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Original Article

The effects of forearm support and shoulder posture on upper trapezius and anterior deltoid activity

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Abstract. [Purpose] To assess the effects of forearm support and shoulder posture on upper trapezius and anterior deltoid activity. [Subjects and Methods] Twenty-three female university students were evaluated. Muscle activity was assessed by a portable surface electromyography (sEMG) system (Myomonitor IV, Delsys, USA). Upper trapezius and anterior deltoid activity were recorded in five shoulder flexion postures: 0°, 15°, 30°, 45° and 60° and in two conditions: with the forearm supported and unsupported. Descriptive data analysis was performed and statistical analysis was conducted by a multivariate analysis of variance with three repeated factors (posture, support and side). [Results] Three-way interactions were not significant. Two-way interaction was significant for support and posture for both muscles, indicating that the muscular activity depends on the forearm support and shoulder posture. The forearm support reduced upper trapezius and anterior deltoid activity for all shoulder flexion angles. The mean and standard deviation for this decrease was 7.8 (SD=4.6)% of the maximal voluntary contraction for anterior deltoid and 3.8 (SD=2.0)% of the maximal voluntary contraction for upper trapezius. In the unsupported condition, increasing the shoulder flexion angle caused an increase in the upper trapezius and anterior deltoid activation. [Conclusion] These results highlight the importance of using forearm support and to maintain neutral shoulder posture, when the upper arms are not supported, to reduce muscle activation. Thus, this study provides evidence about the effect of these recommendations to reduce muscular activity.
Key words: Biomechanics, Ergonomics, Physical therapy

INTRODUCTION

The use of computers and portable devices, such as laptops, tablets, smartphones, has increased dramatically among workers and the general population[1–4], as well as musculoskeletal symptoms among their users[5–8]. Portable device users tend to adopt non-neutral shoulder postures and forearm unsupported for long periods of time, which may increase muscular activity[3, 9–12].

Low intensity and continuous upper trapezius and deltoid activation are regarded as a main cause of neck/shoulder symptoms (pain or discomfort)[13, 14]. The mechanisms include a stereotype recruitment of low threshold motor units (type 1 muscle fibers) associated with a lack of temporal and spatial variation[14].

In order to prevent musculoskeletal symptoms ergonomic recommendations are proposed, among them to support the forearm and to maintain the shoulders in a neutral posture[15–20]. Several studies evaluated muscle activity in forearm and wrist

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support during typing and mouse tasks. However, among the identified studies there is still divergence about the effect of the forearm support[15, 16, 20–27] and about the recommendation for safe limits for the shoulder posture[28–30].

A recent meta-analysis about the effect of forearm support in reducing upper body disorders showed that forearm support had statistically significant effect on preventing upper limb disorders[27]. However, this conclusion was based on only four studies, and none of them controlled for the shoulder posture in a supported condition. Thus, the evidence of combined ergonomic interventions is not established, indicating the practical application of this study.

It is noteworthy that these recommendations are mostly applied to computer and industrial tasks and the introduction of new technologies make the duration of the exposure higher and in postural conditions less controlled. Therefore, the aim of this study was to assess the effects of forearm support and shoulder posture on upper trapezius and anterior deltoid activity. The study hypothesis is that the forearm support will reduce muscle activity in relation to the unsupported condition, and the reduction of shoulder flexion angle will also reduce the muscle activity.

Table 1. Demographic and anthropometric characteristics of the sample

	Females students (n=23)
Age (years)	23.7 ± 3.1
Educational level (%)	
Incomplete University	11 (47.9)
Incomplete Post Graduation	12 (52.1)
Conjugal status (%)	
Single	22 (95.7)
Married	1 (4.3)
Height (cm)	1.64 ± 0.04
Weight (kg)	60.2 ± 7.3
Body mass index (kg/cm²)	22.2 ± 2.6

Quantitative data are presented as mean ± SD and categorical data are presented as absolute and relative frequencies [n (%)].

SUBJECTS AND METHODS

This study was designed as an observational cross-sectional study. Twenty-three university students, female, right-handed and asymptomatic for musculoskeletal symptoms were recruited among the university community by means of personal contact with the research group members, pamphlets and posters fixed at high circulation places. The inclusion criteria for the study were: to be apparently healthy, i.e., with no history of musculoskeletal injury, chronic or acute disease (flu, cold, fever, diabetes, hypertension, etc.) and to use computer and portable devices more than four hours per day, five days a week[31]. Participants who had a history of traumas (falls or accidents) or musculoskeletal symptoms in the upper limbs were excluded from the study.

The sample size was defined a priori and calculated in G*Power Program. The calculation considered the application of a multivariate analysis of variance with three repeated factors (posture, support and side), the power was set at 80% and the level of significance at 5%. The primary outcome of this study is the upper trapezius muscle activation and the effect size for this was calculated from pilot tests and was 0.4. The effect size was calculated from partial eta squared. Personal and anthropometric characteristics of the sample are presented in Table 1. The study was approved by the Ethics Committee for Human Research (CAAE 05658612.5.0000.5504) and a written informed consent was obtained from each subject.

For recording upper arm movements, two inclinometers, which are small transducers consisting of triaxial accelerometers and an acquisition unit (Logger Tecknologi HB, Åkarp, Sweden) with a frequency of 20 Hz were used. The inclinometers present average angular error of the transducer associated with the 1.3° software in three-dimensional conditions, the reproducibility is high (0.2°). The noise is small (0.04°), independent of device orientation and highly accurate[32].

Muscle activity was assessed by surface electromyography (sEMG) using a portable system (Myomonitor IV, Delsys, USA) composed of single differential electrodes (DE-2.3, Delsys, Boston, USA) geometry with two parallel bars (1 mm × 1 cm, 99.9% Ag) separated by 1 cm. The main characteristics of the electrodes are: CMRR of 92 dB, input impedance >1,015 in parallel with 0.2 pF, the voltage gain of 10 times, noise of 1.2 uV (RMS). The acquisition frequency used was 1,000 Hz and packaged by the main amplifier (Myomonitor IV, Delsys, USA) with a gain set to 1,000 times, band-pass frequency 20–450 Hz, 16-bit resolution and 1.2 uV of noise.

An instrumented table with four load cell coupled, designed for this particular study (Kratos Model CD, maximum capacity of 50 kgf, the output signal of 2 mV/V) with 20 Hz frequency acquisition was used to measure the weight bearing of the upper limbs on the table[33]. The table has 65 cm height, 59.5 cm wide and 86 cm length. The level of sensitivity of the load cells is 3 mV, excitement between 1,500 to 1,600 mV. Load cells were tested for validity and test-retest reliability and the results showed that errors were less than 5% of the measured value, which is within the limits established by the manufacturer[33]. In order to standardize the shoulder flexion angles and forearm support timber chocks used were designed to adjust the table height. These chocks have heights between 1.8 and 10 cm that were placed under the table according to the anthropometric measurements of each participant.

Anthropometric digital scale with stadiometer (Wiso W721, maximum capacity of 180 kg and grading 100 g) was also used.

The preparation of the participants and the data collection was performed in the Laboratory of Ergonomics and Preventive Physical Therapy at the Federal University of São Carlos, Brazil. Personal and anthropometric data were collected. The

furniture was adjusted according to the anthropometric measurements of each participant[34]. After these measures the equipments were attached to the subjects.

The sEMG was recorded in the upper trapezius muscle and the anterior deltoid muscle bilaterally. For better skin-electrode contact, the skin was cleaned. The placement of the electrodes had reference to the seventh cervical vertebra and the acromion. For recording the upper trapezius muscle, electrodes were placed two inches away from the middle line between the seventh cervical vertebra and the acromion[35, 36]. For the anterior deltoid muscle, electrodes were placed at one finger width distal and anterior to the acromion[36]. The reference electrode was placed in the manubrium of the sternum. Muscle activity was normalized by the EMG activity obtained during maximal voluntary isometric contraction (MVIC). To obtain this reference value, three maximal isometric contractions were performed for each muscle, lasting 5 seconds each and 1 minute rest between them[35]. The MVIC of the upper trapezius and anterior deltoid muscles were obtained with participants seated with the head in an upright position without flexion, extension, lateral inclination or rotation, keeping the shoulders at 90° of abduction, with the elbow extended and palms pointing down[35]. The volunteers were instructed to perform arm abduction against resistance, which was applied by means of inelastic bands positioned in the final third of the arm and fixed to the ground.

To collect the data for flexion angles of the right and left arms, two inclinometers were attached below the insertion of the anterior deltoid muscle[37]. First, the inclinometers were calibrated with respect to gravity in the X, Y and Z. Thus, each of the six faces of the inclinometer was placed on a flat surface for 5 seconds each. After calibration, the inclinometers were attached to the participants. For fixing the inclinometers palpation was performed to identify the distal insertion of the deltoid muscle. After fixation of the transducers, the neutral reference position for upper limb was recorded with the subject seated, with the axillary region resting on the chair back and the free arm vertically. The support of a halter 2 kg ensured that the arm be maintained perpendicular to the ground. The position of reference indicative of the direction of movement of the upper limb was recorded during 90° arm abduction in the scapular plane[38]. Immediately after the fixation of equipment participants were able to perform the task with and without forearm support on the table.

Initially, participants were instructed to sit in the chair and table height was adjusted to the elbow level height[34]. To adjust the table height, ensuring the forearm support on the table and the lumbar spine in the back of the chair were used timber chocks, which have increased in the shoulder flexion angles without modification of spine position. Before starting the data collection, a physical therapist trained the participants to perform both task conditions: sitting still with and without forearm support on the table with load cells. The subjects were positioned with the shoulder at different flexion angles (0°, 15°, 30°, 45°, 60°) with the aid of the inclinometer. This training consisted of one repetition in each position with and without the forearm support. It was provided 5 minutes rest before starting the collection of actual data. After training, the participants performed the task with and without forearm support in different shoulder flexion angles (0°, 15°, 30°, 45°, 60°) and the data were recorded. To collect data, the tasks and shoulder flexion angles order were randomized. During the conditions, upper trapezius and anterior deltoid activity were measured, as well as shoulder posture and weight bearing on the table by the load cells. Each position was recorded during 30 seconds and there was two minutes rest time between the conditions.

Data from sEMG, inclinometer and load cells were processed for routine developed in Matlab (version 7.6, the Mathworks Inc., Natick, MA, USA). Posture data were filtered with a Butterworth filter 2nd order low pass 5 Hz. sEMG data were filtered with a 4th order Butterworth filter, band-pass 20–450 Hz and the root mean square (RMS) was calculated from raw data with 100 ms windows. After calculating the RMS obtained during the central 10 seconds of the tasks, the data were normalized by the RMS peak obtained in the three central seconds CIVMs of the three trials[35]. The average values of shoulder flexion and weight bearing were obtained in each of the test conditions (with and without support) at different amplitudes of shoulder flexion (0°, 15°, 30°, 45° e 60°).

Data were descriptively analyzed by calculating the mean and standard deviation. Statistical analysis was performed by multivariate analysis with three factors (three way MANOVA with repeated measures). The dependent variables were the upper trapezius and anterior deltoid activity. The independent variables were the sides (right and left), forearm support condition (supported and unsupported) and the shoulder angle (0°, 15°, 30°, 45° e 60°). All independent variables were considered within factors. As the assumption of sphericity was not held ($p<0.05$ in the Mauchly test), the results obtained by the Greenhouse-Geisser adjustment, which reduces the degrees of freedom for the test compensate for the lack of sphericity of the data, were retrieved. When the interaction was significant simple effects were obtained. Multiple comparisons (Bonferroni post hoc tests) were applied to identify conditions that differed from each other. Effect sizes (partial eta squared) and observed power were also reported. Analyses were performed using SPSS (version 11.5) and the level of significance was set at 5%.

RESULTS

The forearm support reduced upper trapezius and anterior deltoid muscular activity bilaterally, for all upper arm angles. The mean and standard deviation for this reduction was 7.8% (SD=4.6) MVIC for anterior deltoid and 3.8% (SD=2.0) MVIC for upper trapezius. In the unsupported condition, increasing arm elevation caused an increase in muscle activity, this increase was 11.9% MVIC for anterior deltoid and 3.2% MVIC for upper trapezius. In the supported condition, increasing the arm flexion caused a significant increase in weight bearing on the table, except between 30° and 45° (Table 2).

Table 2. Mean values ± SD for upper trapezius and anterior deltoid muscle activity (% of MVIC) in supported and unsupported conditions according to the upper arm angles and mean values ± SD for weight bearing (% of the upper arm weight) measured by strain gauges at the desk according to the upper arm angles

	Upper arm angles (º)				
	0	15	30	45	60
Unsupported forearm					
Upper trapezius	3.44 ± 2.15	4.25 ± 2.45	5.21 ± 2.67	6.53 ± 3.05	6.59 ± 3.24
Anterior deltoid	1.18 ± 1.18	6.72 ± 3.33	9.85 ± 4.93	11.54 ± 6.24	13.12 ± 7.21
Supported forearm					
Upper trapezius	1.69 ± 1.70	2.46 ± 2.07	1.13 ± 1.16	0.69 ± 0.99	0.82 ± 1.35
Anterior deltoid	0.43 ± 0.29	0.67 ± 0.61	0.78 ± 0.84	0.75 ± 0.71	0.84 ± 1.25
Weight bearing	0.65 ± 0.15	0.94 ± 0.24	1.62 ± 0.46	1.64 ± 0.46	1.94 ± 0.39

Table 3. Summary MANOVA three-way repeated measures

Dependent variable	Fixed factors	p	Effect size	Power
Upper trapezius	laterality*support*angle	0.71	0.02	0.14
	support*laterality	0.67	0.01	0.07
	angle*laterality	0.78	0.02	0.11
	support*angle	0.001	0.60	1.00
Anterior deltoid	laterality*support*angle	0.12	0.10	0.40
	support*laterality	0.07	0.14	0.45
	angle*laterality	0.23	0.06	0.25
	support*angle	0.001	0.75	1.00

The statistical results showed no significant three-way interaction (side*support*angle) for the upper trapezius and anterior deltoid muscles. Similarly, no significant interactions between side*support and side*angle for both muscles were found (Table 3).

The two way interaction between support*angle was significant for both muscles. The simple effects analysis indicated a difference between the conditions for all angles, both for the upper trapezius and anterior deltoid ($p<0.01$), with higher muscle activity in the condition without support ($p<0.01$). In the supported condition, the upper trapezius muscle showed a higher activation at 15° than all other angles ($p<0.01$) and the neutral position (0°) have higher levels of activation in relation to angles of 45° and 60° ($p<0.01$). On the other hand, for the unsupported condition the upper trapezius and anterior deltoid activation progressively increases with increasing arm flexion angle.

DISCUSSION

The results showed differences between the support conditions and arm flexion angles for upper trapezius and anterior deltoid muscles, and muscle activity was higher in the absence of support for all angles of arm flexion. However, in the supported condition the increased arm flexion angle did not cause progressive increase in the activation of both muscles.

The studies found in the literature did not investigate the effect of forearm support on muscle activation in a static condition. Besides this, few studies have examined muscle activity at different angles of arm flexion and abduction. Some studies identified increased muscle activity in upper trapezius and anterior deltoid due to the increased arm angles in unsupported condition[39, 40]. Unlike previous studies that evaluated only the flexion angles of the arm without support, this study had as

main novelty to evaluate the combined effect of forearm posture and support for musculoskeletal overload. These findings are consistent with the results of this study, which indicate that there is a progressive increase in muscle activity due to the increase of the arm flexion in the unsupported condition.

Besides that, the literature recognizes that there is an association between sEMG activity of both muscles and the development of musculoskeletal complaints. Low intensity and continuous upper trapezius and deltoid activation are regarded as a main cause of neck/shoulder symptoms (pain or discomfort)[13, 14]. The mechanisms include a stereotype recruitment of low threshold motor units (type 1 muscle fibers) associated with a lack of temporal and spatial variation.

In supported condition, there was a reduction in muscle activation with increased arm flexion angles. The highest level of activation in 15° of flexion in relation to the neutral position can be attributed to the need to maintain this posture, which was not compensated by increased weight bearing.

Furthermore, the results indicate that the anterior deltoid muscle showed greater activation at all angles of arm flexion in the condition without support compared to the upper trapezius muscle. This may be related to the different muscle functions as the anterior deltoid muscle's main function is to stabilize the shoulder complex, the anterior portion being the primary active for the movement of arm flexion[41] and the function of the upper trapezius is to stabilize the cervical spine and the scapula[41, 42].

Considering the weight bearing on the table, the results indicate that the higher arm angles increased weight bearing and decreased muscle activation of the upper trapezius and anterior deltoid muscles. Some studies assessed muscle activity while using the forearm support and wrist in computer users and also showed a decrease in muscle activation with the use of forearm support[16–22, 25, 26].

These results emphasized the interaction between the forearm support and the arm angles to determine upper trapezius and anterior deltoid activity, which reveals that it is important to consider the forearm support, besides the shoulder posture, to estimate the neck/shoulder activation.

Some limitations can be identified in this study. The sample size was not sufficient to detect three-way interactions, as showed by power results. Muscle fatigue in the unsupported condition was not evaluated, however, because the short duration (30s) of each test and randomization of the angles and the test conditions (with or without support), it is believed that this source of error was minimized. Only female and right-handed subjects were recruited. Therefore, the results of this study may not be generalized to male population.

The results of this study indicated that the forearm support decreased the upper trapezius and anterior deltoid activation in different angles of shoulder flexion when compared to the condition without support. These results highlight the importance of combined ergonomic interventions to minimize the neck/shoulder muscle activation. In addition, the results allow us to suggest the design of future studies, with longitudinal design, with the evaluation of the use of forearm support during the work to verify its effect on the risk of musculoskeletal disorders. Thus, a practical and ergonomic suggestion to reduce muscle work for people with no arm space rests is to keep the arms closer to the body (i.e. reduce the shoulder flexion angle), which can reduce stress in the shoulder region.

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