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# ASSESSMENT OF UPPER LIMB ASYMMETRY DURING TYPING ACTIVITY ON DESKTOP AND NOTEBOOK COMPUTERS

Josiane Sotrate Gonçalves[1]*

Cristiane Shinohara Moriguchi[2]

Karina Satiko Takekawa[3]

Tatiana de Oliveira Sato[4]

## Abstract

This study aimed to compare the right and left sides in relation to the movements of the upper limbs, muscle activity and weight bearing on the table during a simulated activity of typing on the computer desktop and notebook. Fifteen university students were evaluated during five minutes of simulated typing activity in both types of computers. The evaluation order was randomized. Upper trapezius and anterior deltoid activation were recorded bilaterally by surface electromyography. Shoulder movements were assessed by inclinometers, wrist and elbow movements were measured using electrogoniometers. Forearm weight discharge was evaluated by load cells placed under the table surface. There was no difference between the different types of computers during the activity of typing, but musculoskeletal load was higher in the right upper limb. Therefore, preventive measures and ergonomic strategies to reduce the asymmetry between limbs in the use of computers are required.

**Keywords:** Muscle Activity, Movements of the Upper Limbs, Desktop, Notebook, Laterality.

## 1. INTRODUCTION

University students constitute a population that has shown increasing exposure to the computer, whether during educational, social or recreational activities (Hlossberg et al., 2004; Noack-Cooper et al., 2009).

The posture and movements adopted, discomfort, performance and productivity in university students during computer use have been the target of studies due to their frequent use and in inadequate conditions (Saito et al., 1997; Szeto et al., 2002; Berkhouth et al., 2004; Jacobs et al., 2009; Gold et al., 2012). These studies identified the presence of biomechanical risk factors in computer use, but the asymmetry during typing activity in *desktop* and *notebook computers* has not yet been explored.

[1] Department of Physical Therapy, Federal University of São Carlos - UFSCar. * josi.sotrate@yahoo.com.br.
[2] Department of Physical Therapy, Federal University of São Carlos - UFSCar.
[3] Department of Physical Therapy, Federal University of São Carlos - UFSCar.
[4] Department of Physical Therapy, Federal University of São Carlos – UFSCar.

This aspect deserves attention, since there is a growing use of computers and portable mobile devices, making it important to understand the biomechanical exposure to upper limb asymmetry so that preventive measures can be taken.

Therefore, the objective of this study is to compare the right and left sides in relation to upper limb movements, muscle activity, and weight bearing on the table during a simulated typing activity on *desktop* and *notebook computers*.

## 2. Methods

### 2.1. Study Location and Participants

The study was carried out at the Laboratory of Preventive Physiotherapy and Ergonomics (LAFIPE) of the Federal University of São Carlos. Fifteen healthy and right-handed college students were evaluated during a simulated typing activity on *desktop* and *notebook* computers. Participants who had a history of injuries, traumas (falls or accidents) or musculoskeletal symptoms in the upper limbs were excluded from the study.

Table 1 shows the personal characteristics and demographics of the sample. Each participant received information about the purpose and procedures of the study and signed an Informed Consent Form. The study was approved by the Ethics and Research Committee with Human Beings of UFSCar (Protocol CEP: CAAE 05658612.5.0000.5504).

**Table 1.** Personal and demographic data of the sample. Quantitative data are presented as mean, standard deviation (SD), minimum-maximum, and categorical data are presented as relative and absolute frequency [n (%)].

| | Mean (SD) | Minimum - Maximum |
|---|---|---|
| Age (years) | 23,4 (3,9) | 19 - 31 |
| Height (cm) | 1,65 (0,47) | 1,58-1,72 |
| Weight (kg) | 59,5 (7,8) | 45,3-72,1 |
| Education [n (%)] | | |
| Incomplete higher education | 7 (46,7) | |
| Incomplete postgraduate studies | 8 (53,3) | |
| Marital status [n (%)] | | |
| Single | 14 (93,3) | |
| Married woman | 1 (6,7) | |
| Manual Dominance [n (%)] | | |
| Right Hand | 15 (100) | |
| Lefty | 0 (0) | |

### 2.2. Tasks

Before the beginning of the tasks, the furniture was adjusted according to the anthropometric measurements of the participants. Participants adjusted the position and angle of the screen and keyboard according to their own preferences and comfort. Each participant performed the task for one minute on each computer for familiarization. Soon after, the typing of a standardized text was performed on both types of computer, and the order of evaluation was randomized.

The task consisted of typing a standardized text in the *Microsoft Word* program at the speed chosen by each participant, lasting 5 minutes on each type of computer and 2 minutes of rest between tasks. During the performance of the tasks, data were collected on the muscle activity of the upper trapezius and anterior deltoid, movements of the shoulders, elbows and wrist, and weight bearing on the table (Figure 1).

**Figure 1.** Participant during data collection performing the simulated typing task.

Figure 1A: Task with the use of the *desktop*; Figure 1B: Task with the use of the *notebook.*

## 2.3. Instruments and Equipment

An anthropometric scale and digital stadiometer (Wiso W721, maximum capacity of 180 kg and graduation of 100g), measuring tape for anthropometric measurements, dermographic pen for anatomical markings, adhesive tapes, and materials for skin cleaning and trichotomy were used for data collection.

The muscular activity of the upper trapezius and anterior deltoid muscles was recorded bilaterally by means of surface electromyography composed of single differential electrodes (DE-2.3, Delsys, Boston, USA) with geometry in two parallel bars (1 mm x 1 cm, 99.9% Ag) separated by 1 cm. The main characteristics of the electrodes are: RRMC of 92 dB, input impedance > 1015 in parallel, with 0.2 pF, voltage gain of 10 times, noise of 1.2 uV (RMS). The acquisition frequency used was 1000 Hz and conditioned by the main amplifier (Myomonitor IV, Delsys, USA) with a gain set at 1000 times, bandpass frequency of 20-450 Hz, 16-bit resolution and noise of 1.2 uV (Delsys, Boston, USA).

Wrist and elbow movements were measured using electrogoniometers. Sensors models SG65 (flexion, extension, radial and ulnar deviations of the wrist) and SG110 (elbow flexion and extension) and an acquisition unit (DataLog) with an acquisition frequency of 20 Hz (Biometrics, Gwent, United Kingdom) were used. Right and left shoulder movements were evaluated using inclinometers at 20 Hz (Logger Teknologi, Malmo, Sweden).

For the simulated typing task, an instrumented table with four plates was used, each with a load cell coupled with an acquisition frequency of 20Hz (Kratos, CD model, capacity of 50kgf, output signal of 2mV/V) to measure the weight discharge of the upper limbs on its surface, a *desktop* computer (Leadership), with a 17-inch monitor (Samsung, SyncMaster 740N model) and a *Notebook* (Acer), with a 14-inch screen (Acer® Aspire, model V5-472-6_BR826).

### 2.4. Procedures

For data collection, a questionnaire was applied containing general questions with demographic and health data (age, dominance of members, marital status and education). Soon after the initial data were collected, the sensors for recording muscle activity and posture were fixed. Subsequently, the participants performed the typing task.

*Electromyography:* Before placing the electrodes, skin hygiene and trichotomy were performed. The electrodes were fixed at a distance of 2 cm from the midline between the seventh cervical vertebra and the acromion for the descending portion of the trapezius muscle (Mathiassen et al., 1995; SENIAM, 2013), in a finger of distal width and anterior to the acromion for the deltoid muscle (SENIAM, 2013), and the reference electrode was placed in the manubrium of the sternum. Muscle activity was normalized by electromyographic activity obtained during maximal voluntary isometric contraction (MICW). The MVIC of the trapezius and deltoid muscles were obtained with the participants seated with the head in an upright position without flexion, extension, lateral inclination or rotation, keeping the shoulders in 90º abduction, elbow extended and with the palm of the hands pointing downwards (Mathiassen et al., 1995). The volunteers were instructed to perform shoulder abduction against resistance of bands positioned in the final third of the arm.

*Electrogoniometry:* For the fixation of the sensors in the wrist joint, the participant positioned the shoulder in abduction at 90º and elbows flexed at 90º with the arm in full pronation. The telescopic terminal of the electrogoniometer was fixed on the dorsal surface of the third metacarpal. For the fixation of the fixed terminal, the participant completely flexed the wrist joint and the electrogoniometer was slightly elongated to fix the terminal on the forearm. For the elbow joint, the participant was positioned in abduction at 90º and elbow in extension and at the side of the body, with the palms of the hands facing the body. Then, the telescopic terminal of the electrogoniometer was attached to the forearm and the fixed terminal on the upper arm. The mechanical zero position of the equipment was established by recording the electrogoniometer on a ruler aligned at 0°. The anatomical reference position, predetermined for the joints was recorded for 60 seconds. For the wrist and elbow joint, the participants remained standing, with the shoulders relaxed, the elbow flexed at 90° and the wrist pronated on a flat surface, with neutral wrist posture in terms of flexion and extension and radial and ulnar deviations (Kotani et al., 2007).

*Inclinemetry:* Two inclinometers were fixed below the deltoid muscle insertion bilaterally (Hansson et al., 2001). The inclinometers were calibrated with respect to gravity in the X, Y, and Z directions. To fix the inclinometers, palpation was performed to identify the distal insertion of the deltoid muscle. After the transducers were fixed, the neutral position of reference for the upper limbs was recorded with the subject seated, with the axillary region resting on the back of the chair and the arm free vertically. The support of a 2 kg dumbbell ensured that the arm was kept perpendicular to the ground. The reference position indicating the direction of movement of the upper limbs was the abduction of the arms at 90º in the scapular plane (Moriguchi et al., 2011).

### 2.5. Data analysis

The data were processed in a MatLab environment (version 7. 01, MathWorks Inc, Natick, USA) and reduced using the Amplitude Probability Distribution Function (APDF) method to estimate the 10th, 50th, and 90th percentiles. The data were analyzed descriptively.

Statistical analysis was performed using a two-way multivariate analysis (MANOVA *two way*) to verify whether there was an interaction between the type of computer (*desktop* and *notebook*) and the sides (right and left). The analysis was performed using the SPSS program (version 11.5) and the level of significance adopted was 5%.

## 3. Findings

The results show that there was a difference between the right and left sides during the use of computers for posture, weight bearing and muscle activity. Greater musculoskeletal overload was found in the right upper limb. The mean and standard deviation for the posture percentiles of the right (D) and left (E) upper limbs can be seen in Table 2. The data of forearm weight bearing on the table are shown in Figure 2 and muscle activation in Figure 3.

The two-way MANOVA indicated that there was no interaction between the two factors (type of computer and sides) for the variables related to movement, muscle activity, and weight-bearing, i.e., the type of computer did not interfere with movements, muscle activity, and weight-bearing. There was a significant difference between the sides for the 10th percentile of shoulder posture; 10th, 50th, and 90th percentiles for elbow and 50th and 90th percentiles for wrist deviation (Table 2). A significant difference was also found for forearm weight bearing at the 10th, 50th, and 90th percentiles (p10: *P=0.006; p50: P=0.005; p90: P=0.003). There is a greater weight bearing of the forearm on the table on the left side when compared to the right side (Figure 2). There was a significant difference in muscle activation for the upper trapezius muscle for the 10th, 50th, and 90th percentiles (P<0.01). Greater muscle activation in the upper trapezius muscle can be observed on the right side, as shown in Figure 3.*

**Table 2.** Mean and standard deviation (SD) for right and left upper limb posture during *notebook* and *desktop use* for the 10th, 50th, and 90th percentiles.

| | Notebook | | Desktop | | *P* |
|---|---|---|---|---|---|
| Shoulder Elevation (°) | Right | Left | Right | Left | |
| *10th percentile* | 27,30 (10,68) | 29,10 (11,26) | 24,77 (10,27) | 27,93 (11,11) | 0,01 |
| *50th percentile* | 29,41 (10,41) | 30,63 (11,13) | 27,62 (10,00) | 29,73 (10,63) | 0,07 |
| *90th percentile* | 31,78 (9,16) | 32,34 (11,00) | 30,37 (9,74) | 32,01 (10,33) | 0,27 |
| Elbow | | | | | |
| *10th percentile* | 94,16 (11,55) | 90,26 (13,59) | 95,41 (11,41) | 87,82 (16,59) | <0.01 |
| *50th percentile* | 96,98 (11,92) | 93,07 (13,64) | 98,85 (10,78) | 91,87 (16,53) | <0.01 |
| *90th percentile* | 100,58 (12,40) | 96,14 (13,82) | 103,48 (9,82) | 94,74 (16,78) | <0.01 |
| Flexion/Extension Wrist (°) | | | | | |
| *10th percentile* | -19,26 (13,29) | -21,93 (12,97) | -25,20 (17,12) | -32,07 (18,85) | 0,98 |
| *50th percentile* | -9,19 (14,30) | -14,21 (14,38) | -16,31 (17,03) | -23,53 (17,93) | 0,79 |
| *90th percentile* | -9,70 (7,69) | -3,97 (12,50) | -5,03 (17,62) | -13,41 (15,62) | 0,53 |
| Handle Deviation (°) | | | | | |
| *10th percentile* | -9,70 (7,69) | -12,48 (9,37) | -8,59 (7,10) | -11,07 (11,60) | 0,36 |
| *50th percentile* | -0,71 (8,51) | -6,91 (9,71) | 1,52 (8,64) | -5,66 (11,85) | <0.01 |
| *90th percentile* | 7,58 (8,92) | -1,03 (9,45) | 7,89 (9,07) | 0,98 (11,87) | 0,01 |

**Figure 2.** Average of the right and left weight discharge values during the use of *Notebook* and *Desktop computers* for the 10th, 50th and 90th percentiles.

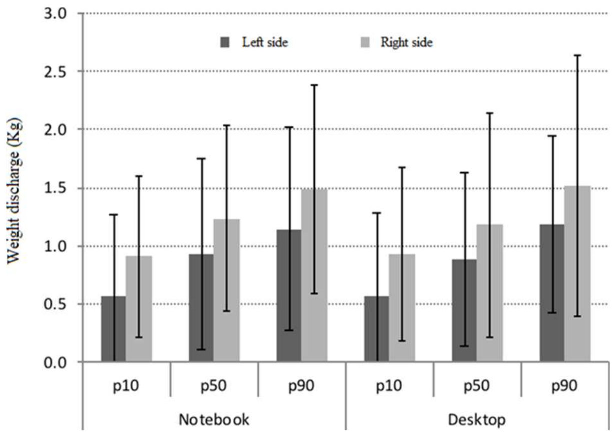
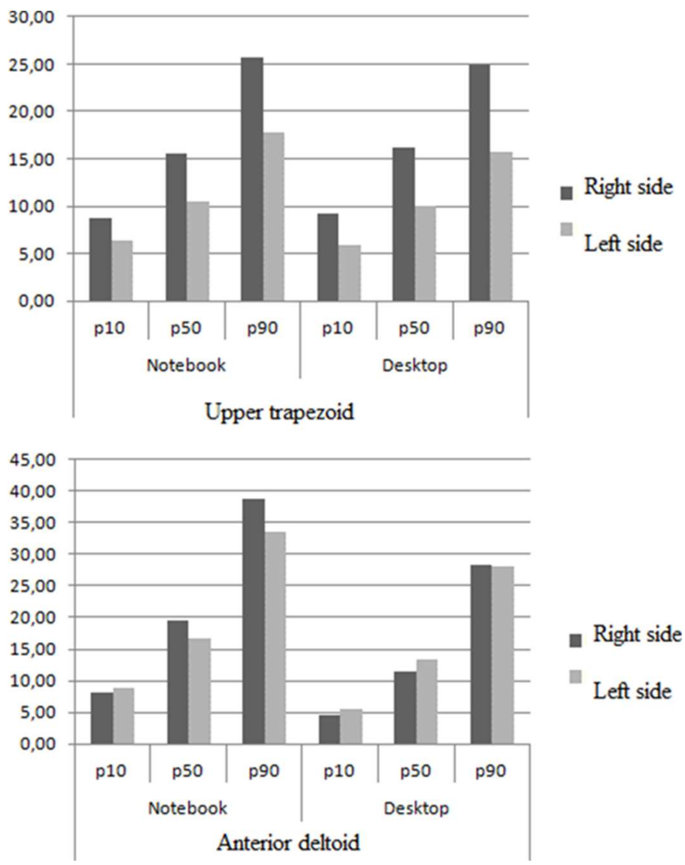



**Figure 3.** Mean distribution values of the 10th, 50th and 90th percentiles of muscle activity during the use of the *Notebook* and *Desktop* to the right and left sides.




## 4. DISCUSSION

In the present study, there was a significant difference between the right and left sides for shoulder posture, elbow, wrist deviation, forearm weight bearing, and muscle activation for the upper trapezius muscle. Previous studies on the subject have not investigated the comparison between the right and left sides during typing activity (Saito et al., 1997; Straker et al., 1997; Villanueva et al., 1998; Szeto et al., 2002), so there are no data available for a comparative analysis.

Higher values in elbow movements and upper trapezius activation were found on the right side and the angles of shoulder movements and wrist deviation and weight bearing on the left side. Thus, greater musculoskeletal overload was observed on the right side during *desktop* and *notebook use*. This overload can be explained by the manual dominance of the students, the use of the traditional keyboard and the lack of support of the forearm during the execution of the task, which can lead to greater muscle demand for the proximal region of the upper limb.

Conventional keyboards can overload the musculoskeletal structures of the upper limbs during computer use due to their geometry (Rempel, 2008). Ergonomic studies in the literature indicate that the use of keyboards with alternative configurations reduces the overload on the upper extremity (Rempel et al., 2007; Mc Loone et al., 2009; Baker et al., 2009).

The absence of support is also one of the risk factors for symptoms in the neck, shoulder and hand (Bergvist et al., 1995) and should deserve attention in interventions aimed at preventing and controlling dysfunctions. Although differences in the angles of shoulder movements and wrist deviation have been identified, lower musculoskeletal overload may be related to greater weight bearing on the left side. Some studies show that forearm and wrist support during computer activity reduces muscle load on the neck and shoulder (Cook et al., 2004; Nag et al., 2009). These findings are consistent with the results of the present study, since greater forearm support was found on the left side.

The results indicate that there is no difference between the two types of computers for the variables related to movement, muscle activity and weight bearing. Previous studies comparing the use of *desktop* and *notebook computers* also found no significant differences in relation to the posture of the shoulders, elbows, and wrists and the activation of the upper trapezius and anterior deltoid muscles (Straker et al., 1997; Saito et al., 1997; Villanueva et al., 1998; Szeto et al., 2002).

Unlike this study, greater muscle activation was detected for the wrist extensor muscles in the study by Villanueva et al. (1998), and this result can be explained by the greater extension of the wrist using the *notebook* when compared to the use of the *desktop*.

The main limitations of this study were the small sample size and the short time of task execution.

## 5. Conclusion

There was no difference between the different types of computers during typing activity, but greater musculoskeletal overload was found in the right upper limb. Therefore, preventive measures and ergonomic strategies aimed at reducing asymmetry during computer use are necessary.

## 6. Financial support

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## References

Baker NA, Cidboy EL. The effect of three alternative keyboard designs on forearm pronation, wrist extension, and ulnar deviation: a meta-analysis. Am J Occup Ther. 2006;60(1):40-49.

Bergqvist U, Wolgast E, Nilsson B, Voss M. Musculoskeletal disorders among visual display terminal workers: individual, ergonomic and work organisational factors. Ergonomics. 1995;38(4):763-776.

Berkhout AL, Hendriksson-Larsen K, Bongers P. The effect of using a laptop station compared to using a standard laptop PC on the cervical spine torque, perceived strain and productivity. Appl Ergon. 2004,35:147-152.

Cook C, Burgess-LImerick R, Papalia S. The effect of upper extremity support on upper extremity posture and muscle activity during keyboard use. Appl Ergon. 2004a;35:285-392.

Gold JE, Driban JB, Yingling VR, Komaroff E. Characterization of posture and comfort in laptop users in non-desk settings. Appl Ergon. 2012;43:392-399.

Hansson GA, Balogh I, Byström JU, Ohlsson K, Nordander C, Asterland P, Sjölander S, Rylander L, Winkel J, Skerfving S. Questionnaire versus direct technical measurements in assessing postures and movements of the head, upper back, arms and hands. Scand J Work Environ Health. 2001;27(1):30-40.

Hansson GA, Balogh I, Ohlsson K, Granqvist L, Nordander C, Arvidsson I, Åkesson I, Unge J, Rittner R, Strömberg U, Skerfving S. Physical workload in various types of work: Part I. Wrist and forearm. Int J Ind Ergon. 2009;39(1):221-233.

Jacobs K, Johnson P, Dennerlein J, Peterson D, Kaufman J, Gold J, Williams S, Richmond N, Karban S, Firn E, Ansong E, Hudak S, Tung K, Hall V, Pencina K, Pencina M. University students' notebook computer use. Appl Ergon. 2009;40:404-409.

Mathiassen SE, Winkel J, Hagg G. Normalization of surface EMG amplitude from the upper trapezius muscle in ergonomic studies - a review. J Electromyogr Kinesiol. 1995;5:197-226.

McLoone H.E, Jacobson M, Clark P, Opina R, Hegg C, Johnson P. Design and evaluation of a curved computer keyboard. Ergonomics. 2009;52(12):1529-1539.

Moriguchi CS, Carnaz L, Alencar JF, Miranda Junior LC, Granqvist L, Hansson GA, Gil Coury HJC. Postures and movements in the most common tasks of power line workers. Ind Health. 2011;49(4):482-491.

Nag PK, Pal S, Nag A, Vyas H. Influence of arm and wrist support on forearm and back muscle activity in computer keyboard operation. Appl Ergon. 2009;40:286-291.

Noack-Coopera KL, Sommerich CM, Mirka GA. College students and computers: assessment of usage patterns and musculoskeletal discomfort. Work. 2009;32:285-298.

Rempel D, Barr A, Brafman D, Young E. The effects of six keyboard designs on wrist and forearm postures. Appl Ergon. 2007;38(3):293-298.

Rempel D. The split keyboard: an ergonomics success story. Hum Factors. 2008; 50(3):385-392.

Saito S, Miyao M, Kondo T, Sakakibara H, Toyoshima H. Ergonomic evaluation VDT operation using flat panel display. Ind Health. 1997;35:264-270.

Schlossberg EB, Morrow S, Llosa AE, Mamary E, Dietrich P, Rempel DM. Upper extremity pain and computer use among engineering graduate students. Am J Ind Med. 2004,46:297-303.

SENIAM (Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles) disponível em: http://www.seniam.org/. Acesso em: 05/06/2013.

Szeto GP, Lee R. An ergonomic evaluation comparing desktop, notebook, and subnotebook computers. Arch Phys Med Rehabil. 2002;83(4):527-532.