Work 50 (2015) 677–686
DOI 10.3233/WOR-131797
IOS Press

The effect of an alternative keyboard on musculoskeletal discomfort: A randomized cross-over trial

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Received 22 January 2013
Accepted 16 October 2013

Abstract.
BACKGROUND: There is limited research on the effectiveness of alternative keyboards in reducing discomfort in the workplace.
OBJECTIVE: We hypothesized that participants using a fixed split-angle (alternative) keyboard would report significantly greater improvements in discomfort in comparison to those using a standard keyboard. Additionally, we hypothesized that at 5 months participants would significantly prefer the configuration of the alternative keyboard in comparison to the standard keyboard.
METHOD: In this randomized cross-over trial 77 symptomatic computer operators used fixed split-angle or standard flat keyboards for five months in their workplace, then switched to the other keyboard. Discomfort was collected weekly using the Weekly Discomfort Survey and usability was measured monthly.
RESULTS: There was no significant keyboard by period effect on any discomfort measure. The number of participants with discomfort decreased dramatically in the first month of use, regardless of keyboard type, and this number remained relatively unchanged for the remainder of the study. Participants' ratings significantly favored the standard flat keyboard for usability.
CONCLUSIONS: This study does not support the use of fixed split-angle keyboards over standard flat keyboards to reduce discomfort in the workplace. Further research is needed to evaluate if subgroups of keyboard users might benefit.

Keywords: Musculoskeletal disorders, discomfort, office ergonomics, typing

1. Introduction

Musculoskeletal discomfort is common during computer use. Studies have reported that between 20 and 62% of computer users experience discomfort while using a computer [1,2]. Musculoskeletal discomfort is viewed as one indicator that a job is a risk factor for musculoskeletal disorders (MSD) and is often seen as a precursor to the development of MSD; in studies on the incidence of discomfort in computer users, between 68 and 81 percent of subjects with moderate to severe discomfort were subsequently diagnosed with MSD [3,4].

Current theory postulates that the sustained awkward postures assumed during standard keyboard use, such as forearm pronation, wrist extension or ulnar deviation, are risk factors for musculoskeletal discomfort [5,6]. One method to modify these postures is to use alternatively configured split or angled keyboards. In 1997, the National Institute of Occupational Safety and Health (NIOSH) [7] published a position paper on

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alternative keyboards. In this paper they commented that while research supported the efficacy of alternative keyboards in positively modifying postures thought to cause musculoskeletal discomfort, they did not provide conclusive evidence that alternative keyboard reduced the risk of musculoskeletal discomfort or the risk of MSD. The paper called on researchers to test the effectiveness of alternative keyboards on reducing musculoskeletal discomfort in the workplace.

Unfortunately, since this position paper came out, there have been very few studies that have examined the effect of alternative keyboards on musculoskeletal discomfort. While numerous studies indicate that split or angled keyboards effectively alter awkward postures typically associated with musculoskeletal discomfort and MSD [8,9] these studies do not generally evaluate the effect of alternative keyboards on discomfort directly. The studies were cross-sectional and were completed in laboratory settings with ideal workstation setups [10–20], thus, reducing their ecological validity in the workplace. Therefore, while these studies find that alternative keyboards effectively alter postures, they do not demonstrate that these changes in posture actually reduce discomfort in the workplace.

There are surprisingly few studies that have examined the effect of alternative keyboards on discomfort in the workplace [21–25], and only three that have used a randomized clinical design with a standard keyboard control group [21,24,25]. Tittiranonda and colleagues [24] reported a significant reduction in overall discomfort at six months in participants with carpal tunnel syndrome and flexor extensor tendonitis who used a fixed split adjustable keyboard, but no other significant results for other alternative designs. Moore and colleagues [25] reported significant differences in the proportion of participants experiencing discomfort between a standard keyboard and two types of alternative keyboards. Despite completing 24 contrasts that examined symptoms and disorders for the neck, shoulder, upper arm, back, elbow, forearm, wrist, and hand, the authors found only four significant differences between those using the standard and either of the two keyboards. Finally, although participants preferred alternative keyboard designs, Hedge and colleagues [21] reported only within group reductions of discomfort and did not find any significant effects on discomfort between groups when comparing an alternate and standard keyboard on 17 possible areas of discomfort. Due to these mixed results systematic reviews evaluating computer workplace interventions have not strongly supported using alternate keyboards to reduce discomfort [26,27].

Despite mixed evidence on their effectiveness, the use of alternative keyboards to prevent and reduce musculoskeletal discomfort continues in practice. Sales for split keyboards outrank standard keyboards in the United States [6], and at least a dozen different designs are available on the market [9]. If alternative keyboards continue to be marketed as a means to address discomfort, additional well-designed trials are needed to determine if they are effective. The purpose of this study was to determine if a fixed split-angle keyboard could significantly reduce musculoskeletal discomfort of the neck/shoulder, back, and/or right/left lower arm and hand in symptomatic computer operators who used a standard flat keyboard. We hypothesized that significantly fewer participants would report musculoskeletal discomfort in one or more of these four areas when using a fixed split-angle (alternative) keyboard then when using a standard, flat keyboard. Additionally, we hypothesized that at five months, participants would significantly prefer the configuration of the alternative keyboard in comparison to the standard keyboard.

2. Methods

2.1. Design and participants

This study was a randomized, prospective, crossover design in which participants were randomized to the order in which they used both a standard flat keyboard and an alternative split keyboard. This study took place at a large university in the United States, between January 2009 and May 2011 and was approved by the university's institutional review board. Written informed consent was obtained from all study participants prior to data collection. Participants were recruited via posted study flyers, a mass mailing of flyers to university staff, and a university wide telephone broadcast message. Additional recruitment occurred through word of mouth.

Eligible participants were adults aged 18–65 years who reported use of a work computer for at least 20 hours/week and discomfort in the neck, back, or upper extremity during the preceding six months that they believed was due to computer use, at a level of 2 or greater on a numerical rating scale [NRS] scale (0 = no discomfort, 10 = unbearable discomfort). Participants who had a history of serious upper-extremity trauma injury, rheumatic disorders, or current use of an alternative keyboard were excluded from the study. Using data derived from other studies of keyboard interventions [20], we determined that to achieve an alpha of 0.05 with a power of at least 0.80 we would need 70 subjects (effect size d of 0.6). As we expected an attrition rate of 0.20 we recruited 85 subjects.

2.2. *Randomization and intervention*

A research assistant not involved in obtaining participant consent or assessment developed an *a priori* randomization sequence by flipping a non-weighted quarter. The sequence was concealed in sequentially numbered, opaque, sealed, security envelopes. Each envelope labeled with the appropriate participant identification number, was placed inside the corresponding participant folder prior to recruitment. Participant numbers were assigned sequentially after consent, but before baseline data were obtained.

Study intervention included replacing each participant's current keyboard with an alternative and standard keyboard provided by the study team. The alternative keyboard was the Microsoft Natural Ergonomics 4000 (version 1.0), which has both a fixed slant angle to reduce ulnar deviation and a fixed tilt angle to reduce pronation [8,9]. The standard keyboard was Lenovo Model No. Ku-0225 (Morrisville, NC); this keyboard is flat and contains a broad, thin wrist rest. When providing either new keyboard, the researchers did not make any suggestions on the best way to set-up the worksite, and no additional interventions, such as education or computer workstation redesign were provided.

Participants were not informed which keyboard was considered to be more likely to reduce discomfort, and were encouraged to believe that both keyboards had the potential to reduce their symptoms. The Lenovo acted as a "placebo" for this study. It was different from participants' regular keyboards in that it had a built in wrist rest, but was not angled in any way.

Participants used each keyboard for 5–6 months before switching to the second keyboard based on the *a priori* randomization sequence.

2.3. *Data collection*

Demographic variables. At baseline participants completed a demographic questionnaire which included questions about age, anthropometrics (e.g. height and weight), computer use, and general health. Baseline musculoskeletal discomfort was obtained for the neck/shoulder, back, and right/left elbow/forearm/wrist/hand (see Table 1).

Two subjective rating questionnaires were used to obtain data from the participants. The Weekly Discomfort Survey (WDS) [4,28], was used to assess symptoms and activity limitations. Participants reported on their work schedule, medication used for pain control, and discomfort in their neck/shoulder, back, and bilateral lower arms (elbows, forearms, wrists, and hands) using an 11-point numerical rating scale (0 = no discomfort/no limitations; 10 = unbearable discomfort/major limitations). The computer rating form (CRF) used a 5-point Likert-type scale (1 = strongly disagree; 5 = strongly agree) to assess participant perception of the usability of the keyboard. Participants indicated whether the keyboard was causing discomfort in the neck, shoulders, arms, wrists, or hands; if it was awkward to use; if it was easy to adapt to the keyboard design; the usability of different configurations such as the position of the letter keys, number keys and the spacebar; and whether they would prefer to continue to use the keyboard.

Baseline measures were collected using both questionnaires via web-based data collection method (Survey Monkey^{TM}) after participants had received their first keyboards. Participants completed the baseline CRF after a trial period of approximately 10 minutes use on the new keyboard. Thereafter, the WDS was completed weekly and the CRF was completed monthly. Participants received a weekly reminder e-mail to complete the online questionnaires. If the questionnaire was not completed by Friday, participants were contacted again on Monday. Data collection continued across both 5–6 month periods for a total of one year per participant.

2.4. *Statistical analyses*

For demographics, continuous variables were summarized by mean and standard deviation, and categorical variables were presented by count and percentage of total. Data were normally distributed. To ensure the two groups were comparable, we performed two-sample t-tests and Fisher's exact tests for continuous and categorical variables, respectively.

All participants completed at least 5 months of WDS and CRF data for each keyboard, but some did not complete a full 6 months, due to the logistics of obtaining the keyboard kinematic performance and switching from the first study keyboard to the second study keyboard. Therefore, we only analyzed data for the first 5 months of each period.

Although our hypothesis was to examine reductions in discomfort, the dependent variables of the numeri-

Table 1
Demographics and baseline characteristics

Variable	Total ($N = 77$)	ST/ALT ($n = 40$)	ALT/ST ($n = 37$)	p-value
Demographics				
Age (years)	44.4 (12.4)	43.3 (12.9)	45.6 (11.9)	0.41
BMI (kg/m^2)	26.9 (5.8)	26.1 (5.2)	27.8 (6.4)	0.22
Gender (female)	71 (92.2%)	36 (90.0%)	35 (94.6%)	0.68
Average computer use (hrs/day)	6.2 (1.3)	6.3 (1.1)	6.1 (1.5)	0.63
% mouse use	37.0 (17.0)	38.8 (17.8)	35.0 (16.0)	0.32
% keyboard use	63.0 (17.0)	61.2 (17.8)	65.0 (16.0)	0.32
Touch-typing course (yes)	46 (60.5%)	24 (60.0%)	22 (61.1%)	0.92
Typing Speed				0.58
Slow	10 (13.0%)	7 (17.5%)	3 (8.1%)	
Moderately fast	30 (37.0%)	16 (40.0%)	14 (37.8%)	
Fast	23 (30.0%)	11 (27.5%)	12 (32.4%)	
Don't know	14 (18.2%)	6 (15.0%)	8 (21.6%)	
Health Status				0.50
Excellent	18 (23.4%)	10 (25.0%)	8 (21.6%)	
Very good	39 (50.7%)	17 (52.5%)	22 (50.5%)	
Good	17 (22.1%)	11 (27.5%)	6 (16.2%)	
Fair	3 (3.9%)	2 (5.0%)	1 (2.7%)	
Baseline WDS				
Discomfort (binary) (yes)				
Neck/shoulder	72 (93.5%)	36 (90.0%)	36 (97.3%)	0.36
Back	66 (85.7%)	33 (82.5%)	33 (89.2%)	0.40
Right elbow/wrist/hand	69 (89.6%)	33 (82.5%)	36 (97.3%)	0.06
Left elbow/wrist/hand	46 (59.7%)	22 (55.0%)	24 (64.9%)	0.38
Discomfort (mean, SD)				
Neck/shoulder	4.0 (2.3)	3.7 (2.3)	4.3 (2.3)	0.16
Back	3.6 (2.6)	3.3 (2.6)	3.9 (2.6)	0.34
Right elbow/wrist/hand	3.4 (2.5)	3.4 (2.7)	3.5 (2.2)	0.85
Left elbow/wrist/hand	2.1 (2.3)	2.1 (2.3)	2.2 (2.6)	0.91

Results are either Mean (SD) or n (%); WDS = Weekly discomfort Survey; ST = Standard Keyboard; ALT = Alternative Keyboard.

cal rating scales outcomes (neck, back, right and left elbow/wrist/hand discomfort) were not normally distributed. Too many participants discomfort was entirely eliminated, skewing the data. We, therefore, dichotomized our outcome into binary variables (discomfort/no discomfort).

Thus, we had multiple binary data points for discomfort, and, due to the longitudinal cross-over design, these data points were autocorrelated. Autocorrelation is the tendency for adjacent measurements to be highly correlated with each other. Autocorrelation tends to inflate the effect of the results and increases the chance for spurious significance. Discomfort is an outcome that fluctuates, participants can have discomfort one week, and no discomfort the next. To capitalize on the ability of multiple points to provide an accurate picture of whether participants were or were not experiencing musculoskeletal discomfort over the 5 months they were using each keyboard, we selected statistical analyses that allowed us to compare all data points across the data collection period to look for overall trends in difference while adjusting for autocorrelation. We chose generalized estimating equations (GEE), a form of generalized linear modeling (GLM), which allowed us to use a binary outcome. We used an AR(1) correlation structure to control for autocorrelation. We used 3 main categorical independent variables: keyboard which evaluated the difference in overall discomfort when participants used the alternative keyboards compared to the standard keyboards; period, which evaluated whether there was a difference between those who received the standard keyboard first and those who received the alternative keyboard first; and the interaction term, keyboard by period which evaluated the difference in keyboard use between the two periods. Interaction terms between keyboard and period demonstrate the effect of order, and are the result that indicates the overall treatment was significant. The period variable was necessary to ensure that any differences were not due to the order in which participants received their keyboards.

An additional strength of the GEE method is that it is robust, even with missing data. In our cross over design, several participants who did not complete the full, year-long study completed enough of the first data period to be included in the overall data analyses. Since

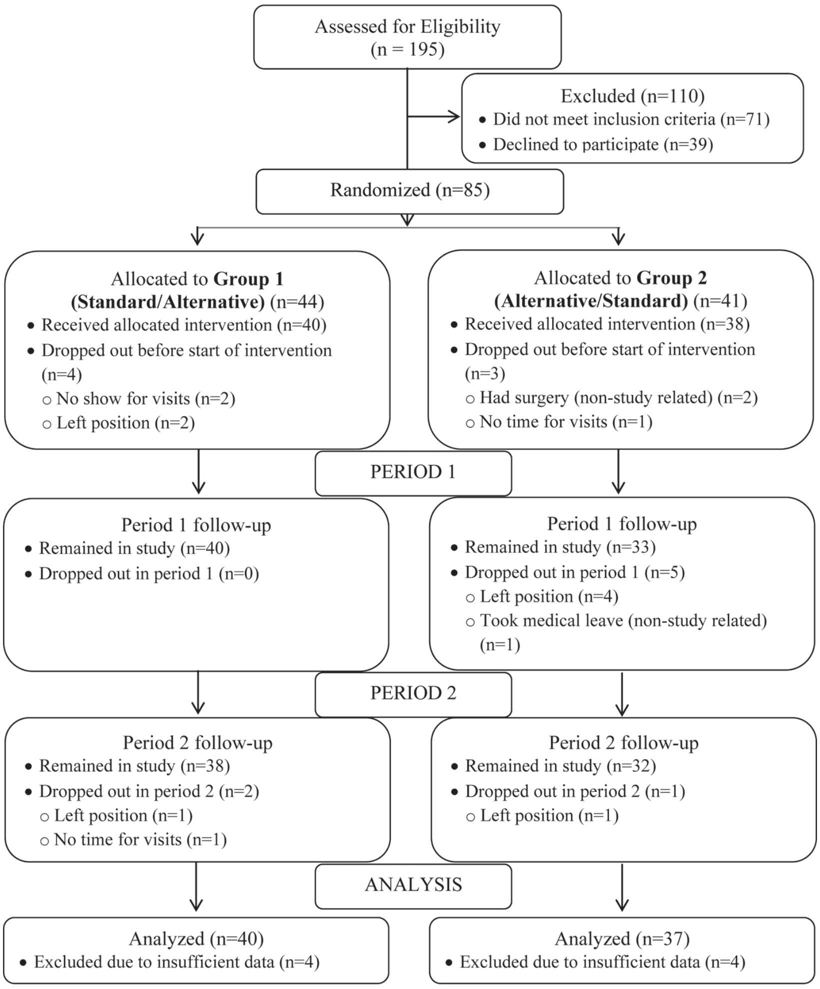

Fig. 1. Study flow.

the study was a cross over design, participants who completed a majority of one period completed one full arm of the study. During data analyses we simply lacked their data as a comparator for the second keyboard. Thus, although only 70 participants completed the full study, 77 were included in the analyses.

A further advantage of the GEE method over a more traditional ANOVA type non-parametric test is that we could include covariates. We included the following covariates in separate GEE models: age at baseline, body mass index (BMI), average daily computer use, proportion of time using keyboard per day, touch typing training (self-report: yes/no), typing speed (self-report: "slow", "moderately fast", "fast"), hand length (as a marker for anthropometrics), and perceived health status. None of these covariates had significant effects on discomfort. However, in the final model we adjusted for age, average computer use, and health status as these have been significantly associated with discomfort in other studies.

The CRF outcomes were also analyzed using GEE linear regressions with AR(1) correlation structure to adjust for the autocorrelation of measurements from each participant. Since participants rated their keyboards every month, this method allowed us to compare the mean ratings of keyboard over the full use period and reduced any outliers related to the novel versus familiar keyboard. Keyboard, period, interaction of keyboard and period were the independent variables in this model. As with musculoskeletal discomfort we adjusted for age, average computer use, and health status with no significant change in results. At the end of the study participants indicated which keyboard they preferred. We completed a Chi square analysis to determine if this preference was affected by the order in which they received the keyboard.

Table 2
Results of GEE examining the differences between ratings of computer characteristics on the Computer Rating Form (CRF)

CRF criterion	Period	Keyboard	Period x Keyboard
In general, using this keyboard made my neck uncomfortable	0.52	0.67	0.58
In general, using this keyboard made my shoulder(s) uncomfortable	0.84	0.76	0.58
In general, using this keyboard made my arm(s) uncomfortable	0.58	0.43	0.91
In general, using this keyboard made my wrist(s) uncomfortable	0.87	0.91	0.45
In general, using this keyboard made my hand(s) uncomfortable	0.75	0.57	0.63
This keyboard was awkward to use	*0.03**	*< 0.001**	0.22
The keys on this keyboard were smooth and easy to use	0.98	*0.003**	0.82
I found it easy to adapt to this keyboard	0.36	*< 0.001**	0.28
I found the position of the letter keys on this keyboard easy to use	0.72	*0.002**	0.73
I found the position of the numeric keys on this keyboard easy to use	0.77	*0.01**	0.79
I found the configuration of the spacebar on this keyboard easy to use	0.38	*< 0.001**	0.42
I really liked the appearance of this keyboard	0.21	0.87	0.99
Given a choice, I would continue to use this keyboard	0.38	0.20	0.98

*Significant outcome favored the standard keyboard.

3. Results

3.1. Demographics

Of the 124 eligible people responding to recruitment, 85 were enrolled in the study, 44 in standard/alternative group and 41 in the alternative/standard group (Fig. 1). The trial was ended when we had recruited 85 subjects. Although only 70 participants completed the entire year long data collection period (38 in the standard/alternative group and 32 in the alternative/standard group; 18% attrition rate), we had sufficient complete data from 77 participants for longitudinal data analyses.

The sample was primarily female, mean age 44 (SD = 12.4) years, and slightly overweight (BMI = 26.9, SD = 5.8). Participants came from a broad variety of departments and jobs at the university, including faculty, graduate students, and administrative assistants. They reported an average of 6.2 hours per day of computer use, and a majority (67%) typed moderately fast to fast. At baseline their mean discomfort was greatest for the neck/shoulder followed by the back, right arm and left arm. To be included in our study, subjects had to have discomfort in at least one of four body parts (neck/shoulder, low back, right or left elbow/wrist/hand). Due to this criteria, no body part had 100% of the sample with discomfort in that area: 93.5% in the sample reported discomfort for the neck, 85.7% reported discomfort in the back, 89.6% and 59.7% reported discomfort for the right and left elbow/forearm/wrist/hands respectively (Table 1). There were no significant differences between groups at baseline. Fifty-three (68.8%) participants completed 90–100% of WDS, while an additional 15 (19.5%) completed 80 to 90%. The remaining participants completed at least half of one period.

3.2. Keyboard comparisons

There were significant differences in the percentage of participants reporting that they did or did not have discomfort for the neck and back for the main effect of period, with the greater proportion reporting discomfort in period 1. There were no significant differences for the main effect of keyboard or for the keyboard by period interaction for any of the body areas (Fig. 2), indicating that both keyboards, alternative and standard, were equally effective in eliminating discomfort.

3.3. Subjective perceptions of keyboards

Subjective perceptions of the alternative and standard keyboard as rated by the CRF favored the standard keyboard. One item on the CRF showed significant improvement for the main effect of period; regardless of keyboard, participants found their keyboard less awkward to use in period 2. There were several significant main effects for type of keyboard. Participants rated the standard keyboard as significantly better than the alternative keyboard for items related to usability (e.g. "this keyboard was [not] awkward to use"; "the keys on this keyboard were smooth and easy to use") (Table 2). There were no significant interactions for the CRF, indicating, that participants' initial perception of the keyboards did not change significantly while using them. On their final rating of the keyboards, participants were asked to identify which keyboard they preferred. Sixty-six responded, and they were equally divided in their preference: 32 preferred the standard keyboard, 33 preferred the alternative keyboard, and one preferred the original board. Chi square analyses indicated that this preference was not related to the order in which they used the keyboards (χ^2 [2, N = 66] = 0.90, $p = 0.64$).

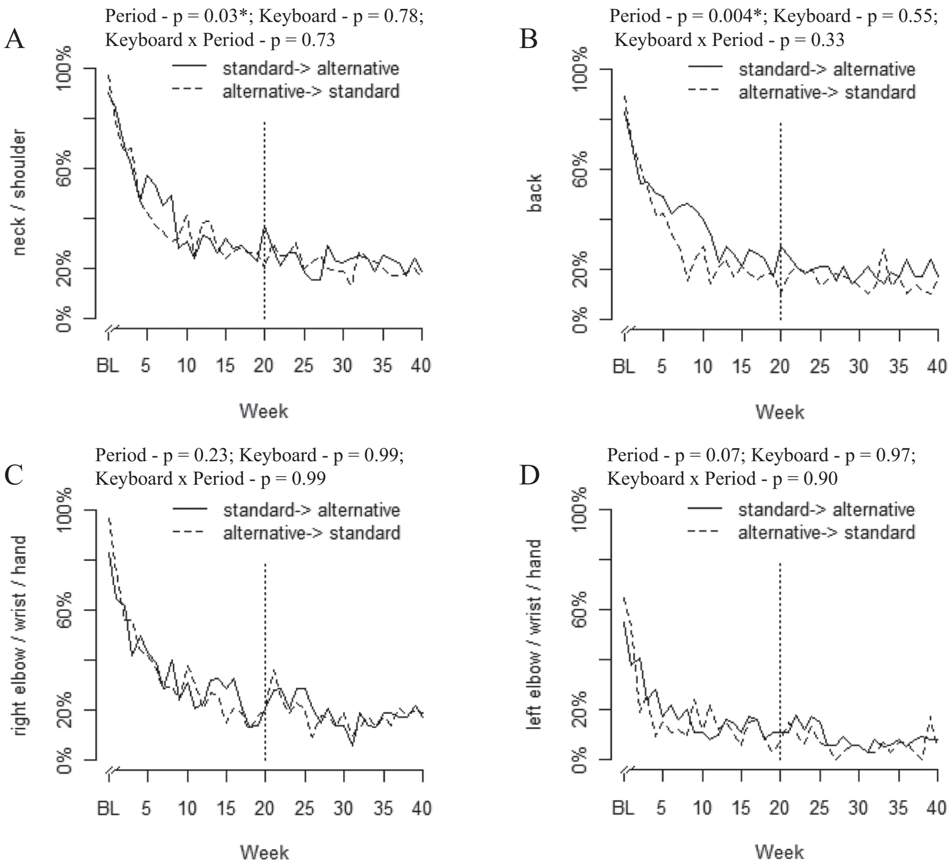

Fig. 2. Weekly percentage of participants reporting discomfort for each body area for each keyboard during study period. A) neck/shoulder; B) back; C) right elbow/wrist/hand; D) left elbow/wrist/hand; BL is baseline week. An * indicates the results for Period 1were significantly higher than and Period 2. The model was adjusted for age, average computer use and health status.

4. Discussion

The data suggests that, overall, there is no significant difference between the alternative and standard keyboard in their ability to eliminate discomfort in a general population of computer users. Figure 2 demonstrates that the percentage of participants with discomfort dropped swiftly within the first few weeks regardless of the keyboard used, and then remained relatively stable for the remainder of the study. There was no significant difference in the percentage of subjects reporting discomfort based on which keyboard they used. There were variations in the data on a weekly basis, but these variations did not favor one keyboard over the other. Alternative keyboards have been shown to effectively change postures associated with musculoskeletal discomfort [8]. If improved posture was the mechanism for the reduction of musculoskeletal discomfort, as hypothesized by proponents of alternative keyboards, participants should have reduced or eliminated discomfort during alternative keyboard use, and should have maintained or increased musculoskeletal discomfort during standard keyboard use. Instead a similar percentage of participants eliminated musculoskeletal discomfort regardless of which keyboard they were using, and the reintroduction of a standard keyboard did not correspond with an increase in the number of participants reporting any musculoskeletal discomfort.

Anticipating that the limited results of previous studies might have been related to the comparison of different users, we used a cross-over design to thoroughly control for each participant's unique characteristics such as their workstation design, stress levels, and perception of discomfort. These rigorous controls only served to highlight the ambiguous nature of the results of the previous studies; our participants improved regardless of the type of keyboard they used.

The rapid and steep drop in the percentage of participants with discomfort seen in this study may be related to expectation of improvement rather than biomechanical factors. Expectation of improvement has been shown to be associated with reduction in discomfort for a variety of disorders and for a variety of interventions [29]. Models examining health outcomes suggest that the behavioral, cognitive and emotional reactions to an intervention are as important as the intervention itself [30] and provide the impetus for the placebo effect. Expectation is one of these underlying causes of the placebo effect, which has been shown to have a powerful effect on pain that is actually physiological in nature [31]. In our study, the emotional response to the attention of the researcher to participant discomfort and participants' belief that study keyboards would affect a cure may have had a powerful effect on participant discomfort. Both keyboards were promoted as potentially effective interventions, and it appears the simple receipt of any keyboard was enough to eliminate most participants' discomfort.

We hypothesized that participants would prefer the alternative keyboard to the standard keyboard, as Hedges et al. had reported that his participants preferred the alternative design [21]. However, our participants reported that they found the standard keyboard design to be more usable than the alternative keyboard design. Participants preferred the standard keyboard's letter and numerical layout as well as the position of the space bar. They also reported that the alternative keyboard was awkward to use, and this observation remained even after five months of use, suggesting that some participants may never have fully acclimatized to the keyboard. These preferences were not affected by keyboard order, and did not change significantly over time. Interestingly, despite the preference for the standard keyboard, half the participants indicated that they would prefer to continue to use the alternative keyboard rather than the standard keyboard. Participants may have attributed the differences they felt in using the alternative keyboard as the underlying cause of their improvement in discomfort.

We chose the fixed angle alternative keyboard for two reasons. First, it was the keyboard that was reported to be most effective in other studies examining discomfort [24,25]. Second, in those same studies, participants had a high dropout rate for the keyboard with greater angles, suggesting that participants were less likely to tolerate a keyboard that had a very different configuration than a typical keyboard. Despite the relatively conservative reductions in wrist and hand postures for this keyboard when compared to other alternative keyboards, participants still found it awkward to use even after an extensive acclimation period.

The study had several limitations. The study would have been stronger with a washout period between the trial periods as well as the addition of a longer period at the beginning with participants using their own keyboard. Obtaining data from participants using their own keyboard prior to using the study keyboards over a longer period of time would have provided a more precise baseline level of musculoskeletal discomfort. A washout period between the two study periods in which the participants returned to their own keyboards would have served two purposes: participants would have had the opportunity to return to pre-study levels of musculoskeletal discomfort; the transition between keyboards would have been comparable, i.e. subjects would always have used their own keyboards prior to using a study keyboard. Without the washout period, subjects in period 1 switched from their own keyboard to a study keyboard, but in period 2 they switched from a study keyboard to a study keyboard. In particular the switch from alternative to standard in period 2 may have had a different effect than the switch from participants own keyboard to the standard in period 1. However, if posture was the primary reason that participants were experiencing musculoskeletal discomfort, those using the standard keyboard after using the alternative keyboard should have reverted back to experiencing some musculoskeletal discomfort. Since our outcome measure was dichotomous, any participant experiencing any level of musculoskeletal discomfort would have been included. As it was, many of our participants remained free of discomfort when using either keyboard.

After reporting discomfort symptoms for almost a year, participants may have been less precise in their reports at the end of the study than at the beginning. Again, our ultimate choice to use an outcome with all or nothing would have helped control for this imprecision. We would have expected to see their discomfort return during the year-long study. In general, it did not. One final limitation of our study was our standard keyboard. Although we chose it because it did not believe it would have an effect posture, it is possible that it did effect some underlying cause of musculoskeletal discomfort, such as force.

5. Conclusions

In 1997, NIOSH indicated that although there was strong evidence that alternative keyboards reduced postures considered to be risk factors for discomfort, there was no strong conclusive evidence that these keyboards affected discomfort in the workplace [7]. The study reported here, like other studies that have examined the effectiveness of alternative keyboards, does not strongly support the use of fixed angle alternate keyboards over standard keyboards to reduce discomfort for the general population of computer users: the standard keyboard was as effective as the alternative keyboard in reducing discomfort. Thus, for the general computer user with musculoskeletal discomfort, an alternative keyboard is unlikely to offer any greater benefit than using a standardly configured keyboard, will require an acclimation period, and is not likely to be perceived as more usable than a standard keyboard. However, question still remain about alternative keyboard effectiveness. Future research should focus less on determining if alternative keyboards reduce discomfort in a general population, and more on determining if alternative keyboards are more effective for a particular group of people, for example, those with more severe discomfort. These studies could identify protective habits that place users at reduced risk for discomfort. Other proxy measures of discomfort, such as medication use, could be explored to determine if other outcomes are more sensitive to alternative keyboard use. Other alternative keyboards with more extreme postural changes may have a greater effect on discomfort and should be evaluated. Additionally, future studies may benefit from examining expectation as a moderator of effect to help understand how expectation shapes discomfort.

Keyboard users should consider carefully before deciding to use an alternative keyboard. Participants in this study generally preferred characteristics of the standard keyboard, although the overall final preference for a keyboard was equally divided between the two. Users should consider cost, typing style, level of discomfort, and willingness to commit to a potentially extensive acclimation period before switching to an alternative keyboard.

Acknowledgements

The authors would like to acknowledge the National Institute for Occupational Safety and Health (NIOSH) (R01 OH008961) for providing funding for this project.

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