

Muscle Activity in the Hand and Forearm using a Traditional and a Chording Keyboard

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Introduction

The increase of computer use in recent years has caused an increase in occupationally related upper extremity disorders. The traditional 101-key ("QWERTY") keyboard has come under much scrutiny in recent years as being detrimental to user health. The nature of the complaints centre around the user-keyboard interface, that is, the postures and movements of the fingers, wrists, and shoulders and the forces necessary to activate the keys.

Alternative keyboard configurations have attempted to address these issues. Keyboards have been designed to maintain the traditional keyboard shape while remapping the key configuration to reduce finger motion, (eg., the Dvorak keyboard, Dvorak, 1943). The complementary approach has developed a keyboard which retains the usual "QWERTY" key configuration but the physical layout of the has been markedly altered to promote neutral wrist postures and reduced finger travel, (eg., the Kinesis keyboard) These alternatives maintain the historical image of the keyboard; chord keyboards change the manner in which the user interacts with the keyboard. Each finger actuates a single key: to obtain sufficient combinations multiple keys must be depressed simultaneously. These sometimes complex "chords" must therefore be learned.

The ternary chord keyboard reduces the complexity of the chord because each key has three states (ternary) rather than the more common two states (on/off), ("Accukey" keyboard, VATELL Corp.) A ternary keyboard can achieve a large number of key combinations with just two fingers (one on each hand). This simplifies learning: "Subjects are able to learn these chords required for normal typing quite easily, in under four hours", Kroemer et al., (1992).

The ternary chord keyboard has built in wrist rests to promote a more neutral to slightly flexed wrist posture. The keys (four for each hand) are arranged in a curved formation approximating the natural position of the fingers. Each key has three positions, off, forward, and backward. The chords are created using one finger from each hand "rocking" the keys into the forward or backward position depending on the character to be typed.

Measurement of the quality of the user-keyboard interface has been made using measures of forces exerted during keying (forces transducers under the keyboard or mounted under the keycaps), postures adopted during keying measured using video or electrogoniometry (Smutz et al., 1995) and the activation of arm and shoulder musculature monitored by electromyography (EMG), Wells, Moore and Keir (1994), Gerard et al., (1995). In using EMG to evaluate the quality of the interface, both the amplitude of activation as well as the time variation of the activation appear important. A good interface should possess low static loading coupled with moderate median and peak levels (Jonsson, 1982) with periods of time when the activation drops to zero (EMG gaps, Veiersted et al 1990).

The purpose of this phenomenological study is to quantify the activity of some of the major muscles responsible for keying in computer input tasks.

Experimental Procedures

Each of eight participants visited the laboratory twice, once to become familiar with all experimental tasks and practice typing with the new keyboard, and once for the actual testing. The training session ensured that the test sequence could be typed without error. The testing session began with attachment of disposable Ag-AgCl surface electrodes over the muscle bellies of the following five muscles: first dorsal interosseous, extensor carpi ulnaris, common extensor site (over the extensor muscle mass 5cm distal to the lateral epicondyle), pronator teres, and the forearm flexor. Smaller electrodes were used for the first dorsal interosseous to ensure the signal was from that muscle and so as to not hinder movement.

After attachment of the surface electrodes the wrist goniometer (Penny & Giles) was attached and calibrated by positioning the wrist the neutral position of the wrist, in 30 degrees of extension, and moving through a range from 20 degrees radial to 20 degrees ulnar deviation.

After confirming placement and function

of the surface EMG and electrogoniometer signals, the fine wires electrodes were inserted into the first lumbrical, first palmar interosseous, and the flexor digitorum profundus to the index finger. Bipolar fine wire electrodes were inserted using a 27 gauge hypodermic needle. Fine wire electrode placement was verified using functional tests. For the first dorsal interosseous (FDI), myoelectric activity with radial deviation (abduction) was a primary indicator as was FDI activity in the absence of lumbrical activity with active full flexion of the metacarpophalangeal (MCP) and interphalangeal (IP) joints. For the palmar interosseous, similar tests with the ulnar deviation rather than radial deviation. Placement of the lumbrical electrodes were tested by full extension of the IP joint where the lumbrical should be active with little or no interosseous activity. Thumb adduction against resistance was performed to eliminate the possibility that any of the electrodes were inadvertently inserted into adductor pollicis. Electromyographic signals were differentially amplified, full wave rectified and processed with a 6Hz low pass filter to produce a linear enveloped signal. The raw signals were monitored for quality using an oscilloscope. The linear enveloped signals were then analog to digital converted at 60Hz, along with the goniometer channels, using commercial hardware and custom software.

After confirming the placement of all electrodes, a series of basic hand movements was performed. Maximal voluntary exertions were performed for each of the following: i) tip pinch; ii) lateral pinch (key pinch); iii) index finger adduction; iv) grasp (hook grip); v) grasp + flexion; vi) grasp + extension; vii) resisted pronation.

For each subject the workstation was adjusted, within recommended guidelines, to subject preference for keyboard height and angle, as well as chair height. The order of keyboard presentation was alternated between subjects, thus one half (4) used the standard extended keyboard first and one half used the chording keyboard first.

A standard text passage was used for comparison between the keyboards. The text passages were designed to require the same fingers to be used in the same orders with similar finger placement between the keyboards. Thus the muscle activity levels represent a difference in muscle usage between the keyboard types rather than an activation difference due to "typing". A trial consisted of a block of 100 error-free (10 characters times 10 repeats) characters. The muscular activity was summarized using the Amplitude Probability Distribution Function (APDF) and the 10th, 50th and 90th percentiles were selected

for analysis, (Jonsson, 1982).

Results

Table 1 summarizes the levels of muscle activity whilst keying on the two keyboards. Figure 1 shows the patterns of muscular activity of a typical participant (who showed responses similar to the group mean response) during keying with the two keyboards.

Discussion

The three levels of EMG amplitude from the APDF, static, median, and peak, each tell a different story: for long term keyboard use the static level is probably most important. All levels are scaled to a maximum voluntary isometric contraction (MVC). The presence of a static load (defined as the 10th percentile of the activation cumulative amplitude probability) tells us that the muscle involved is active 10% of the time at the static level or less and thus does not have much rest (zero activation). This has been suggested as being an important risk factor for muscular disorders. The median level (similar to the mean but as the distribution is heavily non-normal not numerically equal) indicates the average demand while the peak value gives the 90th percentile activation level. In general a better keyboard will have low or zero "static" level and a moderate median and peak level.

Overall there was a trend to lower levels of activation when using the chord keyboard with a large proportion of the differences being significant statistically, Table 1. The most consistent differences were seen at the extensor sites where the chord keyboard showed lower activation levels. The main exception to this trend was seen in the flexor sites where the chord keyboard tended to have higher activations.

The possible overuse of the wrist and finger musculature during keyboard use has been noted by a number of authors, (Rose, 1991 and Wells, Moore and Keir, 1994) and the presence of muscular disorders in the forearm noted in both VDT (Pascarelli and Kella, 1993) and non-VDT users (Ranney et al., 1995). In the studies cited, the extensor musculature was notable for the large number of problems found. This is understandable as during keyboard use, the extensors of the wrist must maintain the wrist in neutral to extended postures against the pull of the finger flexors, (Wells, Keir and Moore, 1995). The lower activation of the extensor musculature is thus an advantage of the chord keyboard compared to the

standard keyboard tested here although one modification of the standard keyboard showed reduced activation on all muscles tested, Gerard et al., (1994). The similar or possibly increased levels of activation seen in the flexor musculature during use of the chord compared to the standard keyboard may be related to the pushing and pulling action of the fingertip on the chord keyboard. This would elicit activation of the FDP muscle, the only muscle acting directly on the distal phalanx.

It might have been expected that the push/pull action of the fingertip would recruit the intrinsic muscles: extending the PIP joint and flexing the MP joint (to push the finger tip out) recruits the lumbrical. However, the intrinsic muscles measured showed either similar or reduced activation when using the chord keyboard. Cadaver studies have shown that the lumbricals can enter the carpal tunnel. When a muscle is active, it shortens in length and becomes thicker (keeping its volume constant), thus if the lumbricals were active, they could take up more space in the carpal tunnel resulting in increased carpal tunnel pressures, a finding highly correlated with carpal tunnel syndrome. Use of the chord keyboard may thus lessen the risk of CTS due to active lumbrical muscles within the carpal canal.

In summary, use of a ternary chord keyboard under the conditions described, lead to lower activations in most of the muscles monitored. This was noted especially in the extensors of the wrist and fingers. The flexor musculature showed a trend to higher activation, possibly due to the push/pull action of the fingertip. The relative ease of training on this keyboard makes it a potentially viable alternative to "standard" keyboards however further investigation is needed to substantiate these preliminary findings.

Acknowledgements

The authors gratefully acknowledge the support of the Centre for Occupational Health and Safety, University of Waterloo as well as the patience and perseverance of the experimental participants.

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Table 1 Summary of Activation of 8 Muscles of the Hand and Forearm whilst keying on a Standard and a Chord Keyboard. Activation levels are presented as a percentage of a maximum isometric voluntary effort.

Muscle	10th Percentile "Static"		50th Percentile "Dynamic"		90th Percentile "Peak"		Notes
	Chord	Standard	Chord	Standard	Chord	Standard	
First dorsal interosseous	0	0	0.7	0.4	5.2	7.6	Surface
Lumbrical	4.1	5.1	7.2*	10.5	15.1**	21.7	Indwelling fine-wire (index finger)
Palmar interosseous	0	5.5	1.7	16.4	12.1	30.8	Indwelling fine-wire (index finger)
Common extensor site	0.12**	1.98	1.0***	4.7	5.7	8.0	Surface
Extensor carpi ulnaris	3.5*	7.5	6.5**	13.8	10.7**	21.6	Surface
Pronator teres	0.3*	1.8	1.6*	4.5	5.9	8.6	Surface
Forearm flexor	1.4	.34	2.5	1.5	6.9	7.1	Surface
Flexor digitorum profundus	0.2	0.2	3.7	1.6	15.5	11.2	Indwelling fine-wire (index finger)

* p < 0.1, **p<0.05, ***p<0.01

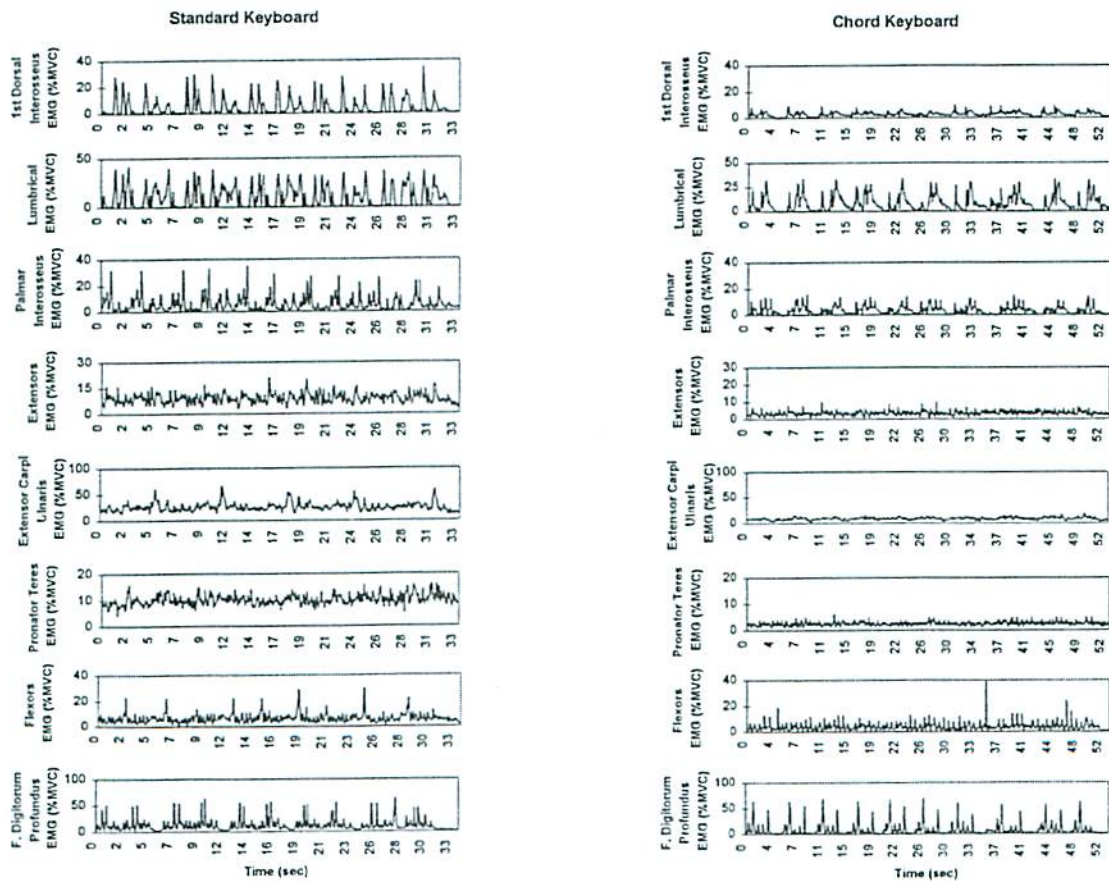


Figure 1. Patterns of Muscular Activation whilst Using a Standard Keyboard and a Chord Keyboard