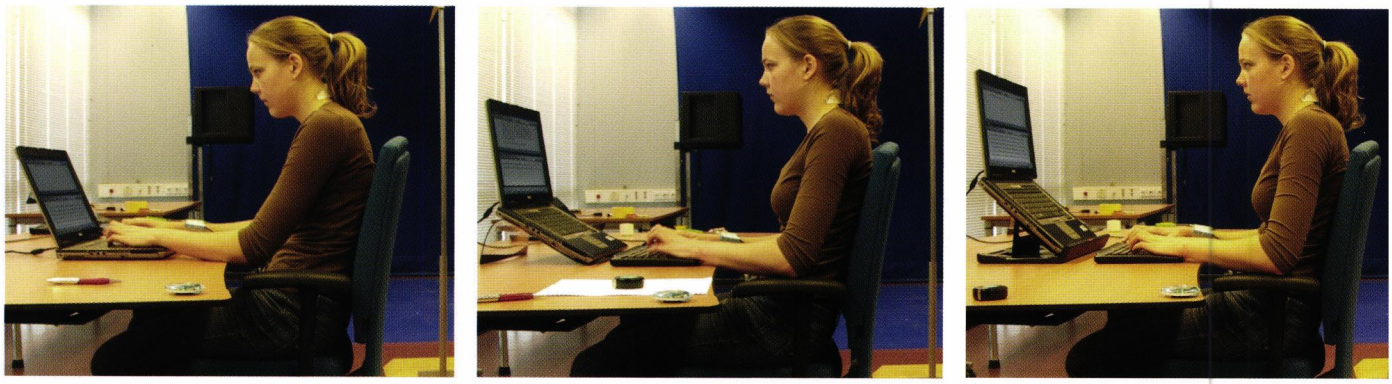


Figure 2. Notebook setups, from left to right: NB, EX and CL.

Participants were allowed to adjust the height of their chair and to position the chair relative to the table as preferred.

Independent variable - notebook setup

The notebook used in the study had a 15.4 inch display. In all three conditions an external wireless mouse was used. In one of the three conditions only the notebook was used (NB condition). In the two other conditions the notebook was mounted in one of two different notebook stands (Logitech Alto Cordless and Alto Express, CL and EX condition, respectively) with an external keyboard (Logitech Alto keyboard). The display height, from the floor to the center of the display, was 80 cm for the NB, 103 cm for the EX and 107 cm for the CL.

Dependent variables

Posture

To assess the posture of the subjects, electrogoniometers and photographs were used. The goniometer measured the flexion-extension angle (relative to trunk) from the neck. Flexion was defined as positive. The sample frequency was set at 100Hz and the signal was filtered (2nd order Butterworth, 2Hz low-pass). The electrogoniometers were attached to the skin by double-sided tape. In addition, photos were used to determine the trunk relative to vertical and neck angle relative to horizontal, backward or upward angles were defined as negative. The camera was mounted on a tripod and positioned at the left of the subjects. A vertical line was placed behind the subjects for angle reference. Twelve photos of a lateral view were taken during each condition. One representative photo per task per condition was chosen and analyzed by hand (figure 2). For the neck angle a line was drawn from the top insertion of the ear to the middle of the eye. This line was compared to the vertical. The line for the trunk was constructed between the shoulder (acromion) and the hip joint (trochanter major). In figure 2 shows how the angles are defined.

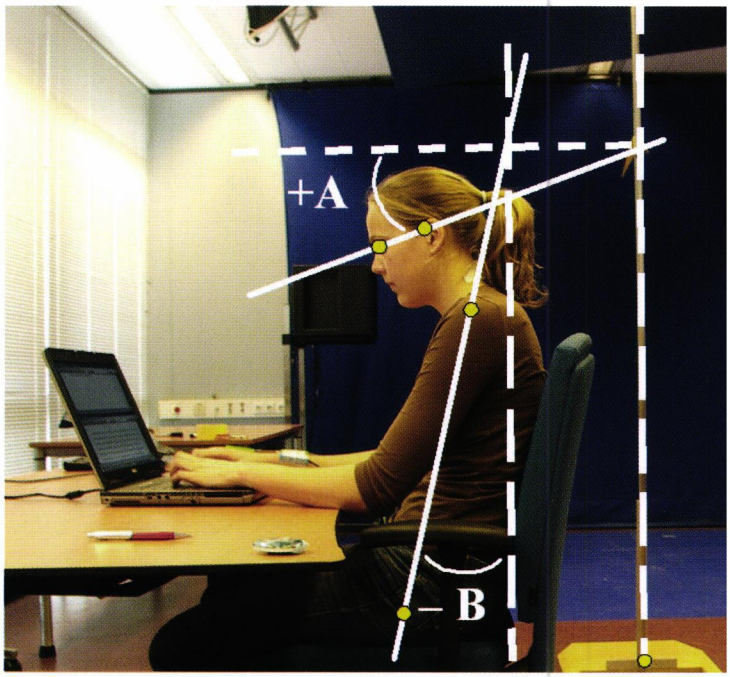
Productivity

Productivity was measured by counting the number of words the subjects completed during each task and for the mouse task, the time between two hits. The relative productivity of words per task was counted up to a total productivity per condition. The mouse task was evaluated separately in which the average time between hits of the targets was used as measure of productivity.

Fatigue and preferences

In a questionnaire, subjects were asked about subjec-

Figure 3. Example of photo with lines used for determination of neck (A = positive) and trunk (B = negative) angle. Dashed lines are for reference (horizontal and vertical) and circles are the reference spots on the body.



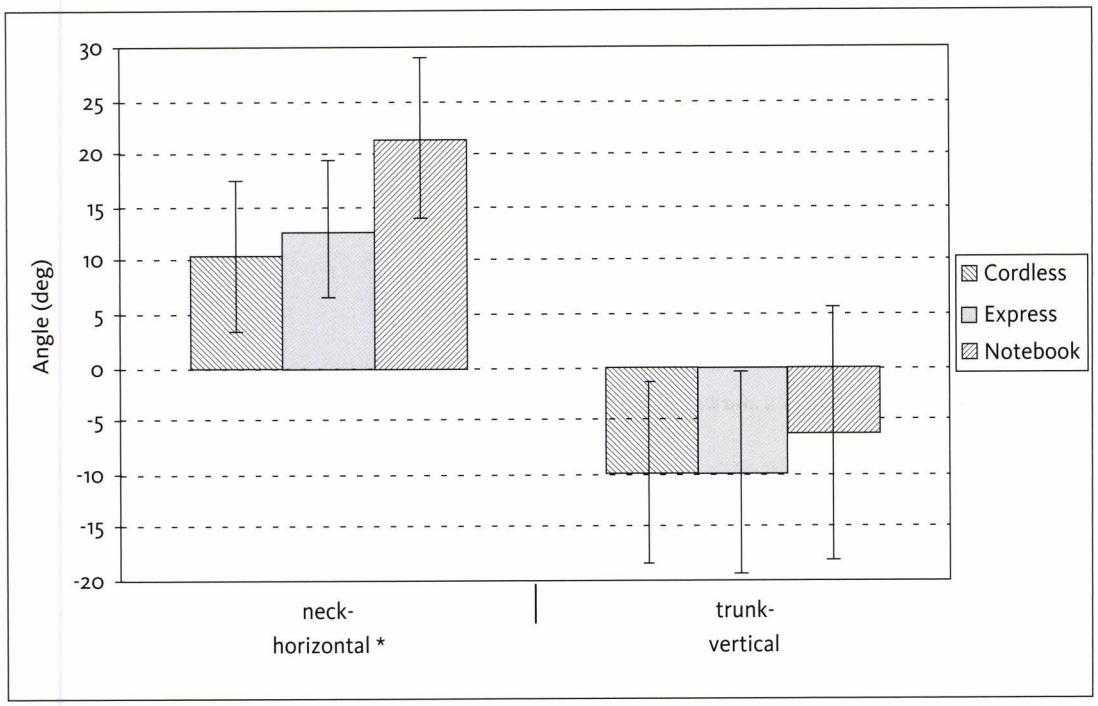


Figure 4: Mean angle with SD of 5 postural variables, with 0° as neutral or vertical, neck-horizontal = angle of neck to vertical, trunk-vertical = angle of trunk to vertical. * Significant difference between CL and NB, EX and NB (p<0.05).

tive fatigue in the hands, arms, shoulder, eyes and neck using a 7-point scale (1 = very much fatigue; 7 = very little fatigue) and their personal preferences of the working condition.

Controlled variables

The workplace in the laboratory was designed to be representative of the situation in which many users use a notebook at home. Therefore, the notebook and the notebook stand were placed on a desk with a fixed table height of 74cm representative of a dining table and the subjects were sitting on a chair with adjustable height which the subjects set to a comfortable working height.

Procedure

The subjects were informed about the study and signed the informed consent. After that, they were asked to adjust the chair height to their preferred settings. An instruction was given on how to perform the tasks. The subjects practiced each task for 1 minute on the notebook and the external mouse. The goniometer was calibrated with the subjects' neck in a neutral position (sitting upright with horizontal sight line). Before each condition, subjects were free to move the notebook or notebook stand with notebook on the desk to their preference. All conditions started with the emailing task, followed by the reading and the surfing task. Between tasks there was a 1 minute break. After each condition a questionnaire was filled in followed by 5-minute break. At the end a questionnaire about the overall experiment was filled in.

Statistical analysis

Data are presented as mean and standard deviation. ANOVA for repeated measures was used to evaluate the main effects of posture, productivity, fatigue and experiences (p=0.05) for the factor of notebook condition. LSD post-hoc tests were used to determine differences among the notebook conditions for all significant main effects.

Results

Posture

Figure 4 and table 1 (top) show the results from the posture measurements. Significant differences were only found for the neck angles. The neck angles relative to the horizontal were significantly smaller when working with the notebook stands compared to working without a notebook stand. No significant differences were found for trunk angle among the notebook conditions. The results from the neck-trunk angles measured by electrogoniometer could not be used for further data analysis due to unreliable results from placement and measurement difficulties. The sensors overlap multiple vertebrae which results in displacement of the sensor and bad validity.

Productivity

There were no significant differences between the

	CL mean (sd)	EX mean (sd)	NB mean (sd)
Posture (angle)			
Neck-horizontal*	10.5° (7.1)[n]	13.0° (6.5)[n]	21.5° (7.7)[c,e]
Trunk-vertical	-9.8° (8.5)	-10.0° (9.4)	-6.2° (11.8)
Fatigue (7-point scale)	*1 = very little fatigue, 7 = very much fatigue*		
Hand-Wrist	2.0 (0.3)	2.3 (0.4)	2.3 (0.3)
Arms	1.8 (0.3)	2.3 (0.4)	2.1 (0.3)
Shoulders	1.8 (0.3)	2.1 (0.3)	2.7 (0.4)
Neck*	2.5 (0.2)[n]	2.6 (0.3)[n]	3.7 (0.3)[c,e]
Eyes	2.6 (0.4)	2.8 (0.4)	3.2 (0.5)
Overall Preference			
Number of votes for Notebook condition	9	4	3

Table 1: Posture, fatigue, work setup questions and preferences results, in mean with standard deviation. * Significant difference ($p<0.05$), [c] with cordless, [e] with express, [n] with notebook

total relative number of words finished and the time between hits (in the mouse task) in each notebook condition.

Subjective fatigue, preferences and experiences

The results from the subjective fatigue questions showed a main effect for subjective fatigue in the neck. The subjective fatigue in the neck was significantly higher with the NB condition than with the CL condition and the EX condition. No significant differences were found for the hand, arms, shoulders and eyes by notebook condition.

When working with a notebook computer, 13 of the 16 subjects preferred using a notebook stand.

Discussion

When we compare the results of our study with the results of other studies, we find that our results can be confirmed for the effects on body posture, productivity and fatigue. The effect of using a notebook stand on body postures is mainly caused by the display height. All studies that we found, which compared low display height to higher display settings (mostly for desktop computers), concluded that low display height results in more neck flexion (Straker et al., 2008a; Saito et al., 2007; Seghers et al., 2003; Moffet et al., 2002; Villanueva et al., 1997; Straker et al., 1997; Saito et al., 1997).

In some studies the productivity differed between using a notebook and using a notebook with peripheral devices (notebook stand, keyboard and mouse) or a desktop computer. Subjects were more productive (text entry for 4 hours) when using a notebook with peripheral devices than when only using a notebook (Berkhout et al., 2004). This contradicts with our findings. This can probably be explained by the duration of the task or our use of control with a mouse for all tasks. Villaneuva et al. (1997) and Straker et al. (1997) did not find any significant differences in productivity (task of 20 min.) between notebook and desktop computers as a result of different types of keyboards, mice and display height.

Subjective fatigue on a VAS or Borg scale tends to be lower with higher display placement (Seghers et al., 2003; Straker et al., 1997). Only one study found significantly lower subjective fatigue (Borg scale) when using a notebook stand compared to no notebook stand (Berkhout et al., 2004). This was confirmed by the results of our study. Subjective rating of neck fatigue was significantly lower when working with a notebook stand. In the long term, this may lead to productivity loss if a notebook stand is not used.

Our study shows the same results for neck angle with different display heights as other studies. Lower display height results in larger neck flexion angles. The change in neck angle is also comparable. In this study a 27 cm difference in display height results in 11° difference in neck angle. Other studies report 13° difference for 30 cm and 11° for 20 cm (Seghers et al., 2003; Villanueva et al., 1997).

Mean neck angles for all notebook conditions stay within the limit (25°) for an 8 hour working day according to the ISO standard and the TNO guideline for physical workload.

Conclusions

From this study, we can conclude that the neck posture is more neutral with the use of a notebook stand. The lower display height of the notebook alone results in more neck flexion; however, all neck angles

stay within the limit of 25° (ISO 11226). Subjective fatigue in the neck was higher for the notebook only compared to the notebook stands. There were no significant differences between the notebook stands. Based on the results of this study, use of a notebook stand, separate keyboard and mouse in home situations instead of working on the notebook without peripheral devices is recommended, in order to reduce fatigue and to reduce the risk on neck complaints due to a more flexed neck posture.

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