



# GET

*Global Ergonomic Technologies, Inc.*

## **Ergonomic Test of the Kinesis Contoured Keyboard**

Prepared by  
Wanda Smith, President  
Dan Cronin, Engineer  
December 16, 1992

### **Executive Summary**

A study was conducted of postures, muscle activity, keying performance and preferences of subjects keying on a standard (traditional type) keyboard and the Kinesis keyboard. The main purpose of the study was to determine if the design of the Kinesis keyboard resulted in reduced muscle load, improved performance, and was preferred to a traditional keyboard.

Twenty five subjects participated in the test. Each subject was required to key text and random letters for six 20-minute sessions on each of the two (traditional and Kinesis) keyboards. Subjects were given seven hours of keying practice on the Kinesis keyboard the day before the test.

Throughout the test, measures were taken of hand angles, electrical muscle potential, keying (speed and accuracy), and comparative ratings of each keyboard.

Postural analysis showed hand deviation and extension were substantially less on the Kinesis keyboard than on the traditional keyboard.

Analysis of muscle load revealed substantially less load on muscles controlling hand deviation, extension, and pronation on the Kinesis keyboard. Subjects exhibited virtually the same muscle load for elbow abduction for both keyboards by the end of each test.

Analysis of subjects' performance showed a statistically significant increase in throughput for test entry when subjects used the traditional keyboard, but no significant difference in error frequency between the two keyboards.

Subjects indicated substantial preference for the Kinesis in areas of comfort, fatigue, and usability. They preferred the Kinesis by almost two to one as an overall choice.

### **Introduction**

The design of the Kinesis keyboard is radically different than a traditional keyboard. On the Kinesis keyboard, the traditional QWERTY keyboard layout is located in two separate sections, one on each side of the keyboard. The Kinesis key field profile is concave; special keys (like Backspace, Delete and Enter) are located in the center of the key area at approximately a 60 degree angle to the front edge of the keyboard or there is a built-in palm rest.

A primary purpose of the design of the Kinesis keyboard is to reduce stress on the upper body and the hands from the keying force, ulnar-lateral deviation, and extension that often occur while using a traditionally designed keyboard. The Kinesis intends to achieve these results by customizing and reducing displacement force of specific keys, customizing the shape of the keys to the shape of the fingers, separating keying sections, and providing a palm rest.

The following test was conducted to determine the extent that the Kinesis keyboard reduces muscle load, and compares to the traditional keyboard in performance and preference.

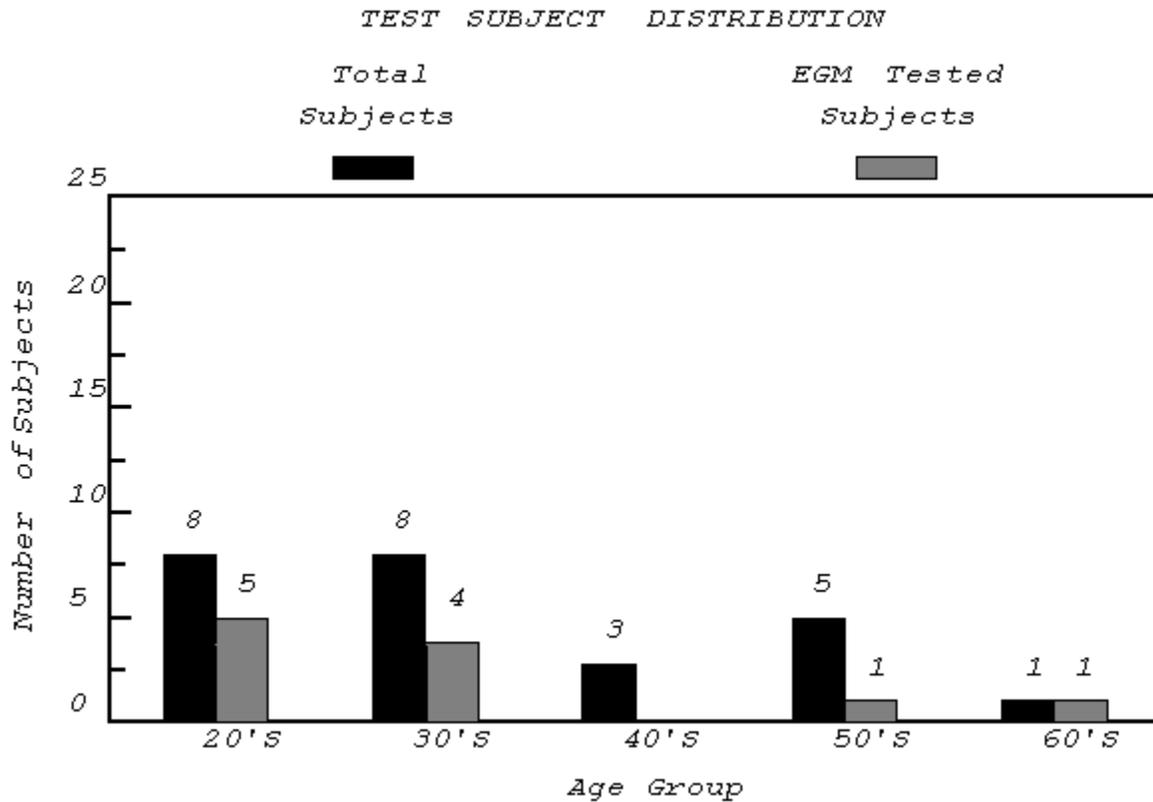
**Method**

The experimental protocol used in this study was based on that as specified in the Part 4 (Keyboard Requirements) draft of the ISO ergonomic standard 9241. Part 4 specifies test subjects, stimuli, experimental design, environmental conditions, furniture adjustments, performance data analysis, and a preference metric.

**Subjects**

Twenty-five subjects (20 women and 5 men) between 20 to 60 years of age participated in the study; eleven of these subjects participated in the EMG analysis (see Figure 1). The subjects were obtained from a temporary employment agency and all pre-tested at a typing proficiency of at least 45 words per minute. All subjects had several years' experience using traditional computer keyboards.

Figure 1:



**Stimuli**

The test stimuli consisted of pages of double-spaced lines of text and five groups of five lines of seven random capital letters (see Appendix A). The stimuli pages were placed on a document holder located to the left side of the computer display.

**Equipment**

The following equipment was used to present stimuli, monitor keying performance, record hand and upper body position, and EMG activity, and to perform data analysis. The ISO reference (traditional) keyboard was an AST KB101 keyboard with an angle of 5 degrees, a key field angle of 8 degrees, and a home row height of 30 mm with no palm rest; the test keyboard was the Kinesis Ergonomic Keyboard Model 100.

A Precision Biometrics Inc. MyoVision 4000 instrument and software package was used to collect and analyze EMG activity. The software was installed on a Hewlett-Packard Vectra PC - RS/20.

Two Sony DXC-930 video cameras recorded subject posture. One was located directly above the subject and recorded the upper body posture so that any deviation of the hands and the elbows from a neutral position could be recorded and later measured. The other camera, located at the side of the subject, recorded vertical angulation of the right hand. A Panasonic WJ-MX50 Switcher allowed the superimposition of the video image from one camera onto a section of the image from the other camera.

Subjects' keying activity was recorded onto a JVC BR-S822U video tape deck in a S (Super)-VHS format. Time and date stamping were incorporated on the video images, via a Panasonic WY-KBS0 Character Generator. Audio instructions ("start, stop and break time") to subjects. Comments from subjects, and comments from test observers, were recorded via JVC MI-3000 audio board.

A Hewlett-Packard Vectra PC was used to analyze keying performance.

TAB Products computer terminal tables with adjustable keyboard trays and ergonomic chairs were used for subject's workstations. The environmental conditions (temperature, humidity and illumination) were set to ISO test specifications.

**Procedure**

The study was conducted in the GET usability lab. Each subject participated in the study for three days at the same time each day, either in the morning or in the afternoon. At the beginning of the first day, each subject was briefed about the test and asked to complete Kinesis questionnaire (see Appendix B). The subjects were asked to adjust their chairs to a preferred comfortable position. The keyboard height was then adjusted to an ergonomically correct position at the preferred chair height.

Electrodes were next placed on eleven of the subjects at four locations on the forearm and at one location on the upper arm to monitor the muscle activity levels of ulnar deviation, extension, pronation, and arm abduction. A ground electrode was attached to the neck of each subject. Table 1 shows the names of the muscles, activity controlled by these muscles, and assignment of the electrode to an EMG channel.

**Table 1**

Muscle Name	Activity Indicator	Channel
extensor carpi ulnaris	hand ulnar deviation	1
extensor communis digitorum	hand extension	2
deltoid	abduction of elbow	3
pronator radii teres	inward twist of forearm	4

Each subject was tested on the two keyboards at the same time on two different days. Each subject practiced keying on the Kinesis keyboard for seven hours the day before they were tested on it. Keyboard assignment was altered between subjects to provide for balanced experimental design (see Table 2).

**Table 2**

Subjects	Day 1	Day 2
1-2	Traditional	Kinesis
3-8	Kinesis	Traditional
9-12	Traditional	Kinesis
13-16	Kinesis	Traditional
17-20	Traditional	Kinesis
21-25	Kinesis	Traditional

The keying tasks consisted of typing text for four 20-minute sessions and then typing random letters for two 20-minute sessions on each keyboard. Each subject was given 5-minute break at the end of each 20-minute session, and 15-minute break between the third and fourth sessions (see Table 3). The subjects were instructed to turn each

page when they completed keying the page. Each subject was instructed to use the left hand to turn the page in order not to interfere with muscle activity monitoring of the right hand.

**Table 3**

Day 1 Test		Day 2 Test	
Activity	Time	Activity	Time
Instructions and Questionnaire	25 minutes		
Electrode Attachment	15 minutes	Electrode Attachment	15 minutes
Type text	20 minutes	Type text	20 minutes
Break	5 minutes	Break	5 minutes
Type text	20 minutes	Type text	20 minutes
Break	5 minutes	Break	5 minutes
Type text	20 minutes	Type text	20 minutes
Break	15 minutes	Break	15 minutes
Type text	20 minutes	Type text	20 minutes
Break	5 minutes	Break	5 minutes
Type random letters	20 minutes	Type random letters	20 minutes
Break	5 minutes	Break	5 minutes
Type random letters	20 minutes	Type random letters	20 minutes
Break	5 minutes	Break	5 minutes
Questionnaire	20 minutes	Questionnaire	20 minutes

After all of the six sessions had been completed, each subject was given two questionnaires to complete. One questionnaire was required by the ISO test methodology (see Appendix P) and the other was developed by Kinesis (see Appendices C & D). Subjects were also given another questionnaire developed by Kinesis at the completion of the final day of testing (see Appendix E).

All subject input was stored on the HP PC. Keying performance was evaluated by calculating the number of words in text entry, keystrokes in random entry, and errors during each session.

Action EMG Dynamic Evaluation Software recorded eight EMG measures per second in 30- second increments for each of the six 20-minute sessions per keyboard. Of the possible 9,600 measurements (480 measures/minute x 20 minutes/session), 7,600 measurements were recorded for each session (due to the down time between each of thirty four 30-second increments). There were thus 7,600 measurements per channel for each 20-minute session, totaling 45,600 measurements per channel for the 6 sessions per day.

Postural data was calculated by measuring band and arm angle deviation from neutral postures on video images with a goniometer.

## **Results**

### *Posture Analysis*

The eleven subjects that participated in the EMG analysis were video-taped for postural analysis. The following are some observations from review of postural data;

#### Hand Extension:

Subjects demonstrated hand extensions one and one half times higher on the traditional keyboard (19.9 degrees) than on the Kinesis (12.4 degrees). Extension on the traditional keyboard was about 5 degrees greater than the maximum recommended hand extension of 15 degrees from neutral position. Extension on the Kinesis averaged three degrees less (12 degrees) than the maximum recommended position of 15 degrees.

During later sessions, subjects sat in more reclined position while using both keyboards and exhibited less hand extension.

**Hand Deviation:**

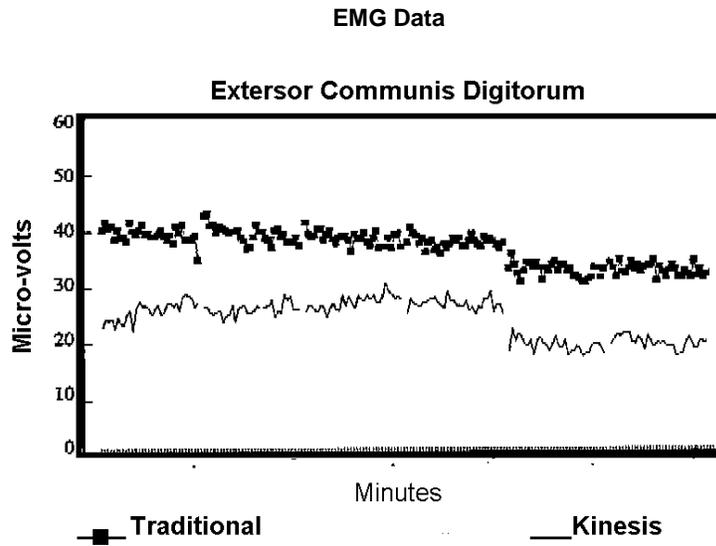
Average hand deviation was substantially higher on the traditional than on the Kinesis keyboard. Average hand deviations on the traditional keyboard ranged from 2 to 15 degrees greater than the recommended maximum deviation of 10 degrees; average deviation on the Kinesis was one degree less than the maximum recommendation.

**EMG Analysis**

Electrical activity of the muscles controlling deviation, extension and pronation was substantially higher during keying on the traditional keyboard. This trend was consistent throughout all six sessions. EMG activity of all four muscles was lower during random letter keying than during text entry with both keyboards.

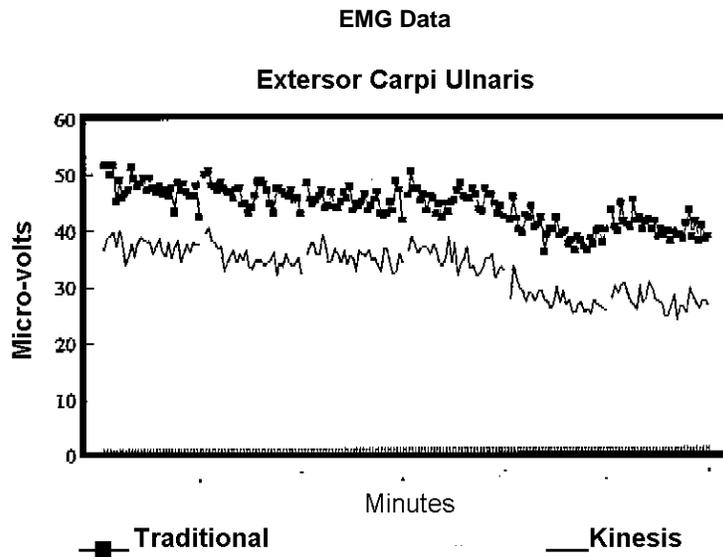
Channel 1: The EMG activity of the extensor carpi ulnaris muscle (indicating ulnar deviation) was substantially and consistently higher on the traditional keyboard than on the Kinesis (see Figure 2). There was a slight decrease in EMG activity during random letter keying for both keyboards.

Figure 2:



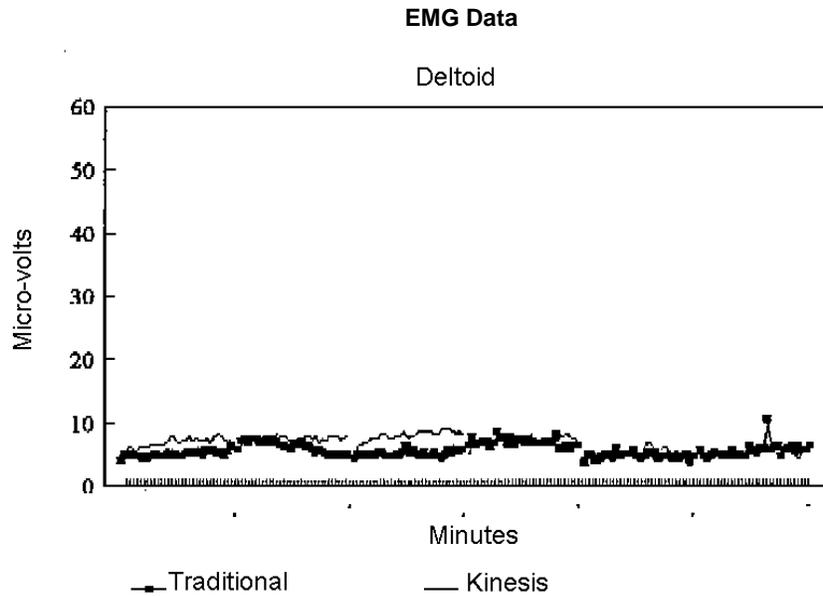
Channel 2: The EMG activity for the extensor communis digitorum muscle (indicating extension) was substantially and consistently higher on the traditional keyboard than on the Kinesis (see Figure 3). There was a decrease in EMG activity during random letter keying for both keyboards. The decrease in EMG was greater for the Kinesis keyboard, indicating lower muscle load.

Figure 3:



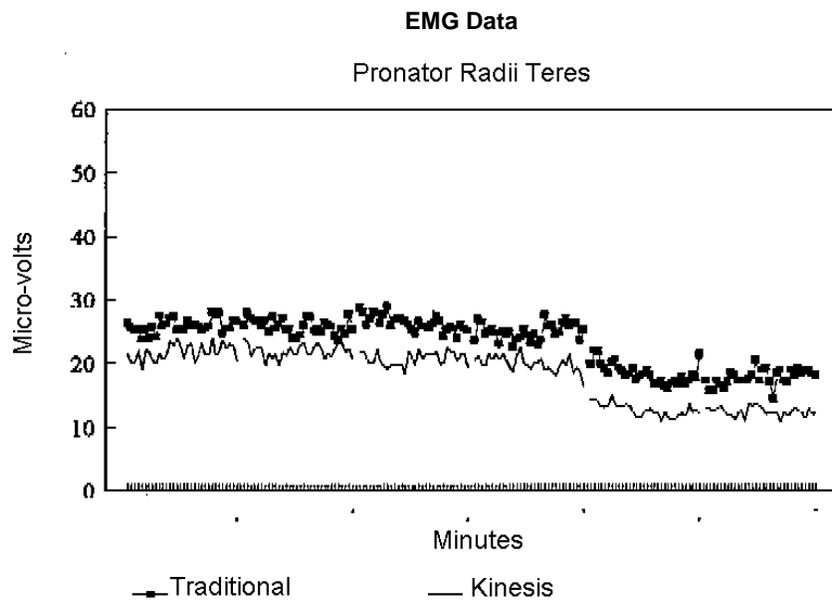
Channel 3: The EMG activity for the deltoid muscle (indicating arm abduction at the elbow) was almost the same for the two keyboards (see Figure 4). The activity of this muscle was lowest of all the recorded muscle activity. There was a slight decrease in EMG activity during random letter keying on both keyboards.

Figure 4:



Channel 4: The EMG activity for the pronator radii teres (indicating arm pronation) was higher on the traditional keyboard than on the Kinesis (see Figure 5). There was an equivalent decrease in EMG activity during random letter keying for both keyboards.

Figure 5:



### Keying performance

ANOVAs (Analysis of Variance) were calculated to determine significant differences in performance between subjects, keyboards, and sessions

### Text Entry

Text entry throughput, calculated in words per minute (see Figure 6, and Appendix A), was significantly higher on the traditional keyboard than on the Kinesis keyboard ( $F=41.854$ ,  $p= .0001$ ). The differences in errors for text entry between the two keyboards were not significant (see Figure 7). During the text entry session, the number of errors substantially decreased on the Kinesis keyboard, but not on the traditional keyboard.

Figure 6:

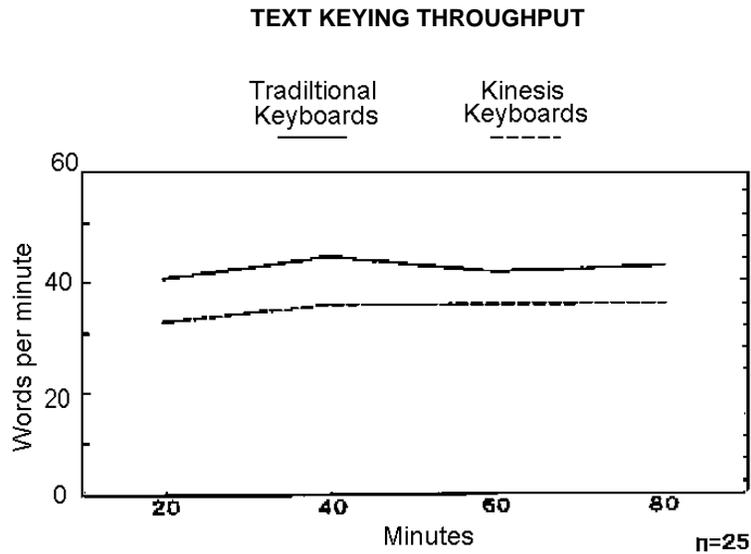
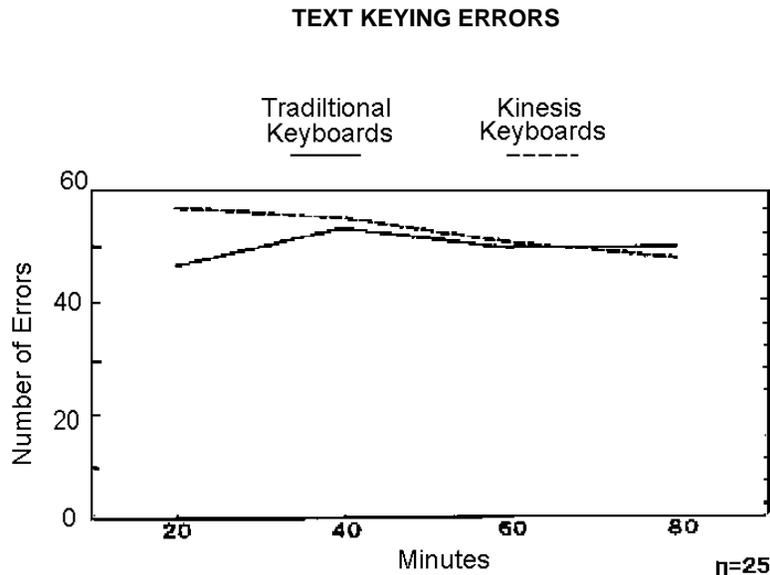


Figure 7:



### Random Letter Entry

Random letter entry calculated in keystrokes per session (see Figure 8, and Appendix A), was significantly higher on the traditional keyboard. There was a slight but insignificant increase in the number of keystrokes in the last session on the traditional keyboard ( $F = 26.807$ ,  $p = .0001$ ). There were no significant differences in errors for random letter entry between the two keyboards (see Figure 9).

Figure 8:

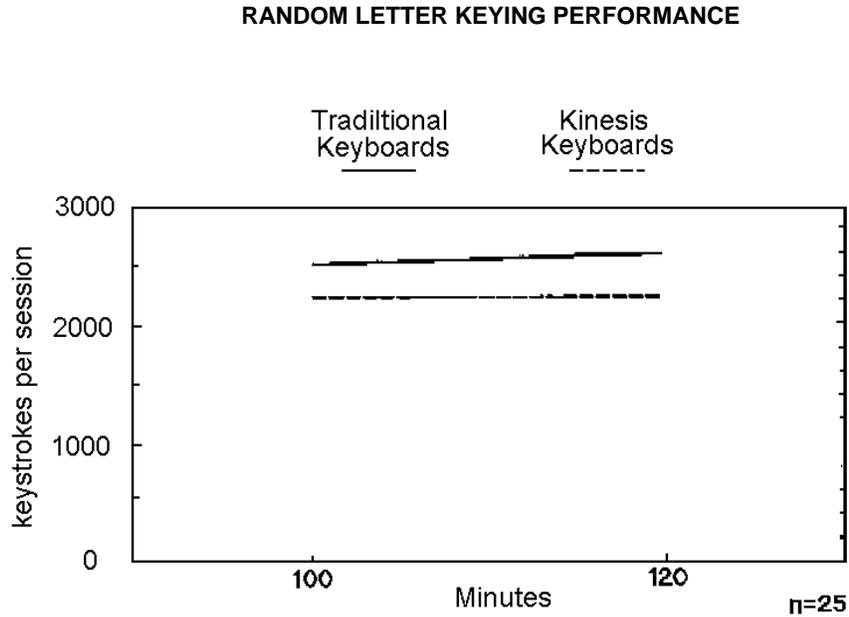
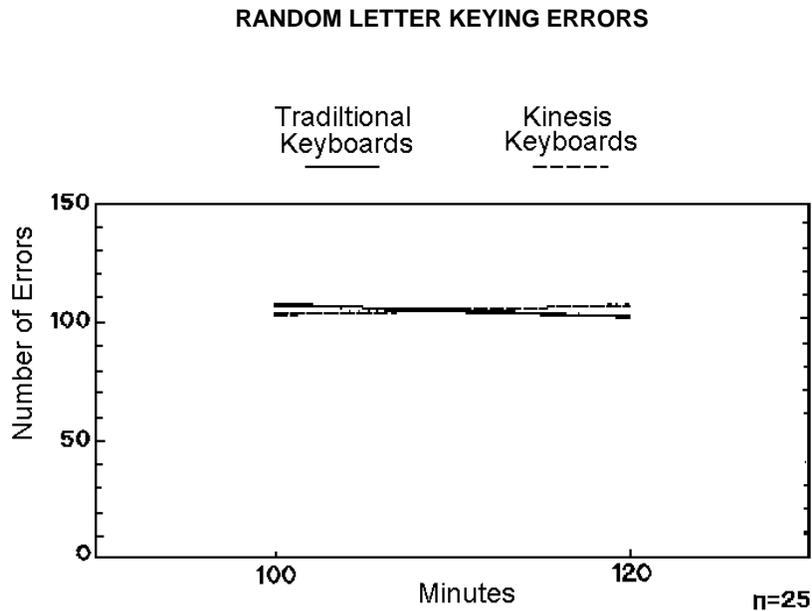


Figure 9:



### ISO Performance Calculations

The ISO test protocol requires that performance analysis be conducted on the middle three test sessions (i.e., 3, 4, and 5). Due to a required modification of the protocol, calculations were performed on the last session as well; this test thus included analysis of sessions 3, 4, 5, and 6. This allowed calculations on the last two text entry sessions and the two random letter entry sessions and thus equal sample calculations for each task (i.e., text and random entry).

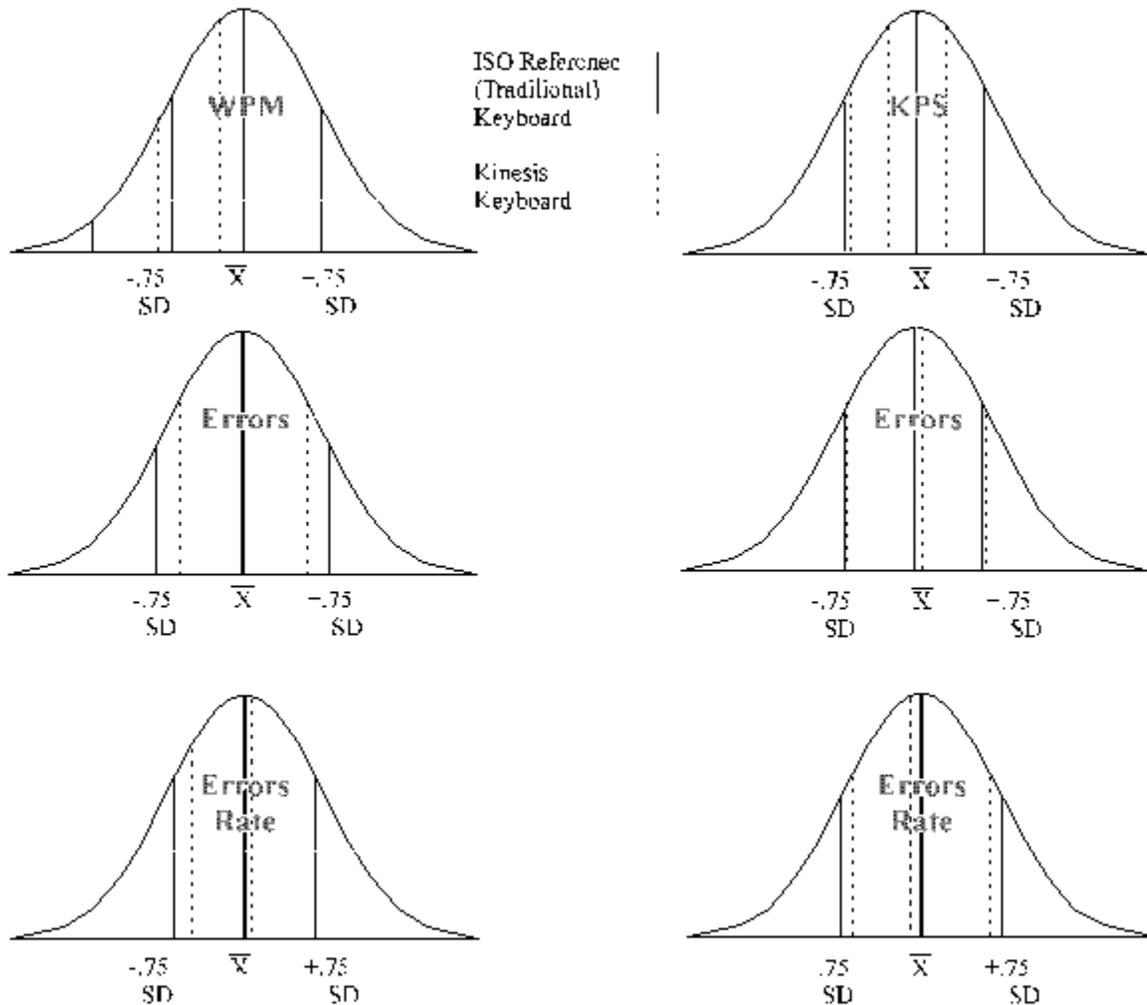
The ISO protocol also requires that calculations be conducted on four measures: 1) keying rate, 2) average error rate, 3) distribution of scores on the acceptability scale, and 4) comparative judgment of acceptability.

ISO specifies that a difference in performance which constitutes unacceptable performance is a difference greater than 0.75 SD (standard deviation) from the reference i.e., traditional) keyboard in the direction of poorer performance.

Calculations of keying performance (see Appendix B) demonstrated that all of the ISO required measures of subject performance (KPS or keystrokes per second, errors and error rate), except throughput (by 1.5 WPM or words per minute), showed no significant differences and thus were inside the ISO standard keyboard acceptable range (see Figure 10).

Figure 10:

### ISO ACCEPTABILITY LIMITS



ISO Compliance Limits and Kinesis Performance Scores

## Preferences

Subjects were administered three different types of questionnaires (see Appendices C, D, E and F).

Questionnaire 1 was developed by Kinesis and asked questions regarding impressions of each keyboard immediately after its use. The results of Questionnaire 1 showed subjects' impressions to be nearly the same for each keyboard. Slightly more subjects preferred the Kinesis for comfort, and slightly more subjects preferred the traditional keyboard for confidence and performance.

Questionnaire 2 was also developed by Kinesis and asked subjects to indicate their keyboard preferences after they had used both keyboards. Results of Questionnaire 2 showed that subjects preferred the Kinesis in most of the categories listed except speed, accuracy, confidence and function keys (although the function keys were never used during any of the testing procedures). Subjects indicated considerable preference for the Kinesis in areas of comfort, fatigue, usability and preferred the Kinesis by almost two to one as an overall choice.

Questionnaire 3 was from the ISO test protocol. Subjects completed the questionnaire following testing on the first keyboard and again after testing on the second keyboard. They rated various aspects of the first keyboard such as comfort and usability on a continuous scale and rated the second keyboard by indicating only if they thought it was worse, better or the same as the first keyboard. This procedure allowed the subjects to observe their impressions immediately following usage of the first keyboard and judge the second accordingly. Results of the ISO comparison showed almost no difference in preference in most categories except for aches/pains, tiredness and posture, where subjects showed a preference for the Kinesis keyboard.

## Discussion

### *Keying Performance*

Although subjects only had 7 hours of training on the Kinesis keyboard, keying performance was almost up to their performance level on a traditional keyboard. Past studies of keyboards radically different than the traditional keyboard have demonstrated that subjects require about one week of keying to reach their traditional keying rate. This may also be the case for the Kinesis keyboard as visual inspection of the plotted data indicates continuing throughput improvement.

The placement of the hands, keying motion, and the shape of the Kinesis keyboard are significantly different than the traditional keyboard and could account for the lower performance. Also, because of the Kinesis unique design, users may have been more cautious while keying and thus slower.

### *Hand Angle*

Research indicates that hand extension beyond 15 degrees for an extended period of time is highly correlated with hand repetitive strain disorders and injuries. Subjects keying on the traditional keyboard typically had substantially greater hand extension and ulnar deviation than when keying on the Kinesis keyboard. These results were demonstrated in both the EMG and postural analysis.

### *Preferences*

Subjects showed an overall preference for the Kinesis keyboard on most characteristics. The positive impressions after using the Kinesis keyboard appeared to overcome the initial trepidation subjects may have had from the initial exposure to its unique design.

### *Conclusions*

The Kinesis keyboard demonstrated substantial physiological advantages, good performance, and more preferences compared to the traditional keyboard. Of the measures taken in this study, the only one (i.e., throughput) in which Kinesis was not as good as the traditional was the one where subjects might most easily improve with practice.