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EFFECT OF FOUR COMPUTER KEYBOARDS IN COMPUTER USERS WITH UPPER EXTREMITY MUSCULOSKELETAL DISORDERS

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Eighty computer users with musculoskeletal disorders participated in a six-month, randomized, placebo-controlled trial evaluating the effects of four computer keyboards on clinical findings, pain severity, functional hand status, and comfort. The alternative geometry keyboards tested were: the Apple Adjustable Keyboard™ [kb1], Comfort Keyboard System™ [kb2], Microsoft Natural Keyboard™ [kb3] and placebo. Compared to placebo, kb3 and to a lesser extent kb1 groups demonstrated an improving trend in pain severity and hand function following six months of keyboard use. However, there was no corresponding consistent improvement in clinical findings in the alternative geometry keyboard groups compared to the placebo group. Overall, there was a significant correlation between improvement of pain severity and greater satisfaction with the keyboards. These results provide evidence that keyboard users may experience a reduction in hand pain after several months of use of some alternative geometry keyboards.

Introduction

According to the U.S. Bureau of Labor Statistics (1992), musculoskeletal disorders MSDs in the office sector more than doubled each year from 1988 to 1992. Significant associations between the number of hours of computer usage and MSDs have been reported in several epidemiologic studies (Bergqvist, 1995; Faucett and Rempel, 1994; Bernard, 1993). Several investigations have suggested that the conventional linear QWERTY keyboard designs may contribute to the development of MSDs by requiring users to assume arm and wrist postures of forearm pronation, ulnar deviation and wrist extension during typing (Kroemer, 1972; Duncan and Ferguson; 1974; Nakaseko, 1985). Within the past decade, variety of alternative split geometry keyboards, developed to increase user's comfort and reduce the posture-related risk factors associated with MSDs) have become commercially available. Laboratory-based performance and preference studies have examined the effects of these keyboards on subjects over short time periods (20 minutes to 2 days) (Swanson, 1997; Cakir, 1995; Gerard. 1994; Burastero, 1994). Other workplace studies have also investigated the effects of split keyboards on performance, preference and wrist postures among asymptomatic typists after 2 to 6 weeks of keyboard use (Cakir, 1995; Tittiranonda, 1994). To date, no long-term studies have evaluated the effectiveness of these keyboards to increase comfort among symptomatic computer users. The goal of this study was to determine whether computer users with can gain health benefit from long-term use of alternative geometry keyboards.

Methods

Eighty workers at the Lawrence Livermore National Laboratory who had no previous exposure to the alternative keyboards were recruited through the onsite's workers' compensation database. Eligible subjects were diagnosed with carpal tunnel syndrome and/or tendonitis according to a standardized physical examination and used the keyboard ≥20 hours per week. Participants were randomized to 4 keyboard groups (n=20 per group) : the Apple Adjustable [kb1], Comfort Keyboard System [kb2], Microsoft Natural [kb3] or conventional (placebo) keyboard.

A Standardized physical examination of the upper extremity was conducted at the beginning of the study and at the end of the 6-month trial. Pain and functional activity questionnaires were administered on the day the keyboards were distributed, 6 week, 12 weeks, 18 weeks and 24 weeks after the keyboards were used. All procedures were reviewed and approved by LLNL Human Subjects Committee.

Statistical Analysis. Analysis of variance (ANOVA) and Kruskal Wallis test were used to examine the differences in baseline characteristics between keyboard groups for continuous variables and Chi-Squared test for categorical variables ($p<0.05$). Changes in outcome measures were calculated as the difference between the values at baseline and at sixth month.. Posthoc multiple comparisons was used to assess significant improvement in the symptoms between the alternative keyboard and placebo groups. The temporal pattern of improvement in overall pain severity over the four intervals within the six months for keyboard group was investigated using Repeated measures ANOVA followed by a post-hoc Tukey-Kramer procedure.

Results

Arm and Hand Symptoms. There was a significant trend of reduced overall pain severity in the alternative keyboard groups, with significant reductions in overall pain severity in kb3 at 6 months compared to the placebo group (Posthoc Dunnett's test, $p<0.05$). Further analyses of tendonitis and CTS subgroups showed that the corresponding decrement in pain severity at 6 months for kb3 was significant

among those diagnosed with tendonitis , but was not for the CTS subgroup (p>0.05).

The distribution of subjects who improved, worsened or remained the same in overall pain severity at 6 months (or withdrawal) was compared to baseline. At six months, the number of subjects who reported substantial improvement (>50% change) in overall pain were greatest in the kb3 group (55%), followed by kb2 (40%) and kb1 (35%). For the placebo group, a majority of the subjects (50%) reported no changes in pain severity compared to 30% in kb2, 35% in kb3 and 40% in kb1. Moderate (>25% change) or substantial (>50% change) worsening in overall pain was reported by 25% of the placebo group, compared to 15% in kb1, 15% in kb2; and 10% in kb3.

Table 1. Changes in Overall Pain Severity♦ between Baseline and Sixth Months by Keyboard Group 1 (negative values indicate worsening of pain severity over time)

	Placebo	Kb1	Kb2	Kb3
All	-0.29±1.5	0.52±2.0	0.84±1.9	1.21±3.1*
Tendonitis	-0.28±1.9	0.67±1.6	1.00±1.2	2.00±2.3*
CTS	-0.29+1.3	0.41+2.5	0.68+2.4	0.50+3.7

1Value as mean±standard deviations are given.
♦ (rated as none at all [0] to worst imaginable [10])
* In follow-up, mean significantly different from placebo (p<0.05) using a one-tailed Dunnett's test.

Temporal Pattern of Pain Severity. Overall pain severity by 6 week time periods by keyboard group are shown in figure 2. Repeated measures ANOVA comparing the change in overall pain severity over time between keyboard groups was borderline significant (p=0.06). Each keyboard group demonstrated a reduction in pain at 6 weeks, after which the mean pain scores reversed back toward baseline for kb2 and placebo, but continued to decrease for kb1 and kb3 at 12 weeks. For the placebo group, posthoc Tukey-Kramer procedure indicated a significant pain decrease from baseline at 6 weeks for the placebo group, but no difference at later weeks. For kb3, the reduction in overall pain severity from baseline was statistically significant at 18 and 24 weeks for kb3 (p<0.05). Within both of these time periods, overall pain severity for kb3 was significantly lower than the placebo group (Posthoc Tukey-Kramer procedure, p<0.05).

Functional Status. In general, consistent improvements in functional activities were demonstrated for kb3, while a decline in hand function was observed for the placebo. In comparison to the placebo group, kb3 group experienced significantly less difficulties in writing (p=0.04), driving greater than 30 minutes (p=0.04), typing shoelaces (p=0.01), performing current job (p=0.1), using a keyboard (p=0.04) and doing housework (p=0.02), after 6 months of keyboard usage. The improvement in overall functional status score for kb3 at the 6 month follow-up visit was statistically significant (p<0.05). Additional analyses revealed that the directional changes in the difficulties related to functional activities in the tendonitis and CTS subgroups were similar to the overall trend. For the kb1 group, a significant decrease in the difficulty associated with using a keyboard was observed (p<0.05).

Clinical Outcomes. Overall, kb1 and kb3 groups showed no significant decrease in the prevalence of the Phalen's test, Tinel's sign and Finkelstein's test, after 6 months of keyboard use. Among those who tested positive for Phalen's test, the average changes in Phalen's test time were similar across keyboards. Clinical status, based on Phalen's test, Tinel's sign and Finkelstein's test remained unchanged for a majority of the participants after 6 months of keyboard use (i.e., those with positive tests remained positive and those with negative tests remained negative).

In general, alternative geometry keyboard groups demonstrated a positive, although not significant trend for improvements in severity within the 4 tendon categories. Improvements in tendonitis severity from baseline to 6 months were examined separately for the CTS and tendonitis subgroups. With the CTS subgroup, the right extensor digitorum communis/extensor carpi radialis /lateral epicondyle tendonitis category improved significantly for kb1 (0.91±2.9) and kb3 (0.6±1.5) compared to the placebo (-1.91±3.1) (p<0.05).

Study Limitations

First, the physical examinations were focused on both nerve- and tendon-related findings. These measures are less sensitive outcome measures than symptom or hand function ratings (Levine, 1993). The small sample size of 20 per group may not yield the statistical power needed for the detection of effects in clinical outcome measures. Second, the high drop-out rate (45%) in kb2 may result in an underestimation of the true intervention effect due to "survivor bias." Third, cost and invasiveness of the nerve conduction velocity studies did not permit us to include this test as part of the diagnostic criteria.

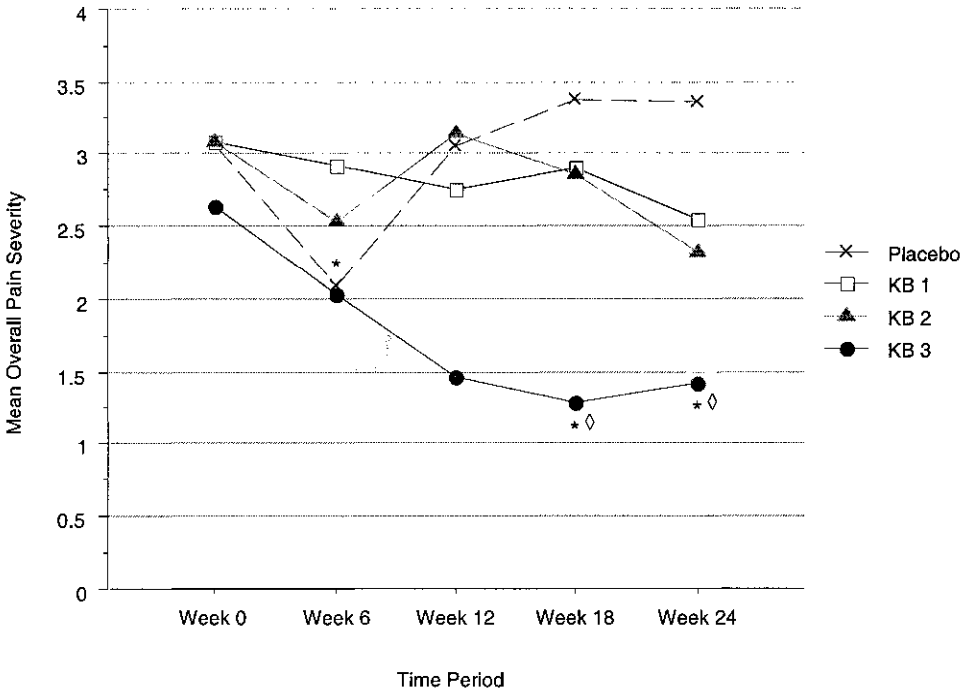

Figure 2. Changes in the mean overall pain severity measured during the intervention trial by keyboard group assignments.
* A significant difference in mean overall pain severity between week 0 and follow-up time periods within a keyboard group (Tukey-Kramer procedure, $p<0.05$).
◊ A significant difference in mean overall pain severity between placebo and alternative keyboard groups at each time period (Tukey-Kramer procedure, $p<0.05$).

Discussion

This study demonstrates a trend toward greater improvement in overall pain, symptom severity and functional status in kb3 and to a lesser degree in kb1 users compared to placebo. For kb3, the trend toward lower pain was significant. These findings were consistent with the overall pattern of change in functional status scores. Those assigned to kb3 showed the greatest improvement, followed by kb1 and kb2, while those assigned to the placebo showed worsening pain and discomfort as well as declined functional status. The region of symptom improvement was limited to the forearm regions of the CTS and tendonitis subgroups. There were no significant changes in physical examination findings when the alternative keyboard groups were compared to placebo. Changes in tendonitis severity based on physical examination, however, showed a positive trend toward improvement in kb1 and kb3, with significant severity reduction in the right digital flexors/ flexor carpi radialis/ medial epicondyle category in the CTS subgroup.

Previous laboratory studies of split geometry keyboards have examined performance, user preference, postural improvement, comfort, or electromyographic activities in healthy subjects following short-term exposure to various experimental conditions. (Swanson, 1997; Cakir, 1995; Rempel, 1995; Gerard , 1994,; Nakaseko, 1985). The findings of these studies are not consistent and the differences may be related to differences in keyboards evaluated and experimental protocols. For example,Swanson et al., (1997) reported no significant differences in fatigue, discomfort and performance between three alternative geometry keyboards used over a two-day period. In the Swanson study, keyboard E corresponds to kb2 in this study and the configurations of keyboard D which were based on the settings previously recommended by Kroemer (1972), Nakaseko et al., (1985) and Zipp (1983) were close to the kb3 design, although subjects in her experiment were not permitted to adjust their keyboards.

In our study, overall pain severity decreased initially (week 6) in all keyboard groups, including the placebo group. Such an early decrease in pain suggests a possible "placebo effect." Indeed, in the conventional/placebo group, this effect disappeared in week 12 and later. Only in kb3, did the initial reduction in pain persist. Hence, subjective measures of user preference and comfort ratings reported in short-term studies may be misinterpreted as they are likely to be influenced by the "placebo effect" (Skov , 1996) or resistance to a new design and probably do not predict long-term health effects. It is likely that exposure periods of 12 weeks or more are needed to detect persistent health effects associated with alternative keyboards. Short-term laboratory studies, however, can be beneficial in evaluating muscle load, postural patterns or other physiological effects that are unlikely to change even after prolonged use.

In summary, our findings suggest that computer users with hand pain may experience a reduction in pain and improvement in function if they use kb3. However, this is the first long-term intervention trial to evaluate split geometry keyboards. These initial findings should be replicated in other clinical intervention trials.

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