The effect of three alternative keyboard designs on forearm pronation, wrist extension, and ulnar deviation: a meta-analysis

Baker N A, Cidboy E L

CRD summary
This review concluded that alternative designs of keyboards encourage more neutral positions than standard keyboards, but none of the keyboards evaluated had a significant effect on all three postures. A conclusion that acknowledged the limitations of the evidence may have been more appropriate.

Authors' objectives
To evaluate the effects of three different computer keyboard designs on forearm pronation, wrist extension and ulnar deviation.

Searching
MEDLINE, PEDro, CINAHL, ISI Web of Knowledge, OTseeker and the Cochrane Database of Systematic Reviews were searched from inception to the present day using the reported keywords. In addition, reference lists of retrieved articles and personal files were screened. Unpublished and ongoing studies were identified using Internet search engines.

Study selection
Study designs of evaluations included in the review
Randomised controlled trials (RCTs) were eligible for inclusion. All of the included studies were crossover studies in which alternative keyboards were used in random order.

Specific interventions included in the review
Studies that compared a standard flat keyboard with a split fixed-angle keyboard (FA), an adjustable open-tented keyboard (AT), or an adjustable slope keyboard (AS) that could be adjusted with keys tilted towards and away from the user, were eligible for inclusion. Some of the included studies evaluated more than one keyboard. Where reported, the period of adaptation to the alternative keyboards used in the included studies varied considerably (from 5 minutes to 10 hours), as did the length of the task used in the evaluation (from 4 sessions of 8 minutes to 4 sessions of 1 hour). The content of the keyboarding task varied from only alphabetic text to a combination of alphabetic and alpha-numeric.

Participants included in the review
Studies with at least 10 adult computer users who had no symptoms of musculoskeletal disorders of the upper extremity (MSD-UE) or other disorders of the upper extremity were eligible for inclusion. Studies in patients with MSD-UE, acute trauma, inflammatory disease, neurological disease or neoplasm were excluded. Most of the participants in the included studies were female (93%), most were in employment requiring considerable computer use (using computers for an average of 3.6 hours per day), and most were considered to be expert users of computers. The mean age of the participants was 27.7 years.

Outcomes assessed in the review
The review outcomes were ulnar deviation angle, wrist extension angle and forearm pronation angle. The included studies assessed outcomes using goniometric monitors, video analysis with and without a computer-based programme, or retro-reflective circular markers with and without electromyography tests. The studies had to present adequate information for the calculation of an effect size (r).

How were decisions on the relevance of primary studies made?
One reviewer conducted the hand searches. The authors did not state how the papers were selected for the review, or how many reviewers performed the initial stages of study selection. The methods used to select studies according to validity criteria are reported above. Neither of the reviewers was blind to the results of the primary studies.
Assessment of study quality
Studies were assessed for clarity of description of study aims, reporting of pre-intervention screening response, adequacy of reporting of statistical analysis, randomisation, clarity of inclusion and exclusion criteria, sample size greater than 20, baseline comparability of the treatment groups, clarity of description of keyboards evaluated, blinding of the participants and outcome assessors, losses to follow-up, and adequacy of description of methods used to measure outcomes. The maximum quality score was 22 points; only studies that scored at least 17 were included in the review. It appears that one reviewer rated the validity of the studies on three separate occasions, and then both reviewers discussed each rating to determine if the study met the minimum validity criteria for inclusion.

Data extraction
The authors did not state how the data were extracted for the review, or how many reviewers performed the data extraction. For each study, appropriate statistics were extracted for each outcome of interest and transformed into correlation effect sizes (r) with 95% confidence intervals (CIs). Details of transformations used in the calculations were reported.

Methods of synthesis
How were the studies combined?
The studies were grouped by outcome and intervention, then combined using meta-analyses in which individual correlation effect sizes were weighted by the inverse of the variance to produce overall effect sizes (r) with 95% CIs. In addition, pooled effect sizes for each outcome were calculated for any type of alternative keyboard versus the standard keyboard. Effect sizes were classified as small (between 0.10 and 0.29), moderate (between 0.30 and 0.49) and large (0.5 or more).

How were differences between studies investigated?
Statistical heterogeneity was assessed using the Q statistic.

Results of the review
Six crossover RCTs (n=182) were included in the review.

Forearm pronation angle (2 RCTs). There was a moderate but non significant decrease in forearm pronation with an FA keyboard compared with a standard keyboard (based on 1 RCT). There was a large significant decrease in forearm pronation with an AT keyboard compared with a standard keyboard (r=0.85, 95% CI: 0.65, 1.05, p<0.05 in the text; based on 2 RCTs).

For both types of alternative keyboard combined (AT or FA), there was a large significant decrease in forearm pronation angle compared with a standard keyboard (r=0.82, 95% CI: 0.64, 1.00, p=0.05; based on 2 RCTs; homogeneity, Q=0.10).

Ulnar deviation (5 RCTs).
There was a large significant decrease in ulnar deviation with an FA keyboard compared with a standard keyboard (r=0.79, 95% CI: 0.60, 0.98, p=0.0003; based on 3 RCTs). There was a large significant decrease in ulnar deviation with an AT keyboard compared with a standard keyboard (r=0.77, 95% CI: 0.59, 0.95, p=0.0003; based on 3 RCTs). There was a small non significant decrease in ulnar deviation with increasing positive tilt and a small non significant increase in ulnar deviation with increasing negative tilt of an AS keyboard compared with a standard flat keyboard (based on 1 RCT).

For all types of alternative keyboards combined (AS, AT or FA), there was a significant decrease in ulnar deviation compared with a standard keyboard (r=0.42, 95% CI: 0.26, 0.58, p=0.05). Statistical homogeneity was observed.

Wrist extension (5 RCTs). There was a large significant increase in wrist extension angle with increasing positive tilt (r=0.54, 95% CI: 0.27, 0.81; based on 1 RCT) and a large significant decrease in wrist extension with negative tilt
(r=0.77, 95% CI: 0.41, 1.13; based on 2 RCTs) of an AS keyboard compared with a standard flat keyboard. There was a moderate significant decrease in wrist extension angle with an FA keyboard compared with a standard keyboard (r=0.30, 95% CI: 0.11, 0.49, p=0.0113; based on 3 RCTs). There was a small non significant decrease in wrist extension with an AT keyboard compared with a standard flat keyboard (based on 2 RCTs).

For AS and FA keyboards combined, there was a large significant decrease in wrist extension compared with a standard keyboard (r=0.52, 95% CI: 0.17, 0.87, p=0.05). Statistical homogeneity was observed.

Authors' conclusions
Alternative designs of computer keyboards encourage more neutral positions than the standard keyboard, but none of the three alternative keyboards (FA, AT or AS) had a significant effect on all three evaluated postures (ulnar deviation angle, wrist extension angle and forearm pronation angle).

CRD commentary
The review addressed a clear question that was defined in terms of the participants, intervention, outcomes and study design. Several relevant sources were searched and attempts were made to locate unpublished studies, thus limiting the possibility of publication bias. It was unclear whether any language limitations had been applied, so the potential for language bias could not be assessed. Methods were used to minimise reviewer errors and bias in the assessment of validity, but it was not clear whether similar steps were taken for all parts of the study selection and data extraction processes. Validity was assessed using specified criteria, and only RCTs meeting a minimum validity score were included in the review; however, only the composite validity score was presented, making it difficult to independently comment on the reliability of the evidence presented.

Adequate information about the participants was presented. The methods used to statistically combine the studies seemed appropriate, but the studies were generally small and there were few studies for each comparison, which limited the statistical power of the analyses. Statistical heterogeneity was assessed but the results were unclear. A conclusion that acknowledged the potential limitations of the evidence and the possible underpowering of analyses may have been more appropriate.

Implications of the review for practice and research
Practice: The authors stated that occupational therapists should identify which posture is causing problems and select the most appropriate keyboard to alleviate the specific problem.

Research: The authors stated the need for further research on the effects of specific elements of keyboard design (slope, tilt and split angle) and individual characteristics (hand size, wrist and finger position and keyboard style) on biomechanically awkward postures during keyboard use. Modifications of psychosocial factors should be evaluated in addition to physical factors.

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