ISSN 0103-5150
Fisioter. Mov., Curitiba, v. 27, n. 2, p. 271-279, abr./jun. 2014
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DOI: http://dx.doi.org.10.1590/0103-5150.027.002.AO12

Comparison of the electrical activity in upper trapezius and wrist extensor muscles during two typewriting conditions

Comparação da atividade elétrica dos músculos trapézio superior e extensores do punho em duas condições de digitação

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Abstract

Introduction: The proper use of the position of the arm and wrist while typing may reduce muscle overload and prevent musculoskeletal disorders. **Objective**: To evaluate the electromyographic activity of upper trapezius and wrist extensor muscles during two typewriting conditions. **Materials and methods**: Six healthy females ($\overline{X}_{age}$ = 42 years, SD = 10), ($\overline{X}_{height}$ = 1.65m, SD = 0.05) and ($\overline{X}_{weight}$ = 71kg, SD = 16) participated in this study. The task was performed with a newly developed arm support and without the support. A perceived exertion scale was used with all subjects. An ANOVA with repeated measures was used to verify differences in perceived exertion and root mean square (RMS). **Results**: There were no statistically significant differences for the RMS between the typewriting tasks. The condition without arm support presented a significantly greater mean velocity and amount of words typed (P = 0.02; P = 0.03) and there was a significant difference in perceived exertion during the condition without arm support (P = 0.03). Electromyographic activity did not present differences. **Conclusion**: The muscle electrical activity was not altered regardless the arm support and occurred the improvement of the perceived exertion after 10 minutes of typing without support. Long-term studies are needed.

Keywords: Electromyography. Ergonomics. Working environment.

Resumo

Introdução: *O uso adequado da posição do braço e do punho durante a digitação pode reduzir a sobrecarga muscular e prevenir doenças musculoesqueléticas.* ***Objetivo****: Avaliar a atividade eletromiográfica dos músculos trapézio superior e extensores do punho durante duas condições de digitação.* ***Materiais e métodos****: Seis mulheres sadias ($\bar{X}_{idade}$ = 42 anos, DP = 10), ($\bar{X}_{altura}$ = 1,65m, DP = 0,05) e ($\bar{X}_{massa}$ = 71 kg, DP = 16) participaram deste estudo. A tarefa foi realizada com e sem um apoio de braço. Uma escala de percepção de esforço foi aplicada para todos participantes. ANOVA de medidas repetidas foi utilizada para verificar diferenças na percepção de esforço e root mean square (RMS) para a atividade eletromiográfica.* ***Resultados****: Não houve diferença estatisticamente significante para o RMS entre as tarefas de digitação. A condição sem apoio de braço apresentou maior média de velocidade e quantidade de palavras digitadas (P = 0,02; P = 0,03) e houve uma diferença significante na percepção de esforço durante a condição sem apoio de braço (P = 0,03). A atividade eletromiográfica não apresentou diferença.* ***Conclusão****: A atividade elétrica muscular não se alterou independente do apoio e ocorreu a melhora do esforço percebido após 10 minutos de digitação sem apoio. Estudos em longo prazo são necessários..*

Palavras-chave*: Eletromiografia. Ergonomia. Ambiente de trabalho.*

Introduction

Work-related musculoskeletal disorders (WRMD) affect workers in a wide variety of occupations and are recognized as the main cause of absenteeism and work-related disability (1, 2). Several occupations require workers to use a visual display unit (VDU), keyboard and mouse extensively over the course of a workday, which can lead to an increased risk for WRMD. Factors that have been described as necessary for the development of musculoskeletal disorders in such occupations are insufficient recovery time, high task repetition, awkward posture and excessive force (3, 4).

Because of the recent rapid computerization of industry and commerce, office workers are often seated at VDUs for more than 8 hours a day (3). Willey in 2011 (4) related the possible role of the keyboard in the development of musculoskeletal disorders. For instance, some examples of risk factors associated with keyboard usage could be awkward wrist and arm positions, static work positions and seated work positions for prolonged time. Thus, characteristics inherent in typing tasks, such as dynamic and static muscle contractions, are necessary for data entry and mouse use, and are recognized as an occupational hazard, with significant risk of shoulder and neck pain (5, 6). Another factor is frequent finger and wrist extension during typing which demands static contractions that, if maintained for prolonged time, can be responsible for perceived discomfort and pain (7, 8), as well as the presence of fatigue (9).

It is generally believed that these symptoms originate with and are exacerbated by the accumulation of muscle fatigue (10, 11). According to Enoka et al. (12), the term “muscle fatigue” is used to denote a transient decrease in the capacity to perform physical actions. It can be described as the gradual decrease in force capacity of muscle and it can be measured as a reduction in muscle force or a change in electromyographic activity.

Mork et al. (8) suggest that overexertion of low-threshold motor units can explain pain development at low muscle activity levels, such as those involved in typewriting tasks. Blangsted et al. (13) also affirmed that fatigue from low force contractions may indicate homeostatic disturbances. Therefore, studies about fatigue at low force should increase understanding of WRMD.

In order to improve musculoskeletal health, Ribeiro et al. (14) affirm that it is important to consider the effects, among other factors, of working postures, repetitive movements and workplace layout on musculoskeletal health. In fact, it has been demonstrated that adequate illumination and arm support, for instance, could reduce the recruitment of trapezius muscles during VDU tasks. Consequently, musculoskeletal overload is reduced and disorders can be prevented (15, 16). Thus, the purpose of this study was to evaluate the electromyographic activity of upper trapezius and wrist extensor muscles during two typewriting conditions; the first one being a standard office workstation and the second a station equipped with a newly developed arm support device. The hypothesis of this study was that there is no difference in the muscles electrical activity during two typewriting tasks.

Materials and methods

Participants

Six healthy females ($\overline{X}_{age}$ = 42 years, SD = 10), ($\overline{X}_{height}$ = 1.65m, SD = 0.05) and ($\overline{X}_{weight}$ = 71kg, SD = 16) participated in this study. All were full time secretaries in the Health Sciences Center departments, University Hospital, UEL, with at least one year of occupational experience. Subjects constituted a convenience sample since there was a need for controlling the subjects' previous typing experience. The inclusion criteria were: (a) professional experience with office duties for at least one year and (b) the absence of musculoskeletal symptoms. Subjects were excluded if they had histories of orthopedic problems such as fractures, surgery and pain in the shoulders and low back.

Personal data was collected from the subjects through a self-administered questionnaire which presented general information regarding socio-demographic data, occupational activities, musculoskeletal symptoms and perceived exertion during work. The selected individuals were familiarized with the experimental setting, which took place in the Laboratory of Biomechanics and Clinical Epidemiology (PAIFIT Research Group, UEL), informed about the procedures of the study and signed an informed consent. The project was approved by the Research Ethics Committee of the University Estadual de Londrina (CEP # 265/2007).

Equipment

Surface electromyography

An 8 channel electromyography system (*MP150; BIOPAC System Inc., Aero Camino, CA, USA*) was used. This device has two amplifiers connected to a microcomputer with an input impedance of 2 MΩ. Active bipolar surface electrodes (TSD 150) with diameters of 13.5 mm, impedance of 100 MΩ and fixed center-to-center interelectrode distance of 20 mm were used for data collection, with a reference electrode placed on the olecranon. The raw signal was recorded on a personal computer, amplified (gain = 1000), filtered through a 20-450 Hz bandpass filter, with common-mode rejection ratio at 120 dB and sampled at 2000 Hz.

Arm support

The newly developed device mentioned above refers to an articulated arm support, coupled bilaterally and arranged in a symmetrical manner (Figure 1). The supports are polycarbonate based and were attached to an office chair under the seat. Each support has three articulated sections that, through their interdependent design, allowing the user supported, free arm movement. The device's design allows users to adjust it to suit the demands of their work.

Procedures

EMG acquisition and analysis

Electrodes were placed on the muscle tendinous junction of the upper trapezius and wrist extensor muscles, based on the recommendations of the SENIAM project and the Standards for Reporting EMG Data (17, 18, 19, 20). Subjects were shaved at electrode sites, abraded and cleaned with 70% alcohol in order to reduce impedance and prevent signal interference. Normalization procedures considered the peak electromyographic value during the typing task (21, 22). The EMG signals (Root Mean Square [RMS]) were analyzed in repeated 30 second windows during the task. All data were processed using specific software for acquisition and analysis (AcqKnowledge 3.9.1; BIOPAC System Inc., Aero Camino, CA, USA) and MATLAB (7.7.0) subroutines (MathWorks Inc., Natick, MA, USA).

Occupational task

For the task, a workstation involving a personal computer was simulated in a laboratory setting mentioned above. The participants were instructed to perform a typing activity, in which a standard text of

500 words would be reproduced. All subjects had 20 minutes to perform the activity. Anyone who finished the text before the 20 minutes expired was instructed to continue re-typing it from the beginning until time ran out. Afterwards, a word-count was performed to evaluate mean velocity (words per minute). The task was performed under two conditions: with the arm support and without it. The trials were separated by 24 hours and randomized.

The chair was adjusted to the anthropometric measures of each of the subjects, who were instructed to adopt symmetrical postures during the trial, with feet well placed on the ground. If necessary, foot support was offered, in order to prevent thigh compression. Further, subjects were instructed to make proper use of the chair's backrest for adequate support of the lumbar region. The task is illustrated in Figure 1.

Figure 1 - Illustration of the typewriting activity during the trial with the developed arm support
Source: Research data.

Perceived exertion

Perceived exertion during the typing activity was reported through a numeric scale, in which 0 referred to the absence of muscle effort and 10 to maximal muscle effort. The scale was applied at the end of the first 10 minutes and at the end of the task (20 minutes). Subjects were instructed to draw a mark that best represented their perceived exertion at that moment.

Statistical analysis

Normality of the data was investigated using the Shapiro-Wilk test and was presented as mean and standard deviation ($\overline{X}$(SD)). In order to verify differences among dependent variables (RMS, velocity and perceived exertion) and independent variables (typing conditions – with support and without support), the analysis of variance with repeated measures in general linear model was used. Mauchly's test of sphericity was applied and, whenever violated, the necessary technical corrections were performed using Greenhouse-Geisser test. Whenever the F test was significant, the analysis was complemented by means of the Tukey multiple comparison test. A paired Student's *t*-test was used to determine the differences between conditions, for words typed and for mean velocity (23). The statistical significance adopted was 5% ($P \leq 0.05$). For data analysis the Statistical Package for Social Sciences (SPSS) software version 20.0 was used.

Results

There were no significant differences for the amplitude (RMS) during the typewriting task. Figure 2 present data regarding mean amplitude during the task.

The condition without arm support presented a significant greater mean velocity and amount of words typed (Table 1).

With respect to perceived exertion during the typewriting task, there were no significant differences between conditions at either the 10 or 20 minute marks. However, there was a significant difference during the condition without arm support, between 10 minutes and 20 minutes ($p = 0.03$) (Figure 3).

Discussion

The results of this study accepted the null hypothesis presented by the authors; in other words, the arm support did not reduce muscle electrical activity. However, the use of the device seems to improve perceived exertion, despite reducing performance. Electromyographic amplitude (RMS) did not differ throughout the task.

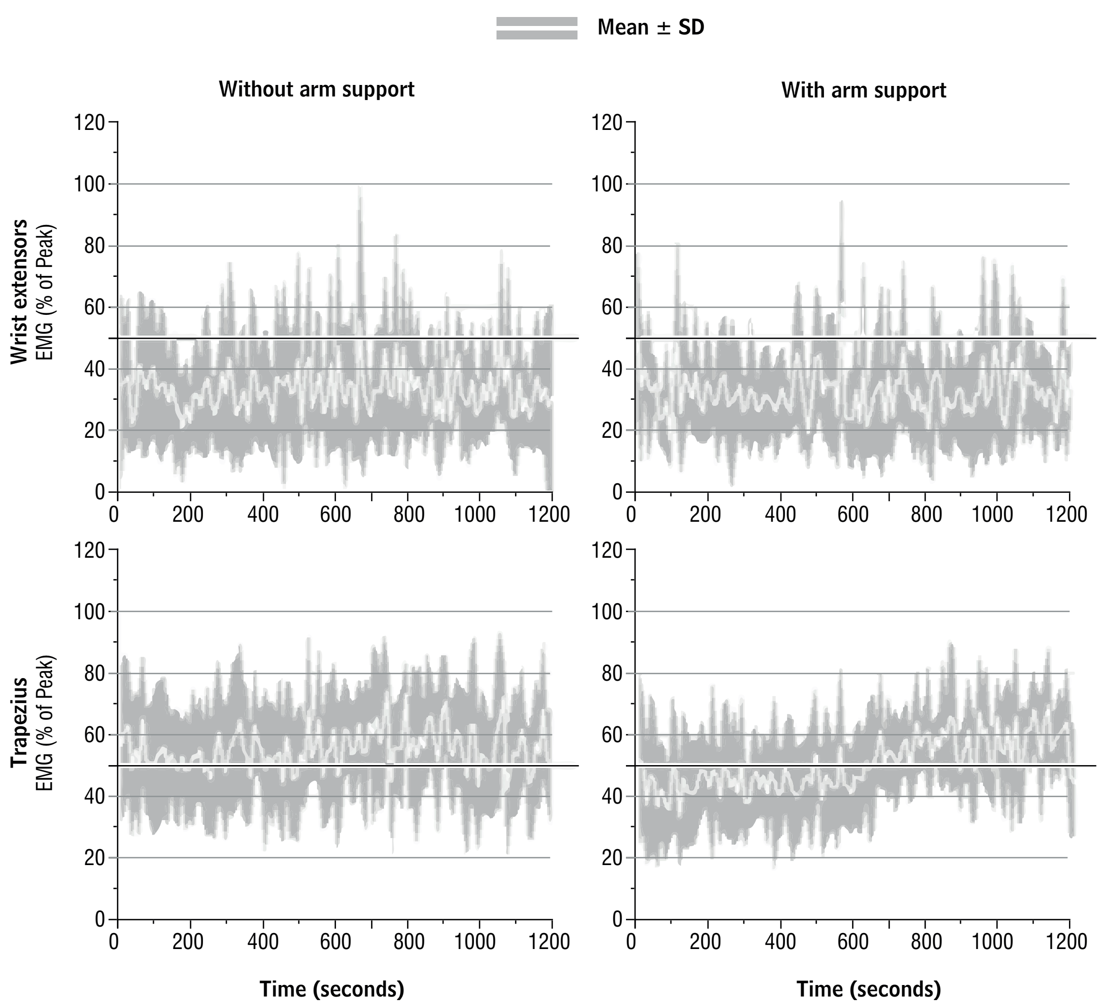

Figure 2 - Electromyographic signals (RMS) collected during the 20 minutes period of the occupational task

Note: The signal was normalized by the peak value during the typewriting task. Solid horizontal lines were placed at 50% peak for interpretation purposes.

Source: Research data.

Table 1 - Number of words typed in each condition and velocity (words/minute) in mean (SD)

Conditions	Words typed*	Mean velocity**
With arm support	694 (274)	34.7 (13.7)
Without arm support	769 (283)	38.4 (14.1)

Note: * ($P = 0.03$); ** ($P = 0.02$).
Source: Research data.

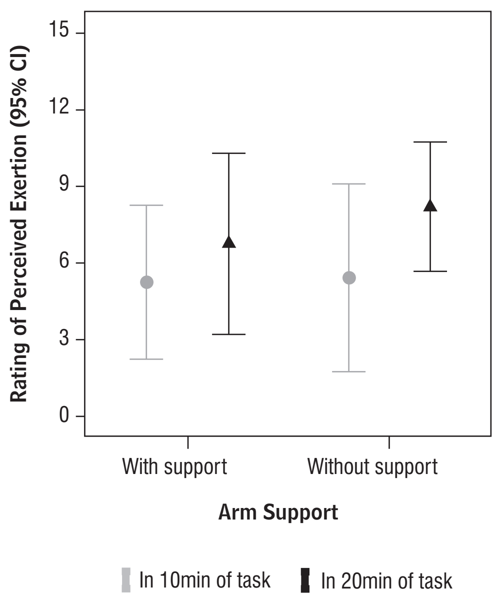

Figure 3 - Error bar (95% CI)
Note: Ratings of perceived exertion referred by subjects during both conditions (with and without arm support). * Significant difference between 10 minutes and 20 minutes in the condition without arm support ($P = 0.03$).
Source: Research data.

Farina et al. (24) demonstrated that during low-force sustained contractions, spectral frequencies of surface electromyography did not change over time. The authors suggested that the inability to detect modifications over time could be related to methodological issues such as electrode location and measurement noise, and they also pointed out that the motor unit (MU) recruitment during low-force contractions is not accompanied by a similar value in spectral frequency analysis, considering the compensating effect of newly recruited MUs. However, studies found significant differences for RMS (6.25) during a typing activity. Kimura et al. (6) found significant increases of RMS values at 60 minutes of typing, and significant decreases of median frequencies at 60, 90 and 120 minutes of task. The contrast of results could be explained by the fact that Kimura et al. (6) and Kleine et al. (25) studied typing performance at a desk, as did in the present study. On the other hand, Farina et al. (24) performed 5 min of fatiguing contractions with subjects who stood in an erect position. In this case, time is an important factor for analyzing fatigue, especially if associated with the physical demands of typing. Thus, the 20 minute period used in our study does not seem to have been enough to elicit such responses.

There were no significant differences between typing with or without the arm support for both the wrist extensors and upper trapezius. Nevertheless, visual analysis of Figures 2 and 3 may raise some important questions: for the upper trapezius muscles, it appears that between 600 and 700 seconds RMS values increase only while using the arm support. This fact indicates that the subjects began the activity with reduced electrical activity and as time passed this strategy was not maintained. However, without arm support, despite the absence of significance, the RMS of upper trapezius was higher for almost every task. This agrees with Kleine et al. (25), who found that the higher RMS values for upper trapezius during 1 hour of a simulated VDU task could have been due to either fatigue or increasing force required of the trapezius muscle. It is important to note that in Klein's study, all chairs were equipped with armrests, but the subjects never used them during typing. The same study also presented postural parameters, which were not evaluated in the present study, such that higher RMS in the trapezius was associated with postural changes, namely, the lifting of the shoulders. On the other hand, Huang et al. (26), pointed out that taping may not only alter the activity of the trapezius muscle during typing but also may have the potential to be applied in computer users to prevent over-activation of this muscle.

With respect to RMS of wrist extensor muscles, the lack of a control for mouse and hand positioning could also explain the absence of significance for these measurements. It was hypothesized that the new arm support could influence wrist muscles, but in fact, as showed by results of Gustafsson et al. (27), mouse positioning and design, as well as keyboard design, may represent better indexes for evaluating electromyographic behavior of forearm muscles.

Interestingly, perceived exertion presented a significant difference in the condition without arm support, i.e, subjects perceived a higher exertion between 10 and 20 minutes of the typewriting task. These findings corroborated with Kimura et al. (6), who found that subjects presented subjective ratings from slight to moderate fatigue after 30 minutes of typing. It is suggested that the use of arm support led to a reduction in perceived exertion during the task but, despite this, the muscular performance was not improved. Subjects also presented higher productivity in the number of words typed and a higher mean velocity without arm support than when with arm support. One important factor that might explain this issue is the lack of experience using the new device for long periods of typing. This finding emphasizes the need for a familiarization or training period, considering that the articulated arms with an interdependent design are different from common arm supports present in the market. It was apparent that subjects were not accustomed to such a design, which raises questions about the importance of training strategies in the workplace before implementing new equipment and intervention procedures. In fact, Sigurdsson et al. (28) confirmed that occupational training represents an important systematic development of abilities and knowledge, both of which are necessary for task performance in the workplace. VDU training for workers appears to present satisfactory results, and such strategies include understanding of not only the necessary pauses from and changes or adjustments to components that are not physiologically adequate, but how and when to perform such actions.

The multifactorial mechanisms of fatigue provide another explanation for the results, in that changes in electromyographic signals had only a moderate correlation with perceived exertion and, therefore, it can be concluded that the central nervous system's perception of exertion is more complex than a simple registry of muscular electrical activity. During fatiguing activities, it is probable that diminishing muscle force could cause a joint imbalance and, consequently, impose abnormal mechanical forces (29, 30). Besides, fatigue could alter neuromuscular coordination and promote vulnerability to musculoskeletal disorders (30). It is possible that the low intensity and static characteristics of the typing task presented in this study did not elicit such responses. Consequently, it is suggested that perceived exertion represented a better estimator of subjects´ comfort during 20 minutes of typing with the new arm support, despite there being no reduction in electrical activity. Hughes et al. (31) suggest that the influence of individual and/or psychosocial risk factors may play a significant role in WRMD development. The positive results of perceived exertion could be explained by the fact that the mental workload inherent in a typing task increases subjective experience of both time load and mental effort load, and could therefore serve as a useful index for evaluating the new arm support presented in our study.

A possible limitation of the study was the small sample size, which allows the possibility of a type II error, and must be accounted for, considering that statistical analyses did not present significant differences. Also, it is suggested that for evaluating new equipment used in typewriting tasks, such as a new arm support, a familiarization period followed by a longer testing period should be considered, in order to promote a better understanding of its usefulness and physiological effects. Long-term studies are needed.

Conclusion

There was no significant difference between typewriting conditions, suggesting that subjects should have had a familiarization period with the new device for arm support, in order to better adapt to its peculiar functioning. Although electromyographic measurements did not present differences, after 10 minutes of typing subjects without the arm support reported higher perceived exertion than subjects using it.

Acknowledgments

The last author wishes to thank CNPq, for the productivity scholarship and, the CAPES/Fulbright Visiting Scholar scholarship (Grants 033/2013) at the Northeastern University, Boston, USA as well as affirms that no specific funding was provided for the preparation of this study.

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Received: 08/15/2013
Recebido: 15/08/2013

Approved: 04/13/2014
Aprovado: 13/04/2014