

A study of three computer keyboards: Comparison of muscular effort and subjective pain and tiredness ratings

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Working with computer keyboards has been reported to cause development of pain in the upper limb and shoulder/neck areas. In this study, the aim was to investigate possible differences in muscular effort, pain and tiredness when using three different keyboards. This study was a within-subjects design. 18 subjects completed 20 minutes of word processing tasks on three different keyboards. Electromyogram was used to measure muscular effort. Pain and tiredness was rated using Borg's CR10 scale. The findings indicate that a keyboard offering open angle/negative slope may lead to less perceived pain and/or tiredness of the neck and arms during typing.

Keywords: computer keyboard, negative slope, musculoskeletal symptoms, electromyography

1. Introduction

More and more people are using computers at work as well as at home. It is estimated that in the year 2000 60% of workers used computers in the USA (World Health Organisation - WHO, 1998).

There seem to be an overwhelming consensus that excessive force, repetition and awkward postures are risk factors for and work related musculoskeletal disorders - WMSDs (Jensen et al 2002, Smutz et al 1995, Hagberg et al 1995, Nelson et al 2000, Gilad and Harel 2000, Amell and Kumar 1999, Haahr and Andersen 2003, Latko et al 1999, Westgaard et al 1994, Juul-Kristensen et al 2004). The force exerted when typing on a keyboard is not high enough to cause tendinitis (Smutz et al 1995). There is a positive association between computer work duration and WMSDs and repetitiveness is believed to be the cause for this (Jensen et al 2002b).

Computer operators adopt awkward postures when typing. On a conventional keyboard, the operator adopts a posture of extension and ulnar deviation of the wrist (Smith et al 1998, Simoneau et al 1999, Simoneau et al 1996b, Marklin and Simoneau 2001), pronation of the forearm (Hagberg et al 1995, Simoneau et al 1996b) and abduction of the shoulders. These postures are associated with WMSD risk factors (Smith et al 1998, Werner et al 1997) and increased muscular load, especially of the muscles on the forearm extensor side (Gilad and Harel 2000).

'Ergonomic' keyboards aim at targeting the issues with awkward postures related to computer keyboard work. A negative slope keyboard results in less extension of the wrist (Marklin and Simoneau 2001, Hedge and Powers 1995, Simoneau et al 2003). An open angle keyboard (see figure 1) results in less ulnar deviation (Simoneau et al 1999b, Smith et al 1998, Tittiranonda et al 1999, Zecevic et al 2000). To the best of the researcher's knowledge, no study has investigated any effects of a keyboard with both negative slope and open angle. No study has measured m. extensor digitorum communis - EDC and m. extensor carpi radialis brevis - ECRB EMG activity in either a negative slope or an open angle keyboard.

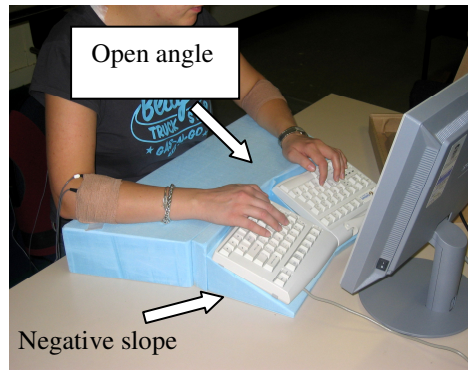


Figure 1. Keyboards with open angle and negative slope.

2. Objectives

In this study three different computer keyboards were investigated. The study aims to answer if there is a difference in participants' EMG activity of the wrist extensors, deltoid, trapezius and erector spinae muscles between the three keyboards, and if there is a difference in participants' perceived pain and muscular tiredness, between the three keyboards.

3. Methods

There were 18 participants in this study. The study was a within-subjects/repeated measures design with all subjects typing on each of the three keyboards investigated. Three different data entry texts were used. The order of keyboards and data entry text was arranged in a Latin square fashion to avoid any order bias. The three keyboards were:

1. Belkin ® keyboard. The keyboard has a slope of 8° . It was placed 5 cm from the edge of the table. This keyboard is referred to as the 'conventional keyboard' in the rest of this report.
2. Goldtouch ® keyboard adjusted to 18° open angle and has a slope of 6° . It was placed with the home row corners at a distance of 22 cm from the table edge. This keyboard is referred to as the 'angle keyboard' in the rest of this report.
3. Goldtouch ® keyboard put in a platform offering forearm support adjusted to -15° slope and 18° yaw/open angle. The platform was put at the table edge. See figure 1. This keyboard is referred to as the 'platform keyboard' in the rest of this report. The platform was designed for this study.

EMG was used to measure muscular effort during typing. The muscles measured were:

M. erector spinae/ M. trapezius/ M. deltoideus/ M. extensor carpi radialis brevis – ECRB and M. extensor digitorum communis – EDC. All measurements were done on the participants' right hand side. Before the keyboard trials, measurements of the maximum voluntary contraction – MVC were done for each of these muscles. EMG measures of the subjects' MVC were done, giving manual resistance. All contractions were isometric.

During the trials the typists typed for 20 minutes on each of the three keyboards and EMG measurements were made after 1, 5, 10, 15 and 19 minutes for 30 seconds with each keyboard. The participants were instructed to type as they normally would, and to correct their mistakes. The spell check was activated. There was a 10 minutes break between the trials.

EMG values for each participant at each keyboard was normalised against the MVC EMG value.

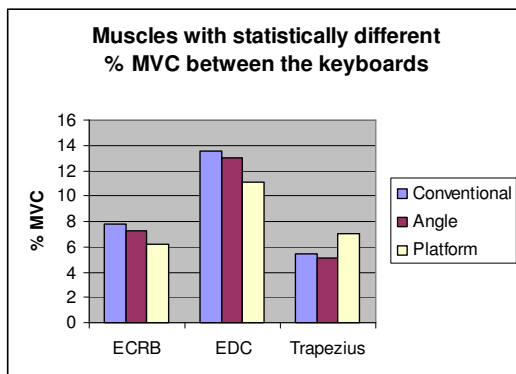
Participants were asked to rate perceived pain and muscular tiredness using a modified Borg's CR10 scales. For the pain rating the word 'pain' was added to the verbal anchors of the scale. For the muscular tiredness rating the word 'tired' was added to the verbal anchors of the scale. SPSS and Microsoft Excel were used to carry out the statistical analysis. Differences in %MVC values for each muscle between each of the three keyboards were tested for statistical

significance using a two-way analysis of variance – ANOVA. The Tukey HDS was used in the post hoc testing.

4. Results

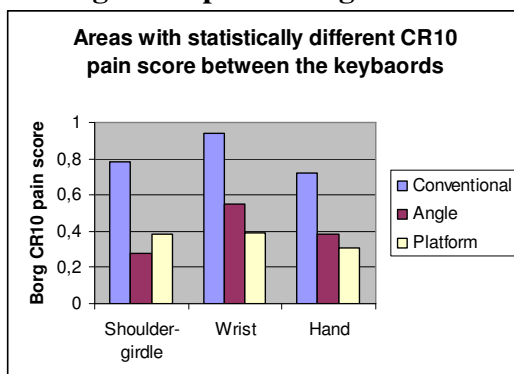
The results of the %MVC and the Borg CR10 pain and tiredness scale-ratings are presented in graphs for those muscles and bodyparts that had different values between the three keyboards, that were statistically significant. The post hoc statistical testing is presented in the tables next to the graphs and shows for which keyboards the values for the respective muscles and bodyparts are different with statistical significance. (* marks statistical significance with $p < 0.05$).

4.1 % MVC-values



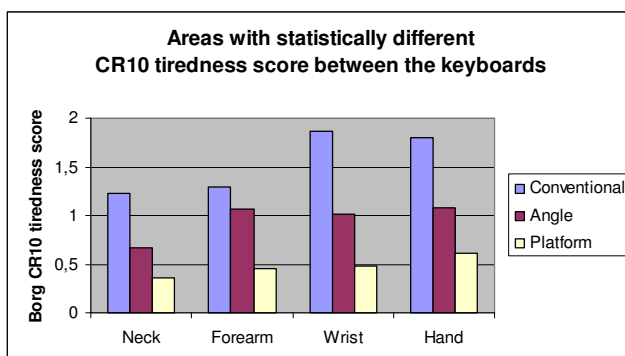
TUKEY HSD %MVC POST HOC STATISTICAL TESTING		
ECRB	Angle	Platform
Conventional	0.37	0.001*
Angle		0.041*
EDC	Angle	Platform
Conventional	0.783	0.023*
Angle		0.10
Trapezius	Angle	Platform
Conventional	0.861	0.092
Angle		0.029*

4.2 Borg CR10 pain rating score



TUKEY HSD CR10 pain POST HOC STATISTICAL TESTING		
Shoulder-girdle	Angle	Platform
Conventional	0.044*	0.12
Angle		0.884
Wrist	Angle	Platform
Conventional	0.111	0.016*
Angle		0.67
Hand	Angle	Platform
Conventional	0.072	0.027*
Angle		0.899

4.3 Borg CR10 tiredness rating score



TUKEY HSD CR10 tiredness POST HOC STATISTICAL TESTING		
Neck	Angle	Platform
Conventional	0.074	0.041*
Angle		0.961
Forearm	Angle	Platform
Conventional	0.613	0.004*
Angle		0.042*
Wrist	Angle	Platform
Conventional	0.069	0.002*
Angle		0.322
Hand	Angle	Platform
Conventional	0.062	0.001*
Angle		0.288

CORRELATION BETWEEN %MVC AND CR10 PAIN/ CR10 MUSCULAR TIREDNESS SCORE DURING TYPING		
Muscle %MVC/bodypart	CR10 pain score	CR10 muscular tiredness score
ECRB %MVC/forearm	r = 0.02	r = -0.21
EDC %MVC/forearm	r = 0.08	r = -0.22
Deltoid %MVC/shoulder	r = 0.14	r = 0.23
Trapezius %MVC/shoulder	r = 0.23	r = 0.03
Erector spinae %MVC/back	r = 0.28	r = 0.18

r = value of correlation.

5. Discussion

The results show that the ECRB and EDC muscles reduced the % MVC level by 20-25 % when using the platform keyboard compared to the conventional keyboard. Although there were statistically significant differences between the MVC % levels between at least two of the keyboards for the ECRB and EDC muscles, there were no statistically significant differences between the keyboards in terms of CR10 pain scores of the forearm. However, there was a statistically significant decrease in muscular tiredness rating scores for the forearm when using the platform keyboard compared to using both the conventional and the angle keyboards. The reason is probably linked to the wrist posture. With the conventional and the angle keyboards, the wrist is extended and the anti-gravity muscles of the forearm have to exert more force than when typing on the platform keyboard. This probably explains the reduced %MVC levels of these muscles when using the platform keyboard. The clinical significance for such a reduction is not known.

With the trapezius muscle, the % MVC level is lowest when typing on the angle keyboard and highest when typing on the platform keyboard. The increase in % MVC level was about 37%. This increase may be due to the platform's bulkiness, causing the participants to shrug their shoulders. The increase is statistically significant.

There was a significant difference in the pain rating score of the shoulder girdle between the keyboards, but the difference was between the conventional keyboard and the angle keyboard, with the conventional keyboard scoring the highest. It seems that increases and decreases in the muscle load did not affect how subjects rated pain for the shoulder-girdle. This is supported by the fact that there was poor correlation between %MVC and CR10 ratings.

There was a statistically significant difference in the muscular tiredness score of the neck between the conventional and the platform keyboards. The difference between the conventional keyboard and the angle keyboard was marginally significant. The reason for this difference could be that when using the conventional platform, the subjects had to look down at the keyboard that was placed 5 cm from the table edge and then look at the screen, causing continuous flexion and extension movement of the neck. The other two keyboards were placed 22 cm from the table edge making neck movement when alternately viewing the keyboard and the screen less than with the conventional keyboard.

There was a statistically significant decrease in muscular tiredness score for the wrist when using the platform keyboard compared to the conventional keyboard. The decrease between the conventional and the angle keyboards was marginally significant. There probably is no such thing as muscular tiredness of the wrist. A layman may not be aware of this fact. In order to keep the terms in the questionnaire as simple as possible it was decided to ask the questions

in this fashion. The rating of the wrist muscular tiredness may therefore represent a sensation of tiredness in the wrist area. With a conventional keyboard, subjects need to ulnar deviate and extend their wrists (Simoneau et al 1999). With the platform keyboard, the wrist was in a more neutral position in both the deviation plane and the flexion/extension plane. With the angle keyboard, the wrist was still extended but in a neutral position in terms of deviation. The decrease in tiredness score for the wrist when using the angle keyboard compared to the conventional keyboard was marginally significant. This suggests that a neutral wrist in the deviation plane may lead to less sensation of tiredness in the wrist. The fact that the decrease in tiredness score from the conventional keyboard to the platform keyboard was substantially significant, suggest that the combination of a neutral wrist in both the ulnar and the flexion/extension planes, led to less sensation of tiredness in the wrist area compared to only neutral deviation. This is supported by the results showing there is a significant decrease in pain rating scores for the hand and wrist between the conventional and the platform keyboard. However, the average rating was >2. This is close to the verbal anchors 'weakly tired/light' of the CR10 scale, thus it may not pose a substantial problem. The reasons for the decreases in hand muscular tiredness scores are possibly the same as for the wrist.

Although not part of the initial aim of this study, it was discovered that there was poor correlation between the % MVC levels and the CR10 pain rating scores as well as for the CR10 muscular tiredness scores. These results suggest that more than just muscular effort led to perceived pain and perceived muscular tiredness. Position of the limbs may influence these sensations. These results might lead one to question how the results of EMG are used in task assessments. EMG is a tool used by the professional ergonomist in task assessments (Chaffin et al 1999) to obtain objective measures of the muscular loads of tasks. Now, if the muscular load is not correlated to the worker's perceived pain and muscular tiredness, other tools such as posture analysis tools might be used in combination with EMG in task assessments.

The results of this study suggest that a keyboard such as the platform keyboard, offering negative slope, open angle and forearm support, led to reduced pain levels of the wrist and the hand. It led to reduced muscular tiredness levels of the neck, forearm, wrist and hands. It further led to reduced % MVC levels of the ECRB and EDC muscles. These reductions are possibly related to posture.

It was discovered that there was no association between muscular load and pain/muscular tiredness scores. To the best of the author's knowledge, this issue has not been addressed in the literature and should be addressed further in prospective studies with a large study population.

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