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Evaluation of two posture survey instruments for assessing computing postures among college students

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Abstract. *Objective*: To determine agreement between two posture assessment survey instruments and which, if any, were correlated with experiencing upper extremity musculoskeletal symptoms.
Methods: Thirty undergraduate participants had three postural assessment surveys completed, one each for three separate 7-day data collection periods during a semester. Two observation assessment tools were used, a modified Rapid Upper Limb Assessment (mRULA) for computer users for the right and left limbs and the University of California Computer Use Checklist. Concurrently, upper extremity musculoskeletal symptom experience paired to each postural assessment was measured. Lin's concordance correlation coefficient evaluated survey agreement and multi-level statistical models described associations between survey responses and symptoms.
Results: There was no agreement between the two postural assessment tool scores ($p > 0.85$). In adjusted models, the UC Computer Use Checklist was positively associated with symptoms occurrence ($OR = 1.4$, 90% CI 1.2–1.6 for *any* symptoms; $OR = 1.3$, 90% CI 1.0–1.6 for *moderate or greater* symptoms). Associations with mRULA scores were inconsistent in that they were sometimes protective and sometimes indicators of risk, depending on the covariates included in the models.
Conclusion: The mRULA for computer users and the UC Computer Use Checklist were independent of each other; however, due to the inconsistent associations with symptoms we cannot conclude one instrument is superior to the other. Our data do suggest the UC Computer Use Checklist demonstrates a traditional relationship with symptoms, where increasing scores signifiy greater risk. We observed a nontraditional relatioship with symptoms for the mRULA for computer users that needs to be further examined. This is a pilot study and, thus, findings should be interpreted as exploratory. Associations observed in the current study will be used to test hypotheses in the cohort study recently conducted.

Keywords: Computer use, musculoskeletal symptoms, posture, college student

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1. Introduction

Upper extremity musculoskeletal disorders (UEMSDs) continue to play a large role in work-related health and productivity costs [15]. It is estimated at least 50% of the U.S. working population uses computers at work [22]. Accepted risk factors for computing-related UEMSDs include non-neutral computing postures [10]. Tools for evaluating postural risk range from simple workstation checklist (e.g. NIOSH's Elements of Ergonomics Program) to use of manual goniometers or a sophisticated full range body motion analysis system [16]. While debate remains about the validity of observational versus direct measurement methods of work-related physical exposures [19], there is a clear need for rapid (20 minutes or less) postural assessment tools that require minimal interruption of work. Survey instruments completed by trained observers may be a quicker and more comprehensive method than direct measures as they are observational measures of how workers are interacting with their workspace. Rapid assessments of computing postures and workstation configuration incorporated into employer office ergonomics programs for risk assessment and employee training purposes would be helpful in raising ergonomics awareness and developing solutions. However, it is not clear how useful current observational assessments are in predicting UEMSDs.

Two tools developed to specifically address the need for a rapid risk assessment and incorporate assessment of how office workers are interacting with their workstation are the modified Rapid Upper Limb Assessment (mRULA) for computer users [9,11] and the University of California Computer Use Checklist [5]. RULA was originally developed for use among industrial workers, but a modified version for computer use among office workers has been developed (mRULA). The UC Computer Use Checklist was also developed specifically for use among office workers. Both observational assessments were designed to be administered quickly and easily in an office environment to identify ergonomic modifications to control hazards and identify solutions. Two key assumptions in using observational assessment tools is that (1) they are likely to identify similar risks when making comparisons across tools and (2) each tool can significantly predict symptoms occurrence. However, these assumptions have not been tested for the two tools by examining the level of agreement between the observational assessments and the extent to which each predicts musculoskeletal health outcomes.

To evaluate the two observational assessment tools, we took advantage of an ongoing research collaborative involving a local university focused on evaluating the musculoskeletal health of college students [13]. College students are a unique and practical population to focus on for work-related musculoskeletal health outcomes as previous research documents they are already experiencing symptoms [1,4,6,12]. It is logical to suggest that computing behaviors observed in the workplace originated earlier in an employee's life experience (such as during college where 'working' habits are forming). That is, computing posture behaviors are likely learned and adopted as part of computing habits during college when computing becomes an integral part of productivity and communication. It is expected these computing habits stem from workstations characterized by limited, if any, adjustability. Notably, in a small study among 60 college students Tullar et al observed 75% were exposed to nine potential postural strains [21]. Recent studies have demonstrated the prevalence of upper extremity musculoskeletal symptoms and disorders in undergraduate and graduate student populations further justifying testing in this cohort [1,4,6,7,13,18].

The purpose of the current work is to (1) determine the agreement between two observational assessments (the mRULA and UC Computer Use Checklist) and (2) compare their concurrent validity in describing upper extremity musculoskeletal symptoms.

2. Methods

2.1. Study design

A repeated measures study was conducted among 30 undergraduate students at a private university in the Southwest United States during the spring 2004 academic semester. The study was divided into 2 components: a baseline component and a data collection period component. The baseline component involved one Sunday evening a month after the school semester started, where a 20-minute survey was administered from 9:00pm to 11:00pm to students invited and agreeing to participate. At this time, contact information was obtained to make appointments for data collection at a later date once data collection periods began. Data collection periods started roughly 6 weeks after school started (end of February) and occurred at three different times over the semester. Each data collection period spanned three calendar weeks where 7-day data collection weeks were staggered to accommodate available staffing and instrumentation resources. During a data collection week, participants were asked to carry a handheld computer and respond to a 2-minute electronic survey prompted by random beeping throughout the day. Within each data collection week, a 30-minute observation session to measure computing postures was completed in the student's dorm room.

2.2. Study sample

A single undergraduate college (sic dormitory) provided the sample. Fifteen men and fifteen women aged 18 years and older participated. All students from a single residential college were invited to attend a presentation about the study accompanied by food on a Sunday evening. The first 30 eligible students (owning a computer and being 18 years and older) were invited to participate in the study. After informed consent was obtained, the participants were enrolled in the study. Both the University of Texas at Houston Health Science Center Committee for the Protection of Human Subjects and the University's Institutional Review Board approved the study protocol.

2.3. Outcome measures

Two upper extremity musculoskeletal symptom outcome measures were created from responses to the question "How much pain are you now experiencing in your _?" for each of 13 body parts: left finger, right finger, left wrist, right wrist, left forearm, right forearm, left upper arm, right upper arm, left shoulder, right shoulder, neck, upper back and lower back. Possible responses included none, mild, moderate, severe and very severe. The two dichotomous dependent variables were created based on differing cut points of symptoms severity: (1) any symptoms reported for any body part (any) and, (2) only moderate, severe or very severe symptoms reported for any body part (moderate or greater). The questions specified pain rather than discomfort to allow for modeling of pain on posture. In the interest of brevity (the electronic survey was administered several times a day), 13 separate questions asking about discomfort for the 13 body parts were not added. However, there were two separate questions that asked about numbness and tingling, which helped the participants distinguish between pain from numbness and tingling when evaluating their pain level.

2.4. Independent variables

During the observation period, two observational posture assessment survey instruments were used to evaluate computing postures. An observer trained by certified ergonomists involved in the development of both the mRULA and the UC Computer Use Checklist conducted both assessments and visited each study participant at his/her desk while performing a computing task and recorded the upper extremity postures for each half of the body. No standard observation time was used as the meetings were scheduled at the participants' convenience. Observational meetings occurred as early as 7:30 in the morning and as late as 10:30 at night on any day of the week. Each sudent was asked to work as they usually do when working at the computer. The mRULA takes roughly 20 minutes to conduct and is based on a series of pictured computing postures and behaviors organized by body part [11, 19]. The modified version was adapted for non-neutral postures associated with computer use [11]. Possible values for the mRULA range from 1 to 9 where a value of 1 indicates an acceptable posture if not maintained or repeated for long periods of time and a value of 7 or greater indicates immediate investigation and changes. Data on mRULA for both the left side and right side were collected and statistically analyzed separately. It is important to distinguish between the two and their potential association with symptoms because the left side represents exposure to one type of input device (keyboard use) while the right side includes both keyboarding and mousing behavior (two different input devices). The mRULA was categorized into recommended cutpoints for assigning risk: 1–2, 3–4, 5–6, and 7, hereafter referred to as Lueder cutpoints [9]. However, in order to make direct comparisons with the UC Computer Checklist, the mRULA scores were further categorized into ordinal variables based on quartiles of frequency so the association between mRULA and symptoms could be compared to the UC Computer Use Checklist. The left and right mRULA quartiles were: 2–3, 4–5, 6 and 7.

The UC Computer Use Checklist was originally developed for use in assessing non-neutral postures and movements associated with computer use at work and is accompanied by a guidebook [5]. The Checklist takes approximately 30 minutes to complete and is organized by a series of pictures indicating computing postures, behaviors and workstation characteristics. The overall score ranges from 14 to 121 where 121 indicates highest risk. Preliminary analyses **of the current data** indicated quartiles were: 35.5–47.5, 48–55, 55.5–62, 62.5–87.

2.5. Covariates

Potential covariates were selected using a procedure described previously [12]. Briefly, the association between three time-related variables created to describe temporal patterns in upper extremity musculoskeletal symptoms throughout the semester were evaluated using multilevel logistic regression models. Two temporal variables were found to be statistically significant ($p < 0.05$) for both outcomes: *time into day* and *days into the semester*. Time into day is dichotomized into 0 (outcome events occurring before midnight) and 1 (outcome events occurring after midnight). Days into the semester is presented in different models as a continuous variable that ranges from 1 (first day of school) to 120 (last day of school) and as a categorical variable based on quartiles (35–57 days, 58–76 days, 77–90 days, 91–117 days). Additionally, two separate omnibus pain measures, created from multiple pain indicators, were found to be statistically significant ($p < 0.05$) for both outcomes.

In previous analyses a wide range of covariates were examined and found to not be related to the outcome and thus were not considered in this analysis $\{9\}$. A single variable evaluating ergonomic improvements made to the workstation was not included. Others not related to the outcome and, therefore, not included were: individual factors such as gender and race/ethnicity, extracurricular activities, an abbreviated mental health index and baseline measurements of functional or student impact due to any symptoms.

2.6. Statistical analysis

Lin's concordance correlation coefficient (rho $_c$) was used to assess agreement between each mRULA (right half and left half) with the UC Checklist [8]. Two components used to calculate the rho$_c$ are a precision component (Pearson r) and an accuracy component (rho $_a$). Lin's concordance correlation coefficient is an appropriate statistic for measuring agreement because it determines correlation while accounting for differences in scale and location (accuracy) of the measurements. The rho$_c$is the product of the Pearson's r^2 and the rho$_a$, and is measured on a scale from 1 (perfect agreement) to 0 (no agreement) to –1 (perfect reversed agreement). A confidence interval of 95% and a p-value less than 0.10 indicates a statistically significant agreement. Scatterplots fitted with a trendline and presented by data collection period of the UC Computer Use Checklist and mRULA scores (using maximum values for either side of the body for mRULA to signify greater risk) were constructed to graphically depict agreement at a basic level.

Two-level logistic regression models were constructed to test the association between posture assessments and each outcome measure. The two levels are participant (level 2) and repeated symptom measures within each participant (level 1). The following model was used to describe the outcome:

$$\text{Logit}[\pi_{ij}] = \beta_{0j}(\textit{constant}) + \beta_p(\text{time-related predictor})_{ij} + \beta_c(\text{posture assessment})_j$$

$$\beta_{0j} = \beta_0 + u_{0j}$$

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 a specific posture assessment within individual j,
u$_{0j}$ follows a normal distribution with mean 0 and variance σ^2_{u0}

Separate multilevel logistic models were estimated for each posture survey tool to examine associations ($p \leqslant 0.10$) of the predictors with the outcome event, both unadjusted and adjusted for selected covariates. Interaction terms were created for posture assessments with significant temporal measures (time of day or number of days into semester) to assess whether the temporal factors modified the relationship between non-neutral postures and symptoms. 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 discovered. The multilevel models were fitted using MlwiN 2.0 and all other analyses were carried out with STATA 8 [14,20].

3. Results

3.1. Study sample

Thirty undergraduate students agreed to participate: 15 men and 15 women. There were almost as many underclassmen (48% first and second year students) as there were upperclassmen (52% third and fourth

Table 1
Posture assessment tool mean (and standard deviation) values by elapsed days* into semester

	Elapsed days			
Posture assessment tool	35–57	58–76	77–90	91–117
RULA (left)	5.3 (1.4)	5.3 (1.7)	5.7 (1.3)	5.9 (1.6)
RULA (right)	5.3 (1.4)	5.5 (1.5)	5.7 (1.2)	5.9 (1.6)
UC Computer Use Checklist	50.9 (9.8)	53.6 (11.5)	58.4 (9.0)	59.0 (10.2)

*Please note 'elapsed days' signifies a direct measure of days and do not directly correspond to data collection periods.

year students 52%). Fifty-five percent described themselves as belonging to a minority group, the majority of which were Asian. The majority of students were science/engineering majors (54%); 43% were liberal arts majors. At baseline, self-reported computer use averaged 3.2 hours a day (SD 1.8). A significant portion (81%) of computing was done in student rooms and 97% of computing in the student's room was done at their desk. More than half of the participants played a sport (55%) and 35% played a musical instrument [13]. There was 100% participation and 100% retention for the study. The workstations (desk, desk chairs and beds) were standard and non-adjustable as the same furniture was purchased for every dorm. Students had the option of replacing the center drawer in their desk with a sliding platform to support a keyboard tray – however, no students in this study requested this option. Sixteen of the 30 participants used a desktop.

3.2. *Distribution of posture assessment tools scores into the semester*

There was no significant difference in mean values for the right and left mRULA and the UC Computer Use Checklist by elapsed days into the semester (Table 1). However, as the semester progressed values for both the right mRULA and the UC Computer Use Checklist tended to increase.

3.3. *Agreement of posture assessment tools*

There was little agreement between the UC Computer Use Checklist and the mRULA. The rho_c between the UC Computer Use Checklist and the mRULA score representing the right side of the body was 0.000 ($p =$ 0.93) and the Pearson's r^2 was 0.009. The rho_c between the UC Computer Use Checklist and the mRULA score representing the left side of the body was 0.000 ($p =$ 0.87) and the Pearson's r^2 was 0.018. Scatterplots of the Computer Use Checklist with the maximum value for either the left or right mRULA are depicted in Figs 1a–1c (separated by data collection period) show little correspondence.

3.4. *Unadjusted effects*

For *any* symptoms the UC Computer Use Checklist was found to be marginally statistically significant in describing symptom occurrence (see Table 2). Specifically, the odds ratio for the UC Computer Use Checklist in its continuous form was 1.02 (90% CI: 1.01–1.03), and 1.1 (90% CI: 1.0–1.3) in its categorical (ordinal) form based on quartiles of frequencies of response events. Neither of the mRULA assessments (right or left) was significantly associated with the occurrence of *any* symptoms.

For *moderate or greater* symptoms neither the UC Computer Use Checklist nor the left mRULA score was statistically significant. The right mRULA score was found to be associated with symptoms in its continuous form ($OR = 0.8$; 90% CI 0.6–0.9) and using the Lueder cut points ($OR = 0.6$; 90% CI 0.4–0.8).

3.5. *Adjusted effects*

Table 3 illustrates the effects of each posture assessment tool in describing symptoms adjusted for selected covariates. The UC Computer Use Checklist was positively associated with *any* symptoms ($OR = 1.4$; 90% CI 1.2–1.6). There was no effect observed for the left and right mRULA ($OR = 1.1$, 90% CI 0.9–1.3 for both left and right mRULA). Indicator variables for the UC Computer Use Checklist revealed a general increase in odds ratios for each quartile of score frequency. There was no effect observed for the mRULA when examining different scoring frequency quartiles.

The association between *any* symptoms and left mRULA using the Lueder cut points was positive and significant overall ($OR = 1.4$; 90% CI 1.1–1.8) and for the two highest cut points based on risk (scores 5 or 6: $OR = 3.9$, 90% CI 1.3–11.6; scores 7 or greater: $OR = 3.8$, 90% CI 1.2–12.4). There was no effect observed for the right mRULA categorized using the Lueder cut points.

Table 3 shows the UC Computer Use Checklist was positively associated with experiencing *moderate or*

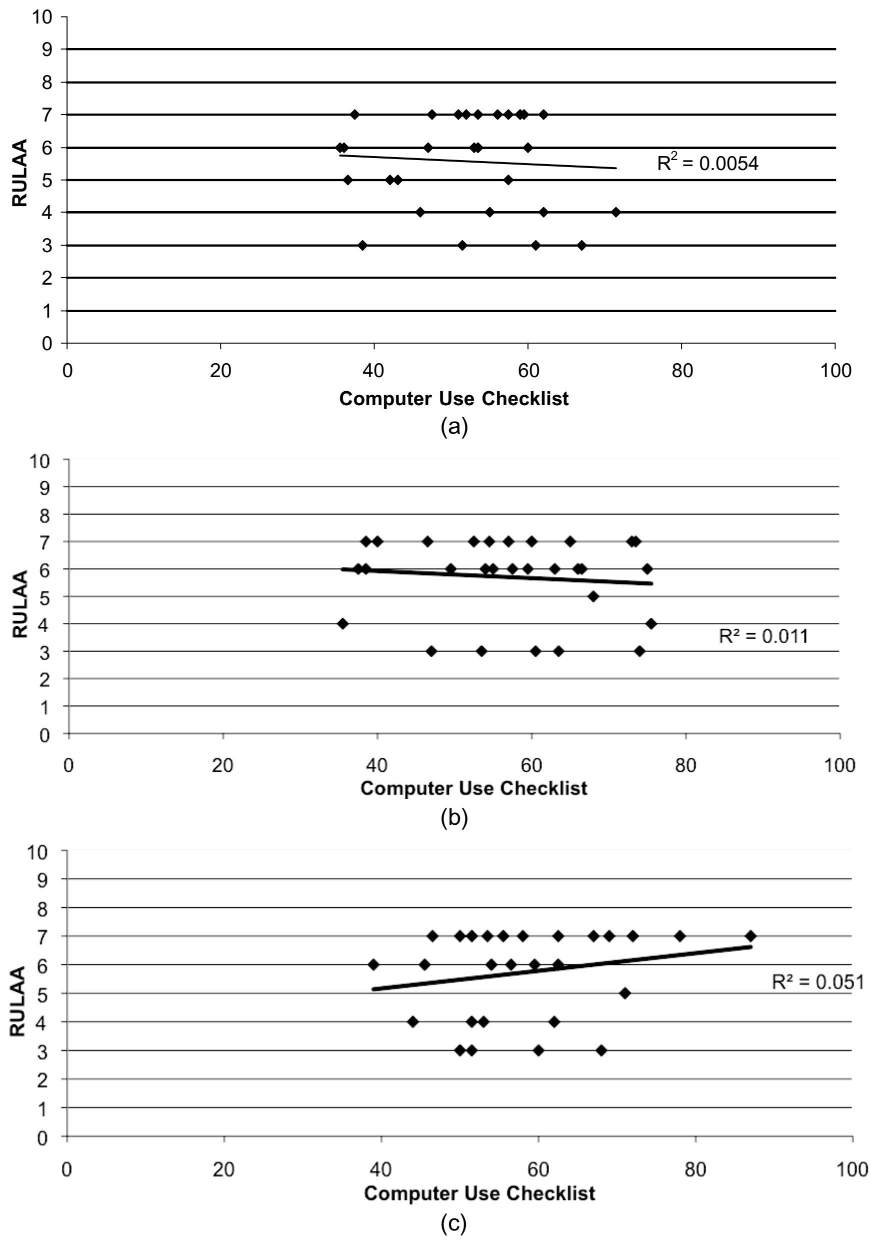

Fig. 1. Figure 1(a) Scatterplot with trendline of UC Computer Use Checklist and maximum value for either side's mRULA for data collection period 1. (b) Scatterplot with trendline of UC Computer Use Checklist and maximum value for either side's mRULA for data collection period 2. (c) Scatterplot with trendline of UC Computer Use Checklist and maximum value for either side's mRULA for data collection period 3.

greater symptoms ($OR = 1.3$; 90% CI 1.0–1.6). The overall association between the mRULA and symptoms was negative (OR for left mRULA: 0.7, 90% CI 0.6–1.0; OR for right mRULA: 0.7, 90% CI 0.6–0.9). The odds ratio for UC Computer Use Checklist scores 58–76 was 0.7 (90% CI 0.4–1.3) compared with scores 35–57, 1.3 (90% CI 0.7–2.4) for scores 77–90, and 1.9 (90% CI 1.0–3.7) for scores 91–117. The odds ratio for the left mRULA was 0.8 (90% CI 0.5–1.3) for a score of 2 or 3 compared to the referent (1), 0.5 (90% CI 0.3–0.9) for a score of 4 or 5 compared to the referent, and 0.4 (90% CI 0.2–0.9) for a score of 6 or 7 compared to the referent. The associations for right mRULA were very similar to those observed for left mRULA.

When evaluating the Lueder cut points with the *moderate or greater* symptoms, the overall association for

Table 2
Unadjusted odds ratios for symptoms by posture assessment tool

Variable	**OR (90% CI)**
Any symptoms	
RULA (right side) – continuous	1.0 (0.9–1.1)
RULA (right side) – ordinal (quartiles)	1.0 (0.9–1.2)
RULA (right side) – ordinal (Lueder cut points)	0.9 (0.7–1.1)
RULA (left side) – continuous	1.1 (0.9–1.6)
RULA (left side) – ordinal (quartiles)	1.0 (0.8–1.2)
RULA (left side) – ordinal (Lueder cut points)	1.2 (0.9–1.5)
UC Computer Use Checklist – continuous	1.0 (1.0–1.0)*
UC Computer Use Checklist – ordinal (quartiles)	1.1 (1.0–1.3)*
Moderate or greater symptoms	
RULA (right side) – continuous	0.8 (0.6–0.9)*
RULA (right side) – ordinal (quartiles)	0.8 (0.7–1.1)
RULA (right side) – ordinal (Lueder cut points)	0.6 (0.4–0.8)*
RULA (left side) – continuous	0.9 (0.7–1.0)*
RULA (left side) – ordinal (quartiles)	0.8 (0.7–1.1)
RULA (left side) – ordinal (Lueder cut points)	0.9 (0.7–1.3)
UC Computer Use Checklist – continuous	1.0 (1.0–1.0)*
UC Computer Use Checklist – ordinal (quartiles)	1.0 (0.9–1.2)

*p-value < 0.10.

Table 3
Adjusted Logistic model for symptoms by posture assessment tool

Variable	UC computer use checklist-quartiles OR (90% CI)	RULA (left) – quartiles OR (90% CI)	RULA (left) – Lueder cut points OR (90% CI)	RULA (right) – quartiles OR (90% CI)	RULA (right) – Lueder cut points OR (90% CI)
Any symptoms					
Posture assessment[a]	1.4 (1.2–1.6)*	1.1 (0.9–1.3)	1.4 (1.1–1.8)*	1.1 (0.9–1.3)	0.9 (0.7–1.2)
1st quartile	Referent	Referent	Referent	Referent	—±
2nd quartile	0.7 (0.5–1.1)	0.9 (0.7–1.3)	2.4 (0.9–6.7)	0.8 (0.6–1.2)	Referent
3rd quartile	0.9 (0.6–1.4)	1.2 (0.8–2.0)	3.9 (1.3–11.6)*	1.2 (0.7–2.0)	0.8 (0.6–1.1)
4th quartile	1.9 (1.2–3.0)*	1.3 (0.7–2.4)	3.8 (1.2–12.4)*	1.5 (0.8–2.6)	1.1 (0.7–1.9)
Elapsed days†	0.7 (0.7–0.8)*	0.8 (0.7–0.9)*	0.8 (0.7–1.0)*	0.8 (0.7–0.9)*	0.8 (0.7–0.9)*
Pain∞	17.6 (8.6–36.3)*	15.8 (7.1–35.3)*	16.0 (7.0–37.0)*	16.0 (7.1–35.6)*	15.8 (7.4–33.6)*
Moderate or greater symptoms					
Posture assessment[b]	1.3 (1.0–1.6)*	0.7 (0.6–1.0)*	0.8 (0.5–1.1)	0.7 (0.6–0.9)*	0.4 (0.3–0.6)*
1st quartile	Referent	Referent	Referent	Referent	—±
2nd quartile	0.7 (0.4–1.3)	0.8 (0.5–1.3)	2.5 (0.7–8.7)	0.7 (0.5–1.2)	Referent
3rd quartile	1.3 (0.7–2.4)	0.5 (0.3–0.9)*	1.7 (0.4–6.4)	0.5 (0.2–0.9)*	0.3 (0.2–0.5)*
4th quartile	1.9 (1.0–3.7)*	0.4 (0.2–0.9)*	1.6 (0.4–6.9)	0.4 (0.2–0.8)*	0.3 (0.1–0.6)*
Elapsed days†	0.8 (0.7–1.0)*	0.9 (0.8–1.1)	0.8 (0.7–0.9)	0.9 (0.8–1.1)	0.9 (0.7–1.0)*
Time into day	16.6 (5.6–49.0)*	19.9 (6.6–59.7)*	16.8 (5.5–51.2)*	19.9 (6.6–59.7)*	16.8 (5.5–51.2)*
Pain∞	17.3 (6.5–46.3)*	14.2 (4.7–42.5)*	17.5 (5.8–52.4)*	14.4 (4.9–42.6)*	13.9 (4.3–44.5)*

[a]Test for trend.
[b]Test for trend
±RULA (right) values available for only 3 Lueder cut points due to range of observed values (3–7).
†Elapsed divided into the following quartiles: 35–57, 58–76, 77–90, 91–117.
∞Pain values range from 0–3 when modeling *any symptoms* and 0–2 when modeling *moderate or greater symptoms.*

the left mRULA remains negative (OR = 0.8; 90% CI 0.5–1.1). The association for the right mRULA is significantly negative (OR = 0.4; 90% CI 0.3–0.6).

4. Discussion

The goal of this pilot study of college students was to examine the agreement between two computer user observational assessments (the mRULA and UC Computer Use Checklist) and compare their concurrent validity in describing upper extremity musculoskeletal symptoms. Overall, the two assessments were independent of each other and their associations with symptoms were not consistent and often depended upon inclusions of various covariates into the model.

While we expected that the Rapid Upper Limb Assessments and the UC Computer Use Checklist findings to be somewhat related, there was essentially no agreement between the two. Furthermore, the scatterplots, combined with the r^2 values associated with the trendline, illustrate the uniqueness of the posture assessments to each other. One potential reason for the lack of correspondence is that each instrument has different origins. The UC Computer Use Checklist was originally designed to be used among computer users whereas the modified RULA was adapted from the RULA which was originally intended for industrial workplaces rather than office environments. The modified Rapid Upper Limb Assessment scores the posture of the upper extremities separately while the UC Computer Use Checklist measures computing postures relevant to upper extremities and neck musculoskeletal health. It seems reasonable that two survey instruments with different origins would not agree.

We do not consider the lack of correspondence as due to a single rater. While using one rater does not prevent information bias from occurring, the use of a single trained rater eliminates potential bias resulting from low inter-rater reliability. We do recognize that the small sample size could result in methodological limitations. The frequency-based quartiles created for each survey allowed as direct a comparison as possible for describing musculoskeletal symptoms.

Another interesting observation is the temporal variation in the overall effect of posture score on symptoms. In unadjusted models almost all effects were null when predicting *any* symptoms, whether statistically significant or not. Most effects were negative or towards the null when predicting *moderate or greater* symptoms, an unexpected finding. After adjusting for temporal variation (days into the semester and time into day), the relationship between the UC Computer Use Checklist and symptoms changed to be significant and positive (from the null to $OR = 1.4$ for *any* symptoms and $OR = 1.3$ for *moderate or greater* symptoms).

The directly comparable transformation of mRULA did not change after adjustment for *any* symptoms, but when time of day was adjusted for (to predict *moderate or greater* symptoms) the association became significant with a lower (more negative) point estimate. Using the Lueder cut points for mRULA the adjusted effects were unexpected. The association with left mRULA became positive and statistically significant when predicting *any* symptoms while the right mRULA remained at no effect. The association with right mRULA was more negative ($OR = 0.4$ from 0.6) while that of the left mRULA experienced no change. The temporal variability of effect is an interesting finding as Ortiz [16] states that a single measure of posture is enough when using goniometers. The developers of the UC Computer Use Checklist recommend that scoring be based on at least two (one morning and one afternoon) observation periods; more may be needed if the subject uses different software applications. Temporal variation of these two postural assessment tools has not been reported in previous studies. Further research using these tools to predict symptoms should consider multiple measurements throughout the observation period.

A major finding is that the UC Computer Use Checklist, when adjusted for temporal variation, consistently predicted symptoms in the expected positive direction. This finding makes sense as it was originally designed for use in computing environments with a goal to incorporate both non-neutral postures and workspace characteristics when estimating risk for symptoms.

Overall, the direction of association of mRULA with symptoms is inconsistent. The direction of the association of both mRULA scores when modeled for *moderate or greater* symptoms is consistently negative when adjusted for covariates, with or without interaction terms. This is an unexpected finding. One explanation is there is a limited range in age and postures relative to the population of workers and type of tasks performed for which the original RULA was developed. Although the activities assessed ranged from gaming to communicating to assignments, the variability of possible postures was small. One reason for the more constricted range of values for the right mRULA (3–7 when 1–7 is possible) is the lack of workstation adjustability for every dorm room that was observed. Based on these scores all of the students are at risk. This coincides with past findings reported by Tullar, et al. that identified 7 potential postural risk factors in a previous survey of college students [19]. Further research using this tool among computer users is needed to understand how it is associated with symptoms. In addition, RULA has specific definitions of neutral postures, which have been called into question recently, as Marcus et al. have demonstrated that postures previously thought to be “neutral” (such as 90 degree angles at the elbow) may not, in fact, be protective. RULA is limited in that it does not take into consideration specific workstation design fundamentals such as arm supports and the position of devices within the computer workstation [10].

One study limitation is the absence of a comprehensive exposure assessment capturing frequency, duration and intensity [23]. Postural assessment tools provide a measure of exposure intensity, only one of the three dimensions. Our analysis and results are limited to exploring the intensity measure. Specific methods of combining postural risk and duration and frequency have not been developed for the current instruments or by others. However, we did explore the interactions of the intensity and duration via our last model. Here we saw stronger associations suggesting that intensity alone is not powerful; however, when we correct the models for the temporal parameters the intensity parameters become important.

The findings presented here were not meant to be generalizable to neither student nor working populations and, therefore, are of limited generalizability. The current study is a pilot study limited to 30 participants for the purpose of exploring the agreement between two widely used posture surveys and comparing their associations with upper extremity musculoskeletal symptoms. Comparisons of the findings with the working population cannot be made as the current study is the first to evaluate the association between upper extremity musculoskeletal symptoms and posture surveys designed to predict symptoms. While student exposure patterns experienced in dorm rooms with unadjustable furniture are expected to be similar to work environments with limited adjustability, it is impossible to comment on symptoms patterns as the current study was the first to evaluate symptoms over a semester. Previous studies on working populations found a lack of symptoms growth over a workweek [2], as was observed with data from the current study. Our preliminary finding of symptoms remaining fairly steady throughout the day then increasing after midnight is not incompatible with those observing symptoms growth throughout a workday [2], especially since a "workday" for students can conceivably occur well into the early hours. Further evaluation of widely used posture surveys is planned as we have just completed a prospective cohort study of just over 150 undergraduate students in a single dorm.

Both the modified Rapid Upper Limb Assessment and the UC Computer Use Checklist have been widely used by public health practitioners and ergonomists in the field in addition to have been designed to assess postural risk for computing-related upper extremity musculoskeletal disorders. Inherent has been the belief scores from the two surveys on one observation are in agreement. However, the only data available comparing two posture assessments in the field found they classified exposure differently [3]. Our data suggest the mRULA and the UC Computer Use Checklist characterize symptoms differently. The UC Computer Use Checklist appears to have a traditional relationship with both symptoms outcomes: after adjusting for covariates, increasing scores correspond with increasing point estimates. The mRULA, when directly compared with the UC Computer Use Checklist, has a nontraditional relationship with symptoms: increasing scores (though non-significant) are associated with roughly increasing point estimates that plateau for experiencing any symptoms, but a negative association (and statistically significant) for moderate or greater symptoms. When the mRULA is categorized by the cutpoints recommended by Lueder and Corlett, for any symptoms both sides suggest a traditional relationship where increasing scores indicates greater risk of symptoms occurrence (though significant for the left side and not the right side which includes mousing postures). For moderate or greater symptoms, the left side mRULA suggests risk is decreasing with increasing scores and the right side shows no change in risk as scores increase (statistically significant). The relationship between mRULA and symptoms will be re-examined with the longitudinal cohort study where multiple posture assessments over a semester were recorded on a larger ($n = 155$) population.

The current work is preliminary and more research involving the time relationship between posture assessment and outcomes is needed to understand the roles of these risk assessment tools in predicting symptoms occurrence.

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