Myoelectric Signs of Sustained Muscular Activity During Smartphone Texting

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Abstract. The aim of the present study was to analyze the upper trapezius activity, and its relationship with muscular discomfort perceived, during prolonged smartphone texting. Seventeen healthy young subjects participated in the experiment; they were asked to use their own smartphone for texting (10 min), maintaining two different postures, sitting and standing. The muscular activity of the right and left upper trapezius was recorded, and the CR10 BorgScale was administered after each experimental section. To normalize the EMG signals, the maximum voluntary contraction was acquired at the beginning of the experiment. The median, the 10^{th} percentile (P10) and the range (difference between 90^{th} and 10^{th}) of EMG RMS, the relative rest time (RRT), the correlation between P10 and RRT and between P10 and CR10 scale were calculated. The results showed no statistical difference between the postures, and the body side. The value of RMS parameters was around the 2% of MVC, showing a constant muscular activity throughout the experimental section. A significant negative correlation between P10 and RRT suggested that the subjects with greater P10 showed a lower rest period; moreover, the significant positive correlation between P10 and CR10 Borg scale, for both postures, suggested that the subjects with high P10 values perceived greater discomfort in neck and cervical zone. The results support the hypothesis that the prolonged use of smartphone for texting influences the upper trapezius activity and it is strictly linked with the absence of a period of muscular recovery, and with the perception of muscular discomfort: that may be a potential risk factor to develop neck pain and musculoskeletal cervical disorders.

Keywords: Text-neck · Electromyography · Discomfort · Upper trapezius · Posture

1 Introduction

For the last two decades, the use of mobile touch screen devices (MTSDs) in daily life has been steadily growing: affordable prices, simplicity of usage and portability have encouraged the widespread and intensive use among teenagers and adults for communication and information exchange, and the introduction in education [1], healthcare

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[2] and various working environments [3]. The study of the effects that the intensive and daily use of MTSD could have on health is today matter of interest: if on one hand the association between electromagnetics field exposure and some non-specific symptoms such as fatigue, sleep disturbance, headache and earache, was widely investigated [4, 5], on the other, the potential negative effects on musculoskeletal system associated with MTSD overuse are still unclear.

Recently, the term “text-neck” [6] was introduced to indicate a set of musculoskeletal symptoms, such as neck and shoulder pain, linked to the incorrect and prolonged neck posture during smartphone and tablet use during texting activity as it is the most frequent activity carries out during the day [7]. It has been hypothesized that the continuous head-down tilt posture could stress the muscular activity, causing alteration on cervical spine [8] and also suggesting that a larger head flexion [9] could be associated with higher muscular loads and strain on neck region.

However, few recent studies have investigated the effect of the MTSD use on muscular activity: Straker et al. [10] showed that muscle activity of the neck muscles is greater during tablet use than during computer desktop use in a children sample; in an opposite way, Xie et al. [11] found lower upper trapezius (UT) activity during smartphone texting than during computer typing. Kietrys et al. [12] showed a relationship between MTSD screen size and UT muscle activity. The increased perception of the muscle fatigue after smartphone use was investigated by Kim et al. [13] and Choi et al. [14], while the muscle activity of UT during active (texting, gaming) and passive (reading) tasks was showed by Chiu et al. [15].

Even if the relationship between UT activation and sustained and prolonged work activities (typing, medical surgical activity) is considered a risk factor for developing cervical disorders [16, 17], no study has focussed yet on the effect that prolonged MTSD use for texting could have on muscular activity and its relationship with the perceived cervical fatigue. The current research thus aims at analysing UT activity during prolonged texting sessions, by considering two different postures and to evaluate the correlation between muscular activity and perceived cervical discomfort.

2 Materials and Method

2.1 Participants

Seventeen young adults without musculoskeletal symptoms and diseases were recruited for the study. All participants have been using smartphones for at least six years and reported a daily use of more than three hours, principally for texting. All of them were right-handed, used both hands to hold the smartphone and to text. Anthropometric data and information about smartphone usage are reported on Table 1.

2.2 Experimental Protocol

The experiment was conducted considering two different postures administered randomly: *Seat* and *Stance*. In both conditions, we asked the subjects to maintain a comfortable posture and to use their own smartphone in a natural way for texting (see Fig. 1). In particular, in *Seat* posture the participants sat on a stool without armrests and backrest and they were instructed to modify the setting height to stay comfortable, instead in *Stance* posture the participants stood in upright stance naturally. For each posture condition, the texting task was 10 min long: the participant was asked to message with the experimenter using his/her own smartphone and a common messaging app.

Table 1. Anthropometric data, years of use and time of use for texting during the day (group mean ± standard deviation).

Age (yrs)	22.70 ± 1.82
Height (cm)	170.52 ± 10.13
Weight (kg)	66.88 ± 13.41
Smartphone usage (yrs)	8.64 ± 2.34
Day time spent using the smartphone (hrs/day)	3.35 ± 0.78

Fig. 1. Experimental set-up in both posture (left Seat right Stance)

The muscular activity of the right and left upper trapezius was acquired at a sampling frequency equal to 1000 Hz using FreeEMG300 System, BTS. After skin preparation, bi-polar Ag/AgCl surface electrodes (2-cm diameter) were placed over each muscle (2-cm distance between the centers of the electrodes) according to [18].

Before the experimental session, for sEMG normalization, the maximal voluntary contraction (MVC) of each muscle was acquired three times following the European Recommendations for Surface Electromyography [18].

Table 2. Borg's CR 10 Scale

0	Nothing at all
0.5	Extremely weak
1	Very weak
2	Weak
3	Moderate
4	Somewhat strong
5	Strong (heavy)
6	
7	Very strong
8	
9	
10	Extremely strong

In order to collect some information about the smartphone use and about the level of muscular fatigue and/or pain perceived during the texting task, the participants were requested to fill a questionnaire, to collect information regarding smartphone use frequency, and perceived fatigue, based on Borg's CR 10 Scale [19]. The questions asked in the questionnaire were the following:

1) How many years have you been using your smartphone?
2) How many hours a day?
3) Did you feel pain and/or fatigue in cranio-cervical zone?
4) If yes, select the level that you feel from 1 to 10 (CR10 Borg Scale, Table 2).

Questions 3) and 4) were repeated twice, after each posture task.

2.3 Data Processing

Surface EMG signal processing was performed in Matlab2019a (MathWorks Inc. USA) following these steps: 1) raw surface EMG data, for both MVC and experimental conditions, were band-pass filtered (4^{th} order, Butterworth filter f_t = 20–300 Hz) and the powerline interference was removed applying a notch filter (4^{th} order, Butterworth f_t = 49.8–50.2 Hz). The filtered signals were then full-wave rectified and low-pass filtered with a 4^{th}order Butterworth filter (cut-off frequency 10 Hz) to obtain the linear envelopes of each muscle; 2) the sEMG envelopes were normalized to the average MVC peak value coming from the three MVC repetitions (% MVC).The root mean square (RMS) values from 100 ms no-overlapping windows were calculated; 3) the 50^{th} percentile (median_RMS) and the 10^{th} percentile of the RMS levels (P10_RMS, and the difference between the 90^{th} and 10^{th} percentile (RMS_range) were calculated. In particular, P10 is an indicator of the static muscular activity [20], while the RMS range is linked to the size of change in muscle activity [21]; 4) the percentage relative rest time (RRT) [22], defined as the total time duration when RMS is below 1% MVC for more than 100 ms, was calculated. The chosen threshold (1% MVC) was found sensitive to individual differences in terms of gap frequency analysis [23].

2.4 Statistics

For each parameter, values were calculated for both postures (*Seat* and *Stance*) and body side (*UT_right* and *UT_left*). Since data for all parameters were non-normally distributed, to evaluate the statistical differences between postures and UT side the Wilcoxon rank sum test was applied. Proportionality between RRT and P10_RMS was calculated according to Spearman's rank coefficient ρ, while linear correlation between P10_RMS and Borg's scale was assessed through Pearson's coefficient. The level of significance was set at $p < 0.05$.

3 Results

No significant difference appeared between parameters of the non-dominant side and those of the dominant side (except for RMS_range in *Seat*, and RRT in both postures). In the same way, no statistical difference was found between the postures. The numerical values (median, first and third quartile) are reported on Table 3.

Table 3. Median values (lower-upper quartile) of median_RMS, P10_RMS, RMS_range and RRT of the UT right and left are reported.

	median_RMS (% MVC)		P10_RMS (% MVC)	
	Seat	Stance	Seat	Stance
UT_right	2.60 (1.01–8.73)	2.54 (1.37–8.55)	2.14 (0.85–6.83)	2.23 (0.95–4.18)
UT_left	1.77 (1.41–9.84)	1.50 (0.88–3.90)	1.34 (0.74–7.51)	1.09 (0.67–2.36)
	RMS_range (% MVC)		RRT (% time)	
	Seat	Stance	Seat	Stance
UT_right	1.99 (1.05–4.80)	2.26 (0.76–4.94)	0.05 (0–45.25)	0 (0–12.12)
UT_left	2.50 (0.64–5.62)	0.90 (0.41–3.98)	0.28 (0–42.8)	2.00 (0–72.93)

P10_RMS correlated significantly ($p < 0.05$) with RRT, for both postures and body sides. In particular, inverse proportionality was found for both sides and postures: the Spearman coefficients for right side were −0.79 and −0.85 for *Seat* and *Stance*, while for left side −0.84 and −0.92, respectively (See Fig. 1 and Fig. 2).

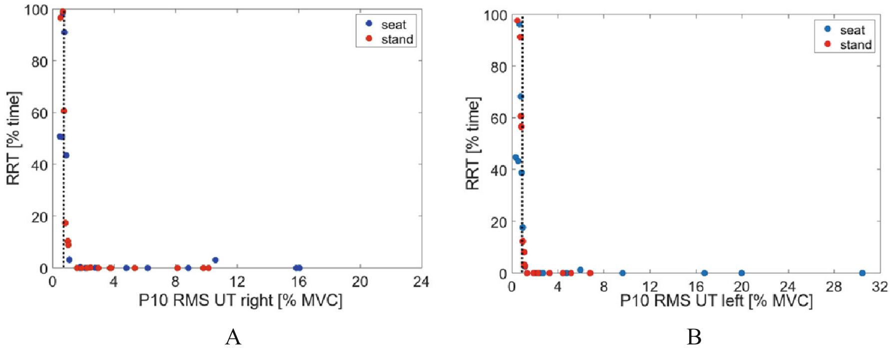

Fig. 2. (A) Scatter plot for all subjects of the P10_RMS UT right and RRT for both postures (blue for seat, red for stance). (B) Scatter plot for all subjects of the P10 RMS UT left and RRT for both postures (blue seat, red stance). The dashed vertical line marks the RRT threshold level set to 1%MVC.

Adirect relationship was found between P10_RMS and Borg's scale ($p < 0.05$) for both postures, showing a higher correlation when standing than when sitting ($\rho_{\_stance} = 0.80$, $\rho_{\_seat} = 0.36$). P_10 RMS UT was calculated as the mean between the left and right side of the body. The regression line is shown in Fig. 3.

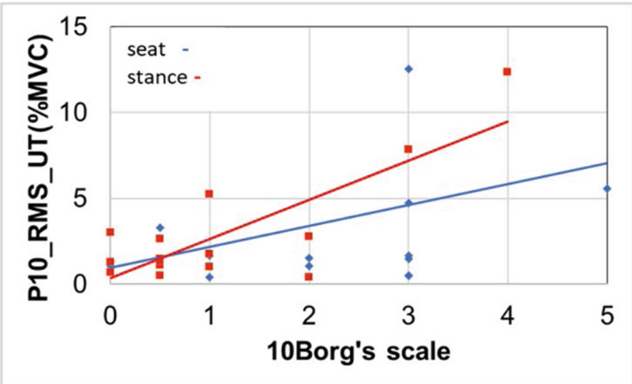

Fig. 3. Correlation between 10 Borg's scale values and P10_RMS_UT for both postures (blue seat, red stance).

4 Discussion and Conclusion

The main findings of this study show, through the analysis of the muscular activation during sustained activity [22], the potential negative effect that the prolonged use of smartphone for texting could generate (i.e. cervical discomfort and/or chronic cervical pain).

As presented in the above paragraph, the median muscle activity, which was around 2.5% of MVC for dominant side in both postures, confirmed the results reported by Thorn et al. [22] for precision typing activity; in the same way, the P10_RMS level around 2% of MVC indicates a non-negligible degree of muscular static activity during texting: it reflects the continuous muscle load during sustained activity and could be linked to the potential development of musculoskeletal disorders [11]. This aspect was better investigated through the analysis of the relative rest time and its strong inverse proportionality with P10_RMS: the lower RRT values (around 0%) and higher P10_RMS level during smartphone texting, for all the tasks and both sides of the trapezius, showed that the effect of the sustained activity is strictly correlated with the absence of a muscle rest period. As presented by a previous research [24], this absence is a plausible risk factor for the development of trapezius myalgia, neck pain and cervical discomfort. In addition, the hypothesis was confirmed by the direct correlation between P10_RMS and the muscular cervical discomfort perceived by the subjects during the experiment, supporting the link between the prolonged activity and the cervical discomfort. The observed difference between postures, in these regards, may be ascribed to the reduced ability of the Borg scale to capture specific muscular effort. Finally, the results have showed that, for both sitting and standing postures, the upper trapezius muscular activity of both sides maintained the same level of activity; moreover, a value around 2% of MVC for all RMS parameters (median, P10 and range) indicated a constant muscular activity throughout the experiment.

In conclusion, the results obtained by the present study suggest that the prolonged use of smartphone for texting could be a plausible factor for developing cervical discomfort and neck pain. The observed correlation of amplitude-based surface EMG parameters with the indicators of fatigue perception further highlights the utility of using electromyography also for such kind of applications, where low-level sustained tonic muscular activity may play a relevant role in the onset of work-related musculoskeletal disorders. In this specific scenario, particular attention should be devoted to processing techniques for myoelectric signals that suffer from a relatively low signal-to-noise ratio [25, 26]. With the aim to define the intervention strategies for prevent the biomechanical risk, further studies will be necessary to investigate the relationship between kinematics of posture (i.e. neck angle), and muscular activity.

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