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Original Article

Gender and posture are significant risk factors to musculoskeletal symptoms during touchscreen tablet computer use

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Abstract. [Purpose] To investigate the prevalence of neck and shoulder symptoms during the use of tablet computer, and to identify the risk factors associated with these symptoms. [Subjects and Methods] A cross-sectional survey was conducted to study tablet computer usage, posture during use, and neck and shoulder symptoms in 412 participants in a school setting. Significant risk factors for musculoskeletal symptoms during tablet computer use were identified. [Results] Overall prevalence of musculoskeletal symptoms during tablet computer use was 67.9% with greater prevalence of neck symptoms (neck: 84.6%; shoulder/upper extremity: 65.4%). Significant risk factors associated with symptoms during use were: current musculoskeletal symptoms, gender, roles, and postural factors including: sitting without back support, sitting with device in lap, and lying on the side and on the back during tablet computer use. A multivariate analysis further showed that the odds for females to have symptoms were 2.059 times higher than males. [Conclusion] The findings revealed that female gender and other postural factors were significantly associated with musculoskeletal symptoms during the use of tablet computer. Among all postural factors, sitting without back support was identified as the most important risk factor for having musculoskeletal symptoms.
Key words: Pain, Posture, Gender

INTRODUCTION

Neck and shoulder musculoskeletal symptoms are common health complaints. A recent epidemiologic study by Hoy et al. demonstrated that the annual incidence rate of neck pain to be 10.4–21.3% with a higher rate for office and computer workers[1]. In the college student population, a one-year prospective cohort study demonstrated a high incidence rate at 46% and of whom 33% reported persistent neck pain[2]. Such high prevalence of neck and shoulder symptoms, especially among the younger populations, presents a substantial burden to the society.

Musculoskeletal symptoms of the neck and shoulder are theorized to have a multi-factorial origin including physical and demographic contributors[2–5]. Current evidence suggests that significant risk factors include female gender[1, 2, 6], having high job demands[7], and having a history of spinal disorders[8]. Noticeably, some physical factors are associated with neck pain, including prolonged computer work for students[9–11] and prolonged sitting and neck flexion for office workers[12]. A systematic review regarding individuals with documented musculoskeletal disorders showed an association between computer use

and tension neck syndrome[13]. It is logical that posture and workplace ergonomics are related to the development of neck and shoulder symptoms. For example, Marcus et al. found that keying with a more extended elbow, proper head tilt, and use of arm rests could reduce the risk of developing neck and shoulder disorders[14]. Since computer use often involves maintaining the same posture for prolonged periods of time, the muscles of the neck and shoulder may become overworked. Several studies have documented a relationship between trapezius muscle load and the development of musculoskeletal discomfort in the upper body[15, 16].

In recent years, the use of touchscreen tablet computers has increased dramatically. According to the report from the International Data Corporation in 2013, tablet computers account for 14.6% of all connected-device market, and the growth rate of these devices was expected to be the highest over the next few years[17]. Findings from an industrial survey in 2013 in the U.S. showed that 43% of the population owns a tablet computer or e-book reader[18]. The ownership and usage of such devices are perhaps even higher among the student population[19]. Despite the increased popularity of the tablet computers, the device is new enough that only few studies have investigated the association between its usage and musculoskeletal disorders. A recent study in a university population showed significant associations between the total time spent using a mobile phone and pain in the neck and shoulder regions[20].

Ergonomic studies have suggested that the use of mobile electronic devices such as laptop computers exhibits the tendency to lead to even poorer head and neck posture than desktop computers[21]. With mobile devices, one's posture often depends on the available supporting surfaces and environments (e.g. holding a device in hand while sitting in a chair). Prolonged cervical flexion is commonly observed when the tablet computer is placed flat on a desk or when held in a position below eye level. This may cause the cervical extensor muscles to lengthened and put a larger load on these muscles[22]. It is logical that the postures users assume when using tablet computers can have implications for developing neck and shoulder symptoms.

The purposes of the current study was to 1) investigate the prevalence of neck and shoulder symptoms during use of tablet computers, and 2) identify the risk factors associated with the symptoms during device use.

SUBJECTS AND METHODS

A cross-sectional survey was developed and distributed to a public university population. Self-reported usage of touch-screen tablet computers, usage behavior, musculoskeletal complaints, and demographic data were collected via an online survey using Qualtrics Research Suite (Qualtrics, LLC.) in a 3-month period.

Participants were recruited using word of mouth solicitation and online communication. The inclusion criteria are: 1) having access to the online survey, 2) being able to read the survey written in English, and 3) being a university student, staff, faculty, or alumni. The word of mouth solicitation consisted of visits to university faculty and staff, presenting the survey to various undergraduate classes, and soliciting the survey on campus. Online communication consisted of social media, university mass email announcements, campus newsletters, and an access link to the survey on the university website. The study was approved by the Institutional Review Board for Biomedical Research at the University of Nevada, Las Vegas and exempted from written consent.

The online questionnaire was composed of 22 items in 3 categories: 1) demographic information, 2) typical device usage behavior, and 3) current neck and shoulder symptoms and symptoms during use which include duration, types, severity, and location of symptoms. We limited our study to the ownership of tablet computers only (with a diagonal dimension from 9–10 inches to 4–6 inches), and not smart phones. All the items related to specific postures (including the use of tablet support), environments, and symptom locations were illustrated to help participants understand the description correctly. The question-naire was reviewed and revised by two experts in the field of the musculoskeletal science and clinical practice to establish face validity. Also, a preliminary study was conducted to examine the reliability of the survey.

The collected data were analyzed using the Statistical Packet for the Social Sciences (IBM SPSS Statistics Version 22.0, International Business Machines Corp., New York, USA). Descriptive statistics were used to report the prevalence of muscu-loskeletal symptoms of neck and shoulder, and various postural factors. The collected data, except for severity of symptoms, are categorical, including gender, age group, role, and typical time of use (<3 hours, 3–6 hours, and >6 hours). Other variables are dichotomous and answered by "yes" or "no", such as current symptoms, symptoms during use and postural factors.

Chi-Square analyses were conducted to examine significant risk factors associated with current symptoms and symptoms during device use at the univariate level. The identified risk factors were then entered into a logistic regression model to examine the association at the multivariate level. Specifically, the regression model investigated the contribution of sitting postures, demographic, and behavioral risk factors related to symptoms during tablet use. Furthermore, the Homsmer and Lemeshow test for logistic regression was conducted to examine the goodness of fit. Odds ratios were reported to compare the effects of the risk factors included in the model. The significant level was set at 0.05. Since researchers intended to liberally explore potential risk factors, variables with a p-value between 0.05–0.08 at the univariate level were included in the multivariate logistic regression model.

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Table 1. Participant demographics, tablet computer ownership, usage time, and symptoms

	Percentage (%)	Frequency (N=412)
Age (years)		
18–25	60.2	248
26–39	19.4	80
40–59	16.0	66
≥60	3.4	18
Missing	1.0	4
Role		
Student	68.9	284
Faculty	12.4	51
Staff	10.4	43
Alumni	7.0	29
Missing	1.2	5
Tablet computer ownership		
Yes	76.5	315
No	23.5	97
Current neck/shoulder symptoms		
Yes (symptomatic)	60.0	247
No	40.0	165
	Percentage (%)	Frequency (N=315)[†]
Tablet use time (hours)		
<3	57.1	180
3–6	23.2	73
>6	19.7	62
Neck/shoulder symptoms during Use		
Yes (symptomatic)	67.9	214
No	32.1	101

[†]Individuals who own table computers only.

RESULTS

The final sample size of this survey was 412 (135 men and 275 women). Since two participants preferred not to identify their gender, the two cases were excluded from analyses related to gender. A summary of the demographic information of the participants is included in Table 1.

315 out of 412 participants (76.5%) reported owning at least one touchscreen tablet computer. Most of the device owners have a typical device usage time of less than 3 hours per day (57.1%). Prevalence of symptoms during tablet use was 67.9% (Table 1). For device users with musculoskeletal symptoms during use, most symptoms were reported in the neck (84.6%), upper back/shoulder (65.4%), arms/hands (33.6%), and head (15.0%). The most common types of symptoms are stiffness (74.3%), soreness (48.1%) and aching or pain (42.5%). The most severe level of discomfort during tablet use was moderate (55.4%), but noticeably, 10.0% of participants reported severe symptoms (i.e. 7–10 on a 10-point Visual Analog Scale). Only 46.1% of the respondents reported that they would stop using the device when experiencing discomforts using device use. 15% of the users reported that the symptoms affect their sleep.

Gender comparison for symptoms during tablet use was summarized in Table 2. Significant gender difference in symptom prevalence was observed (p=0.019): 70.1% of the female respondents reported to experience symptoms in comparison to only 29.9% among the male respondents. During tablet use, significantly more women reported symptoms in the upper back and shoulder region than men (75.7 vs. 24.3%; p=0.014). In addition, 77.0% of women reported using their devices while sitting on floor, comparing to only 23.0% in men (p=0.02).

Chi-square analysis identified two significant factors associated with current symptoms: role (faculty, staff, alumni, and students; p=0.041) and symptom during use (p<0.001; Table 3). For risk factors associated with symptoms during device use, the results showed that role (p=0.022) and female gender (p=0.019) are significant factors. Also, daily time of usage exhibited

Table 2. Effect of gender on musculoskeletal symptoms during tablet computer use

	Women (N=275)		Men (N=135)		
	N	%	N	%	p-value
Symptoms during use					
Yes	193	70.1	40	29.9	0.019
No	82	29.8	95	70.4	
Regions of symptoms during use					
Head	180	65.6	46	34.4	0.549
Neck	187	68.0	43	32.0	0.110
Upper back/Shoulder	208	75.7	33	24.3	0.014
Arm/Hand	191	69.4	41	30.6	0.883

Table 3. Demographic factors associated with current musculoskeletal symptoms

	Current musculoskeletal symptoms				
	with		without		
	N	%	N	%	p-value
Role					0.041
Student	163	57.4	121	42.6	
Faculty	28	54.9	23	45.1	
Staff	33	76.7	10	23.3	
Alumni	21	72.4	8	27.6	
Gender					0.054
Female	174	63.3	101	36.7	
Male	72	53.3	63	46.7	

a trend of positive association (p=0.075). When examining risk factors while sitting, sitting without back support (p=0.016) and sitting with the device in lap (p=0.002) are significant postural factors associated with symptoms during use. When sitting in a chair at a desk, placing the device flat on the desk surface also exhibited a trend of association with symptom during use (p=0.053). Interestingly, we also found some of the more uncommon postures, including lying on the sides (p=0.002) and lying on the back (p=0.016) are significantly associated with symptoms during use (Table 4). Since the primary interest is in sitting postures, these two variables were not further included in the regression model.

Based on the potential risk factors identified from the Chi-square analyses, the regression model included gender, role, use time, and sitting postures on a chair (without back support and device in lap) and at a desk (device placing flat on a table or desk). The model was significant ($\chi^2(9)=32.751$, p<0.001) and the Hosmer and Lemeshow test indicated a good model fit ($\chi^2(8)=6.643$, p=0.576). In the multivariate model, gender was again shown to be a significant predictor of symptoms during tablet computer use. The odds for women to have symptoms were 2.059 times higher than men. (Odds Ratio=2.059, 95% CI [1.211, 3.502], p=0.008). When controlling for the sitting postures, sitting in a chair without back support (Odds Ratio=2.231, 95% CI [1.126, 4.419], p=0.021) was the only significant postural factor. Also, being a university alumnus was a significant negative predictor of having symptoms when compare to being a current university student, (Odds Ratio=0.310, 95% CI [0.124, 0.772], p=0.012). However, the model did not indicate usage hours being a positive predictor (p=0.155).

A separate model was developed to assess specifically the sitting postures; we have identified specific postural factors associated with symptoms during the use of tablet computers, including sitting without back support (p=0.016) and sitting with device in the lap (p=0.002) based on Chi-square analyses. A multiple logistic regression analysis demonstrated that female gender (p=0.004) and sitting in a chair without back support (p=0.006) are the significant predictors of experiencing symptoms during the use of tablet computer.

DISCUSSION

With the increasing popularity of touchscreen tablet computers for personal, school, and business uses, it is pertinent to identify the prevalence and risk factors associated with musculoskeletal symptoms related to the use of such devices. Our study revealed that females and individuals with current musculoskeletal symptoms were more likely to be at risk for neck and shoulder symptoms. Certain postures during use were also identified as important risk factors, specifically sitting without

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Table 4. Risk factors associated with symptoms during device use

	% with musculoskeletal symptoms during tablet use	Frequency	p-value
Role			0.022
Student	73.4	152/207	
Faculty	54.5	24/44	
Staff	64.9	24/37	
Alumni	52.0	13/25	
Gender			0.019
Women	72.8	150/206	
Men	59.8	64/107	
Device usage hours			0.075
<3	62.8	113/180	
3–6	74.0	54/73	
>6	75.8	47/62	
Device use posture			
Lying on sides	78.8	89/113	0.002
Lying on back	74.2	118/159	0.016
Lying on stomach	74.0	74/100	0.116
Standing	73.5	61/83	0.206
Sitting on floor	76.0	57/75	0.087
Sitting on couch/chair	67.7	180/266	0.813
Sitting posture			
Without back support	78.8	63/80	0.016
Device in lap	76.6	111/145	0.002
Device on stand	71.6	78/109	0.316
Holding device with hands	71.3	134/188	0.122
Device flat on desk	73.1	114/156	0.053
Using a tablet stand	65.5	131/200	0.222

back support and with the tablet in lap were significantly associated with symptoms during use.

Results of the current study showed that females were significantly more likely to have symptoms during use, especially in the neck and upper shoulder regions. This finding was consistent with the current literature on the prevalence of neck and shoulder dysfunctions. For example, according to the data from Stockholm Public Health Cohort study, the one-year prevalence of neck pain was 25% for women and 16% for men. Also, women are more likely to develop neck pain than men and less likely to recover[23]. In addition, the prevalence of neck and shoulder musculoskeletal symptoms in our study population of university students, faculty, staff, and alumni was much higher (up to 60%) than in the general population. This is likely because of the sedentary behavior and the associated posture commonly seen in this group[1, 24, 25].

Gender differences in anthropometry and biomechanics may explain the disparity in neck and shoulder musculoskeletal symptoms. It has been shown that in the workplace, women assume neck flexion more often[26]. Karlqvist et al. examined computer mouse tasks and reported that female computer operators who are shorter and narrow-shouldered exhibited more extreme postures[27]. Furthermore, Won et al., compared gender difference in applied forces, upper extremity muscle activities, and upper extremity postures during computer tasks[28]. They found that when typing, women have significantly higher normalized keyboard forces than men and tend to have higher muscle activities, and less neutral shoulder postures. The muscle activities and shoulder postures were also higher for the office workers with smaller stature. In addition, the study found that shoulder width and arm length were significantly negatively correlated with normalized typing forces, muscle activation levels, and postural measurements. While a tablet computer is not excessively heavy, users may maintain the posture for extended time (i.e. >40% of subjects in this study use more than 3 hours per day). The female gender's generally lower muscle strength and smaller body size may predispose them to neck and shoulder symptoms during such use.

For individuals performing computer related activities, a previous study suggested that prolonged sitting and having the neck in forward flexion were risk predictors for neck pain[29]. Neck flexion postures can lead to an increase in gravitational load moment on the cervical spine, which increases cervical extensor muscle activity and may cause muscle strain of the neck extensors if such posture is prolonged[30]. Our study revealed that the odds of having symptoms during use for individuals who sit in a chair without back support, which may be related to a "slump" position, are 2.231 times greater than the odds of those

sitting with back support. It has been shown that in a slump sitting position, greater cervical and thoracic extensor activities are required to support the head in the forward position. The combination of neck flexion and cervical extensor activities may produce specific stress regions and cause postural neck pain[31]. On the other hand, sitting postures that offer support to the lumbo-pelvic region of the spine in a neutral position may significantly reduce the levels of the cervical extensor activities. In addition, a recent study concluded that positions that cause the gaze angle less than 45 degrees from neutral (downward gaze) can cause significant increases neck extensor strain[30]. This was consistent with our findings that placing the tablet in the lap or flat on the desk were significant risk factors for neck and shoulder symptoms during use. Perhaps supportive to this finding was our results that the students reported higher prevalence of neck and shoulder symptoms (73.4%) during the use of tablet computer relative to other studied roles (52–64.9%). University students in the U.S. typically do not have a permanent workstation and are constantly moving between classes. It may be more common for the students to use their tablet computers in compromised postures such as placing them in the lap while sitting without back support. More research is needed to elucidate the cause of the observed high prevalence in this subgroup.

Our results showed that using the tablet computer in more uncommon postures such as lying on the side or on the back was significantly associated with symptoms. This was in agreement with previous findings that non-neutral joint angles from non-desk usage of laptop computers can lead to greater levels of discomfort[32]. Additionally, sustained non-neutral joint angles during laptop use has also been reported to exacerbate symptoms of the neck and upper back[33]. The side lying postures during tablet use can potentially induce non-neutral joint angles and stress in upper extremities and cervical spine. With this posture, musculoskeletal structures are at risk of abnormal and sustained forces. This posture is unique for tablet computers due to their flat profile when compared to laptop or desktop computers. Further research is needed to examine the musculoskeletal stress resulting from maintaining this posture during extended use of tablet computers.

To our knowledge, this was the first study to assess the prevalence and risk factors of neck and shoulder musculoskeletal symptoms related to the use of touchscreen tablet computers. While the results were informative, the observational nature of the study design prevented direct inference of our results. This study had a number of methodological limitations: first, we could not control for confounding factors such as the types of tablet computer used, previous injury, and exposure to other technology. Second, there may have been a gender selection bias in this study since there were more female respondents. Third, at the time of this study (2013–14), larger smart phones (>5") were uncommon. The usage behavior observed in this study may not extrapolate to these newer devices. Lastly, our sample was limited to the students, faculty, staff, and alumni of a university in the U.S. Readers should exercise caution when generalizing findings of this study to other populations.

In summary, touchscreen tablet computers are useful tools that have penetrated our daily lives in a remarkably short time. The current study showed that there were apparent musculoskeletal health implications related to the use of such devices. Female gender, existing neck and shoulder symptoms, and sitting without back support during tablet use were shown as the most important risk factors.

Conflict of interest

None.

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