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The epidemiology of upper extremity musculoskeletal symptoms on a college campus

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Abstract

Objective—The study examines temporal variations in upper-extremity musculoskeletal symptoms throughout the day, over a week and throughout the semester.

Methods—30 undergraduates were followed in a repeated measures study throughout a semester. Upper extremity musculoskeletal symptoms data were collected on handheld computers randomly throughout the day for seven days over three data collection periods. Multilevel statistical models evaluated associations between time-related predictors and symptoms.

Results—In adjusted models, pain reported at baseline was associated with increased odds of experiencing both *any symptoms* (*OR* = 15.64; 90% CI 7.22–33.88) and *moderate or greater* symptoms (*OR* = 16.44; 90% CI 4.57–29.99). *Any symptoms* were less likely to be reported if responses occurred at 58–76 days (*OR* = 0.66; 90% CI 0.49–0.86), 77–90 days (*OR* = 0.29; 90% CI 0.20–0.42) and 91–117 days (*OR* = 0.54; 90% CI 0.39–0.75) into the semester compared to 35–57 days. Similarly, responding after midnight was associated with greater odds of reporting *moderate or greater* symptoms (*OR* = 21.33; 90% CI 6.49–65.97). There was no association observed for day of week and symptoms.

Conclusion—This pilot work suggests upper extremity musculoskeletal symptoms exhibit temporal variations related to time of day and days into semester. Understanding the natural history of musculoskeletal symptoms and disorders is needed when designing epidemiologic research and/or intervention studies using symptom outcome measures.

Keywords

Computer use; musculoskeletal symptoms; upper extremity; college student; temporal patterns

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1. Introduction

Upper extremity musculoskeletal symptoms and disorders at the workplace continue to be a public health burden [4,11]. They cost tens of billions of dollars in the United States annually and contribute to one-third of lost workdays [11]. The National Research Council recently convened and published a report defining the problem, evaluating the epidemiological evidence and making recommendations for intervention and research [11]. As concluded by the National Research Council, the epidemiologic evidence identifies physical exposures (force, repetition), psychosocial exposures (job stress, job demands) and individual factors (gender) as playing a role in the development of disorders [11]. However, there is very little research examining the natural history of symptoms. If there are temporal variations in symptoms occurrence, understanding the temporal variations is crucial for determining when upper extremity musculoskeletal symptoms are assessed and clinical examinations are conducted in epidemiological research [6]. Observing temporal variations also has implications for the validity of previous risk factor findings in prospective studies. Symptom outcomes are typically collected without consideration to time, but rather, with consideration to previous exposure collection [11]. It is important to evaluate temporal variations in symptoms for intervention design and risk factor identification in order to more effectively conduct research and reduce the public health burden of upper extremity musculoskeletal disorders [3,15].

College student populations provide a unique opportunity to study upper extremity musculoskeletal symptoms as previous research has identified several college populations as experiencing symptoms [7,8,10, 13]. Furthermore, college students experience a range of behaviors that place them at risk for upper extremity musculoskeletal symptoms (computer use, sports, musical instruments). The study objective was to characterize the musculoskeletal symptom experience of 30 college students throughout a semester. Specifically, time-related changes (1) throughout the day, (2) over a week, and (3) throughout the semester were examined.

2. Methods

2.1. Study design

We conducted a repeated measures study among 30 university students throughout an academic semester in the 2003/2004 school year [5]. A 20-minute baseline survey was distributed one Sunday evening to students invited and agreeing to participate. Flyers advertising the study were posted a week before the event and the night before the event an email was circulated to all eligible students by the student government association. Thirty students attended the event, comprising the convenience sample. The baseline survey was completed after informed consent was obtained. Contact information provided at baseline was used to schedule three weeklong data collection periods throughout the semester. During each of the three data collection periods, participants responded to a 2-minute electronic survey administered by a randomly beeping handheld computer up to 5 times a day.

2.2. Study sample

Fifteen male and fifteen female undergraduate students aged 18 years and older from a private university were invited to participate if they owned a computer. All study participants belonged to a single college (dormitory) during the Spring, 2004, academic semester. The university’s Institutional Review Board and the University of Texas at Houston Health Science Center Committee for the Protection of Human Subjects approved the study protocol.

2.3. Outcome measures

Pain severity (outcome) was measured throughout the semester by using the handheld electronic surveys. Upper extremity musculoskeletal symptom questions asked "How much pain are you now experiencing in your ?" for each of 13 upper extremity body parts: left fingers, right fingers, left wrist, right wrist, left forearm, right forearm, left upper arm, right upper arm, left shoulder, right shoulder, neck, upper back and lower back. Two dichotomous dependent variables were created based on overall symptom severity after preliminary analyses were conducted. Because the vast majority of symptoms experienced were mild, the first outcome measure indicated any symptoms reported in any body part (*any* symptoms). To explore a second outcome that may have a different set of risk factors, moderate, severe or very severe symptoms in any body part were classified as *moderate or greater* symptoms.

2.4. Predictor variables

Three time-related variables were created to describe temporal variations of upper extremity musculoskeletal symptoms throughout the semester. The first, *time into day*, was created as a continuous variable with a possible range of values from 0 (6:00 am) to 1 (5:59 am of the next day). A value of 0.25 meant that a subject reported an event that occurred at noon. A value of 0.75 signified a subject reported an symptomatic event that occurred at midnight. Based on preliminary analyses, this variable was dichotomized by using a cut point of 0.75 (after midnight). The second time-related variable, *day of week*, was categorized into every day of the week, where Sunday was considered the referent. Although Friday and Saturday have considerably fewer response events (symptoms data) than the rest of the week (241 and 132, respectively, versus 306 to 398), the distribution of response events during the time of day for Friday and Saturday does not vary greatly from the rest of the week to justify excluding Fridays and Saturdays from the analyses. Specifically, on Fridays and Saturdays there was slightly more event-reporting in the afternoon (from 2–5pm) and less in the evening (after 5pm) than the other days. Preliminary graphical analyses did not show any temporal variation by day of week. However, to be certain there was no day of week trend, we included the days in multilevel regression models. The third time-related variable, *days into the semester*, was created as a continuous variable with a possible range of values from 1 (the first day of school) to 120 (the last day of school). Number of days into the semester was further categorized using the following cut points derived from quartiles of frequency: 35–57, 58–76, 77–90 and 91–117 days. Dummy variables were then created for the quartiles where 35–57 days was the reference category. Days into the semester begin at 35 rather than 1 because that is the day sampling began (February 14, 2004, first day of school was January 12, 2004).

Lastly, the relationship between time of day, day of week and days into the semester was examined using summary statistics to describe how they were related.

2.5. Covariate selection

Potential covariates were taken from the baseline administration of the Computer Use and Health Survey used in previous studies among college students [7,8, 10]. Twenty covariates thought to be potentially associated with symptoms were selected for individual logistic regression modeling. The four categories of the potential covariates collected at baseline were: pain, workstation characteristics, healthcare utilization and individual factors. The covariates relating to pain were: pain associated with working on a computer ever or in the past 2 weeks, pain affecting the academic experience, the Brigham & Women's Symptom Severity Scale [9], severity of bodily pain in the past four weeks, pain at the time of the baseline survey ('Current pain'), difficulty performing tasks due to pain, pain interfering with normal activities, overall health and the SF-36 MHI-5 scale [16] for affective mood disorders. Potential covariates describing healthcare utilization were: seeking help from others when in pain, seeing health-care provider when in pain and taking medications to relieve pain. Individual factors included: undergraduate class, study concentration, gender, playing a musical instrument, playing a sport and minority status. A single workstation characteristic was assessed: ergonomic improvements made to the computing environment.

2.6. Statistical analysis

The association ($p = 0.10$) of each potential covariate with the two outcomes was assessed using multilevel regressions. All significant covariates were then evaluated in a backwards stepwise multilevel regression. Due to the small sample, covariates were eliminated from the backwards regression if they were not significant at $p \leq 0.10$. If two covariates were conceptually similar and statistically significant, in the interest of model parsimony, a single omnibus measure was created by dividing the response by the maximum possible response and summing the ratios across the conceptually similar variables.

Final multilevel logistic models were constructed to test the association of time-related variables with each outcome measure adjusting for covariates. The two data levels are participant (level 2) and repeated symptom measures within each participant (level 1). The following equation was used to construct the adjusted model describing the outcome:

$$\text{logit}[\pi_{ij}]=\beta_{0j}(constant)+\beta_p(\text{time}-\text{related predictor})_{ij}+\beta_c(\text{covariates})_j$$
$$\beta_{0j}=\beta_0+u_{0j}$$

Where

π_{ij} is the probability of experiencing *any* or *moderate or greater* musculoskeletal symptoms,

β_{0j} is the intercept for each individual,

β_p is the effect of time-related predictor variable(s) within individual j

β_c is the effect of selected covariate(s) per individual j,

u_{0j} follows a normal distribution with mean 0 and variance σ^2_{u0}

Separate multilevel logistic models were estimated for each time-related variable to identify significant associations ($p \leq 0.10$). Significance was established *a priori* at $p = 0.10$ to reflect the novel research objectives and exploratory nature of the analyses. Only significant variables were included in final models. Three models were presented, unadjusted for temporal variations (Model 1), adjusted for days into semester (Model 2) and adjusted for both days into semester and time of day (Model 3) to determine if time of day had a mediating effect on symptoms. Level 2 residual analyses were performed to determine if distributional assumptions were violated or if systematic variation in the residuals occurred. Although the distributional assumptions were not fully met, no anomalies were uncovered or identified. The multilevel models were fitted using MlwiN 2.0 and all other analyses were carried out with STATA 8 [1,14].

3. Results

3.1. Study sample

Fifteen female and fifteen male undergraduate students agreed to participate. Briefly, 31% were freshmen and 52% were upperclassmen. Fifty-five percent described themselves as belonging to a minority group. The majority of students were science/engineering majors

(54%), while 43% were liberal arts majors. At baseline, self-reported computer use averaged 3.2 hours a day (SD 1.8), with 81% of computing done in student rooms (97% at desk). Just over half (55%) owned a laptop. More than half of the participants played a sport (55%) and 35% played a musical instrument [5].

3.2. Distribution of outcome

In total there were 2112 response events (symptoms data) among the 30 participants. Of these response events, 27% ($n = 553$) were symptomatic: 19% were mild symptoms, 9% moderate symptoms and less than 1% were severe or very severe symptoms.

3.3. Selected covariates

Covariates associated with experiencing *any* symptoms were all pain-related: Brigham & Women's Symptom Severity Scale, pain working on a computer in the past 2 weeks, severity of bodily pain in the past 4 weeks, pain at time of baseline survey, pain interfering with normal activities and seeking help from people when in pain. None of the covariates related to workstation characteristics or individual factors were significantly associated with experiencing *any* symptoms, and only one of the health care utilization variables (seeking help) was associated with the outcome. After a backward stepwise elimination process, the potential covariates remaining were bodily pain experienced in the past 4 weeks, current pain at time of baseline survey and severity of pain interfering with normal activities (all part of the baseline survey). The three pain measures were combined into a single omnibus pain measure used in the final model to adjust for baseline pain levels.

Covariates associated with experiencing *moderate or greater* symptoms were all pain-related: Brigham and Women's Symptom Severity Scale, pain after using a computer in the past 2 weeks, bodily pain in the past 4 weeks, and feeling pain at time of baseline survey. Neither the workstation characteristic variable nor any of the individual factors or healthcare utilization variables were associated with the outcome. After a backward stepwise elimination process, two variables remained: bodily pain in the past 4 weeks and current pain at time of baseline survey. We did not seek to combine them into a single index because only the variable representing current pain at time of baseline survey remained significant in final models.

3.4. Unadjusted effects

3.4.1. Time into day—The dichotomous time of day variable was not statistically significantly associated with *any* symptoms ($OR = 1.68$, 90% CI 0.96–2.92, $p = 0.12$). A statistically significant, positive association was found for *moderate or greater* symptoms ($OR = 4.07$, 90% CI 1.73–9.56, $p < 0.01$).

3.4.2. Day of week—None of the dummy variables for day of week were associated with *any* symptoms (data available from first author). However, Tuesday ($OR = 0.62$, 90% CI 0.40–0.96) and Saturday ($OR = 0.35$, 90% CI 0.16–0.77) were days where *moderate or greater* symptoms were significantly less likely to be reported compared to Sunday. Because there was no overall trend observed and only two days out of six were significantly associated with *moderate or greater* symptoms, day of week was not included in final model building and was not analyzed any further.

3.4.3. Days into the semester—The number of days into a semester was protective for *any* symptoms ($OR = 0.99$, 90% CI 0.985–0.995, $p < 0.001$) and *moderate or greater* symptoms ($OR = 0.99$, 90% CI 0.983–0.997, $p < 0.001$). The categorical variable for days into a semester was protective for *any* symptoms ($OR = 0.82$, 90% CI 0.74–0.90, $p < 0.001$) and *moderate or greater* symptoms ($OR = 0.71$, 90% CI 0.62–0.81, $p < 0.001$). Specifically, for *any* symptoms the odds of experiencing symptoms at 58–76 days into the semester was 0.67 (90% CI 0.52–0.86) compared to 35–57 days into the semester, the odds for 77–90 days into the semester was 0.38 (90% CI 0.29–0.51) compared to the same referent group and the odds for the end of the semester (91–117 days) was 0.62 (0.47–0.83). For *moderate or greater* symptoms the referent group was 35–57 days into the semester and the odds of experiencing this symptom severity level was: 0.50 for 58–76 days (90% CI 0.36–0.69), 0.29 for 77–90 days (90% CI 0.19–0.44) and 0.37 for the end of the semester (91–117 days) (90% CI 0.25–0.56).

3.4.4. Relationship of time variables to each other—To further understand the time-related predictor variables in describing symptoms, the relationship between each of the variables was explored. There were 15 response events that occurred after midnight, representing 5 students. Almost all of them occurred within the first quartile of days into the semester (5^{th}–6^{th} week of school). Additionally, a large proportion (73%) of the response events that occurred after midnight happened on Mondays (*n* = 6) and Tuesdays (*n* = 5). There was 1 event that occurred each on Wednesday and Saturday, and 2 events that occurred on Thursday. It is noteworthy that 4 out of the 5 students who responded to the electronic surveys after midnight reported using the computer (*n* = 10 response events).

3.5. Adjusted effects

For *any* symptoms days into the semester and the combined pain index are both significant predictors (Table 1). To put the risk of elapsed days expressed as a continuous variable in perspective, the odds of experiencing *any* symptoms 60 days into the semester compared with 30 days are 0.74. The odds of experiencing *any* symptoms 90 days into the semester compared with 30 days are 0.55. Examining elapsed days as dummy variables with 35–57 days into the semester as the referent group, the odds of experiencing *any* symptoms are low throughout the semester, but are at their lowest at 77–90 days into the semester (90% CI 0.20–0.42). To further understand how the odds of experiencing *any* symptoms are distributed over time, days into the semester was further categorized into octiles (Table 1.) The octile that included 78–85 days into the semester was associated with the lowest odds of experiencing *any* symptoms (*OR* = 0.26; 90% CI 0.15–0.46). For *moderate or greater* symptoms, those responding after midnight are 21 times more likely to experience moderate or greater symptoms than during the day (Table 2). Because days into the semester is significantly associated with time of day, two separate models are presented: one adjusted for days into the semester (Model 2) and a separate model adjusting for both days into the semester and time of day (Model 3). Including dummy variables for days into the semester (Model 2) yielded a significant, protective effect on *moderate or greater* symptoms. Specifically, after adjusting for baseline levels of pain, the odds of experiencing *moderate or greater* symptoms are 0.41 for 58–76 days into the semester, decreases to 0.36 for 77–90 days in the semester and then increases again to 0.42 for the rest of the semester (91–117 days) (Model 2). When considering days into semester as octiles, the odds of experiencing symptoms were the lowest at 78–85 days into the semester (*OR* = 0.25; 90% CI 0.11–0.58) and peaked at 42–57 days into the semester (*OR* = 1.97; 90% CI 1.04–3.74) (Model 2). After including time of day into the model, the odds ratios remained significant but were attenuated towards the null (Model 3).

To further understand the relationship between days into the semester and symptoms, each symptoms outcome was modeled on octiles of days into semester. Including dummy variables based on octiles in the model revealed a significant drop in symptoms at 78–85 days into the semester (*OR* = 0.24, 90% CI 0.10–0.56) proceeding a significant decline in symptoms at 66–77 days into the semester (*OR* = 0.50, 90% CI 0.25–0.97) (Model 2).

Including time of day in the model (Model 3) did not change the significance nor the odds ratios of the days into semester variables.

4. Discussion

Upper extremity musculoskeletal symptoms and disorders (UEMSDs) have long been an identified occupational health problem. Many studies use symptoms to classify disorders and many classification systems for disorders rely in large part on symptoms. Furthermore, in the epidemiological literature investigating the etiology of upper extremity musculoskeletal symptoms and disorders, symptoms measurement occurs at nonspecific times up to 6 months or a year after risk factors are measured. Thus, there is a need to understand temporal variations in symptoms reporting and questions remain regarding the natural history of UEMSDs.

The temporal variation of upper extremity musculoskeletal symptoms throughout an academic semester was described. In a group of college undergraduates, symptom patterns were found for time of day and number of days into the semester. For number of days into the semester, it could be argued an increasing quadratic effect of days into the semester on symptoms occurrence was discernible. However, because the data is based on a pilot project of 30 participants, a descriptive approach was followed. Number of days into the semester was kept categorical rather than forcing a linear and quadratic term into the model. For both symptoms outcomes, a dip in the odds of experiencing symptoms compared to other times in the semester was noted. One possible explanation for this dip was before this data collection period (77–85 days) Spring Break occurred and at the beginning of the “dip” a week-long university festival was ongoing, giving students a computing break and time to recover if symptomatic. This appears noteworthy as an example of an exposure-response relationship if computer use was associated with symptoms during this semester.

Similar to a previous study examining the effects of an intervention on upper extremity musculoskeletal symptoms among office workers [2], there was no day of week (workweek) trend. Interestingly, the time of day pattern seen was different for the time of day pattern seen among office workers [2]; Amick and colleagues found a linear pattern that increased throughout the day. Students responding after midnight were at a substantially increased risk of reporting *moderate or greater* symptoms. Differences in work patterns among office workers and student workers may affect the time of day patterns seen in both populations. Interestingly, all of the after midnight events occurred during the first quartile of days into the semester and most occurred on either a Monday or Tuesday.

The relationship between time of day and days into the semester is rather complicated. It appears that as the semester progresses, symptoms are generally less likely to occur, and there are no late night responses (possibly late computing hours) after the first half of the semester. The two time-related predictors together are associated with only *moderate or greater* symptoms. It is not clear what time of day represents (computer use duration, ability for body to recover from daytime musculoskeletal stressors). We plan to explore the temporal patterns in future analyses to resolve the role time of day plays in upper extremity musculoskeletal symptoms occurrence.

Before each participant was given their handheld computer for the week, they were interviewed as to typical wake time and sleep onset. The program to then randomly beep the students throughout the day everyday for a week was written according to each participant’s sleep/wake cycle so as not to encourage loss to follow-up. Therefore, data collected after midnight was due to self-reported sleep/wake schedules for students identifying themselves as typically up late at night. While programming according to self-reported sleep/wake schedules may present a sampling bias (although it promotes study retention), we have data that will be evaluated in the future that compares actual computing patterns over midnight measured directly through a computer software to determine if self-reported sleep/wake schedules were accurate and if they changed throughout the semester. Thus, the possible issue of sampling bias will be addressed.

The patterns demonstrating changes in symptoms experiences over the day and over a span of months provides insight into outcome measurement issues when studying the epidemiology of computing-related UEMSDs from both a macro and micro scale. Detecting macro versus micro time changes in symptoms raises an important design issue when deciding what perspective in the etiology of UEMSDs is desired and how to measure specific exposures such as sustained posture and other suspected biomechanical factors (Gerr et al., 2006). Furthermore, office ergonomics intervention studies would also benefit from designing outcome measurements to detect time-related symptoms changes, allowing for more accurate assessments of intervention effect.

The models proposed here are meant to describe temporal variations in upper extremity musculoskeletal symptoms that need to be adjusted for before evaluating the main proposed risk factors: computer use duration and non-neutral computing postures. A profile of college students based on the 30 that participated for the current study were constructed to better understand symptoms distribution over time before further modeling symptoms on suspected risk factors. This pilot project was done in the context of a study focused on computing patterns and non-neutral computing patterns and their association with upper extremity musculoskeletal symptoms. The findings presented here regarding the natural history of upper extremity musculoskeletal symptoms are novel and provocative. Further epidemiologic research is needed to confirm symptoms patterns related to computing in both college and office environments. In the meantime, further work in this field, whether in the form of office ergonomic intervention design or epidemiologic research, should measure temporality of musculoskeletal symptoms throughout a day and over extended periods of time (weeks or months) if conclusions about an intervention's effect or causal role for a risk factor wish to be made.

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Table 1

Multi-level logistic models[a] for any symptoms, Odds Ratios and 90% Confidence Intervals

Variable	OR (90% CI)
Model 1	
Days into semester[b]	
35–57	1.0
58–76	0.66 (0.49–0.86)*
77–90	0.29 (0.20–0.42)*
91–117	0.54 (0.39–0.75)*
Pain index	16.44 (7.42–36.13)*
Model 2	
Days into semester[c]	
35–41	1.0
42–57	1.46 (0.92–2.31)
58–65	1.09 (0.73–1.71)
66–76	0.56 (0.35–0.89)*
77–85	0.26 (0.15–0.46)*
86–90	0.56 (0.34–0.93)*
91–100	0.54 (0.34–0.87)*
101–117	1.02 (0.62–1.67)
Pain index	21.54 (9.03–51.38)

[a] Model 1 is comprised of pain and quartiles of days into semester, Model 2 is comprised of pain and octiles of days into semester.

[b] Overall effect of quartiles: *OR* = 0.79 (0.70–0.88).

[c] Overall effect of octiles: *OR* = 0.91 (0.87–0.96).

* = $p < 0.10$.

Table 2

Adjusted multi-level logistic models for *moderate or greater* symptoms, odds ratios and 90% confidence intervals[a]

	Model 1	Model 2[b]	Model 3[c]
	OR (90% CI)	OR (90% CI)	OR (90% CI)
Current pain[d]	16.44 (4.57–29.99)*	20.70 (6.90–62.10)*	18.36 (6.22–54.18)*
Time of day	21.33 (6.49–65.97)*	–	13.46 (4.56–39.74)*
Days of semester			
35–57	–	1.0	1.0
58–76	–	0.41 (0.27–0.60)*	0.51 (0.33–0.78)*
77–90	–	0.36 (0.22–0.58)*	0.46 (0.28–0.77)*
91–117	–	0.41 (0.26–0.66)*	0.59 (0.37–0.96)*
Current pain	16.44 (4.57–29.99)*	21.12 (7.04–63.36)*	13.33 (4.37–40.66)*
After midnight	21.33 (6.49–65.97)*	–	18.17 (6.16–53.64)*
Days of semester			
35–41	–	1.0	1.0
42–57	–	1.97 (1.04–3.74)*	1.38 (0.71–2.65)
58–65	–	0.56 (0.30–1.06)	0.61 (0.32–1.15)
66–76	–	0.52 (0.27–1.00)*	0.49 (0.25–0.96)*
77–85	–	0.25 (0.11–0.58)*	0.26 (0.11–0.62)*
86–90	–	1.20 (0.61–2.35)	1.21 (0.61–2.41)
91–100	–	0.46 (0.23–0.95)*	0.50 (0.24–1.02)
101–117	–	0.74 (0.38–1.45)	0.89 (0.46–1.71)

[a]Model 1 is comprised of pain and time of day, Model 2 is comprised of pain and days into semester and Model 3 is comprised of pain, time of day and days into semester.

[b]Overall effect for quartiles: *OR* = 0.76; 90% CI 0.66–0.88. Overall effect for octiles: *OR* = 0.94; 90% CI 0.87–1.01.

[c]Overall effect for quartiles: *OR* = 0.87; 90% CI 0.74–1.02. Overall effect for octiles: *OR* = 1.00; 90% CI 0.92–1.08.

[d]Referent group is those experiencing no pain at baseline.

*= $p < 0.10$.