The Effectiveness of Alternative Keyboards at Reducing Musculoskeletal Symptoms at Work: A Review

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Abstract. Alternatively configured keyboards have been extensively marketed as one method to reduce musculoskeletal symptoms and musculoskeletal disorders in computer operators. This paper reviews current evidence about the effectiveness of alternative keyboards at reducing risky postures and improving musculoskeletal symptoms. In general, the literature strongly supports the ability of alternative keyboards to reduce potentially risky postures, but is much more equivocal about their ability to reduce musculoskeletal symptoms in the workplace.

Keywords: Computer keyboards, ergonomics, musculoskeletal symptoms.

1 Introduction

Since 2000 there has been a proliferation of alternative keyboard designs purported to reduce risky postures associated with musculoskeletal disorders of the upper extremity (MSD-UE). There are over a dozen alternative keyboard designs, and alternative keyboards now outsell flat keyboards [1]. Despite this proliferation, there has been only limited research on the effectiveness of alternative keyboard designs in reducing MSD-UE and musculoskeletal symptoms (MSS) in the real world of the workplace.

2 Mechanisms of Alternative Keyboard Designs

Alternative keyboards were created based on the hypothesis that non-neutral postures of the forearm and wrists can affect musculoskeletal health by placing joints at greater mechanical and physiological disadvantage [2]. Studies have found associations between forearm supination, wrist flexion/extension, and wrist ulnar/radial deviation postures and MSS/MSD-UE [3], and several studies [4-7] have found that keyboard operators may assume these potentially risky postures during keyboard operation. Alternative keyboards have focused on reducing these postures by angling parts of the standard flat keyboard to reduce the amount of angle that the forearm or wrist must achieve to allow the fingers to interact with the keyboard. There are three areas of adaptations to standard keyboards that are thought to reduce these postures; roll angle

V.G. Duffy (Ed.): DHM/HCII 2013, Part II, LNCS 8026, pp. 189–195, 2013.

Fig. 1. Keyboard adaptations to reduce postures: a) roll angle (pronation/supination); b) pitch angle (wrist flexion/extension); c) yaw angle (wrist ulnar/radial deviation)

for pronation/supination, pitch angle for wrist flexion/extension, and yaw angle for ulnar/radial deviation (Nelson et al 2000) (Fig. 1). Each alternative keyboard configuration has varying degrees of changes in each of these angles.

3 Effectiveness of Alternative Keyboard Designs

3.1 Effectiveness of Alternative Keyboard Designs at Reducing Risky Postures

Early research examining alternative keyboard designs was cross-sectional, and examined if alternative keyboards improved these risky postures. These studies found that most alternative keyboard designs were very effective at reducing risky forearm and wrist postures [8]. However, these studies had limited generalizability to "real world" keyboard operators, since the studies took place in laboratories under ideal conditions. Most of these efficacy studies assumed that their subjects' kinematics performances were well adapted after a minimal acclimation time, 20 minutes or less. In addition most subjects' data collection were completed in one session with the keying on each keyboard ranging from 3 to 60 minutes [9-17]. Those studies that did provide a longer acclimation period, 5 consecutive days [18] and 20 hours prior to participating in the study [19], did not measure postural changes in depth or did not provide baseline information on the postures prior to the keyboard acclimation. The assumption that subjects' postures are stabilized very quickly on alternative keyboards may be false, as Hedge et al. [20] reported that alternative computer keyboard users took from between 4 to 6 weeks to adjust to the novelty of their new keyboard.

An additional concern for the validity of these efficacy studies is that MSS was rarely included as an outcome. Only five of these studies examined the effect of alternative keyboard on musculoskeletal pain. While the laboratory studies that have examined musculoskeletal pain while using alternative keyboards [10, 12, 13, 21, 22] generally reported that using an alternative keyboard decreased musculoskeletal pain, they had flaws in design or reporting which made this reduction difficult to attribute solely to the presence of the alternative keyboard. Overall, in the laboratory, alternative keyboard configurations appear to have only a slight effect on reducing immediate musculoskeletal pain.

Thus, while these studies indicate that alternative keyboards alter short-term postures, they do not confirm that alternative keyboards alter long term postures. Of more significance, these studies do not make the direct link between reductions in risky postures and reductions in MSS in the workplace over an extended period of time.

3.2 Effectiveness of Alternative Keyboard Designs at Reducing MSS.

There have been only seven studies that have examined alternative keyboard use in the workplace [20, 23-27], and only four were randomized clinical trials with standard keyboard control groups [20, 23, 26, 27]. The most frequently evaluated keyboard was a fixed split-angle keyboard which provides mild reductions in the roll angle and yaw angle. These trials only marginally support the use of alternative keyboards as an effective method to reduce MSS. While subjects in the alternative keyboard group demonstrated significant reductions in MSS over time, differences between groups were generally not significant [20, 23, 26], indicating that users of both keyboards, standard and alternative, improved, or there were only one or two significant results in multiple measures [26, 27], which could be an artifact of multiple statistical testing. Of these studies, only Tittiranonda and colleagues [26] examined workers with MSD-UE such as carpal tunnel syndrome and tendonitis. She found a significant difference in overall symptoms at 6 months in those using the split-angle keyboard in comparison to a standard board, but not in those using other, more angled designs.

Based on the literature, we designed a randomized, cross-over study to examine the effectiveness of one alternative keyboard design, a fixed split-angle keyboard, in reducing MSS in a real-world situation [23]. Our study, as with those cited earlier, did not strongly support the use of this alternative design for a population of symptomatic computer operators. Seventy-seven symptomatic computer operators (2 or greater pain level on a numerical rating scale from 0 to 10) were randomly assigned to receive either a fixed split-angle keyboard first or standard flat board first. After 5 months, subjects "crossed over" and received the other study keyboard for the remaining five months. Thus, all subjects used both keyboards, only the order in which they used them varied. Subjects completed weekly online discomfort surveys [28, 29], and rated the usability of each keyboard after use.

We analyzed the results as dichotomous outcomes (had MSS yes/no), as the data was not normally distributed, using generalized estimating equation (GEE) method for longitudinal data analysis. There were no significant differences between the two groups for MSS for any body part (neck, back, right and left upper extremity). Close to 100% of subjects reported MSS at the start of the study, but by 7 to 8 weeks this number had reduced to approximately one third (See Fig. 2). Even when subjects crossed over to the other study keyboard, this percentage remained essentially the same and remained level to the end. Thus, for this sample of computer operators, the fixed split-angle keyboard was no more effective at eliminating MSS than a standard flat keyboard.

We also examined subjects' perceptions of the ease of use of the fixed split-angle keyboard. We asked them to rate the usability of both keyboards on a likert scale with questions such as "This keyboard was awkward to use," "The keys on this keyboard were smooth and easy to use," and "I found it easy to adapt to this keyboard." For all usability parameters, subjects significantly preferred the standard keyboard at both baseline and follow-up. Many subjects reported that it took a month or more for them to become acclimated to the fixed split-angle design. Despite these perceptions, half the subjects indicated that, overall, they preferred the fixed split-angle keyboard to the standard keyboard [23].

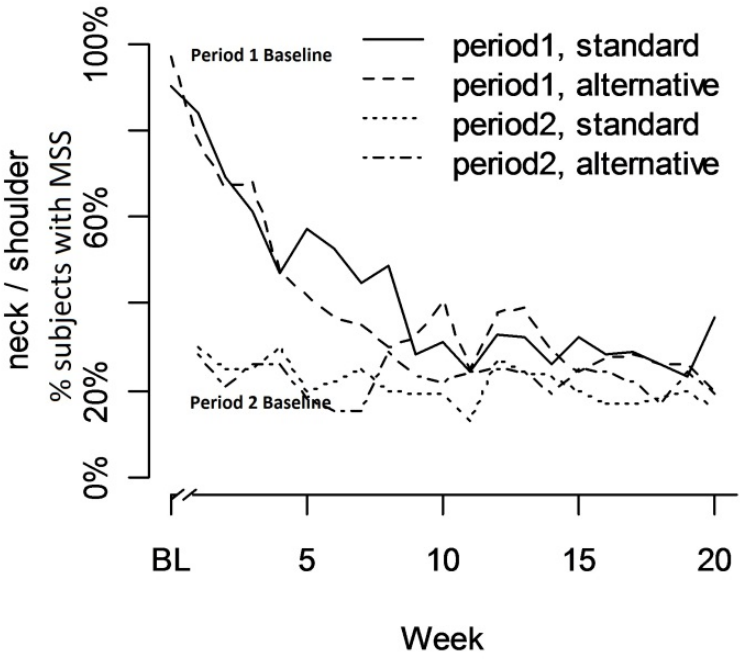

Fig. 2. Percent of subjects experiencing elimination of MSS at the neck/shoulder. Note that almost 100% of subjects started with MSS (Period 1 Baseline) and that regardless of keyboard assignment, approximately 2/3 no longer had MSS by week 7-8. This number remained essentially constant throughout the rest of the study, even with the introduction of the second keyboard (Period 2 Baseline).

We did have one intriguing outcome. There was a significant interaction effect for medication use. This interaction effect suggested that a significantly larger proportion of subjects used medication when they started with the fixed split-angle keyboard and switched to the standard keyboard (20% to 32% = 12%) than when they started with the standard keyboard and switched to the fixed split-angle keyboard (51% to 45% = 6%). Since medication use may be indicative of increased symptoms we inferred that severity of symptoms might be a moderator of the effect of the keyboards. To explore this, we completed post hoc exploratory analyses on the data of the first half of the study only. We examined if baseline symptom severity moderated the effect of type of keyboard on follow-up symptom severity. Our analyses suggested that the fixed split-angle keyboard was significantly more effective in reducing MSS for those with moderate to severe MSS at baseline than those who had none to mild MSS [30]. While these results are promising, they were only obtained on half the data, and should be interpreted with caution. More research is needed to determine if and how baseline severity affects the effectiveness of a fixed split-angle keyboard.

The results of our study exemplify the results of current research related to alternative keyboards. While laboratory studies support the ability of alternative

keyboards to reduce risky postures, "real world" studies do not find an overwhelming significant benefit for alternative keyboard users. Our post hoc analyses may shed light onto why alternative keyboards are believed to be effective. For those with severe MSS, fixed split-angle keyboards may be more effective at reducing computer associated pain than standard keyboards. Thus, computer operators with significant pain, often those with actual disorders, may experience real and significant reductions of their symptoms due to an alternative keyboard. This supposition is supported by the results reported by Tittiranonda and colleagues [26], the only study that has been completed on people with actual MSD-UE.

4 Conclusions

These results offer tentative support to the adoption of alternative keyboards for those experiencing severe MSS. However, our research, and research done by others, does not really support the use of alternative keyboards for those with mild symptoms, or as a preventative measure. Given that the long acclimation period for the alternative keyboard, and that the perceived usability is less than that of the standard keyboard, clinicians should consider carefully before they prescribe an alternative keyboard as a prophylactic measure. Further research which examines the effectiveness of alternative keyboards at reducing MSD-UE must be completed to understand under what circumstances alternative keyboards should be used. In addition, research on the effectiveness of other alternative keyboard designs in the workplace is almost non-existent. Studies examining designs that are more extreme in reducing postures or that are novel in some other way should be completed.

Acknowledgements. The author would like to acknowledge the National Institute for Occupational Safety and Health (NIOSH) (R01 OH008961) for providing funding for the alternative keyboard project reported in this paper.

References

1. Rempel, D.: The split keyboard: An ergonomic success story. Hum. Factors. 50, 385–392 (2008)
2. Kumar, S.: Theories of musculoskeletal injury causation. Ergonomics 44, 17–47 (2013)
3. Gerr, F., Monteilh, C., Marcus, M.: Keyboard use and musculoskeletal outcomes among computer users. J. Occup. Rehabil. 16, 265–277 (2006)
4. Simoneau, G., Marklin, R., Monroe, J.: Wrist and forearm postures of users of conventional computer keyboards. Hum. Factors 41, 413–424 (1999)
5. Baker, N.A., Cham, R., Cidboy, E., Cook, J., Redfern, M.: Kinematics of the fingers and hands during computer keyboard use. Clin. Biomech. 22, 34–43 (2007)
6. Sommerich, C.M., Marras, W.S., Parnianpour, M.: A quantitative description of typing biomechanics. J. Occup. Rehabil. 6, 33–55 (1996)
7. Baker, N.A., Redfern, M.: Potentially problematic postures during work site keyboard use. Am. J. Occup. Ther. 53, 386–397 (2009)

8. Baker, N.A., Cidboy, E.: The effect of three alternative keyboard designs on forearm pronation, wrist extension, and ulnar deviation: A Meta-Analysis. Am. J. Occup. Ther. 60, 40–49 (2006)
9. Baker, N.A., Cham, R., Cidboy, E., Cook, J., Redfern, M.: Digit kinematics during typing with standard and ergonomic keyboard configurations. Int. J. Ind. Ergonom. 37, 345–355 (2007)
10. Chen, C., Burastero, S., Tittiranonda, P., Hollerbach, K., Shih, M., Denhoy, R.: Quantitative evaluation of 4 computer keyboards: Wrist posture and typing performance. In: Proceedings of the Human Factors and Ergonomics Society 38th Annual Meeting. Human Factors and Ergonomics Society (1994)
11. Hedge, A., Powers, J.R.: Wrist postures while keyboarding: Effects of a negative slope keyboard system and full motion forearm supports. Ergonomics 38, 508–517 (1995)
12. Marklin, R.W., Simoneau, G.G.: Effect of setup configurations of split computer keyboards on wrist angle. Phys. Ther. 81, 1038–1048 (2001)
13. Nelson, J.E., Treaster, D.E., Marras, W.S.: Finger motion, wrist motion and tendon travel as a function of keyboard angles. Clin. Biomech. 15, 489–498 (2000)
14. Simoneau, G.G., Marklin, R.W.: Effect of computer keyboard slope and height on wrist extension angle. Hum. Factors 43, 287–298 (2001)
15. Szeto, G.P., Ng, J.: A comparison of wrist postures and forearm muscle activities while using an alternative keyboard and a standard keyboard. J. Occup. Rehabil. 10, 189–197 (2000)
16. Treaster, D.E., Marras, W.S.: An assessment of alternate keyboards using finger motion, wrist motion and tendon travel. Clin. Biomech. 15, 499–503 (2000)
17. Zecevic, A., Miller, D.I., Harburn, K.: An evaluation of the ergonomics of three computer keyboards. Ergonomics 43, 55–72 (2000)
18. Smith, M.J., Karsh, B.-T., Conway, F.T., Cohen, W.J., James, C.A., Morgan, J.J., et al.: Effects of a split keyboard design and wrist rest on performance, posture, and comfort. Hum. Factors 40, 324–336 (1998)
19. Marklin, R.W., Simoneau, G.G., Monroe, J.F.: Wrist and forearm posture from typing on split and vertically inclined computer keyboards. Hum. Factors 41, 559–569 (1999)
20. Hedge, A., Goldstein, M., Hettinger, L., Varner, C., Silva, D., Malafronte, J., et al.: Longitudinal study of the effects of an adjustable ergonomic keyboard on upper body musculoskeletal symptoms. In: Proceedings of the Human Factors and Ergonomics Society 46th Annual Meeting. Mira Digital Publishing, Baltimore (2002)
21. Nordstrom, D.L., Vierkant, R.A., Layde, P.M., Smith, M.J.: Comparison of self-reported and expert-observed physical activities at work in a general population. Am. J. Ind. Med. 34, 29–35 (1998)
22. Woods, M., Babski-Reeves, K.: Effects of negatively sloped keyboard wedges on risk factors for upper extremity work-related musculoskeletal disorders and user performance. Ergonomics 48, 1793–1808 (2005)
23. Baker, N.A., Moehling, K., Park, S.Y.: The effect of a fixed split-angle keyboard on musculoskeletal discomfort: A randomized cross-over trial. Work (submitted)
24. Ripat, J., Giesbrecht, E., Quanbury, A., Kelso, S.: Effectiveness of an ergonomic keyboard for typists with work related upper extremity disorders: A follow-up study. Work 37, 275–283 (2010)
25. Ripat, J., Scatliff, T., Giesbrecht, E., Quanbury, A., Friesen, M., Kelso, S.: The effect of alternative style keyboards on severity of symptoms and functional status of individuals with work-related upper extremity disorders. J. Occup. Rehabil. 16, 707–718 (2006)

26. Tittiranonda, P., Rempel, D.M., Armstrong, T., Burastero, S.: Effect of four computer keyboards in computer users with upper extremity musculoskeletal disorders. Am. J. Ind. Med. 35, 647–661 (1999)
27. Moore, J.S., Swanson, N.G.: The effect of alternative keyboards on musculoskeletal symptoms and disorders. In: Proceedings of the 10th International Conference on Human-Computer Interaction. Erlbaum, Mahwah (2003)
28. Gerr, F., Marcus, M., Monteilh, C., Hannan, L., Ortiz, D.J., Kleinbaum, D.: A randomised controlled trial of postural interventions for prevention of musculoskeletal symptoms among computer users. Occup. Environ. Med. 62, 478–487 (2005)
29. Rempel, D.M., Krause, N., Goldberg, R., Benner, D., Hudes, M., Goldner, G.U.: A randomised controlled trial evaluating the effects of two workstation interventions on upper body pain and incident musculoskeletal disorders among computer operators. Occup. Environ. Med. 63, 300–306 (2006)
30. Baker, N.A., Moehling, K.: The moderating effect of the severity of baseline musculoskeletal discomfort on the effect of an alternative keyboard: A 5-month randomized clinical trial. In: Human Factors and Ergonomics Society 56th Annual Meeting. Human Factors and Ergonomics Society, Boston (2012)

Lecture Notes in Computer Science 8026

Commenced Publication in 1973
Founding and Former Series Editors:
Gerhard Goos, Juris Hartmanis, and Jan van Leeuwen

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Human Body Modeling and Ergonomics

4th International Conference, DHM 2013
Held as Part of HCI International 2013
Las Vegas, NV, USA, July 21-26, 2013
Proceedings, Part II

Springer

Volume Editor

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ISSN 0302-9743 e-ISSN 1611-3349
ISBN 978-3-642-39181-1 e-ISBN 978-3-642-39182-8
DOI 10.1007/978-3-642-39182-8
Springer Heidelberg Dordrecht London New York

Library of Congress Control Number: 2013941252

CR Subject Classification (1998): H.5, J.2, H.3, H.1, I.6

LNCS Sublibrary: SL 3 – Information Systems and Application, incl. Internet/Web and HCI

Typesetting: Camera-ready by author, data conversion by Scientific Publishing Services, Chennai, India

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)