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Research Article

Head and Neck Posture Changes Across Time when Mobile Computing Devices: The Effect of Arm Support

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ABSTRACT

Background: Changes in head and neck position may contribute to the development of various musculoskeletal problems including neck pain. Understanding how time spent performing computing tasks and how the addition of arm support can affect head and neck position will inform guideline development for activity limitation and modification when using portable computing devices.

Objectives: This study compared changes in head, neck and shoulder position across time during tablet and laptop typing and to examine how adding pillow support affects head, neck and shoulder position during tablet typing.

Methods: Marker based two dimensional kinematic analyses were performed on video recordings of 18 participants during three typing tasks (laptop, unsupported tablet, and supported tablet) to examine changes in position across time.

Results: Typing on a tablet was associated with increased head and neck flexion compared to laptop typing while laptop typing was associated with more shoulder flexion compared to unsupported tablet typing.Head, neck and shoulder positions changed significantly at the beginning of the tasks but not at the end, with large effect sizes. Pillow support had a large and significant effect on reducing forward head and neck positioning during tablet typing.

Conclusion: Raising the tablet by use of support at the beginning of tablet typing can be an effective way to minimize sustained forward head and neck postures. Increased head and neck flexion during mobile computing for even short periods has potential implications for the development of neck pain which could be attenuated by the addition of pillow support when mobile computing.

INTRODUCTION

Sustained forward head and neck posture has been suggested as a contributing factor to the development of various musculoskeletal problems through biomechanical and neuromuscular contributions[1]. Sustained abnormal postures contributing to neck pain, such as forward head and flexed neck positions, are seen among computer users [2,3]. Advances in information technology have forced changes in the postural demands during computing tasks, particularly related to the increasing use of mobile technology. Recent technological advances have resulted in a marked increase in the use of handheld tablet devices since the iPad (Apple Inc.) was first introduced in 2010[4]. Technological advances in personal computing have outpaced the development of ergonomic guidelines for the maintenance of musculoskeletal health

and the prevention of musculoskeletal dysfunction. A recent systemic review examining the effect of mobile device use on musculoskeletal symptoms concluded that further research is warranted to develop guidelines for the wise use of mobile devices [5].

Compared to laptop typing, tablet typing is associated with increased cervical flexion [6-8]. Increased cervical flexion affects the line of gaze resulting in increased loading of the cervical spine and associated soft tissues [9]. Consistent with increased cervical loading, pain and fatigue have been shown to worsen with longer durations of device use in individuals with forward head posture [10]. The type of tablet used, the position of the tablet, the way the tablet is held, and the screen size have also been shown to affect head and neck posture by increasing neck flexion [7,11,12]. Less is known however about how posture changes across time with mobile device use. Even ten minutes of device use in sitting has been associated with increased neck discomfort in individuals both with and without neck pain [13].

Postural modifications are a recommended intervention for individuals with neck pain. However, there is limited evidence to show how postural modifications affect head and neck posture during mobile computing. Using pillows to raise the tablet may be a simple at home intervention recommendation to promote reduced neck strain by raising the tablet up to achieve a better head and eye angle. From a biomechanical perspective, raising the device toward the eyes should reduce the need to lower the head, thus reducing flexion and loading on the cervical spine [9]. The purpose of this study was twofold.First, to compare postural deviations of the head and neck during seated laptop typing and handheld tablet typing. We hypothesized that tablet typing would be associated with increased neck and head flexion compared to laptop typing, and that head and neck flexion would consistently increase across time in the hand held tablet task compared to the laptop task. The second purpose of the study was to assess the effect of raising the tablet by adding pillow support while seated. We hypothesized that raising the tablet would reduce the amount of head and neck flexion during the task compared to unsupported tablet typing. Results from this study will help inform needed ergonomic recommendations for the increasing use of tablet technology and provide justification for adding support while using mobile devices in sitting.

MATERIALS AND METHODS

Participants

Eighteen healthy, right handed participants were recruited.An initial pilot study including three subjects was completed and a power analysis was used to inform sample size [14]. The analysis indicated that 9 subjects were needed to have 80% power for detecting a medium-sized effect when employing the traditional .05 criterion of statistical significance in one primary outcome of interest (change in craniovertebral flexion during tablet typing).The target sample size was doubled to be consistent with other studies [9,15]. Seven male and 11 female participants had an average age of 25 years (SD = 2.4). Subjects were screened for handedness using the Edinburgh Handedness Inventory and for general health using a health screening questionnaire. This research complied with the Declaration of Helsinki and was approved by the Institutional Review Board at Midwestern University. Written informed consent was obtained from each participant.

Research protocols

A repeated measures design was used to examine the effect of task and time on head, neck and shoulder position during typing tasks. All tasks were completed in sitting. The three typing tasks examined were 1) two handed typing on a 15.4" laptop computer (Dell Inspiron E1505, Dell Inc. Texas, USA) which sat on a table adjusted to the appropriate height for each subject to allow for a neutral shoulder flexion position with elbows at 90 degrees flexion (forearms unsupported), wrists in neutral and head, neck and trunk in a neutral upright posture; 2) unsupported tablet typing where the tablet (iPad2®, Apple, Cupertino, CA, USA) was held by the subject in their left hand and they touch typed on the tablet screen with their right index finger (i.e. a one handed typing task with forearms unsupported); and 3) supported tablet typing which was identical to the unsupported tablet typing task except that two medium support standard bed pillows were placed horizontally on the participants lap while seated. The start position for tablet typing was a two handed hold of the tablet prior to the go signal (Figure 1). Participants were instructed to type as much of the standardized text across all typing tasks as they could during the 10-minute task while maintaining the

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device in a comfortable position and using their self-selected typing speed.Standardized text was contained in a box at the top half of a Word document (Microsoft Office 2010, Microsoft Corporation) with an equal sized text box below it for the typing entry. The order of tasks was randomized across participants. For all tasks, participants were seated in a standard office chair without arms, adjusted to their height such that the knee and hip angles were at approximately ninety degrees of flexion and their feet rested comfortably on the floor.

Head, neck and shoulder position were recorded at rest before typing (pre-position) and at one minute increments throughout the ten-minute typing task (10 time points). Relative positions of the head, neck and upper arm were used to calculate the following angles/positions: craniovertebral flexion, head flexion, cervical flexion, forward head position, and shoulder flexion (Figure 2). Postural deviations of the head, neck and shoulder across the three typing tasks were calculated at one-minute increments by subtracting the angles/positions at each of the time points from the corresponding pre-position measurement and served as dependent variables.All participants were videotaped during each task using a high definition digital camcorder (Canon Vixia HF R52, Canon U.S.A., Inc., Melville, NY) recording at 60 frames/second. Reflective tape or markers were affixed to each subject, and these points were used to identify key landmarks for offline analysis (Figure 2B). Head, neck and shoulder angles/positions were quantified offline using portable video technology (Dartfish Motion Analysis Software ProSuite 7.0, Dartfish, Fribourg, Switzerland) which has been shown to be a reliable and valid method of two dimensional tracking of joint angles and segment positions throughout a dynamic task [16].

Individual repeated measures analyses of variance (ANOVAs) were performed to examine postural deviations of the head, neck, and shoulder during typing tasks and the effect of adding pillow support under the elbows during tablet typing on head and neck position. Each dependent variable was examined for the main effects of time (10 time points) and task (laptop, unsupported tablet typing, and supported tablet typing) along with the interaction of time and task. To evaluate the proportion of variance in postural deviation explained by task, partial eta squared ($\eta p2$) effect sizes were calculated [17]. Significant main effects of task were followed up using Tukey's post hoc testing. Significant main effects of time were followed up with planned comparisons of position at the first versus fifth minute, first versus tenth minute, and fifth versus tenth minute to show whether changes occurred during the first or last half of the task. To examine any significant interactions, position at each of the 10 time points was examined. Cohen's d was calculated for all significant post hoc and planned comparisons to determine standardized effect size. Effect sizes were interpreted in accordance with Cohen's convention of $\leq$ 0.2 representing a small change, 0.5 representing a moderate change, and $\geq$ 0.8 representing a large change [18].

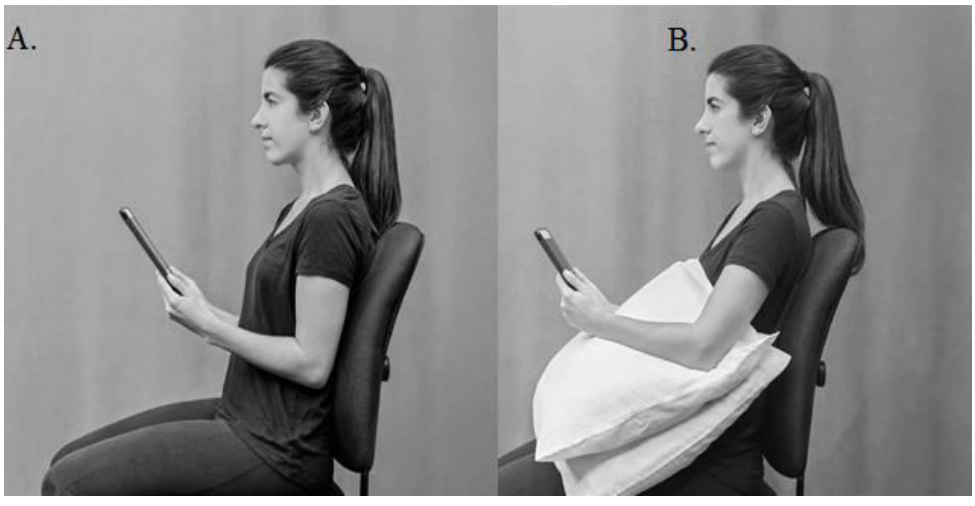

Figure 1: Representative Pre-Task Position for (A) Unsupported Tablet Typing, (B) Supported Tablet Typing

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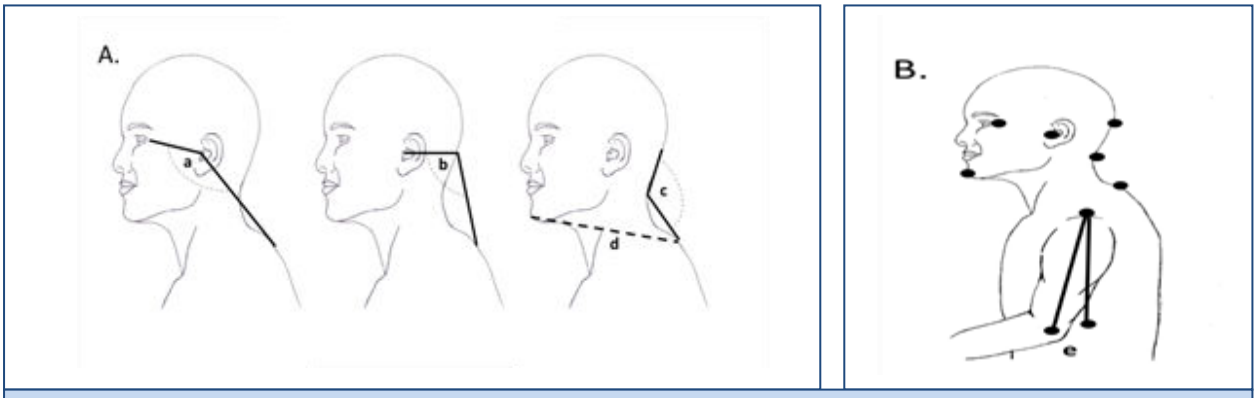

Figure 2: A. Head and Neck Angles: (a) craniovertebral flexion angle: the angle formed between the outer canthus of the eye, the tragus of the ear, and C7; (b) head flexion angle: the angle formed between the tragus of the ear, the occiput and C7; (c) cervical flexion angle: the angle formed between C2/3, the occiput and C7; (d) forward head position: the linear distance measurement between C7 and the chin. B. Marker Placement and shoulder flexion (e): the angle between the thorax, acromion and lateral epicondyle.

RESULTS

Comparison of Head, Neck and Shoulder Position between Unsupported Tablet Typing and Laptop Typing

Head, neck and shoulder position changed significantly across tasks (Table 1) with a bigger change in head and neck position in tablet unsupported typing (Figure 3A-D squares) compared to laptop typing (Figure 3A-D circles).In contrast, there was a bigger change in shoulder position with laptop typing (Figure 3E circles) compared to unsupported tablet typing (Figure 3E squares). Post-hoc testing revealed bigger changes in craniovertebral flexion, headflexion, cervical flexion and forward head position when typing on a tablet compared to laptop typing. These effects were large (Table 1). These results are consistent with large and meaningful increases in head and neck flexion when typing on a tablet.

Effect of Adding Pillow Support to Tablet Typing

Raising the tablet by adding pillow support during tablet typing (Figure 3 triangles) resulted in less change in head and neck position compared to tablet typing without pillow support (Figure 3 squares, Table 1). Post hoc comparisons showed less change in craniovertebral flexion, head flexion, and cervical flexion when tablet typing in a supported position compared to an unsupported position (Table 1). Adding pillow support had a large effect on reducing craniovertebral flexion, head flexion, and cervical flexion (Table 1) but forward head position or shoulder position. Thus, adding pillow support can minimize changes in head and neck position during tablet use.

Effect of Time on Head, Neck and Shoulder Position during Typing Tasks

A task by time interaction was identified for cervical flexion (Table 1). Post hoc analysis showed a difference in slope of change in cervical flexion between time points 3 and 4 for laptop vs. tablet unsupported typing ($p = .001$) and for tablet unsupported vs. tablet supported typing ($p = .043$). There were no statistically significant main effects of time for craniovertebral flexion, but there were for head flexion, forward head position and shoulder flexion. Planned comparisons between position at the first versus fifth minute, first versus tenth minute, and the fifth versus tenth minute showed significant and large effects for the first versus fifth and first versus tenth minutes but not for the fifth versus tenth minutes (Table 1). Consistent with Figure 2, this supports that changes in position occurred at the beginning half of the task but not during the last half.

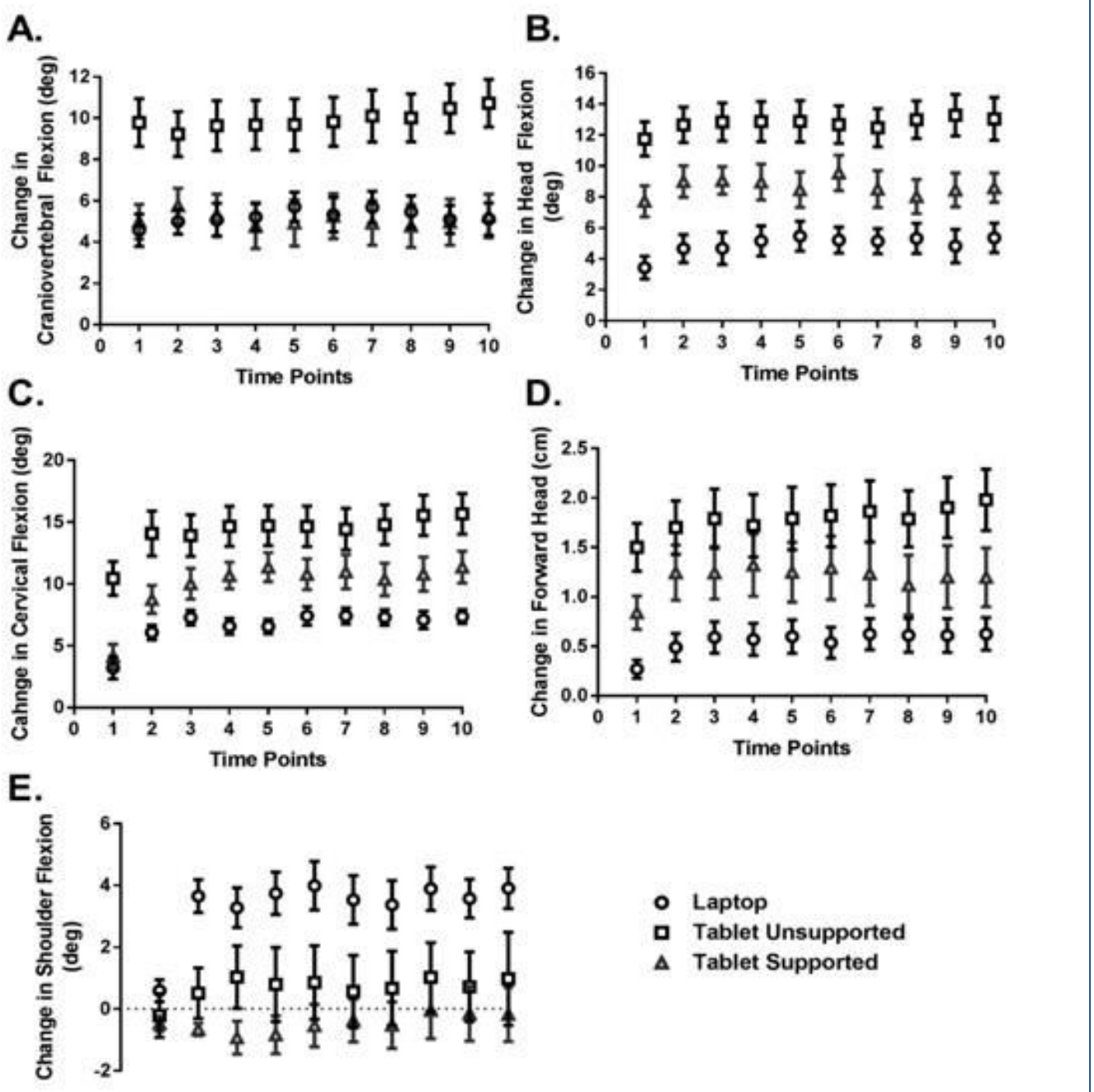

Figure 3: Absolute Change in Head, Neck and Shoulder Position from the Pre-task Rest Position to the Position at the End of Every Minute of Each Ten Minute Task.

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Table 1: Repeated Measure ANOVA (3x10) of Change in Neck, Head and Shoulder Position from the Resting Start Position to Position at the End of Each Minute of the Task with Effect Sizes.

Change in position		F	P	η_p^2	Significant post-hoc results with Cohen's d effect sizes ($CI_{95\%}$)
Craniovertebral flexion	Task	9.09	**.000**	0.26	Tablet Unsupported > Laptop (p=.002, d = 11.95 (7.94, 15.97)) Tablet Unsupported > Tablet Supported (p = .001, d = 12.83 (8.54, 17.12))
	Task x Time	0.76	.622	0.03	
	Time	0.43	.921	0.01	
Head flexion	Task	15.05	**.000**	0.37	Tablet Unsupported > Laptop (p = .000, d = 15.27 (10.20, 20.34)) Tablet Unsupported > Tablet Supported (p = .016, d = 8.60 (5.64, 11.55)) Tablet Supported > Laptop (p = .032, d = 6.62 (4.27, 8.97))
	Task x Time	0.68	.707	0.03	
	Time	2.52	**.043**	0.05	Minute 1 < Minute 5 (p = .036, d = 0.33 (0.60, 1.26)) Minute 1 < Minute 10 (p = .023, d = 0.34 (0.06, 1.27)) Minute 5 < Minute 10 (p = .798, d = 0.02 (-0.91, 0.94))
Cervical flexion	Task	10.72	**.000**	0.30	Tablet Unsupported > Laptop (p = .000, d = 5.57 (3.53, 7.62)) Tablet Unsupported > Tablet Supported (p = .030, d = 2.36 (1.16, 3.56))
	Task x Time	1.94	**.045**	0.07	
	Time	38.89	**.000**	0.43	Minute 1 < Minute 5 (p = .000, d = 1.23 (0.22, 2.24)) Minute 1 < Minute 10 (p = .000, d = 1.37 (0.34, 2.40)) Minute 5 < Minute 10 (p = .059, d = 0.14 (-0.78, 1.07)
Forward head	Task	6.403	**.003**	0.20	Tablet Unsupported > Laptop (p = .002, d = 10.30 (6.81, 13.79))
	Task x Time	0.54	.720	0.02	
	Time	4.96	**.000**	0.09	Minute 1 < Minute 5 (p = .012, d = 0.56 (-0.38, 1.50)) Minute 1 < Minute 10 (p = .005, d = 0.61 (-0.33, 1.56)) Minute 5 < Minute 10 (p = .172, d = 0.09 (-0.83, 1.02))
Shoulder flexion	Task	6.95	**.002**	0.21	Tablet Unsupported < Laptop (p = .038, d = 3.53 (2.06-5.02)) Tablet Supported < Laptop (p = .002, d = 5.20 (3.27-7.14))
	Task x Time	16.27	.198	0.05	
	Time	3.30	**.001**	0.06	Minute 1 < Minute 5 (p = .007, d = 0.87 (-0.10, 1.84)) Minute 1 < Minute 10 (p = .015, d = 1.04 (0.05, 2.02)) Minute 5 < Minute 10 (p = .749, d = 0.05 (-0.87, 0.98))

DISCUSSION

This study examined changes in head, neck, and shoulder position during handheld tablet typing compared to laptop typing, and assessed the effect of adding a pillow support on changes in head and neck position during tablet typing. We hypothesized that while tablet typing would be associated with increased neck and head flexion compared to laptop typing, head and neck flexion would consistently increase across time in the tablet task compared to the laptop task. This hypothesis was partially upheld.Consistent with a study by Riddell et al. (2016) who compared personal computer use to handheld device use and showed that tablet use produced greater cervical spine angles than computer use, we found that tablet typing was associated with significantly increased head and neck flexion compared to laptop typing.We extend these findings however to show that head and neck position changed significantly at the beginning of the trial, but not at the end of the trial. These findings have implications for ergonomic education and intervention.Another novel aspect to the current study was determining how raising the tablet closer to eye level by the addition of external pillow support affected head and neck position during tablet typing. Pillow support significantly improved head and neck position during typing. Understanding how time spent performing mobile computing tasks affects head and neck position may inform recommendations on activity limitations and ergonomic guidelines in response to the increasing use of handheld tablet devices. This will be important in developing strategies for the prevention of neck pain secondary to mobile device use, as well as for recommendations to individuals who already have neck pain.

Changes in personal computing options over the past decade, and an increased use of handheld mobile devices in particular,

necessitate modification of ergonomic instructions for computing [19]. This is driven in part by an increased understanding of the musculoskeletal consequences of sustaining forward postures during dynamic computing tasks, even for relatively short periods of time. Users of mobile devices report pain symptoms primarily in the neck, shoulder and thumb, and symptom severity has been shown to correlate with time spent using devices [20]. Individuals with chronic neck pain have shown a reduced ability to maintain an upright posture when playing a computer game [21]. Prolonged sitting while maintaining a forward head with neck flexed posture as shown during unsupported tablet typing in the current study can induce increased biomechanical stress on the musculoskeletal system [22,23] showed increased biomechanical stress at the seventh cervical and first thoracic vertebrae during a five minute reading task which was minimized by changing the work and sitting surfaces. In the current study, the tablet typing task had a dynamic requirement of typing to it compared to the more static postures typically adopted during reading. Increased head and neck flexion in unsupported tablet typing could be expected to induce similar increased biomechanical loads on the cervico-thoracic junction as previously shown during reading [23,24],used static photographic and radiographic images of subjects after two to five minutes of tablet use to mathematically model gravitational moment changes of the head mass in flexed postures. The ratio of gravitational moment to maximal muscle moment capacity was found to be 3-5 times higher during tablet use compared to neutral posture.Thus, even forward flexed postures of the head and neck sustained for relatively short durations are sufficient to contribute to biomechanical stress on the soft tissues and muscles of the head and neck which has consequences for the development of neck pain.

Compared to typing on a laptop computer, handheld tablet devices offer more choices in how a device can be held (e.g. screen orientation) and how the task can be completed (e.g. using one or both hands).The current study utilized a one handed typing task while holding the tablet in a vertical orientation with the other hand which did not constrain gaze angle.This allowed the tablet to be tilted toward the user compared to a flat tablet in a two handed typing mode.This should have minimized neck flexion during tabletuse [25]. A two handed typing mode would likely have caused even greater head and neck flexion than that seen during the one handed typing mode [7].In the current study we do not know whether the increased head and neck flexion seen in unsupported tablet typing was accompanied by increased cervical muscle activity. However, [26] showed that, compared to corrected upright sitting posture, static seated forward head postures in general are associated with increased neck and shoulder muscle activity. The position of the lower cervical spine has been shown to significantly influence muscle activity levels in contrast to the position of the upper cervical spine [27]. Increased head flexion with tablet use is consistent with that seen in smartphone users where interestingly, head position is also significantly affected by the task used and the general body position. Specifically, head flexion was found to be significantly greater when texting on a smartphone compared to other tasks such as web browsing, and when using a smartphone in sitting compared to standing [15]. However, further study is required to determine the consequences of forward head position on cervical muscle activity during dynamic tablet tasks even of relatively short durations, and how different tablet task features affect head and neck position.

The current study utilized a relatively short dynamic task of 10 minutes and found that once subjects began the task they generally did not modify their head and neck position. During the first part of the task, subjects may have adjusted their initial position to achieve a more sustainable one. Further study is warranted to examine longer duration tasks which could induce more muscular fatigue leading to changes in head and neck position across time. Previous studies have suggested changes in muscle activation attributed to fatigue as a consequence of prolonged maintained postures [28,29]. However, the results of the current study suggest that the position adopted within the first half of the task is representative of the position maintained across a ten-minute time frame. For clinical situations of functional postural evaluation therefore it may not be necessary to assess posture over the full duration of tasks lasting ten minutes or less, although this needs to be further validated across different tasks. In addition to limitations regarding task length and examination of muscle activation patterns, another limitation of

the current study was that postural analysis was only performed in two dimensions.Three dimensional motion analysis may provide additional insight particularly into the coronal and transverse plane components of cervical position and movement during dynamic tasks [30]. However, the methodology used in the current study which utilized offline video analysis provides a useful, cost effective clinically applicable method for assessing changes in posture during dynamic, real world tasks. Additional limitations in this study include the use of a young and healthy population only, a typing task only, and lack of follow-up to assess long-term changes.

The current study has shown that adding pillow support to tablet typing is an effective means of reducing forward flexed positions of the head and neck in individuals without neck pain. Indeed, the effect sizes for these changes were large across all variables ranging from 2.28 to 14.83 (Table 1) suggesting clinically meaningful effects. Previous studies have suggested either a relationship [31-33]or no relationship [34,35] between forward head or neck positions and neck pain. Several studies have also found an association between computer use and neck pain [36,37]. Adding pillow support might be an effective strategy to suggest in individuals with neck pain when they are performing handheld computing tasks, although this should be explored. Understanding the consequences to head and neck position after typing in a prolonged forward head and neck position is another area that should be explored in future studies. Recommendations from a recent review of the state of ergonomics for mobile computing technology included a suggestion to avoid usage in non-neutral postures for long periods of time although no specific time limit was suggested [38]. The results of the current study suggest that even relatively short periods of tablet use might have small but potentially meaningful postural consequences and this should be examined when determining safe time limits for tablet use.The results of the current study support additional investigation to determine possible consequences of these postural changes with tablet use, and to investigate the effects of education or exercise on mitigating these postural changes.

CONCLUSION

In conclusion, typing on a handheld tablet can be associated with increased head, neck and shoulder flexion compared to typing on a laptop. A relatively simple correction of raising the tablet by adding pillow support to the forearms can be an effective way to reduce forward head and neck positioning during short term tablet typing.Increased head and neck flexion during mobile computing for even short periods has potential implications for the development of neck pain.

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