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Postural prevalence, time of day and spent time activities during smartphone weekday use among students: A survey to prevent musculoskeletal disorders

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ABSTRACT

The long time spent on smartphones in awkward postures exposes young users to the risk of developing musculoskeletal disorders (MSDs). This study aimed to investigate 1) how the duration of smartphone use varies by the time of day and activities and 2) the risks of MSDs based on an analysis of the postures used when interacting with smartphones. A cross-sectional survey was conducted among 263 university students. The duration of smartphone use during a typical weekday was investigated over four times of the day and seven activities. After checking for normality, a nonparametric Friedman test was used to study the differences in the time spent using a smartphone according to the time of day and activity. Postural prevalence during weekdays was analyzed using a taxonomy called SmarTaxo, consisting of 41 postures. The Rapid Upper Limb Assessment (RULA) ergonomic score was chosen to assess the MSD risks associated with each posture.

Smartphone use was the highest in the evening (301.1 min; 95 % confidence interval [CI]: 277.4–324.8 min, $p < 0.05$). Texting (170.8 min; 95 % CI: 152.0–189.6 min) and watching videos (163.6 min; 95 % CI: 146.3–180.9 min) were the most common activities. Three sitting and two walking postures were primarily used in the morning (29.3–36.9 %), afternoon (27.0–44.4 %), and evening (28.9%–38.9 %). Standing postures were preferred in the morning and afternoon (36.9 % and 42.2 %, respectively), while one lying posture was widely reported in the evening (39.2 %). The RULA scores for these postures ranged from 3 to 4. However, four lying postures, often observed during the evening (frequency between 20.5 % and 37.6 % of the time), had RULA scores of 6. In conclusion, the study identified an existing MSD risk among smartphone users, especially with long durations of daily use. Special emphasis should be placed on addressing the reclining postures adopted during evening smartphone use, as they subject students to a significantly elevated risk of MSDs.

List of abbreviations: MSDs, Musculoskeletal disorders; SmarTaxo, Taxonomy of posture during smartphone use; DT-POP, Daytime postural prevalence of smartphone use questionnaire; RULA, Rapid Upper Limb Assessment; 95% CI, 95% confidence Interval.

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1. Introduction

The worldwide penetration rate of smartphones is on the rise. According to estimates, 6.92 billion people, or 86.29 % of the world's population, are smartphone owners [1]. Remarkably, digital natives have been using smartphones from a very young age, with international data reporting that over 90 % of those aged 15–30 years own smartphones [2–4]. Moreover, the average rate of daily smartphone use has also steadily increased. Available data from 2018 to 2020 reveal an average daily usage of 3 h and 35 min among both the US [5] and French [6] users, respectively. In 2022, the average daily use exceeded 4 h [7]. These findings are in line with previous studies, such as those by Kim et al. [16] and Iqbal et al. [32] which found that individuals spend approximately 4 h per day using smartphones. More recently, Shah et al. [8] found that 41 % of young people use their smartphones for more than 4 h per day [8]. However, only a few studies have examined activity duration on smartphones, and these studies generally do not distinguish between the activities performed. For instance, Khan et al. [9] that individuals spend 6–9 h on smartphone texting during a typical day, while Kamolthip et al. [10] observed young adults maintaining an 8-h sitting posture while engaged in gaming activities.

Other researchers have investigated smartphone activities to assess the prevalence of musculoskeletal disorders (MSDs) related to the upper limbs [11] upper extremities [12], or postures qualified as good or faulty [13]. Their research evaluated the duration and distribution of several smartphone activities among students, such as chatting, watching videos/movies, playing games, making phone calls, browsing the internet, blogging, making video calls, reading/studying, and engaging in photography. Balakrishnan et al. [12] and Odole et al. [13] provided data on user distribution within a 1–2 h time frame, including percentages for activities such as web browsing (21 % and 21.3 % for 5 h), phone calls (36 % and 28.5 % for 2 h), and watching videos and taking pictures (20 % and 41.3 % for 2 h), respectively. In contrast, Berolo et al. [11] achieved greater precision when it came to mean durations. Their research revealed that users spent an average of 1.05 h on texting, 2.77 h on web browsing, 1.06 h on phone calls, 2.15 h on watching videos, and 1.5 h on gaming during a typical weekday. However, to the best of our knowledge, no study has examined the distribution of smartphone use with respect to both the time of day and the specific activity being undertaken.

Young people increasingly use smartphones throughout the day, which can lead to several physical and psychological problems. Research has highlighted the effects of dependency and fear of being unable to use smartphones [14]. Nomophobia is highly comorbid with other disorders such as eating disorders, obsessive-compulsive disorders, depression, and other behavioral disorders [15]. From a physical point of view, smartphone use is associated with the development of MSDs, with recent studies reporting an MSD prevalence of 50–84 % among smartphone users [11,16]. The spine and upper limbs are the most affected areas, with a prevalence between 1.0 % and 67.8 % [16]. In addition, studies have reported a neck pain prevalence of 43.3%–86.4 [17,18], upper and lower back pain prevalence of 63.5%–76.2 % [13,19], shoulder pain prevalence of 32.6%–76.2 % [13,18], and wrist pain prevalence of 21.1%–51.4 % [13,19].

Based on these prevalence rates, previous studies have addressed the link between posture and MSDs. The quantification of posture provides information about the causes of MSDs. The assessment of joint angles enable an ergonomic evaluation of MSD risks using ergonomic tools such as the Rapid Upper Limb Assessment (RULA [20]), and Rapid Entire Body Assessment (REBA, [21]). This approach has been applied to analyze texting and web browsing activities in sitting and standing postures with and without support [22,23]. These studies highlight the importance of assessing posture to investigate its link with MSD risks.

A typical weekday for a university student involves a variety of activities, including commuting, attending classes, engaging in intercourse, consuming meals, and enjoying free time, leisure time, and time at home. These activities can be performed in various postures, such as standing, sitting, lying down, or walking. However, the distribution of these postures on typical weekdays remains unknown. It would be valuable to understand the prevalence of postures to better understand and prevent the onset of MSDs during smartphone use.

Therefore, this study investigated the following. First, the distribution of smartphone usage by time of day and activity among university students, under the hypothesis that the duration will be influenced by these factors. Second, the study examined the prevalence of postures adopted by users to investigate their association with MSD risk.

2. Materials and methods

2.1. Participants

The participants were recruited from a university sports department. After a detailed presentation of the protocol, 266 students (204 male and 62 female participants) voluntarily participated in the study. All participants were full-time first-year university students aged over 16 years. Their smartphone experience exceeded two years, and they had owned a smartphone for at least one year. None of the patients had any injury or pathology likely to affect their smartphone use or posture. All participants provided consent before starting the experiment.

2.2. Experimental design

A cross-sectional survey was designed to study smartphone use habits among students on a typical weekday at a university using a questionnaire. The protocol was in accordance with the declaration of Helsinki [24] and approved by the Ethics Committee of the International Institute of Biomechanics and Occupational Ergonomics. The questionnaire comprised three sections. The first concerned the participants' socio-demographic data. The second addressed their smartphone usage habits on a typical weekday as a university student. It included questions regarding the duration of use of the most common applications. The third part focused on the postures used to perform different smartphone activities on weekdays. For the last two sections, usage durations were presented at intervals of 15 min to 1 h. The upper bounds of the intervals were considered for statistical analysis.

The "daytime postural prevalence of smartphone use questionnaire" (DT-POP, presented in Appendix 1) employed had two original features. The first concerned the division of the weekday into four 6-h periods and the durations of use proposed in Parts 2 and 3 during these times of the day. The divisions were as follows: morning (6 a.m. to noon), afternoon (noon to 6 p.m.), evening (6 p.m. to midnight), and night (midnight to 6 a.m.). The second feature integrated SmarTaxo [25], a taxonomy of 41 postures observed while engaging in primary smartphone activities, including texting, web browsing, watching videos, gaming, taking pictures, taking selfies, and making phone calls. This taxonomy was based on data from several studies that addressed the issue of posture when using a smartphone [13,22,26–34]. SmarTaxo includes 27 postures — 13 sitting postures, 6 standing, 7 lying, and 1 walking —associated with the above activities, except for phone calls. The 14 remaining postures (i.e. 5 sitting, 5 standing, 3 lying, and 1 walking) were specifically considered for the study of phone calls. This selection was made based on the unique upper limb joint angles required to hold the smartphone to the ear during phone calls.

All postures included in the taxonomy were defined from a biomechanical point of view; that is, all joint angles were known. These data are required for ergonomic assessments of posture-related MSD risks. Among the various tools available in the literature, the RULA [20] is the most widely used, particularly in occupational activities, because it offers the best assessment quality [35]. It is mainly based on information related to the upper limbs; however, it also includes data from the lower limbs and task-related factors (repetition, static posture maintenance, and so on). Because smartphone use mainly involves the upper limbs, the RULA was chosen to assess MSD risk in the context of smartphone use in this study. The 41 postures identified in SmarTaxo and their corresponding RULA scores are shown in Fig. 1.

2.3. Statistical analysis

Statistical analyses were performed using Statistica (Version 7.1, StatSoft, Tulsa, OK, USA). From the questionnaire data, the duration of use of each activity and posture was computed according to the time of day. Normality was checked using the Shapiro–Wilk test. A nonparametric Friedman test was used to study the effect of time of day and smartphone activity on the duration of smartphone use. Postural prevalence by time of day is presented as a percentage. The significance threshold was set at 5 %.

3. Results

3.1. Characteristics of the participants

Of the 266 questionnaires received, three were excluded due to incomplete data. The response rate was 98.87 %. The sample was composed of 62 adult women (23.6 %, 18.3 ± 0.5 years, 164 ± 6.8 cm, 58.1 ± 7.4 kg, BMI: 21.6 ± 2.2) and 201 adult men (73.6 %, 18.6 ± 1.0 years, 179.1 ± 10.2 cm, 72.6 ± 10.3 kg, BMI: 22.3 ± 3.4). Each participant had owned a smartphone for over seven years.

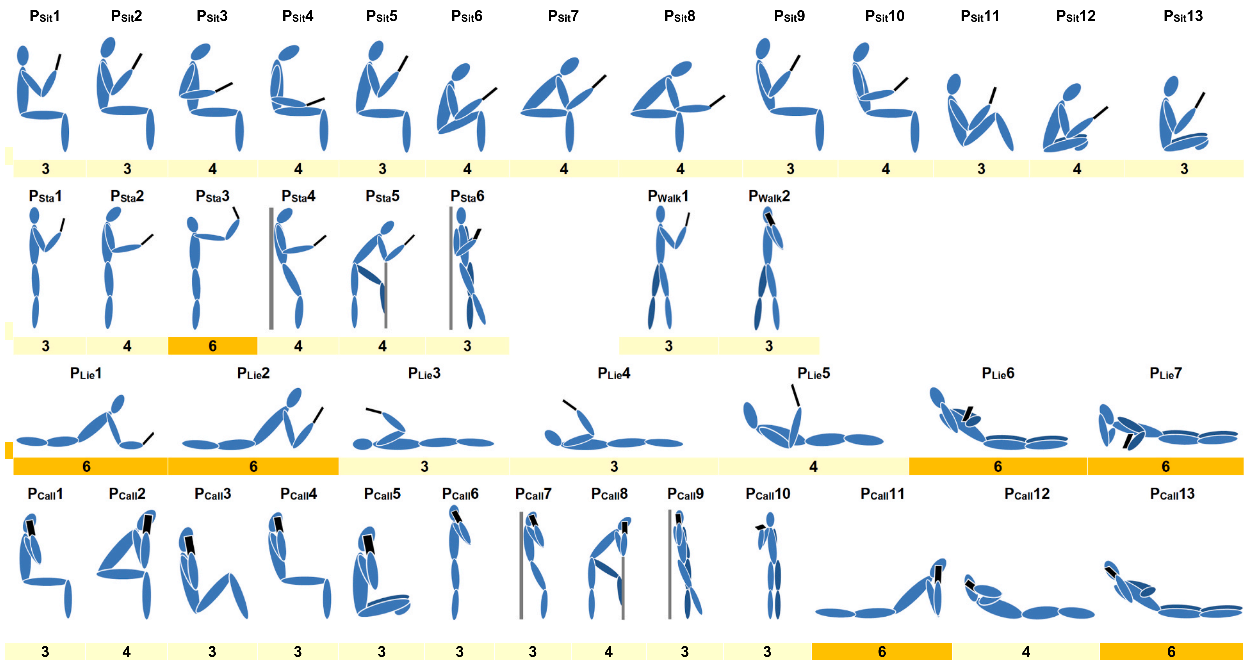


Fig. 1. SmarTaxo: Taxonomy of 41 postures evaluated in the DT-POP with their corresponding RULA scores [25].

Table 1
Socio-demographic characteristics of the participants.

	Male	Female	Total
Number of participants	201 (76.4 %)	62 (23.6 %)	263
Age (years)	18.6 ± 1.0	18.3 ± 0.5	18.5 ± 0.9
Height (m)	1.79 ± 0.1	1.64 ± 0.07	1.76 ± 0.1
Weight (kg)	72.6 ± 10.3	58.1 ± 7.4	69.2 ± 11.5
BMI	22.3 ± 3.4	21.6 ± 2.2	22.9 ± 3.7
Years of experience with a smartphone	7.7 ± 1.7	7.9 ± 1.6	7.8 ± 1.7

Table 1 presents the socio-demographic characteristics of the 263 participants.

3.2. Smartphone use by time of day

Fig. 2 shows the mean duration of smartphone use for each time of day during a typical weekday. Smartphone use was significantly the highest during the evening, with a mean duration of 301.1 min (95 % CI: 277.4–324.8 min, $p < 0.05$). The afternoon emerged as the second-highest period of smartphone use, with an average of 181.8 min (95 % CI: 164.1–199.6 min) significantly surpassing both morning (99.6 min; 95 % CI: 88.5–110.8 min) and night (86.4 min; 95 % CI: 69.7–103.1 min) usage durations.

3.3. Typical weekday smartphone activity patterns

The data analysis revealed that texting (170.8 min; 95 % CI: 152.0–189.6 min) and watching videos (163.6 min; 95 % CI: 146.3–180.9 min) were statistically the two most commonly performed by users on a typical weekday (Fig. 3). Web browsing came third with an average duration of 130.6 min (95 % CI: 113.4–147.8 min). Gaming and phone calls lasted statistically half as long as web browsing (63.5 min; 95 % CI: 54.4–72.5 min and 59.3 min; 95 % CI: 48.5–70.0 min respectively, $p < 0.05$). Finally, photography was statistically the activity with the lowest duration of use (30.9 min; 95 % CI: 26.5–35.3 min).

3.4. Interaction between smartphone activity and time of day

An interaction effect between smartphone activity and time of day was observed (Fig. 4, $p < 0.05$). For texting, the mean durations of use were significantly different across all times of day, averaging 68.2 min (95 % CI: 60.1–76.2 min), 51.9 min (95 % CI: 45.3–58.4 min), 31.7 min (95 % CI: 27.1–36.2 min), and 19.0 min (95 % CI: 14.3–23.6 min) in the evening, afternoon, morning, and night, respectively.

Regarding watching videos and web browsing, evening periods exhibited the longest duration of use, reaching averages of 85.7 min (95 % CI: 77.5–93.7 min) and 56.5 min (95 % CI: 48.9–64.0 min), respectively. Afternoon periods, on the other hand, displayed significantly different durations: 37.6 min (95 % CI: 31.6–43.6 min) for web browsing and 33.9 min (95 % CI: 28.0–39.8 min) for watching videos. Morning and night did not exhibit significant differences and had the lowest mean duration of use (web browsing: 19.7 and 16.7 min; watching videos: 19.7 min and 24.3 min, respectively). For gaming, the afternoon-to-evening period was associated with a significantly longer duration of use compared to the morning-to-night period (20.0 and 27.4 min vs. 8.7 and 7.4 min). Notably, phone calls and selfies were taken significantly more frequently during the evening than during other times of the day (28.2 min (95 % CI: 22.4–33.9 min) and 25.8 min (95 % CI: 20.2–31.3 min), respectively). However, no significant effect of the time of day was found

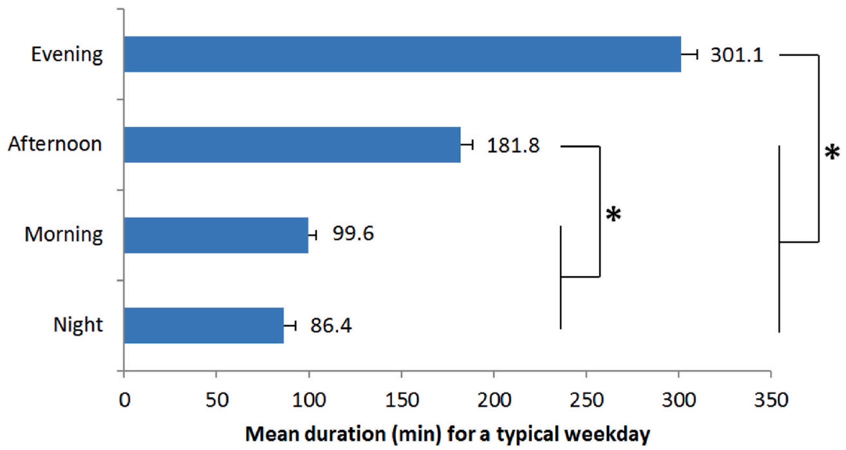


Fig. 2. Mean duration for each time of day during a typical weekday. * Indicates a significant difference in usage duration ($p < 0.05$). Horizontal thin black bars represent the 95 % confidence level.

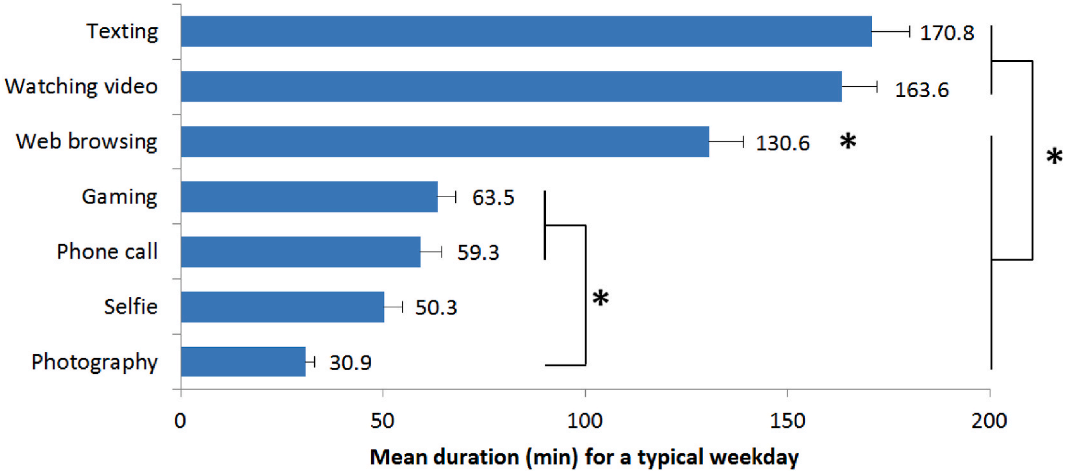


Fig. 3. Mean duration of each smartphone activity during a typical weekday.
* Indicates a significant difference in usage duration ($p < 0.05$). Horizontal thin black bars represent the 95 % confidence level.

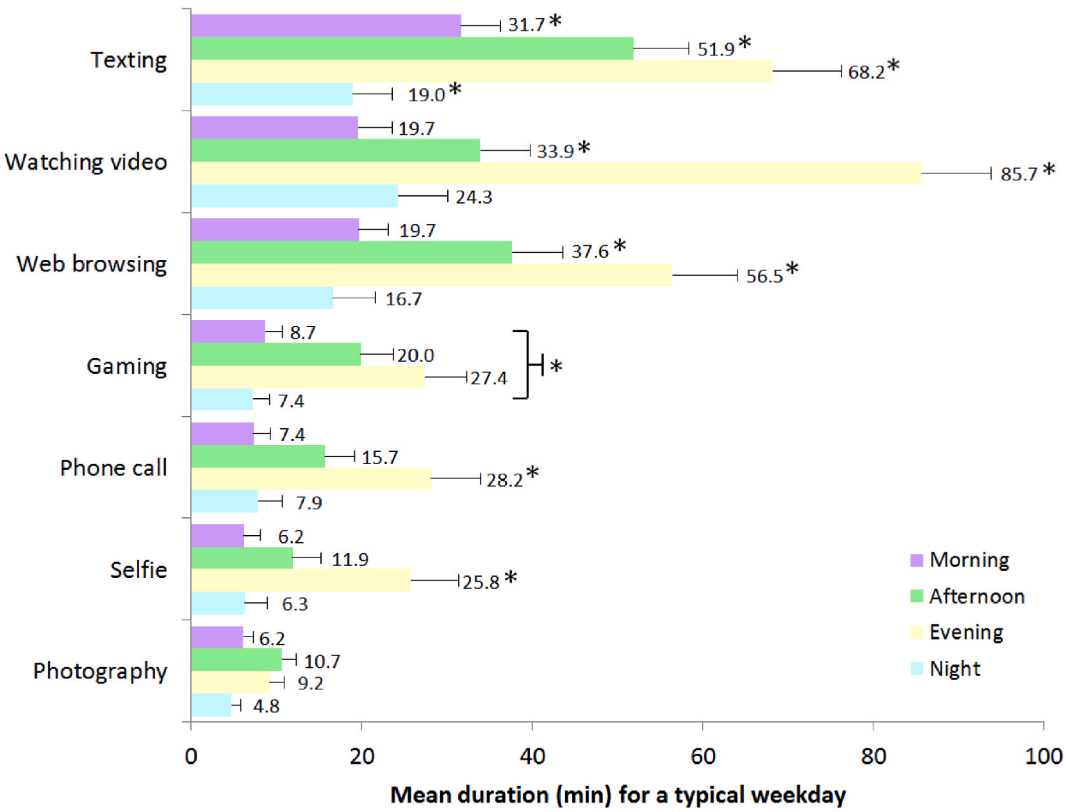


Fig. 4. Mean duration of smartphone activity by the time of day on a typical weekday.
* Indicates a significant difference in usage duration ($p < 0.05$). Horizontal thin black bars represent the 95 % confidence level.

for photography.

In the morning, the most frequently used activity was texting, accounting for 31.7 min (95 % CI: 27.1–36.3 min). Watching videos and web browsing came next, both with a duration of 19.7 min (95 % CI: 16.2–23.2 min). In contrast, gaming, making phone calls, and taking selfies and other photos exhibited no significant differences and had the lowest durations of use, with durations of 8.7 min (95 % CI: 6.7–10.7 min), 7.4 min (95 % CI: 5.5–9.3 min), 6.2 min (95 % CI: 4.3–8.1 min), and 6.2 min (95 % CI: 5.0–7.3 min), respectively. Meanwhile, the results obtained in the afternoon were similar to those obtained in the morning. Texting was the most common activity

Table 2
User distribution (number and percentage) by the duration and time of day for seven smartphone activities during a typical weekday.

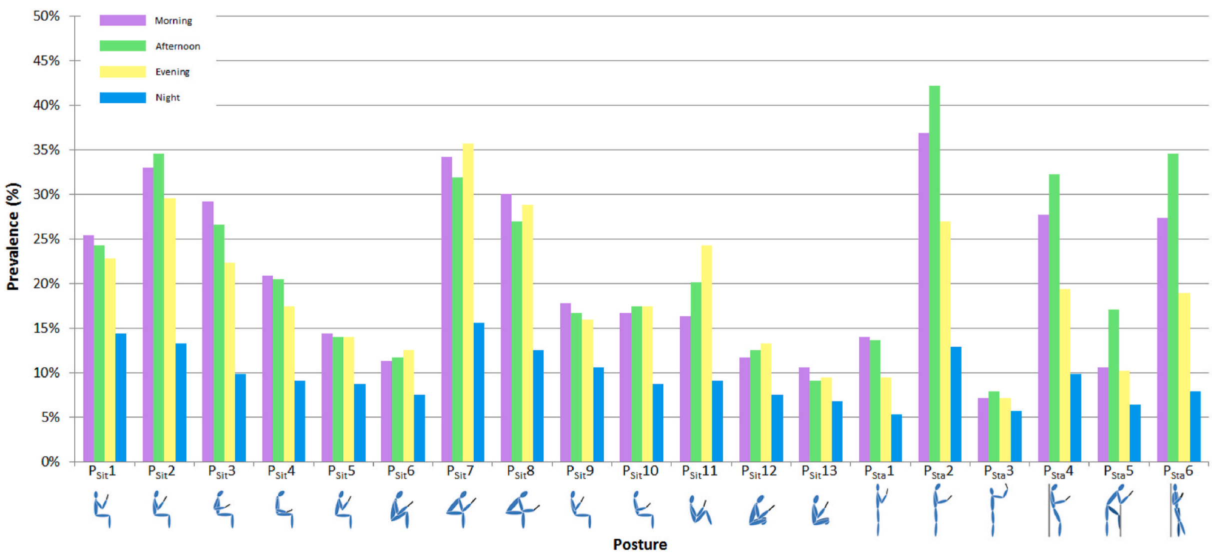
		0 min		<15min		15–30min		30min - 1 h		1–2 h		2–3 h		3–4 h		4–5 h		5–6 h		Mean duration
		n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	min
Phone call	Morning	159	60.5 %	96	36.5 %	5	1.9 %	1	0.4 %	1	0.4 %	1	0.4 %	–	–	–	–	–	–	7.4
	Afternoon	107	40.7 %	112	42.6 %	28	10.6 %	10	3.8 %	3	1.1 %	1	0.4 %	2	0.8 %	–	–	–	–	15.7
	Evening	82	31.2 %	106	40.3 %	30	11.4 %	25	9.5 %	9	3.4 %	8	3.0 %	–	–	3	1.1 %	–	–	28.2
	Night	183	69.6 %	71	27.0 %	–	–	3	1.1 %	5	1.9 %	–	–	1	0.4 %	–	–	–	–	7.9
Texting	Morning	63	24.0 %	80	30.4 %	56	21.3 %	42	16.0 %	18	6.8 %	3	1.1 %	1	0.4 %	–	–	–	–	31.7
	Afternoon	29	11.0 %	58	22.1 %	72	27.4 %	53	20.2 %	36	13.7 %	10	3.8 %	3	1.1 %	2	0.8 %	–	–	51.9
	Evening	29	11.0 %	38	14.4 %	51	19.4 %	72	27.4 %	46	17.5 %	14	5.3 %	8	3.0 %	4	1.5 %	1	0.4 %	68.2
	Night	138	52.5 %	71	27.0 %	19	7.2 %	21	8.0 %	10	3.8 %	3	1.1 %	–	–	–	–	1	0.4 %	19.0
Web browsing	Morning	111	42.2 %	80	30.4 %	33	12.5 %	29	11.0 %	9	3.4 %	1	0.4 %	–	–	–	–	–	–	19.7
	Afternoon	61	23.2 %	70	26.6 %	59	22.4 %	45	17.1 %	17	6.5 %	7	2.7 %	3	1.1 %	–	–	1	0.4 %	37.6
	Evening	53	20.2 %	51	19.4 %	46	17.5 %	49	18.6 %	37	14.1 %	21	8.0 %	5	1.9 %	–	–	1	0.4 %	56.5
	Night	165	62.7 %	59	22.4 %	9	3.4 %	15	5.7 %	10	3.8 %	3	1.1 %	1	0.4 %	–	–	1	0.4 %	16.7
Watching video	Morning	135	51.3 %	59	22.4 %	27	10.3 %	29	11.0 %	10	3.8 %	3	1.1 %	–	–	–	–	–	–	19.7
	Afternoon	119	45.2 %	39	14.8 %	28	10.6 %	40	15.2 %	28	10.6 %	7	2.7 %	2	0.8 %	–	–	–	–	33.9
	Evening	33	12.5 %	16	6.1 %	33	12.5 %	66	25.1 %	70	26.6 %	33	12.5 %	1-	3.8 %	2	0.8 %	–	–	85.7
	Night	159	60.5 %	42	16.0 %	12	4.6 %	24	9.1 %	16	6.1 %	7	2.7 %	2	0.8 %	1	0.4 %	–	–	24.3
Gaming	Morning	166	63.1 %	71	27.0 %	15	5.7 %	9	3.4 %	2	0.8 %	–	–	–	–	–	–	–	–	8.7
	Afternoon	129	49.0 %	62	23.6 %	34	12.9 %	21	8.0 %	17	6.5 %	–	–	–	–	–	–	–	–	20.0
	Evening	110	41.8 %	51	19.4 %	47	17.9 %	33	12.5 %	17	6.5 %	3	1.1 %	2	0.8 %	–	–	–	–	27.4
	Night	182	69.2 %	59	22.4 %	13	4.9 %	7	2.7 %	2	0.8 %	–	–	–	–	–	–	–	–	7.4
Photography	Morning	170	64.6 %	82	31.2 %	9	3.4 %	2	0.8 %	–	–	–	–	–	–	–	–	–	–	6.2
	Afternoon	120	45.6 %	114	43.3 %	23	8.7 %	5	1.9 %	1	0.4 %	–	–	–	–	–	–	–	–	10.7
	Evening	141	53.6 %	100	38.0 %	15	5.7 %	6	2.3 %	1	0.4 %	–	–	–	–	–	–	–	–	9.2
	Night	189	71.9 %	70	26.6 %	1	0.4 %	3	1.1 %	–	–	–	–	–	–	–	–	–	–	4.8
Selfie	Morning	185	70.3 %	69	26.2 %	4	1.5 %	3	1.1 %	1	0.4 %	1	0.4 %	–	–	–	–	–	–	6.2
	Afternoon	155	58.9 %	75	28.5 %	21	8.0 %	5	1.9 %	4	1.5 %	2	0.8 %	1	0.4 %	–	–	–	–	11.9
	Evening	122	46.4 %	65	24.7 %	32	12.2 %	20	7.6 %	14	5.3 %	8	3.0 %	1	0.4 %	1	0.4 %	–	–	25.8
	Night	193	73.4 %	61	23.2 %	3	1.1 %	4	1.5 %	1	0.4 %	–	–	–	–	1	0.4 %	–	–	6.3

at 51.9 min (95 % CI: 45.3–58.3 min), and watching videos and web browsing were the second most common activities at 33.9 min (95 % CI: 28.0–39.8 min) and 37.6 min (95 % CI: 31.6–43.6 min), respectively. Gaming, making phone calls, and taking selfies and other photos exhibited no significant differences and had the lowest durations of use, with durations of 20.0 min (95 % CI: 16.1–23.7 min), 15.7 min (95 % CI: 12.3–19.2 min), 11.9 min (95 % CI: 8.5–15.2 min), and 10.7 min (95 % CI: 9.0–12.3 min), respectively. Notably, the gaming duration was significantly longer than the photography duration ($p < 0.05$).

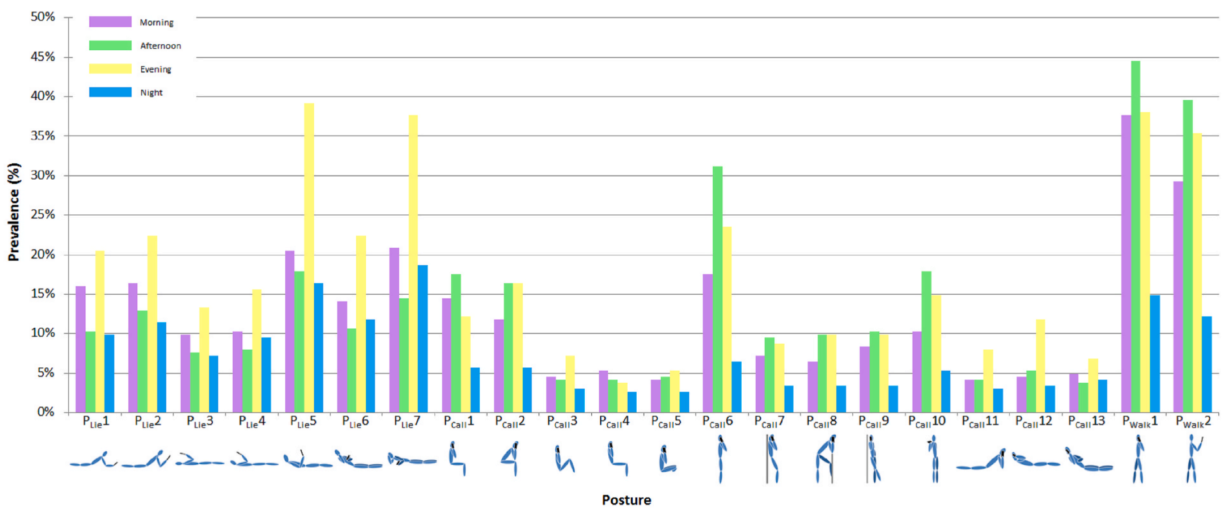
In the evening, the most common activity was watching videos (85.7 min; 95 % CI: 77.5–93.7 min), followed by texting (68.2 min; 95 % CI: 60.1–76.2 min). Web browsing came third at 56.5 min (95 % CI: 48.9–64.0 min). Gaming, phone calls, and selfies each had durations statistically half as long as web browsing, with 27.4 min (95 % CI: 22.5–32.3 min), 28.2 min (95 % CI: 22.4–33.9 min), and 25.8 min (95 % CI: 20.3–31.4 min), respectively. Photography was statistically the less common activity at 9.2 min (95 % CI: 7.5–10.9 min).

Nighttime activities could be grouped into two categories: Watching videos (24.3 min; 95 % CI: 18.4–30.1 min), texting (19.0 min; 95 % CI: 14.3–23.6 min), and web browsing (16.7 min; 95 % CI: 11.7–21.6 min) were the activities with the longest durations. Conversely, gaming (7.4 min; 95 % CI: 5.4–9.2 min), phone calls (7.9 min; 95 % CI: 5.1–10.7 min), selfies (6.3 min; 95 % CI: 3.6–8.9 min), and photography (4.8 min; 95 % CI: 3.6–5.8 min) had durations two to three times shorter.

Table 2 presents the distribution of smartphone usage by activity and time of day. For the seven activities considered, the greatest



a: Sitting and standing weekday postural prevalence during smartphone use by time of day.



b: Lying, calling and walking weekday postural prevalence during smartphone use by time of day.

Fig. 5. aSitting and standing weekday postural prevalence during smartphone use by time of day.
bLying, calling and walking weekday postural prevalence during smartphone use by time of day.

number of users was observed in the afternoon and evening. Texting was the most common activity, with 89 % of the sample texting twice a day. Watching videos was performed by 87.5 % of the population, mainly during the evening. Web browsing was also heavily performed in the afternoon and evening by 76.8 % and 79.8 % of students, respectively. All activities were performed the least at night (<50 % of the participants). Smartphones were also used less frequently in the morning. Texting and web browsing were carried out the most in the morning by 76 % and 57.8 % of the sample, respectively.

3.5. Posture prevalence and associated MSD risk

Fig. 5 illustrates the prevalence of the 41 taxonomic postures according to the time of day. The overall prevalence ranged from 4.0 % for $P_{Call}4$ to 33.8 % for $P_{Walk}1$. The most frequently used postures were $P_{Sit}2$ (27.6 %), $P_{Sit}7$ (29.4 %), $P_{Sit}8$ (24.6 %), $P_{Sta}2$ (29.7 %), $P_{Lie}5$ (23.4 %), $P_{Walk}1$ (33.7 %), and $P_{Walk}2$ (29.0 %). Three sitting postures ($P_{Sit}2$, $P_{Sit}7$, and $P_{Sit}8$) and two walking postures ($P_{Walk}1$ and $P_{Walk}2$) were used throughout the day in the morning (29.3%–36.9 %), afternoon (27.0–44.4 %), and evening (28.9–38.9 %). $P_{Sta}2$ was mainly observed in the morning and afternoon, with prevalence rates of 36.9 % and 42.2 %, respectively. $P_{Lie}5$ was widely reported in the evening (39.2 %) and was the most commonly used posture at night (16.3 %). According to the taxonomy (Fig. 1), the most frequently observed postures had RULA scores of 3–4. However, it is worth noting that some postures with RULA scores of 6 were predominantly used during specific times of the day: $P_{Lie}1$, $P_{Lie}2$, $P_{Lie}6$, and $P_{Lie}7$ in the evening (20.5 %, 22.4 %, 22.4 %, and 37.6 %, respectively).

4. Discussion

This study aimed to investigate the distribution of smartphone usage time by the time of day and activity among university students on a typical weekday while also analyzing postural prevalence (sitting, standing, lying down, and walking). The data analysis revealed that texting (170.8 min; 95 % CI: 152.0–189.6 min) and watching videos (163.6 min; 95 % CI: 146.3–180.9 min) were statistically the two most common activities ($p < 0.05$). Web browsing came third with an average duration of 130.6 min (95 % CI: 113.4–147.8 min).

The results for texting and watching videos were higher than those reported in the literature. Berolo et al. [11] reported average durations of 1.05 h and 2.15 h respectively per day. Meanwhile, Balakrishnan et al. [12] demonstrated that the highest frequency of users wrote e-mails and watched videos for 2 h. It should be noted that in both these studies, the time spent watching videos was coupled with two other activities: listening to music and taking pictures. In contrast, our findings indicated a lower duration for web browsing compared to these two studies. Berolo et al. [11] reported 2.77 h per day, and Balakrishnan et al. [12] found that 21 % of users spent more than 5 h web browsing. However, our results are consistent with those reported by Odole et al. [13], who reported that the majority of students (30.3 %, 38.5 %, and 33.0 % among 400 students, respectively) sent messages, watched videos, and browsed the internet for 2–3 h. These results suggest a change in smartphone usage. Specifically, due to the emergence of social networks and considering the timeline of Berolo et al. and Balakrishnan et al.'s studies, which were performed seven years ago [11,12], it becomes evident that students now dedicate a significant amount of time to activities such as watching video content and texting. In the present study, shorter durations for gaming and phone calls (63.5 min, 95 % CI: 54.4–72.5 min; and 59.3 min, 95 % CI: 48.5–70.0 min, respectively) were observed. These values were slightly lower than those reported by Berolo et al. (1.5 h for gaming and 1.06 h for phone calls [11]) and Balakrishnan et al. (72 (36.0 %) students spending a total of 2 h on phone calls [12]).

Fig. 2 presents the findings regarding smartphone use at different times of day. This information is interesting, and to the best of our knowledge, has never been studied in the literature. Users devoted the most time to smartphone usage in the evening between 6 p.m. and midnight (evening: 301.1 min; 95 % CI: 277.4–324.8 min, $p < 0.05$). However, while at university, they remained connected to their smartphone for over 4 h (morning: 99.6 min; 95 % CI: 88.5–110.8 min; afternoon: 181.8 min; 95 % CI: 164.1–199.6 min). The three primary activities, namely texting (68.2 min; 95 % CI: 60.1–76.2 min), watching videos (85.7 min; 95 % CI: 77.5–93.7 min), and web browsing (56.5 min; 95 % CI: 48.9–64.0 min), were most frequently performed in the evening. However, they still frequently engaged in these activities in the morning and afternoon (between 19.7 and 51.9 min).

The distribution of smartphone usage duration by activity and time of day is shown in Table 2. The most popular activities among young people were texting and watching videos, with over 85 % of them using smartphones in the afternoon or evening. However, only 50 % of the participants used their smartphones at night. This provides precise information on smartphone users, identifying the time of day during which various activities are carried out. This approach complements the data available in the literature, which often focuses on overall use over a day [8,32] or the total duration per activity (e.g. 5 h for web browsing [12], 2–3 h for texting [13], and 2 h 15 min for watching videos [11]).

SmarTaxo was used to identify the most frequently used postures at different times of the day. The total postural prevalence for all 41 postures ranged from 4.0 % for $P_{Call}4$ to 33.8 % for $P_{Walk}1$. This original result provides the postural prevalence of the users, which complements the analyses proposed in the literature for sitting, standing, and lying postures [31,36]. Three sitting postures ($P_{Sit}2$: 27.6 %, $P_{Sit}7$: 29.4 %, $P_{Sit}8$: 24.6 %), one standing posture ($P_{Sta}2$: 29.7 %), one lying posture ($P_{Lie}5$: 23.4 %), and the two walking postures ($P_{Walk}1$: 33.7 % and $P_{Walk}2$: 29.0 %) were particularly prevalent (+25 % of the sample) during the day. Analyzing the distribution by time of day enabled us to distinguish between sitting and walking postures from morning to evening. As a result, we found that the standing posture was preferentially used during the morning and afternoon, while the lying posture was used in the evening.

Associations among posture information, time of day, and activities have never been proposed. In this study, the taxonomy employed also provided RULA scores for each posture, which provided information on the MSD risk associated with each of these. A score of 3–4 was observed for the majority of postures, indicating a low-to-moderate risk of MSD. These results are in line with other studies such as those by Merbah et al. [22] and Gorce et al. [28] which reported equivalent risks during smartphone use. However, some reclining postures (i.e., $P_{Lie}1$, $P_{Lie}2$, $P_{Lie}6$, and $P_{Lie}7$.) in the evening (20.5 %, 22.4 %, 22.4 %, and 37.6 %, respectively) had higher RULA scores of 6. This elevation in risk is primarily attributed to significant extensions and rotations of the neck and trunk, which place users in awkward postures that elevate the risk of MSD.MSDs substantially. Similar high RULA scores have also been observed among smartphone users in sitting and lying positions [31]. Owing to the significant duration of use throughout the day, it is imperative to monitor the postures adopted and modify them as soon as possible in extreme cases to limit the risk of MSDs among users.

This study had some limitations. First, it would have been relevant to integrate data related to injuries and/or MSDs that the students may have experienced, such as through the utilization of the Standardized Nordic Musculoskeletal questionnaire. The second limitation concerns the evaluation of duration of use on weekdays. The participants were asked to choose time slots ranging from a quarter to an hour, and we chose to retain only the upper limit of this interval for computation. This choice may have led to an overestimation of the duration of use. Finally, the questionnaire did not permit establishing a direct association between the postures used and the activities performed on smartphones. Therefore, it is important to integrate these aspects in future research.

Considering these limitations, several recommendations come to light. Given the long durations observed, users should be encouraged to limit smartphone use and, at the very least, take regular breaks and transition to different postures as soon as possible to avoid a prolonged static posture. Notably, SmarTaxo postures with a RULA score of 6, such as selfie and lying postures, should be avoided. It is now evident that to comprehensively examine MSD risk, the interplay between postural prevalence, time of day, and smartphone usage patterns must be taken into account and integrated into future investigations. Additionally, there is a critical need to enhance user awareness through educational initiatives.

5. Conclusion

This study aimed to investigate the duration of smartphone use by activity and time of day among students. Students used their smartphones extensively during a typical university day, despite the significant amount of time they devoted to their studies. Our survey revealed that smartphones were ubiquitously used during free time, particularly in the afternoon and evening. The students allocated a substantial portion of their time to activities such as texting, browsing the web, and watching videos. During this period of smartphone engagement, they adopted a number of awkward postures that could lead to the appearance of MSDs in the medium and long term, especially reclining postures in the evening. Overall, this study's approach enabled a better understanding of smartphone utilization patterns and underscores the associated risks, especially considering the extended duration of use among young individuals.

Ethical approval and consent to participate

The study was approved by the ethics committee of International Institute of Biomechanics and Occupational Ergonomics (IIBOE23-E51). The protocol is agreement with the Helsinki declaration. All subjects were informed of the entire protocol and gave their consent before participate. No minors (<16 years) have participated to the cross-sectional study.

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Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Philippe Gorce: Writing - review & editing, Writing - original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Julien Jacquier-Bret:** Writing - review & editing, Writing - original draft, Visualization, Validation, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e22796.

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