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Texting on mobile phones and musculoskeletal disorders in young adults: A five-year cohort study

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The aim was to examine whether texting on a mobile phone is a risk factor for musculoskeletal disorders in the neck and upper extremities in a population of young adults.

In a longitudinal population-based cohort study with Swedish young adults (aged 20–24 years) data were collected via a web-based questionnaire at baseline (n = 7092) and after one and five years. Cross-sectional associations were found between text messaging and reported ongoing symptoms in neck and upper extremities (odds ratios, ORs 1.3–2.0). Among symptom-free at baseline prospective associations were only found between text messaging and new cases of reported symptoms in the hand/fingers (OR 2.0) at one year follow up. Among those with symptoms at baseline prospective associations were found between text messaging and maintained pain in neck/upper back (OR 1.6). The results imply mostly short-term effects, and to a lesser extent, long-term effects on musculoskeletal disorders in neck and upper extremities.

1. Background

Young adults today have grown up with mobile phones as an evident part of their lives. In Sweden in 2012 the access to mobile phones was 99% among those aged 15–24; 82% had a smartphone, and 79% used the phone for SMS (short message service) text messaging on a daily basis (Nordicom and Carlsson, 2013). In a study of university students in the United States, text messaging (SMS) emerged as the most frequently used type of communicative medium (Skierkowski and Wood, 2012). The physical exposure when text messaging on a mobile phone consists of low physical load, repetitive thumb movements and neck flexion (Gustafsson et al., 2010, 2011).

A number of case studies have identified musculoskeletal disorders (MSDs) in the forearm and thumb, for example, tendonitis, tenosynovitis, and first carpometacarpal (CMC) arthritis, in relation to excessive texting on a mobile phone (Gordon, 2008; Menz, 2005; Ming et al., 2006; Storr and d.V.B.F.Stringer, 2007; Williams and Kennedy, 2011). Also, experimental and observational studies have reported on the potential physical risks related to texting. In an experimental study among young adults, we found differences in posture, typing style, and muscle activity while texting on the phone between those with and without musculoskeletal symptoms in neck and upper extremities (Gustafsson et al., 2010, 2011). In the group with symptoms, almost all individuals had the neck flexed forward and did not support their arms. This causes static muscular load in the neck and shoulders. Furthermore, they held the phone with one hand and used only one thumb, implying increased repetitive movements in hand and fingers. This distinguished them from the group without symptoms, in which it was more common to sit with a straight neck, to support the forearm, to hold the phone with two hands and to use both thumbs. Another study observing posture and typing style of college students typing on mobile devices found that almost all subjects had a flexed neck and a non-neutral typing-side wrist; nearly half of them typed with both thumbs, and one third typed with one thumb (Gold et al., 2012). It is previously known that neck flexion and highly repetitive movements are considered risk factors for musculoskeletal disorders (Andersen et al., 2003; Ariens et al., 2002; Grieco et al., 1998; Malchaire et al., 1996; Thomsen et al., 2007). Furthermore, in a cross-sectional questionnaire study with a population of university students and staff associations were found between time spent browsing the Internet using a mobile device and pain in the base of the right thumb, and between total time spent using a mobile device and pain in the right shoulder and neck (Berolo et al., 2011).

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All in all, the mentioned studies indicate that texting can be associated with musculoskeletal disorders of the neck and upper extremity. However, the published studies are case, observational, small experimental or cross-sectional studies. It is important to investigate whether texting is a risk factor for musculoskeletal disorders also in longitudinal studies and in larger populations in order to confirm that there are causal relations rather than spurious correlations. The time spent using a mobile phone and its small keyboard for texting is likely to increase because of the increased multi-functionality of the smartphones.

Due to young adults being a group with intense use of mobile phones in general and for texting in particular (Nordicom and Carlsson, 2013; Skierkowski and Wood, 2012) they are an urgent group to study. Furthermore, the causes of MSDs are multifactorial (Bongers et al, 2002, 2006; Sjogaard et al., 2000; Sterud et al., 2014). We have previously found mobile phone use to be associated with perceived stress among young adults (Thomée et al., 2007; Thomee et al., 2011). As stress, and lifestyle factors such as physical activity can cause or contribute to MSDs, these factors also need to be taken into account.

The aim of the present study was to examine whether texting on a mobile phone is a risk factor for musculoskeletal disorders in the neck and upper extremities in a population of young adults.

Specific research question.

Does texting on mobile phone predict musculoskeletal disorders in a one-year and a five-year perspective?

2. Methods

2.1. Study design

The present study was a longitudinal population-based cohort study with Swedish young adults (aged 20–24 years). Self-reported data were collected via a web-based questionnaire at baseline and at a one-year and a five-year follow-up.

The study received approval from the Regional Ethics Review Board in Gothenburg, Sweden.

2.2. Study population and procedure

In 2007, a cohort of young adults was recruited. Twenty thousand young adults aged 20–24 years (half men, half women) were randomly selected from the registry of the general population kept by the Swedish Tax Agency. Information about the study and that participation was voluntary was included in an invitation letter. A web-based questionnaire was answered by 7125 participants. In the present study those who did not respond to a specific question about SMS use were excluded. Thus, at baseline in 2007 the study group consisted of 7092 (2759 men, 4333 women). At one-year follow-up 4148 (1452 men, 2696 women), and at five-year follow-up 2724 (991 men, 1733 women) answered an identical questionnaire.

A non-respondent analysis at baseline was performed showing that women and native Swedes were overrepresented in the study population (Ekman et al., 2008). A dropout analysis at the one-year follow up showed that those who remained in the study less often worked and more often studied at baseline. They also, had a slightly lower level of mobile phone use compared to the dropouts (Thomee et al., 2011). A dropout analysis at the five-year follow up showed that the participants were more likely to be female, students, to have a higher education level, and to report a higher level of leisure time physical activity at baseline compared to the dropouts (Thomee et al., 2015).

2.3. Text messaging

Information about the number of text messages sent and received was obtained at baseline and follow-ups using the question *How many SMSs on average have you sent and received per day in the past 30 days?* The response categories were 1 = none, 2 = 1–5 per day, 3 = 6–10 per day, 4 = 11–20 per day, 5 = more than 20 per day. In the cross-sectional (baseline) statistical analysis, the categories 1 and 2 were merged into one and used as the reference category.

For the prospective analyses, we constructed the variable *stabile SMS* by combining the reported text messaging from baseline and the one-year follow-up, in order to capture a steadier exposure. A response of category 4 or 5 at both occasions = high stabile SMS and a response of category 1 or 2 at both occasions = low stabile SMS. Those who did not qualify for either “high” or “low” stabile SMS (42%), e.g. if they had response category 4 or 5 at baseline and 1 or 2 at one-year follow up, were not covered by the variable and thus not included in analysis.

2.4. Musculoskeletal symptoms

Information about perceived symptoms in neck and upper extremities was collected using the question *Are you currently experiencing any of the following symptoms?* (a) *Pain in the upper part of the back/neck*, (b) *Pain in the shoulders/arms/wrists/hands*, (c) *numbness/tingling in the hand/fingers*. There were five response categories: 1 = no, 2 = yes, for less than a week, 3 = yes, for 1 week to 1 month, 4 = yes, for 1–3 months, 5 = yes, for more than 3 months. For clarity, there was an illustration in the questionnaire of an upper half body, with references to the body parts mentioned. In the analysis the responses were dichotomized as no (response category 1) and yes (response categories 2–5).

2.5. Demographic variables and potential confounders

Demographic factors were collected from the questionnaire to describe the study group: sex, age, highest completed educational level (*elementary school*, *upper secondary school*, *college or university studies*), and occupation (*working*, *studying*, or *other*, which included being on long-term sick leave, parental leave, or other leave, or being unemployed). General health was assessed by the item *How do you perceive your general health?* The response categories were 1 = very good, 2 = good, 3 = moderate, 4 = poor, 5 = very poor. Further categorization was done by merging the response sets 1 and 2 into good and 4 and 5 into poor (Undén and Elofsson, 1998).

Perceived stress was assessed by a single item, which was an adaptation of a single-item general indicator of stress (Elo et al., 2003). *Stress means a situation when a person feels tense, restless, nervous, or anxious or is unable to sleep at night because his/her mind is troubled all the time. Have you continuously, for 7 days in a row or more in the past 12 months, experienced this kind of stress?* The response categories were yes and no.

Physical activity (leisure time) was assessed by a single question: *How much do you move and exert yourself physically during leisure time? If your activity varies greatly between, for example, summer and winter, try to estimate an average. The question concerns the last 12 months.* Respondents could choose among four possible answers, defined with examples (Saltin and Grimby, 1968): sedentary, light physical activities, regular physical activity and training, and vigorous physical training or competition sports.

Computer use was assessed by a single question: *On average, how much time per day have you used a computer?* Time span was the past 30 days and response categories were <2 h per day, 2–4 h per day, and <4 h per day.

2.6. Statistical methods

In the present study, all analyses were performed using the SAS statistical package, version 9.3 (SAS Institute, Cary, NC, USA).

Descriptive statistics, as mean and standard deviation (SD) for the variable *age*, and percentages for categorical variables, were calculated with the procedures PROC UNIVARIATE and PROC FREQ, respectively.

Each of the outcomes *neck/upper back*, *shoulder/upper extremities*, and *hand/finger numbness/tingling* were analyzed with logistic regression models (PROC LOGISTIC). In all regression models the potential confounders used were from baseline and checked for multicollinearity together with the exposure variables. All confounders and exposure variables were categorical variables, except for *age*. The categorical variables were considered to be multicollinear if cross-tables of the variables showed a high agreement (>80%) in either of the diagonals. The continuous variable was considered to be multicollinear with categorical variables if the Spearman correlation was >0.7. No multicollinearity was present among the explanatory variables considered.

The model building was based on the strategy recommended by Hosmer and Lemenshow (Bursac et al., 2008; Hosmer and Lemeshow, 2000). First, the primary explanatory variables and the potential confounders *stress*, *age*, *general health*, *education*, *occupation*, *leisure activity level* and *computer use* were tested in bivariable logistic regressions. If the p-value was $\leq$0.20 the variable was included in a multivariable model. Variables were excluded from the multivariable model if the p-value was >0.20.

One cross-sectional regression analysis using baseline data was performed. Prospective analyses of the incidence of MSD outcomes at one-year and five-year follow ups, among the symptom-free at baseline were performed. Prospective analyses of outcomes at one-year and five-year follow ups were also performed among those with symptoms at baseline. In all the prospective analyses the explanatory variable *stabile SMS* was used, i.e. combining the exposure at baseline and one-year follow up. The cross-sectional analyses were stratified by gender, while this was not possible in the prospective analyses due to small sample sizes. The prospective Model I was adjusted for sex and Model II was adjusted for sex and potential confounders, as described above.

The level of significance (alpha) was set at 0.05.

3. Results

3.1. Descriptive statistics

Age at baseline ranged from 20 to 24 years (mean 22, SD 1.40 for men; mean 22, SD 1.42 for women). At baseline a majority of the respondents had completed upper secondary school, and 11% of the men and 15% of the women had completed college or university studies, while 7% of both men and women only had elementary schooling (Table 1). At five-year follow-up, with the age range 25–29, the level of education had naturally increased, with about half of the men and almost two thirds of the women having completed college or university studies. Correspondingly, a higher proportion were working (76% and 63% of men and women, respectively) at five-year follow-up compared to the baseline group (55% and 43%, respectively).

A majority of the participants rated their general health as good, but 4% of the men and 5% of the women at both baseline and five-year follow-up reported poor health. One third of the men and half of the women had experienced continuous stress for a week or more during the past year, at baseline. The prevalence of the reported symptoms was mostly slightly higher at the five-year follow-up compared to the baseline.

Table 1
Descriptive statistics of study groups at baseline and at five-year follow-up.

	Baseline				Five-year follow-up			
Baseline	Men N = 2759		Women N = 4333		Men N = 991		Women N = 1733	
	n	%	n	%	n	%	n	%
SMS								
0 per day	228	8	116	3	47	5	17	1
1–5 per day	1640	59	2508	58	551	56	844	49
6–10 per day	532	19	1031	24	241	24	525	30
11–20 per day	217	8	437	10	99	10	227	13
>20 per day	142	5	241	6	53	5	120	7
Neck/UB pain								
No or missing	2108	76	2323	54	695	70	865	50
Yes, <1 week	277	10	673	16	107	11	232	13
Yes, 1 week-1 month	94	3	340	8	54	5	153	9
Yes, 1–3 months	59	2	221	5	31	3	100	6
Yes, >3 months	221	8	776	18	104	10	383	22
Shoulder/UE pain								
No or missing	2159	78	3035	70	748	75	1185	68
Yes, <1 week	251	9	448	10	86	9	140	8
Yes, 1 week-1 month	124	4	210	5	44	4	95	5
Yes, 1–3 months	59	2	148	3	35	4	85	5
Yes, >3 months	166	6	492	11	78	8	228	13
Hand/finger numbness								
No or missing	2546	92	3845	89	891	90	1464	84
Yes, <1 week	94	3	198	5	38	4	71	4
Yes, 1 week-1 month	30	1	65	2	19	2	47	3
Yes, 1–3 months	23	1	60	1	15	2	33	2
Yes, >3 months	66	2	165	4	28	3	118	7
Stress 7 days or more								
No	1836	67	2148	50	569	58	781	45
Yes	912	33	2174	50	420	42	951	55
General health								
Poor	97	4	202	5	36	4	82	5
Moderate	464	17	1028	24	182	18	321	19
Good	2190	80	3090	72	772	78	1329	77
Physical activity								
Sedentary	459	17	574	14	155	16	204	12
Light	921	34	1921	46	328	33	743	43
Regular	897	33	1475	35	398	40	687	40
Vigorous	428	16	251	6	106	11	92	5
Education								
Elementary	190	7	292	7	34	3	44	3
Upper secondary	2225	82	3312	78	472	48	600	35
University	305	11	646	15	482	49	1087	63
Occupation								
Working	1493	55	1807	43	753	76	1093	63
Studying	968	36	1852	44	173	18	340	20
Other	246	9	557	13	62	6	296	17
Computer use								
<2 h per day	770	28	1695	39	182	18	420	24
2–4 h per day	965	35	1457	34	240	24	416	24
>4 h per day	1006	37	1150	27	569	58	892	52

The number of subjects varied due to partially missing data. SMS = short message service, UB = upper back, UE = upper extremities.

One third reported regular physical activity, 34% of the men and 46% of the women reported light physical activity, and 16% and 6%, respectively, vigorous activity. Seventeen per cent and 14%, respectively, described their leisure time as sedentary.

The women reported slightly higher SMS use than the men (Table 1). A majority of both sexes sent and/or received five or fewer SMSs per day (67% for men, 61% for women). Five percent of the men and 6% of the women reported the highest category, i.e. more than 20 SMSs per day. The proportion of reports in the highest category was similar at the five-year follow-up, while the proportion of low SMS users was somewhat smaller (61% for men, 50% for women). About 50% were categorized as “low stabile SMS”, i.e. reported five or fewer SMSs per day at both baseline and one-year follow-up, while 7% were categorized as “high stabile SMS”, i.e., reported 11 or more SMSs on both occasions.

In general, symptom reports were higher among the women than among the men (not tested statistically). At baseline 23% of the men and 47% of the women reported ongoing pain in the neck, and 21% of the men and 29% of the women reported ongoing pain in the shoulders or upper extremities.

A higher proportion of men (37%) than women (27%) reported using the computer for more than 4 h per day. At five-year follow up the reported use had increased (58% and 52% respectively) and the difference between men and women was smaller.

3.2. *Cross-sectional associations between text messaging and reported pain*

There were associations between text messaging and reported musculoskeletal pain in the neck/upper back, shoulder/upper extremities, and numbness/tingling in the hand/fingers for both men and women (Table 2).

After adjusting for confounders, there were clear associations between the highest category of text messaging and pain in the neck/upper back (OR 1.4 for women and OR 2.0 for men). In analyses of pain in the shoulder/upper extremities, statistically significant associations were found for all three exposure levels in the women (OR 1.3–1.4) and for the highest and the lowest exposure levels in the men (ORs 1.7 and 1.4, respectively). Tingling/numbness in the hand/fingers was associated with the two highest exposure levels (OR 1.5–1.6) in the women, and with the second highest level in the men (OR 1.7) (the highest exposure level in the men lost statistical significance in the adjusted model).

3.3. *Prospective associations between text messaging and reported pain*

Among those who were symptom-free at baseline there were prospective associations found between high stabile SMS (≥11 SMSs/day at baseline and one-year follow-up) and reported numbness/tingling in the hand/fingers (OR 2.0) at the one-year follow-up (Table 3). At the five-year follow-up no associations were found between text messaging and reported symptoms, though there was a tendency of reporting pain in the shoulder/upper extremities (OR 1.4, 0.88; 2.40).

Among those with symptoms at baseline associations were found at the one-year follow-up between high stabile SMS (≥11 SMSs/day at baseline and one-year follow-up) and reported pain in the neck/upper back (OR 1.6) (Table 4). There was a tendency in the same direction for reported pain in the shoulder/upper extremities (OR 1.4, 0.88; 2.12).

4. Discussion

The main results in this study were the cross-sectional associations between text messaging and reporting pain in the neck/upper back and shoulder/upper extremities, and numbness/tingling in the hand/fingers. Prospective associations were found only in the one-year analyses, with new cases of reported numbness/tingling in the hand/fingers, and with maintained pain in the neck/upper back. The results suggest that text messaging mostly is associated with short-term effects, and to a lesser extent, with long-term effects.

At baseline, associations were found between text messaging and reported pain in the neck/upper back, shoulder/upper extremities, and numbness/tingling in the hand/fingers for both men and women (Table 2). The reported pain in the upper extremities is in accordance with earlier published case studies about identified musculoskeletal disorders in the forearm and thumb, in relation to intensive text messaging on mobile phones (Gordon, 2008; Menz, 2005; Ming et al., 2006; Storr and d.V.B.F.Stringer, 2007; Williams and Kennedy, 2011). It is common to sit with a flexed neck while texting (Gustafsson et al., 2011; Gold et al., 2012) and a recently published experimental study has found that the head flexion angle was larger when text messaging compared with web browsing and video watching (Lee et al., 2015). Sustained neck flexion may be a risk factor for developing pain in the neck, shoulder, and upper extremities. We have previously found that sitting with the head bent forward while texting was more common among those with musculoskeletal symptoms (Gustafsson et al., 2011).

Sitting with the head bent forward without supporting the arms causes a static load in the neck and shoulder muscles, which could explain the reported pain from neck/upper back. Furthermore, recently published studies have found that neck/shoulder muscle activity is influenced by visually demanding near work tasks,

Table 2
Cross-sectional associations between text messaging (SMS) and reported pain in neck/upper back (UB), shoulder/upper extremities (UE), and numbness/tingling in hand/fingers at baseline. Statistically significant results are presented in bold.

		Men						Women					
		Crude			Adjusted[a]			Crude			Adjusted[a]		
		n	OR	95% CI	n	OR	95% CI	n	OR	95% CI	n	OR	95% CI
Neck/UB		2759			2662			4333			4169		
SMS	>20		**2.3**	**1.60; 3.27**		**2.0**	**1.35; 2.93**		**1.5**	**1.17; 1.99**		**1.4**	**1.04; 1.83**
	11–20		**1.5**	**1.09; 2.06**		1.4	0.97; 1.92		1.2	0.94; 1.42		1.0	0.81; 1.25
	6–10		**1.5**	**1.22; 1.90**		**1.5**	**1.18; 1.88**		1.1	0.99; 1.32		1.1	0.92; 1.25
	0–5		1.0			1.0			1.0			1.0	
Shoulder/UE		2759			2694			4333			4014		
SMS	>20		**2.1**	**1.43; 2.98**		**1.7**	**1.18; 2.58**		**1.7**	**1.32; 2.27**		**1.4**	**1.005; 1.84**
	11–20		1.4	1.00; 1.92		1.3	0.94; 1.88		**1.5**	**1.24; 1.90**		**1.3**	**1.005; 1.62**
	6–10		**1.5**	**1.17; 1.83**		**1.4**	**1.13; 1.80**		**1.3**	**1.13; 1.54**		**1.3**	**1.06; 1.49**
	0–5		1.0			1.0			1.0			1.0	
Hand/fingers		2759			2680			4333			4100		
SMS	>20		**1.9**	**1.10; 3.22**		1.6	0.92; 2.82		**1.8**	**1.28; 2.64**		**1.6**	**1.06; 2.31**
	11–20		**1.8**	**1.14; 2.84**		**1.7**	**1.06; 2.76**		**1.6**	**1.19; 2.14**		**1.5**	**1.11; 2.06**
	6–10		1.3	0.90; 1.82		1.2	0.79; 1.69		1.2	0.92; 1.46		1.1	0.89; 1.45
	0–5		1.0			1.0			1.0			1.0	

OR = odds ratio, 95% CI = 95% confidence interval.

[a] Adjusted = Neck/UB, men: stress, general health, occupation, education; Neck/UB, women: stress, general health, occupation, computer use; Shoulder/UE, men: stress, age, general health, occupation; Shoulder/UE, women: stress, general health, occupation, education, physical activity, computer use; Hand/fingers, men: stress, general health, occupation, computer use; Hand/fingers, women: stress, general health, occupation, physical activity.

Table 3
Prospective associations between stabile high text messaging (combined baseline and one-year follow-up) and new cases of reported pain in neck/upper back (UB), shoulder/upper extremities (UE), and numbness/tingling in hand/fingers at one- and five-year follow-ups among symptom-free at baseline. Statistically significant results are presented in bold.

	One-year follow-up						Five-year follow-up					
	Model I			Model II			Model I			Model II		
	n	OR	95% CI	n	OR	95% CI	n	OR	95% CI	n	OR	95% CI
Neck/UB	1542	1.1	0.71; 1.57	1522	1.0	0.69; 1.58	870	1.2	0.72; 2.03	868	1.3	0.76; 2.19
Shoulder/UE	1826	0.9	0.63; 1.40	1822	1.0	0.66; 1.59	1012	1.4	0.84; 2.26	1004	1.4	0.88; 2.40
Hand/fingers	2189	**2.3**	**1.52; 3.43**	2147	**2.0**	**1.34; 3.13**	1203	0.7	0.33; 1.48	1199	0.7	0.33; 1.50

OR = odds ratio, 95% CI = 95% confidence interval.
Model I: Adjusted for sex.
Model II: Neck/UB one year: adjusted for sex, stress, general health, education, physical activity; Neck/UB five years: adjusted for sex, stress, education; Shoulder/UE one year: adjusted for sex, general health; Shoulder/UE five years: adjusted for sex, occupation; Hand/fingers one year: adjusted for stress, education, occupation; Hand/fingers five years: adjusted for stress, general health.

Table 4
Prospective associations between stabile high text messaging (combined baseline and one-year) and maintained pain in neck/upper back (UB), shoulder/upper extremities (UE) and, numbness/tingling in hand/fingers at one- and five-year follow-ups among those with reported pain at baseline. Statistically significant results are presented in bold.

	One-year follow-up						Five-year follow-up					
	Model I			Model II			Model I			Model II		
	n	OR	95% CI	n	OR	95% CI	n	OR	95% CI	n	OR	95% CI
Neck/UB	860	**1.7**	**1.13; 2.54**	856	**1.6**	**1.03; 2.35**	444	0.9	0.51; 1.51	444	0.9	0.51; 1.51
Shoulder/UE	576	1.5	0.96; 2.26	574	1.4	0.88; 2.12	302	1.0	0.53; 1.91	302	1.0	0.50; 1.86
Hand/fingers	213	1.1	0.57; 2.13	208	0.8	0.42; 1.74	111	0.3	0.10; 1.15	111	0.3	0.10; 1.14

OR = odds ratio, 95% CI = 95% confidence interval.
Model I: Adjusted for sex.
Model II: Neck/UB one year: adjusted for sex, stress, general health; Neck/UB five years: adjusted for sex; Shoulder/UE one year: adjusted for sex, general health; Shoulder/UE five years: adjusted for sex, computer use; Hand/fingers one year: adjusted for sex, stress, general health, education; Hand/fingers five years: adjusted for sex, stress.

comparable to visual demands when using a mobile phone (Richter et al., 2010, 2011, 2015; Zetterberg et al., 2013). In general, sustained muscle load and posture are considered to be risk factors for developing musculoskeletal disorders (Sjogaard et al., 2000; Mathiassen, 2006).

In the present study the strongest associations with neck/upper back and shoulder pain concerned the highest exposure category (>20 SMSs/day) in both men and women (Table 2). However, associations with neck and upper extremity pain were found at levels of text messaging as low as 6 SMSs/day. The baseline data were collected in 2007. Today an exposure to 6 SMSs/day is considered a rather low exposure compared with the immense amount of texting reported in recent years, especially among young people (Lenhart et al., 2010). The number of key presses or the length of the text messages, were unfortunately not covered by the questionnaire used. However, it is likely that these factors have influenced the results, e.g. neck flexion and visual demands during a longer text message can cause sustained muscle load in the neck/shoulders which is considered to be a risk factor for developing musculoskeletal disorders (Sjogaard et al., 2000; Mathiassen, 2006). This can be one explanation for the association found even at a low number of text messages.

The levels of reported pain in our study was in accordance with reported pain in the general Swedish population of comparable age, in 2007 and 2012, and the same gender differences were seen with women reporting more pain than men (Public Health report, 2014).

The associations between exposure and reported symptoms at baseline followed a similar pattern for men and women. However, one difference was found concerning pain in the neck/upper back, where, in the women, an association was seen only for >20 SMSs/day, whereas in the men, associations were seen already at ≥6 SMSs/day (Table 2). This may be in line with an earlier study of college students where gender differences in health effects from texting were found, in that there was an association between neck/shoulder discomfort and the number of daily text messages sent particularly for the men (Gold et al., 2009). We have previously found differences in texting velocity between women and men, with women texting with higher velocity (Gustafsson et al., 2010). A higher velocity could influence the time spent texting and may partly explain the difference between men and women in the present study. A person texting with a higher velocity perform the same text message in a shorter time than a person texting with a lower velocity. This means that the person texting with a higher velocity will have a shorter duration of static muscular load in the neck and upper back due to the shorter time with a flexed neck. It is likely that the duration of exposure to static load influence the outcome for neck/upper back more than the number of texts, and it is possible that the women spent less time texting than the men for the same number of texts. For the development of MSDs in the neck and upper back the time the neck is flexed essential together with the degree of neck flexion. In a prospective study with a working population, a degree of >20° neck flexion for more than 40% of the working day was a risk factor for sick leave due to neck pain (Ariens et al., 2002). Also for the development of MSDs in the hand or fingers the duration of repetitive thumb movements is probably essential.

In the group who were symptom-free at baseline (Table 3) we found prospective associations at one-year follow-up between text messaging and numbness/tingling in the hand/fingers (≥11 SMSs/day). However, this association did not remain at the five-year follow-up. The hand and fingers are highly exposed when text messaging. Therefore, it is reasonable to expect that, if developing disorders, most people will change the way they use their mobile phones, for example, by reducing their use and/or changing their performance technique, which could explain the lack of associations at the five-year follow-up. Furthermore, it has been found that phone design affects upper extremity discomfort, muscle fatigue, and performance (Chany et al., 2007; Trudeau et al., 2012a, 2012b). Concerning the rapid development of mobile phones, it is likely that many in the study group changed their phone models during the time between baseline and five-year follow-up, giving those with symptoms a chance to choose a more comfortable and suitable phone design.

In the group with symptoms at baseline (Table 4) an association between high exposure of text messaging and reported pain in the neck/upper extremities was found at the one-year follow-up but not at the five-year follow-up.

An explanation for the lack of associations at five-year follow-up for both those with and those without symptoms at baseline could be that the study group was five years older and in an age of transition. During these five years it is likely the life situation and the life style had changed for many of them, and therefore a change in exposure compared to baseline and the one-year follow-up. For example, at the five-year follow-up, fewer were students and a majority were now working.

Surprisingly, considering the immense development of information and communication technology (ICT) use in general and mobile phone use in particular during the five years subsequent to baseline in 2007, the exposure, i.e. reported number of text messages did not increase during the five-year period from baseline to follow-up. This can probably be explained by the change in usage of the mobile phone during the time period, with the breakthrough of smartphones and mobile Internet usage, and thus an increase in other methods of sending messages. It is possible that we had seen an increase in exposure for number of SMS if we had studied a younger age group, for example, 15–20 year olds, who in Sweden constitute the age group that reported the highest SMS use in 2012 (Findahl, 2013).

4.1. Methodological considerations

The strengths of the present study include that it is population-based, involves a relatively large study group, and has a longitudinal design. We also controlled for several potentially confounding factors, including computer use, stress and physical activity.

Limitations of the study include the use of self-reported data for both exposure and outcomes, which may imply response-style biases. Further, recall difficulties may lead to misclassifications. Other studies have found that in evaluations of self-reported mobile phone use in relation to, for example, network operator records, it is common that the duration of calls is overestimated while the frequency is underestimated, though with some inconsistencies (Shum et al., 2011; Tokola et al., 2008). In a recently published study with young adults it was found that a majority of the participants overestimated the number of daily texts sent (Gold et al., 2015).

Another limitation of the study is that we have data only on the number of text messages but not on the length of the text messages, for example, the amount of key presses or time duration, which of course influences the exposure. Furthermore, we do not have data on how much the participants use their mobile phones for other activities, e.g. gaming. It is reasonable to imagine that intensive gaming on the mobile phone would have the same effects as intensive texting, on the outcome.

Another limitation in the study is that we only have data on leisure time physical activity and not all potential physical activity, for example having a physically demanding job. And, although we have adjusted for occupation, i.e. if the person worked or studied, we do not know what type of work.

Due to the cohort study design, we only had measurements at three time points (baseline, after one year and after five year). It would have been preferable with more frequent measurements and/or that the exposure assessment covered longer time spans in order to be able to connect the exposures to the outcomes more clearly. We considered it to be a too long latency period to analyze reported texting at baseline (which concerned "the past 30 days") in relation to outcomes five years later. Thus, we constructed the variable *stabile SMS* which combined reported texting at baseline and after one year, in order to try to capture a more "steady exposure". However, this variable excluded 42% of the study population.

The low response rate at baseline is a common problem in questionnaire studies in the general population, and especially when studying younger age groups. A healthy selection bias can be expected and the lack of prospective associations at the five-year follow-up could be influenced by this. In a previous study in the same population (Thomée, 2012), the group who remained at the one-year follow-up reported slightly lower mobile phone use than the dropouts. This pattern may also be present for participants vs non-participants in our cohort, thus implying a lower mobile phone use in our study than in the general population of (Swedish) young adults. In that case it is possible that associations between exposures and health symptoms are underestimated.

4.2. Implications

This epidemiological study, based on self-report data, showed associations between SMS text messaging and MSDs among young adults. This should cause attention, considering the immense use of mobile phones for SMS text messaging together with other uses of the phone with similar physical exposure, i.e. entering texts on a small keyboard. Although the SMS as a communication method is decreasing in favor of other communication methods and applications of the smartphone, texting in general is expected to be continually abundant.

One obvious ergonomic problem when using a mobile phone or a smartphone for texting is that keys and screen are in the same plane. To reach a comfortable posture for the arms when texting, most hold the phone quite low in front of the belly which means they have to flex the neck to read the screen. To reach a comfortable posture for the neck, i.e. an upright neck, one need to hold the phone quite high in front of the chest.

Efforts have been made to develop the mobile devices technically together with a fancy design but the ergonomic problem with the keys and the screen in the same plane remain. Data entering by voice-command has been introduced and can be a way to solve at least the problem with repetitive thumb movements. However, using voice-command seems so far not so common.

Meanwhile, in order to prevent the development of MSDs due to extensive texting on mobile phones, information about the risks of spending much time texting with an inappropriate technique, together with ergonomic recommendations about good technique when texting on a mobile phone, should be spread, e.g. through school health, primary care and occupational health service.

4.3. Conclusions

Prospective associations were found between text messaging on mobile phones and musculoskeletal disorders. The results imply mostly short-term effects, and to a lesser extent, long-term effects on musculoskeletal disorders in neck and upper extremities.

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