**COMPUTER KEYBOARD SLOPE: WRIST EXTENSION ANGLE AND FOREARM MUSCULATURE ACTIVATION**

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**Introduction**

There are an estimated 100 million computer keyboards in use in the United States. Extended use of computer keyboards has been associated with musculoskeletal disorders (MSDs) of the upper extremity, such as carpal tunnel syndrome (CTS) and tendonitis (Tittirandonda et al., 1999).

Several studies have investigated the magnitude of forearm muscle force from typing on computer keyboards. With electromyography (EMG), Gerard et al. (1999) measured the muscle activity of the flexor digitorum superficialis (FDS) and extensor digitorum communis (EDC) while subjects typed on keyboards of varying keyswitch mechanisms. Using an amplitude probability distribution, these researchers found that the 50th percentile of the EMG signal for the FDS was approximately 7% MVC, while the 10th percentile (baseline) was about 2% MVC. The corresponding 50th and baseline percentiles for the EDC (11.5% and 6.5% MVC, respectively) were much greater than the FDS. Forearm extensor EMG results from Gerard et al. (1999) are similar to findings from Fernstrom et al. (1994) who measured median (50th percentile) extensor EMG that ranged from 6.5 to 14% MVC while subjects were typing on various keyboards.

Although the internal forces of the forearm musculature required to type are relatively low, modifications to the design of the keyboard could possibly minimize muscle force and consequently the occurrence of fatigue. The objective of this study was to determine the effect of computer keyboard slope angle on wrist position and forearm musculature activation in healthy individuals.

**Methods**

Subjects: Fifteen asymptomatic women and one man (mean age: 42 years, range 27 to 53) volunteered to participate in the study. Subjects typed at least 50 words per minute and worked in jobs requiring typing at least two hours per workday.

Instrumentation: A fixture for a conventional QWERTY keyboard was built so a keyboard could be sloped at positive and negative angles. Adjustable-length stilts made out of threaded bolts adjusted the keyboard’s slope angle to four angles: 7.5°, 0°, −7.5°, and −15°. A built-in wrist rest was on the same plane as the keyboard. An adjustable computer workstation (table and chair) was used for testing. Typing speed and accuracy were measured with the Typing Tutor software.

Biaxial electrogoniometers (Biometrics Corporation, Ladysmith, VA) attached to the dorsum of the wrist measured wrist extension and ulnar deviation angles while typing. EMG RMS data for the extensor carpi ulnaris (ECU), flexor carpi ulnaris (FCU) and flexor carpi radialis (FCR) were collected with surface electrodes (Therapeutic Unlimited, Iowa City, IA). On-line wrist joint position and EMG RMS data were sampled at 300 Hz and fed into a 12-bit analog-to-digital converter (National Instruments, Austin, TX) and stored on a personal computer operated with custom written software (LabView, National Instruments, Austin, TX).

Experimental protocol: Upon arrival at the laboratory, the subject signed an approved human consent form. A brief medical survey was completed by the subject, and basic anthropometric dimensions and range of motion of the wrists were recorded by the experimenter. The goniometric monitors and surface EMG electrodes were attached to the subject’s right and left wrists and forearms. The electrogoniometers were then calibrated before establishing the resting and maximum voluntary contraction (MVC) for the three muscles monitored. The subject then sat on a height-adjustable chair next to a VDT workstation that was setup according to 1988 ANSI/HFS guidelines. The height of the chair was adjusted so that the subject’s styloid process was level with her lateral epicondyle.
The keyboard was adjusted to the first of the four randomly assigned keyboard slopes, and the subject practiced typing at that keyboard setting for five minutes. Following a two-minute rest, the subject typed for six minutes, during which data were collected. The subject then rested for five minutes while the keyboard was adjusted to the next slope. The subject practiced typing for five minutes, rested for two minutes, and then typed for another six minutes. This procedure was repeated until the subject typed on the keyboard set at each of the four slope angles.

The conditioned position and EMG data from all subjects were pooled for statistical analysis. A one-way ANOVA was performed to determine whether there were significant differences in the kinematic and RMS EMG dependent variables among the four keyboard slope conditions.

**Results and discussion**

Data presented are for the right upper extremity. As keyboard slope angle decreased 22.5° (from 7.5° to –15°), right wrist extension decreased approximately 15°, from 12.2 ± 6.9° of extension to 2.6 ± 6.1° of flexion (Table 1). This change of wrist angle was statistically significant (p < 0.01), and Tukey posthoc analysis showed that mean wrist extension angles for all four slope conditions were significantly different from each other.

Mean ulnar deviation of the right wrist progressively increased by a total of 5.8 degrees (from 9.1 ± 6.6° to 14.9 ± 6.9°) when the keyboard was sloped downward from 7.5° to –15° (Table 1). This change of wrist angle was statistically significant (p < 0.05). Tukey posthoc analysis showed that mean wrist ulnar deviation angles for all pairwise comparisons of slope conditions were significantly different from each other except for comparison between the –7.5° and –15.0° slope angles.

**Table 1: Mean right wrist position while typing (mean ± s.d.).**

<table>
<thead>
<tr>
<th>Keyboard slope angle</th>
<th>Extension angle*</th>
<th>Ulnar deviation angle‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.5°</td>
<td>12.2 ± 6.9°</td>
<td>9.1 ± 6.6°</td>
</tr>
<tr>
<td>0°</td>
<td>7.6 ± 6.6°</td>
<td>10.6 ± 6.9°</td>
</tr>
<tr>
<td>-7.5°</td>
<td>2.3 ± 5.8°</td>
<td>13.2 ± 6.8°</td>
</tr>
<tr>
<td>-15°</td>
<td>-2.6 ± 6.1°</td>
<td>14.9 ± 6.9°</td>
</tr>
</tbody>
</table>

* All values are different from each other (p < 0.01).
‡ All values are different from each other (p < 0.05), except comparison between keyboard slope angles –7.5° and –15°.

The 50th percentile of the EMG percentage MVC data for the ECU decreased from 13.6 ± 6.1% to 11.7 ± 4.5%. For the FCU and FCR, the 50th percentile of the EMG percentage MVC data changed from 4.2 ± 1.8% to 5.3 ± 2.4% and from 1.8 ± 1.2% to 1.9 ± 1.4%, respectively. Although, the trends noted for the ECU and FCU reach statistical significance (p < 0.05), these differences may not be clinically significant (Table 2). The increase EMG level for the FCU may be related to the increase ulnar deviation noted with the negative slope angles.

Results from this study show that when the keyboard was sloped 22.5° downward (from 7.5° to –15°), right wrist extension decreased approximately 15° (from 12.2° to -2.6°). This is in general agreement with our earlier findings that wrist extension angle decreases approximately one degree for every two degrees of downward slope (Simoneau et al., 2001). Based on wrist biomechanics and carpal tunnel pressure studies, the lower extension angles at the negative keyboard slopes are believed beneficial with respect to etiology of injuries affecting the wrist (Schoenmarklin and Marras 1990; Rempel et al., 1997).
Table 2: 50th percentile of EMG % MVC data (mean ± s.d., values in %MVC).

<table>
<thead>
<tr>
<th>Keyboard slope angle</th>
<th>ECU*</th>
<th>FCU*</th>
<th>FCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.5°</td>
<td>13.6 ± 6.1</td>
<td>4.2 ± 1.8</td>
<td>1.8 ± 1.2</td>
</tr>
<tr>
<td>0°</td>
<td>12.8 ± 4.9</td>
<td>4.7 ± 2.0</td>
<td>2.0 ± 1.4</td>
</tr>
<tr>
<td>-7.5°</td>
<td>12.1 ± 5.0</td>
<td>5.0 ± 2.2</td>
<td>1.9 ± 1.4</td>
</tr>
<tr>
<td>-15°</td>
<td>11.7 ± 4.5</td>
<td>5.3 ± 2.4</td>
<td>1.9 ± 1.4</td>
</tr>
</tbody>
</table>

* For the ECU and FCU, the trend in the data reaches statistical significance (p < 0.05).

The ulnar deviation angles measured in this study for the +7.5° slope, which is similar to the built-in slopes of many commercially available keyboards, is similar to ulnar deviation angles measured on 90 subjects typing on a conventional keyboard in a previous study (Simoneau et al., 1999). As shown in Table 1, ulnar deviation increased significantly by approximately 6 degrees when the keyboard was sloped from 7.5° to −15°. The reason for this increase in ulnar deviation is not clear at this time, but a change in forearm pronation (which was not measured in this study) could play a role.

Our 50th percentile of EMG percentage MVC data for the wrist extensors are around 12 to 14% MVC, which is in general agreement with the values reported for the EDC by Gerard et al. (1999) and for the wrist extensors by Fernstrom et al. (1994). Interestingly, the change in wrist position only created a small change in the muscle activity level of the three muscles studied. Because the reduction in wrist extension angle from a negatively sloping keyboard was not related to an increase in muscular load, a negatively sloping keyboard could possibly aid in the prevention and rehabilitation of CTS among keyboard users without increasing the risk for muscular fatigue or musculotendinous injuries.

References


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