An Investigation of an Ergonomic Intervention on Neck Biomechanics and Pain due to Smartphone Use

THESIS

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By

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Abstract

An engineering control-type intervention was investigated, that was hypothesized to reduce awkward neck posture while viewing a smartphone display (as when reading or typing). The intervention, a pair of eye glasses that incorporated a 90 deg prism in each lens, was hypothesized to reduce neck and head flexion in smartphone users. Fifteen symptomatic subjects with neck pain and 10 asymptomatic subjects were recruited. Subjects performed a 10 minute texting task on their smartphone in four conditions: standing or sitting with or without wearing the prism glasses. Muscle activity in neck (cervical erector spinae) and shoulder (upper trapezius) muscles, neck flexion, head tilt, discomfort level, speed, accuracy, and subjective perceptions were assessed. The prism glasses significantly reduced neck extensor muscle activity, neck flexion, and head tilt when compared to the direct view. In the symptomatic group, the intervention method resulted in significantly less neck and shoulder discomfort at the conclusion of the task when compared to the direct view, irrespective of posture (standing or sitting). The ergonomic intervention in this study appears to offer an alternative method to interact with a smartphone that could reduce the exposure to the pronounced flexed neck and head posture that is so commonly seen in smartphone users, and thereby could reduce musculoskeletal discomfort in the neck region that is associated with smartphone use.

Keywords: Smartphone; Intervention; Musculoskeletal discomfort; Prism; Glass
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Fields of Study

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Chapter 1: Introduction

1. Background

New technologies have expanded the horizon of cellphones. Smartphones, similar to computers with an operating system and numerous software applications, enable people to work and be entertained in almost any location. Smartphones are now ubiquitous. According to recent data, smartphone penetration rate already exceeded 73% globally in 2015 (Meeker 2015). In America, according to the 2014 mobile behavior report conducted by Salesforce (2014), 85% of people said that mobile devices are a central part of everyday life; on average, people spend 3.3 hours per day on smartphones. Emailing, texting, and using social media are the three primary ways for people to connect and communicate with others (eMarketer 2013). With the increase of smartphone intensity and duration of use, concerns of musculoskeletal disorders associated with smartphone use have increased.

Recent studies showed that reported pain symptoms in the neck, shoulders and thumb were associated with smartphone use, and the severity was related to the total time spent using a smartphone (Berolo et al. 2011). Average head flexion angle of 33-45 deg during smartphone use was observed by Lee et al. (2015), in a laboratory study.
Numerous studies have identified prolonged neck flexion as a risk factor associated with neck pain (Jonsson 1988, Ohlsson et al. 1995, Andersen et al. 2002). Although ergonomics recommendations, based on some studies, have suggested avoiding sitting with head bent forward in order to prevent neck pain (Gustafsson 2012), such behavioral recommendations have not provided a specific means by which to avoid neck flexion during smartphone use. Based on the safety hierarchy of controls, the effects of warning and training are temporary; workers are likely to resume their old habits, which limit the effects of this level of intervention. More effective interventions are engineering controls, which change the interface between a worker and the task, thereby altering the worker’s exposure to a hazardous condition.

Prism Glasses, which turn the vision to a downward 90 degree angle, seem to offer an effective way to eliminate neck flexion (Figure 1). One study showed that prism glasses significantly reduced muscle activity, neck flexion, and discomfort, as compared to the direct view in simulated dental hygiene work (Smith et al. 2002). The efficacy, usability, desirability, and efficiency of wearing prism glasses during smartphone use are unknown.
2. Specific Aims

The purpose of the current study is to examine the efficacy, usability, desirability, and efficiency of the intervention of prism glasses worn by users with and without neck pain on smartphone use.

3. Literature Review

Given its capability and portability, the smartphone, one type of Video Display Unit (VDU) that includes computers, and laptops, etc., has become ubiquitous. Based on the analysis from Khalaf (2014), it was found that time spent on mobile devices grew in
the US by 9.3%, which was from 2 hours and 42 minutes to around 3 hours per day in nine months (from Q1 to Q3 in 2014), while time spent on TV has been stagnant, which was 2 hours and 48 minutes according to a 2014 US Bureau of Labor Statistics report (BLS 2014). Overall, time spent on Desktop or Laptop computers has been fluctuating between 2.2 hours and 2.6 hours per day, from 2008 to 2015, while smartphone use has increased almost ten-fold from 0.3 hour per day to 2.8 hours over the same 7 year time period (Figure 2)(Meeker 2015). A 2014 mobile behavior report found that, on average, people self-reported spending 3.3 hours per day on smartphones (Salesforce 2014). Therefore, on average, Americans appear to spend more time on mobile devices than on TV or Desktop or Laptop computers; mobile devices have become the primary VDU in the US in terms of time spent per day.
With the intensity of smartphone use increasing, ergonomic concerns for associated Musculoskeletal Disorders (MSDs) also increases. Most smartphone tasks (emailing, texting, browsing web, watching videos, and playing games) are typically performed with users looking downwards (Lee et al. 2015). More daily time spent using a hand held mobile device was found to be associated with a greater likelihood of reporting recent neck pain (Berolo et al. 2011); this finding may be associated with prolonged neck flexion during use of these mobile devices.
This chapter presents a literature review of neck pain and its risk factors, by examining studies of incidence and prevalence of neck pain, general risk factors that may be relevant to smartphone use, and the effect of current interventions.

**Incidence and Prevalence of Neck Pain**

Neck pain is a common problem. Symptoms of the pain not only can be present in the neck itself, but can be headaches, and/or numbness or tingling into the upper extremity. Neck pain may originate from any of the pain sensitive structures in the neck such as the vertebral bones, the ligaments, the nerve roots, and the particular muscles, etc. (Delisa et al. 1988). Studies have shown that neck pain is associated with significant disability and economic cost in the general population (Hogg-Johnson et al. 2008). According to International Association for the Study of Pain, neck pain affects 30%-50% of the general population annually, 15% of which will experience chronic neck pain (over 3 months) at some point in their life spans (IASP 2009). Korhonen et al. (2003) showed a 34.4% incident neck pain among office employees working with VDUs, and poor physical work environment and poor placement of the keyboard increased the risk of neck pain. Cagneie et al. (2007) found 45.5% 12-month prevalence of neck pain among office workers and indicated that neck pain was significantly associated with holding the neck in a forward bent posture for a long period of time (OR=2.01). The results of the study also showed that psychosocial factors are associated with the frequency of neck pain. Chiu et al. (2002) investigated a 1-year prevalence of neck pain and possible risk factors.
factors among university academic staff in one of the universities in Hong Kong and found the 1-year prevalence of neck pain was 46.7%. The study also indicated that gender was significantly associated with neck pain \( (p = 0.02) \), in which the percentage of females with neck pain (62%) was higher than that in male (38%). Among those with neck pain during VDU tasks, 60.5% had a forward head posture (Chiu et al. 2002).

**Risk Factors for Neck Pain**

A typical posture of smartphone users involves holding the device using one or two hands below eye height with eyes looking down and neck flexed, and using the thumbs to control the device (Lee et al. 2015)(Figure 1). Risk factors are examined that entail similar activity or posture in smartphone users in this review.

**Repetition and Neck Pain**

Studies commonly address repetition as cyclical activities that involved either repetitive neck movements (e.g., the frequency of different head positions during a cycle) or repeated arm/shoulder motions that generate loads to the neck/shoulder area (e.g., trapezius muscle) (Bernard 1997).

In one cross-sectional study (Ohlsson et al. 1995), physical examinations on neck and upper limbs were conducted to compare 82 female industrial assembly-line workers exposed to repetitive work tasks with short cycles (<30 seconds) and 63 workers without exposure to repetitive work tasks. The results showed that repetitive work was
statistically and significantly associated with neck diagnoses (OR = 4.6) and diagnosis of tension neck syndrome (OR = 3.6).

Hünting et al. (1981) conducted physical exams and an extensive exposure assessment using questionnaire, observation, and measurements of workstations and body posture measurements to compare 162 Video Display Terminals (VDTs) users and 133 traditional office workers who involved a diversity of movements. The results showed that VDTs users, whose tasks required more repetitive work than traditional office workers, found an OR of 9.9 in comparison.

In Ranney et al. (1995), physical examination was 146 female workers in highly repetitive job, and the results showed that 31% of them had evidence of Neck MSDs.

Bernard (1997) examined over 40 epidemiologic studies for the evidence for a causal relationship between highly repetitive work and neck MSDs. The results showed that repetitive work involving continuous arm or hand movements which generate loads on neck area was an important risk factor for neck pain.

In sum, tasks that require repetitive movements of arm or hand can be a risk factor for neck pain. Back to the common use of smartphone, emailing, texting, and using social media are the three primary tasks for people to connect and communicate with others (eMarketer 2013). Although no studies have yet been conducted to examine the relationship between repetitive arm or hand movements and neck pain during smartphone use, repetitive movements resulting from these tasks might have similar effects on neck pain. Although, the repetitive activity during smartphone use tends to be focused on the
thumbs, somewhat larger motions or gestures are used while searching for information or gaming.

**Prolonged Static Awkward Posture and Neck Pain**

Studies commonly address the association between neck pain and static or awkward postures of the neck or arm abduction/elevation of the arm (Bernard 1997).

Ohlsson et al. (1995), mentioned previously, also found a significant association between diagnoses in the neck/shoulders and time spent in neck flexion greater than 15° and elevation/abduction of the arm greater than 60° (p=0.005).

A cross-sectional study (Bergqvist et al. 1995) used medical examination, workplace investigation, and questionnaires to explore the risk factors to MSDs among 260 VDT users. Results showed that workers using highly placed keyboards was associated with neck MSDs (OR = 4.4). Therefore, just holding up the smartphone to reduce neck flexion may not be helpful overall.

In Lee et al. (2015), neck flexion angles were measured from 18 participants who used a smartphone to perform some basic tasks such as texting, web browsing, and video watching in standing and sitting postures. The results showed that neck flexion was between 33° to 45°. A cervical spine model was created by Hansraj (2014) with realistic values in Cosmosworks for smartphone users, and calculated the forces on the cervical spine with different degrees of neck flexion (Figure 3). The results showed that the force
on the cervical spine increases markedly from neutral to 60° of flexion, with 10-12 pounds at neutral, 27 pounds at 15°, 40 pounds at 30°, 49 pounds at 45°, and 60 pounds at 60° of flexion. With these two studies combined, it seems that smartphone users may experience up to a fourfold increase in load on the cervical spine as compared to the neutral posture as illustrated in Hansraj (2014).

Figure 3: The weight seen by the spine increases when flexing the neck at varying degrees.

(Retrieved from Hansraj (2014))

Further, Bernard (1997) examined over 40 epidemiologic studies for the evidence for causal relationship between neck MSDs and prolonged static loads, or poor postures at neck/shoulder muscles. Twelve studies showed statistically significant results with
ORs over 3.0, suggesting strong evidence that prolonged static poor postures involving the neck/shoulder muscles are risk factor for neck pain.

Apart from the exhibited poor posture, in Berolo et al. (2011), prolonged use of a mobile hand held device was significantly associated with neck pain (OR = 2.72) and shoulder pain (OR = 2.55). Studies also showed a trend of increasing neck flexion as the time elapses (Hashimoto et al. 2015, Kim 2015), which may further exacerbate neck pain symptom. In a recent study, people with neck pain were found to assume a more neck flexed posture during three 5 min. periods of smartphone use as compared to those without neck pain (Kim 2015).

Neck flexion increases cervical muscle activity (Sommerich et al. 2001). Holding a posture for an extended period of time induces localized muscle fatigue, which is associated with continuous activation of low force/low threshold muscle fibers (Thorn et al. 2002), a main contributor to the development of tension neck syndrome and neck pain in VDT workers and others who perform semi-static tasks (Hagberg et al. 1995, Sjogaard and Sogaard 1998). Tasks that involve neck flexion and arm abduction are a risk factor for neck pain. As people are commonly observed with neck flexion during smartphone use, this prolonged static poor posture deserves more attention.
Ergonomic Interventions

The effect of rest breaks (Galinsky et al. 2000), training on ergonomics (Peper et al. 2004), using arm support (Rempel et al. 2006), and pointing devices (Aaras et al. 1999, Rempel et al. 2006) have been examined and suggested as interventions to either prevent or reduce neck MSDs among VDT users. However, among these intervention methods, there are also studies that showed that rest breaks (McLean et al. 2001), training on ergonomics (Greene et al. 2005), and using arm supports (Lintula et al. 2001) found no effect on neck MSDs. Workstation adjustment was found to have no effect on neck MSDs (Ketola et al. 2002, Cook and Burgess-Limerick 2004). Two systematic reviews further examined these interventions and found no strong evidence that any specific ergonomic interventions had positive effects on MSDs (Brewer et al. 2006, Andersen et al. 2011). In sum, the finding shows that the effect of the interventions on neck MSDs among VDU users is equivocal. Further investigation of these interventions may be needed.

The interventions for smartphone use are scarce. Hashimoto et al. (2015) examined the effect of an awareness signal displayed on smartphone to alert users to poor posture in the middle of a 5 minute task. The results showed that poor postures of the upper extremity were improved right after the signal. However the postures worsened again as time elapsed. The authors suggested that a more effective warning protocol should be developed (Hashimoto et al. 2015). Gustafsson et al. (2011) compared smartphone users with MSDs in neck and/or upper extremities with those without
symptoms, and found that a greater proportion of the latter group used back and forearm support with a more neutral head position as compared to the former group. Based on the results, it was recommended to use forearm support and avoid sitting with neck flexion to prevent MSDs during smartphone use. A comparison study examined the difference in muscle activity between 20 young people with neck-shoulder pain and 20 asymptomatics on three tasks: typing with both hands on the smartphone, with only one hand on the smartphone, and with both hands on a computer keyboard during sitting (Xie et al. 2016). The results indicated higher muscle activity in the cervical erector spinae and upper trapezius on all three tasks in the symptomatic group. The authors suggested that there is a need for new ergonomic guidelines specifically to aide people to interact with smartphones in more neutral postures and with lower muscle activity, in order to reduce postural discomfort associated with smartphone use.

Prism Glasses that turn the vision to a downward 90 degree angle seem to be an effective way to eliminate neck flexion. The use of prism glasses is suggested by occupational therapists for patients with restricted neck flexion ability. In Smith et al. (2002), prism glasses were used as one of the intervention methods for dental hygienists to reduce neck flexion in work. The results showed that prism glasses significantly reduced muscle activity, neck flexion, and discomfort, compared to the direct view in dental hygiene work. Clinically, a case study showed prism glasses successfully treated a patient with chronic, intractable, right-sided neck pain after radical neck dissection (Bartley et al. 2014).
Conclusion

Smartphones are now ubiquitous. The time spent using smartphones has increased almost ten-fold from 2008 to 2015 (Meeker 2015), and has reached, by other estimates, an average at 3.3 hours per day (Salesforce 2014). Peak hours of use occurred in the morning from 8 am to noon (Salesforce 2014), and the duration was typically around 10 mins per hour. Emailing and texting are two primary ways for people to connect and communicate with others (eMarketer 2013). Prolonged static neck flexion with eyes looking down has been observed in smartphone use. This review of the literature shows high incidence and prevalence of neck pain among those with repetitive movements of arm or hand and those with prolonged static neck flexion. Interventions that addressed these risk factors among VDU users and smartphone users were reviewed. The results have not found any effective engineering controls that could reduce or prevent neck pain among smartphone users by directly aiding in reducing neck flexion. Prism glasses seem to offer an alternative method to reduce or even eliminate neck flexion. However, the efficacy, usability, desirability, and efficiency from wearing prism glasses during smartphone use are unknown. Further studies on the prism glasses among smartphone users are recommended. It was hypothesized that the use of prism glasses could reduce neck flexion, neck extensor muscle activity, lower the discomfort from neck pain, and maintain similar productivity.
Chapter 2: Methods

The objective of this study is to assess the potential usability and biomechanical benefits of wearing prism glasses while using a smartphone, in an attempt to reduce the pronounced neck flexion that is commonly seen among smartphone users.

Experimental Design

Given that people use their smartphones while standing and sitting, study subjects were asked to perform an emailing task in both standing and sitting postures. These tasks were done with and without wearing prism glasses. This means that a total of 4 task conditions were examined. During sitting, subjects sat on a chair with forearm support and back support as recommended by Gustafsson et al. (2011)

The independent variables in this study are listed below:

- Independent within subjects variables:
  - Posture (Sitting, Standing)
  - Viewing method (Direct view, Prism view)

- Between subjects (or grouping) variables:
Neck Pain (with, without)

The duration of each task was fixed at 10 min. The sequence of tasks was counterbalanced to control carryover effects and every subject was assigned a different order. This study utilized a repeated measure design, wherein all subjects experienced all testing condition.

The dependent variables were:

1. Muscle activity. Electrodes were placed bilaterally over 4 muscles:
   a. left cervical erector spinae
   b. right cervical erector spinae
   c. left upper trapezius muscle
   d. right upper trapezius muscle.

2. Head Motion. This variable is important as it indicates if there is any difference in the amount of head movement between direct view and prism view.

3. Posture: Neck Flexion, Head Tilt, and Phone Tilt Angles were assessed at the third minute and at the ninth minute of each task (Figure 4). Neck Flexion and Head Tilt angles were also assessed at the baseline. One marker was placed on the C7. A previous study used the same method of measuring neck flexion and head tilt angles (Smith et al. 2002). These variables are important as awkward posture is one of the risk factors for MSDs.
Figure 4: Posture angles for posture assessment.

4. Productivity. In each task, the subject performed a typing task, which was an assigned paragraph, which was sent to the researcher in an email, for analysis. The total characters typed per task were assessed in order to calculate the typing speed, in characters per minute. This variable is important as the implementation of an ergonomic intervention often requires that productivity levels are maintained or improved.
5. Accuracy. The number of errors per 100 characters in each task was measured to determine the accuracy. This variable is important because accuracy to some extent determines the acceptance of an ergonomic intervention.

6. Discomfort questionnaire and final survey: Before and after each task, the subject used a 10-point discomfort scale to report any discomfort in the neck. A variation of Borg Scale for evaluating neck discomfort was used with a 10-point scale (Borg 1990). After completing all four tasks, the subject filled out a final survey concerning his/her preferences between direct view and the use of prism glasses for neck comfort, productivity and accuracy. It is important to determine if subjective assessments do or do not support the objective measurements.

Subjective assessments can also provide ideas for improvement of the design, barriers to use, etc.

**Participants**

This study recruited 25 subjects (11 females and 14 males) aged 26.2 ± 5.3 years: 15 subjects with ongoing neck pain symptoms during the last 12 weeks, and 10 subjects without neck pain during the last 12 weeks as the control group. Flyers containing a brief description of the study and contact information were posted in the Ohio State University campus and Ohio State University Comprehensive Spine Center.

Qualifications for participation include:
1. Being 18 years of age or older, AND
2. Having at least 1 year of experience using a touchscreen Android smartphone or iPhone, AND
3. Not needing eye glasses to read your smartphone (contact lenses are ok), AND
4. Ability to stand unassisted for 10 minutes while using your smartphone, AND
5. Having no history of neck surgery, neck trauma, or debilitating neck pain.

A copy of the flyers appears in the Appendix of this document.

This sample size is similar to other lab-based intervention studies that used electromyography as a dependent measure. Based on the result of a mini-pilot study muscle activity levels and neck flexion angles were noticeably different between the two viewing methods (Figure 4).
Figure 5: Postures with and without Prism Glasses in the mini pilot study.

An intervention study done by Smith et al. (2002) involved 12 students and 5 dental hygienists to determine the benefits of the use of prism glasses, and found statistically significant differences in cervical muscle activity and neck flexion angles as compared to the direct viewing method (p<0.001). In Kim (2015), 13 control subjects and 14 subjects with mild neck pain were recruited to determine the influence of neck pain on cervical movement in the sagittal plane during smartphone use. Results showed that the cervical spine was more flexed in the mild neck pain group than in the control group (p < 0.05). Hence 15 symptomatic subjects and 10 asymptomatic subjects were considered to
be sufficient for the current study, as the variables to be measured were similar with these previous studies.

**Restrictions / Selection Criteria**

The subjects had to be at least 18 years old, and have at least one year of experience with touchscreen Android smartphones or iPhones. In order to meet the requirement of this study, potential subjects were excluded if they required the use of reading glasses; use of contact lenses was allowed. The subjects had to be able to stand unassisted for 10 minutes while typing on their smartphone. Individuals with a history of neck trauma or surgery, or debilitating neck pain, or with medical diagnosis of fibromyalgia, cervical radiculopathy, or headache aggravated by reading, or allergy to hypoallergenic adhesive tape were excluded from this study. All subjects were assigned into either the Control Group or the symptomatic group based on their Neck Disability Index (NDI) Score. Subjects with the Index score $\geq 8$ (out of a total possible score range of 0 to 50) were assigned to the Neck Pain Group, and the rest were in the control group. The NDI contains 10 questions used to determine the severity of neck pain affecting a person’s daily life. The NDI has been demonstrated to achieve a high degree of reliability and internal consistency (Vernon and Mior 1991). An NDI score equal or over 8 has been used as the threshold to identify subjects with neck pain (Kim 2015, Xie et al. 2016). If any of the items in NDI exceeded a score over 3 (too much pain), the potential subject was excluded through the screening process.
The protocol was approved through OSU’s Institutional Review Board process (protocol number 2016H0005, approval date 23 Feb. 2016).

**Apparatus**

1. A chair with adjustable height and adjustable arm support
2. A pair of prism glasses (i90 Tablet Glasses. Matt Franklin, Portland, OR) (128 grams) (Figure 6)

![Figure 6: i90 Tablet Glasses. Matt Franklin, Portland, OR](image)
3. Delsys Bagnoli-8 Surface Electromyographic system (Boston MA) and the MotionMonitor data acquisition system (Innsport, Chicago, IL).

4. Activpal™ (Physical Activity Technologies, Glasgow, Scotland)

5. Two video cameras, located directly to the right side of the subject approximately 2 meters away, were activated to record the subject’s posture during the standing and sitting tasks, respectively, to avoid wasting time on changing camera position from sitting height to standing height during the study.

Data collection procedures

The subject was provided with the consent document upon arrival for study participation. After reviewing and signing the consent document, the subject was provided with the recruitment incentive. General subject data (age and weight) and anthropometry data (height, shoulder height, popliteal height, seat pan height, and sitting shoulder height) were measured.

The subject was prepared for surface electromyographic (sEMG) recording. A razor was used to remove hair and then alcohol wipes were used to clean the surface of the skin over the four areas where the electrodes would be placed. Surface electrodes were then attached to the skin over the left and right cervical erector spinae, and left and right trapezius muscles. Cervical erector spinae electrodes were place 2 cm from the midpoint at C3 (Schuldt and Harms-Ringdahl 1988), and the trapezius electrodes were
placed 2 cm lateral to the midpoint of a line from C7 to the acromion (Jensen et al. 1993). Once adequate signals were confirmed, subjects were asked to maintain neutral head posture during standing and sitting. These data served as the baseline activity for each muscle, to which muscle activity during the tasks would be compared. The set-up procedure for the Activpal™ was conducted to activate the device and then it was mounted on the subject’s forehead with sticky tape (PalStickie). Activpal data were recorded for the whole session.

The subject was asked to sit and stand comfortably in an upright position, gently moving the head fore and aft with eyes closed, and then settling into what felt to him/her to be a comfortable, neutral, balanced posture. EMG muscle activity was sampled in this postures for the baseline. Those neutral (baseline) postures for sitting and standing were also recorded by the video cameras.

In order to control carryover effects, which would interfere with the results, the sequence of the four tasks (Figure 7) was counterbalanced. The sequence for each subject was randomly assigned; each subject performed the tasks in a different order.

- Standing with direct view
- Standing with the use of prism glasses
- Sitting with direct view
- Sitting with the use of prism glasses.
Figure 7: The four tasks in the study: (a) standing, direct view, (b) standing, prism view, (c) sitting, direct view, (d) sitting, prism view.
During each task, the first EMG data were acquired during the third minute of the 10 minute task, allowing the first two minutes for subject to get accustomed to the task condition. EMG data were acquired during minutes 3 through 9, which provided 7 samples of EMG data for each task condition.

In each task, the subject typed an assigned paragraph into an email, which was sent to the researcher after the task. The paragraph was typed repeatedly throughout the 10 min. period. Each paragraph was printed on paper with the size similar to a sticky note and it was taped on the top of the subject’s smartphone. Five different paragraphs were used in this study (1 for the practice and 4 for the 4 tasks). Each paragraph was derived from novels with similar length at around 100 words and similar readability of Flesch-Kincaid Grade Level at around 9. The 4 paragraphs used in the tasks were also counterbalanced and the sequences were randomly assigned to the subjects. Before typing, the subject was instructed to focus on the accuracy instead of speed.

Immediately before and after each task, the subject was asked about his/her level of discomfort, using a 10-point discomfort scale, a variation of the Borg Scale (Borg 1990), to assess the neck and shoulder discomfort. The duration of each task was 10 mins. Between each task, a 5 minute break was given. Longer breaks were provided as needed in order to return the subject to a lower level of discomfort if discomfort had increased during the task.
When all four tasks were finished, the subject completed a final survey concerning his/her preferences between the direct view and the use of prism glasses, regarding neck comfort, productivity, accuracy, and suggestions for the prism glasses.

The total time for each session was about 1.5 hours.

Data Processing

EMG data were collected at 1000 Hz, band pass filtered (20 and 500 Hz), and notch filtered at intervals of 60 Hz. Data were collected for 10 s during minutes 3 through 9 of each 10 min. task, for a total of 7 samples for each task. At the end of the data collection session the EMG data were exported from the Motion Monitor system and were processed using a custom MATLAB program (Matlab 2014R), that included several steps (rectification, 75 ms moving average smoothing, and Hanning filter). Task data were normalized by dividing by the baseline activity level. 10th and 50th percentile muscle activity values were examined in the statistical analysis.

The processing of the ActivPal ™ data was performed in Microsoft Excel 2010. The data were divided into sections (one section per excel sheet, each of which then contained the data for one of the tasks). The standard deviation was calculated using SPSS to reflect the variation of the head motion activity.

The processing of the video footage was performed in Adobe Photoshop CS5.1. Images at the baseline, the third minute, and the ninth minute were derived from the
footage. The neck flexion, head tilt, and phone tilt angles were then measured with tools in Photoshop.

The processing of the speed and accuracy were performed in Microsoft Word 2010 using word count and compare functions, respectively.

**Statistical Analysis**

The data were first checked for normality and equality of variance. Two sample t-test and paired t-test techniques in SPSS were used to analyze the effects of the independent variables (viewing methods, posture, and group) on the dependent measures (posture, discomfort, productivity, and accuracy). The Sign Test was used to analyze the effects on muscle activity.
Chapter 3: Results

3.1 Subject Characteristics

Tables 1 and 2 present and compare the demographic characteristics and preference and patterns for smartphone usage between the symptomatic and control groups. All the data were normally distributed (Shapiro-Wilk test, \( p > 0.05 \)). The mean NDI scores were 11.4 ± 4.1 and 10.7 ± 2.3 in the symptomatic group for females and males, respectively. The mean NDI scores were 2.0 ± 2.5 and 2.1 ± 2.1 in control group for females and males, respectively. The NDI scores were significantly different between the symptomatic group and control group (independent t-test, \( p < 0.001 \)). Other than that, there was no significant difference between groups on age, weight, height, phone weight and total self-reported time spent on smartphone per day (independent t-test, all \( p > 0.05 \)).
<table>
<thead>
<tr>
<th></th>
<th>Symptomatic Mean (SD)</th>
<th>Control Mean (SD)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Female</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Subjects</td>
<td>9</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>NDI Score</td>
<td>11.4 (4.1)</td>
<td>2.0 (2.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age (years)</td>
<td>26.1 (5.6)</td>
<td>25.5 (0.7)</td>
<td>0.761</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>61.7 (13.8)</td>
<td>60.6 (6.2)</td>
<td>0.877</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>164.9 (6.5)</td>
<td>169.2 (5.5)</td>
<td>0.454</td>
</tr>
<tr>
<td><strong>Male</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Subjects</td>
<td>6</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>NDI Score</td>
<td>10.7 (2.3)</td>
<td>2.1 (2.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age (years)</td>
<td>26.2 (5.3)</td>
<td>26.6 (6.1)</td>
<td>0.884</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>75.8 (14.7)</td>
<td>83.6 (6.5)</td>
<td>0.270</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>173.4 (7.4)</td>
<td>181.0 (7.4)</td>
<td>0.082</td>
</tr>
</tbody>
</table>

Table 1: Demographic characteristics for symptomatic and control groups.

<table>
<thead>
<tr>
<th></th>
<th>Symptomatic (n = 15)</th>
<th>Control (n = 10)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phone Brands</strong> [proportion]</td>
<td>iPhone = 53.3%</td>
<td>iPhone = 50%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Android = 46.7%</td>
<td>Android = 50%</td>
<td></td>
</tr>
<tr>
<td><strong>Phone Orientation</strong> [proportion]</td>
<td>93.3% Portrait</td>
<td>100% Portrait</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.7% Horizontal</td>
<td>0% Horizontal</td>
<td></td>
</tr>
<tr>
<td><strong>Typing Style</strong> [proportion]</td>
<td>93.3% both hands type</td>
<td>100% both hands type</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.7% left hand holds, right hand types</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Phone Weight (gram) [mean (SD)]</strong></td>
<td>140.9 (20.2)</td>
<td>140.6 (19.4)</td>
<td>0.974</td>
</tr>
<tr>
<td><strong>Total self-reported time on Smartphone (hours/day) [mean (SD)]</strong></td>
<td>3.2 (2.8)</td>
<td>3.9 (3.3)</td>
<td>0.616</td>
</tr>
</tbody>
</table>

Table 2: Subjects' preference and pattern on Smartphone
3.2 Muscle activity comparisons between groups

Tables 3 and 4 showed the cervical erector spinae and trapezius muscle activity comparisons of viewing methods (direct view and prism view) and posture (standing and sitting) of the symptomatic and control groups. The processed EMG data were first normalized by using average muscle activity during the task divided by the average baseline activity. The sign test was used in this analysis due to nonparametric nature of the data, including large differences in variance between data samples and non-normal distributions. The sign test was used to determine if the ratio of normalized EMG data for the samples of interest were equal to 1 or not. For example, in table 3, for comparing the muscle activity in symptomatic group, the ratio of left cervical erector spinae muscle activity in standing-direct view divided by standing-prism view was 1.7 (sd = 0.6) suggesting that, on average, for the symptomatic group the muscle activity while standing was 1.7 times higher when looking directly at the screen (direct view) than when using the prism glasses (prism view).

3.2.1 Direct View vs. Prism View

Looking across symptom groups, tables 3 and 4 show both the 10th or 50th percentile cervical erector spinae muscle activities when using the direct view were all significantly higher than the muscle activity during the prism view (sign test, all p < 0.05).
In terms of the trapezius muscle, for the symptomatic group while standing, both the 10\textsuperscript{th} and 50\textsuperscript{th} percentile trapezius muscle activities in direct view were significantly higher than the ones in prism view. However, for the symptomatic group while sitting, irrespective of 10\textsuperscript{th} or 50\textsuperscript{th} percentile, there were no significant differences found between the trapezius muscle activities in direct view and the ones in prism view (sign test, all $p > 0.05$).

There were no significant differences found between the trapezius muscle activity in the control group between direct view and prism view (sign test, all $p > 0.05$).

### 3.2.2 Standing vs. sitting

As tables 3 and 4 show, looking across viewing methods and symptom groups irrespective, there were no significant differences found for the cervical erector spinae muscles between standing and sitting posture (sign test, all $p > 0.05$).

In terms of trapezius muscles, in the direct view irrespective of symptom groups in both the 10\textsuperscript{th} and 50\textsuperscript{th} percentile, the trapezius muscle activities in standing posture were significantly higher than the ones in sitting posture.

In the prism view irrespective of 10\textsuperscript{th} or 50\textsuperscript{th} percentile, the trapezius muscle activity in the symptomatic group was not affected by posture (sitting v. standing) (Sign test, $p > 0.05$). However in the prism view irrespective of 10\textsuperscript{th} or 50\textsuperscript{th} percentile, the trapezius muscle activity in the control group was significantly higher during standing than during sitting (Sign test, $p < 0.05$).
<table>
<thead>
<tr>
<th></th>
<th>Ratio</th>
<th>%ile</th>
<th>Cervical Erecter Spinae</th>
<th>Trapezius</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LEFT</td>
<td>Mean (SD)</td>
<td>p-value</td>
<td>LEFT</td>
</tr>
<tr>
<td>Standing</td>
<td>Direct</td>
<td>10th</td>
<td>1.7 (0.6)</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Standing</td>
<td>50th</td>
<td>1.8 (0.7)</td>
<td>0.001</td>
</tr>
<tr>
<td>Sitting</td>
<td>Direct</td>
<td>10th</td>
<td>1.7 (0.6)</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Sitting</td>
<td>50th</td>
<td>1.9 (0.7)</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Standing</td>
<td>Direct</td>
<td>10th</td>
<td>0.9 (0.2)</td>
</tr>
<tr>
<td></td>
<td>Standing</td>
<td>50th</td>
<td>1.0 (0.3)</td>
<td>0.570</td>
</tr>
<tr>
<td></td>
<td>Sitting</td>
<td>Direct</td>
<td>10th</td>
<td>1.0 (0.2)</td>
</tr>
<tr>
<td></td>
<td>Sitting</td>
<td>Prism</td>
<td>50th</td>
<td>1.0 (0.2)</td>
</tr>
</tbody>
</table>

Table 3: Muscle activity comparison in symptomatic group.
Table 4: Muscle activity comparison in control group.

3.3 Neck flexion and head tilt comparisons between groups

Neck flexion is the angle from the vertical to a line from C7 to the tragus; head tilt is the angle from the horizontal to the eye-ear line (Fig. 4). Tables 5, 6 and 7 show the neck flexion and head tilt comparisons as a function of viewing methods (direct view and prism view), postures (standing and sitting), and symptoms (symptomatic and control), respectively. All angles (in degrees) were obtained by averaging the angles in the 3rd
minute and 9th minute, and then subtracting the baseline (neutral posture angles) from the averaged angles during the tasks. This variable showed how the postures in the task differed from their baselines.

### 3.3.1 Symptomatic group vs. Control group

As table 5 shows, in the tasks, irrespective of posture (standing or sitting) and viewing method (direct view or prism view), the neck flexion and head tilt angle differences from baseline (neutral postures) were not significantly different between the symptomatic group and the control group (independent t-test, all $p > 0.05$).

<table>
<thead>
<tr>
<th>Posture</th>
<th>Method</th>
<th>Symptom</th>
<th>Neck Flexion in degree (°)</th>
<th>p-value</th>
<th>Head Tilt in degree (°)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean (SD)</td>
<td></td>
<td>Mean (SD)</td>
<td></td>
</tr>
<tr>
<td>Standing</td>
<td>Direct View</td>
<td>Symptomatic</td>
<td>15.6 (8.6)</td>
<td>0.601</td>
<td>-32.7 (9.8)</td>
<td>0.450</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control</td>
<td>18.2 (13.4)</td>
<td></td>
<td>-37.5 (17.9)</td>
<td></td>
</tr>
<tr>
<td>Standing</td>
<td>Prism View</td>
<td>Symptomatic</td>
<td>0.8 (3.3)</td>
<td>0.915</td>
<td>3.6 (7.2)</td>
<td>0.620</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control</td>
<td>1.0 (7.1)</td>
<td></td>
<td>1.6 (10.6)</td>
<td></td>
</tr>
<tr>
<td>Sitting</td>
<td>Direct View</td>
<td>Symptomatic</td>
<td>18.8 (9.5)</td>
<td>0.141</td>
<td>-32.8 (13.4)</td>
<td>0.071</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control</td>
<td>12.9 (9.2)</td>
<td></td>
<td>-24.1 (9.7)</td>
<td></td>
</tr>
<tr>
<td>Sitting</td>
<td>Prism View</td>
<td>Symptomatic</td>
<td>1.0 (7.4)</td>
<td>0.696</td>
<td>5.4 (9.8)</td>
<td>0.845</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control</td>
<td>1.9 (3.4)</td>
<td></td>
<td>6.0 (5.8)</td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Neck flexion and head tilt, comparisons between symptomatic and control groups. Each angle in the table represents the difference between the reference (baseline) angle and the angle measured during the texting task.
3.3.2 Direct View vs. Prism View

As table 6 shows, in the tasks, irrespective of posture (standing or sitting) and symptom group (symptomatic or control), the neck flexion and head tilt angle difference from baseline (neutral postures) were all significantly lower when using the prism glasses than during the direct view (paired t-test, all $p < 0.001$).

<table>
<thead>
<tr>
<th>Posture</th>
<th>Method</th>
<th>Symptom</th>
<th>Neck Flexion in degree (°)</th>
<th>Head Tilt in degree (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean (SD)</td>
<td>p-value</td>
</tr>
<tr>
<td>Standing</td>
<td>Direct View</td>
<td>Symptomatic</td>
<td>15.6 (8.6)</td>
<td>$&lt;0.001$</td>
</tr>
<tr>
<td>Standing</td>
<td>Prism View</td>
<td>Symptomatic</td>
<td>0.8 (3.3)</td>
<td></td>
</tr>
<tr>
<td>Standing</td>
<td>Direct View</td>
<td>Control</td>
<td>18.2 (13.4)</td>
<td>$&lt;0.001$</td>
</tr>
<tr>
<td>Standing</td>
<td>Prism View</td>
<td>Control</td>
<td>1.0 (7.1)</td>
<td></td>
</tr>
<tr>
<td>Sitting</td>
<td>Direct View</td>
<td>Symptomatic</td>
<td>18.8 (9.5)</td>
<td>$&lt;0.001$</td>
</tr>
<tr>
<td>Sitting</td>
<td>Prism View</td>
<td>Symptomatic</td>
<td>1.0 (7.4)</td>
<td></td>
</tr>
<tr>
<td>Sitting</td>
<td>Direct View</td>
<td>Control</td>
<td>12.9 (9.2)</td>
<td>$&lt;0.001$</td>
</tr>
<tr>
<td>Sitting</td>
<td>Prism View</td>
<td>Control</td>
<td>1.9 (3.4)</td>
<td></td>
</tr>
</tbody>
</table>

Table 6: Neck flexion and head tilt comparisons between viewing methods. Each angle in the table represents the difference between the reference (baseline) angle and the angle measured during the texting task.
3.3.3 Standing vs. Sitting

As table 7 shows, the comparison between standing and sitting in the control group using the direct view showed a difference for head tilt: the head tilt angle in standing (-37.5° ± 17.9°) was significantly lower than in sitting (-24.1° ± 9.7°) (pair t-test, p = 0.032). Other than that, there were no significant differences found for neck flexion or head tilt between standing and sitting (paired t-test, all p > 0.05).

<table>
<thead>
<tr>
<th>Posture</th>
<th>Method</th>
<th>Symptom</th>
<th>Neck Flexion in degree (°)</th>
<th>p-value</th>
<th>Head Tilt in degree (°)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing</td>
<td>Direct View</td>
<td>Symptomatic</td>
<td>15.6 (8.6)</td>
<td>0.241</td>
<td>-32.7 (9.8)</td>
<td>0.962</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>18.8 (9.5)</td>
<td></td>
<td>-32.8 (13.4)</td>
<td></td>
</tr>
<tr>
<td>Standing</td>
<td>Direct View</td>
<td>Control</td>
<td>18.2 (13.4)</td>
<td>0.287</td>
<td>-37.5 (17.9)</td>
<td>0.032</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>12.9 (9.2)</td>
<td></td>
<td>-24.1 (9.7)</td>
<td></td>
</tr>
<tr>
<td>Standing</td>
<td>Prism View</td>
<td>Symptomatic</td>
<td>0.8 (3.3)</td>
<td>0.900</td>
<td>3.6 (7.2)</td>
<td>0.329</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.0 (7.4)</td>
<td></td>
<td>5.4 (9.8)</td>
<td></td>
</tr>
<tr>
<td>Standing</td>
<td>Prism View</td>
<td>Control</td>
<td>1.0 (7.1)</td>
<td>0.692</td>
<td>1.6 (10.6)</td>
<td>0.109</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.9 (3.4)</td>
<td></td>
<td>6.0 (5.8)</td>
<td></td>
</tr>
</tbody>
</table>

Table 7: Neck flexion and head tilt comparisons between postures. Each angle in the table represents the difference between the reference (baseline) angle and the angle measured during the texting task.
3.4 The change in neck flexion, head tilt, and phone tilt comparisons between groups over time

As a reminder, phone tilt is the angle between vertical and line from the side view of the phone (Fig. 4). Tables 8, 9 and 10 compare the effects on angles of neck flexion, head tilt, and phone tilt over time as a function of the test conditions (standing vs. sitting, direct view vs. prism view), and subject group (symptomatic vs. control), respectively. The degrees used in comparison were obtained by subtracting the degrees in 3rd minute from the 9th minute. This variable provided a means to assess the trend of posture change over time during the typing tasks.

3.4.1 Symptomatic vs. Control

As table 8 showed, in the tasks, irrespective of posture (standing or sitting) and viewing method (direct view or prism view), the change of neck flexion, head tilt, and phone tilt angles over time were not significantly different in symptomatic group as compared to the control group (independent t-test, all p > 0.05).
### Table 8: Comparison of the change of neck flexion, head tilt, and phone tilt angles over time (angle_{minute9} – angle_{minute3}) between the symptomatic group and control group.

<table>
<thead>
<tr>
<th>Posture</th>
<th>Method</th>
<th>Symptom</th>
<th>Neck Flexion difference, in degree (°)</th>
<th>Mean (SD)</th>
<th>p</th>
<th>Head Tilt difference, in degree (°)</th>
<th>Mean (SD)</th>
<th>p</th>
<th>Phone Tilt difference, in degree (°)</th>
<th>Mean (SD)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing</td>
<td>Direct</td>
<td>Symptomatic</td>
<td>2.5 (4.8)</td>
<td>0.361</td>
<td></td>
<td>-2.4 (5.9)</td>
<td>0.518</td>
<td></td>
<td>1.3 (6.4)</td>
<td>0.948</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control</td>
<td>3.8 (2.0)</td>
<td></td>
<td></td>
<td>-3.9 (4.8)</td>
<td></td>
<td></td>
<td>1.2 (4.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standing</td>
<td>Prism</td>
<td>Symptomatic</td>
<td>1.5 (3.7)</td>
<td>0.098</td>
<td></td>
<td>-0.2 (4.1)</td>
<td>0.944</td>
<td></td>
<td>0.1 (5.7)</td>
<td>0.179</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control</td>
<td>-0.6 (2.4)</td>
<td></td>
<td></td>
<td>-0.1 (2.9)</td>
<td></td>
<td></td>
<td>2.7 (3.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sitting</td>
<td>Direct</td>
<td>Symptomatic</td>
<td>1.1 (6.2)</td>
<td>0.582</td>
<td></td>
<td>-2.4 (5.4)</td>
<td>0.628</td>
<td></td>
<td>1.2 (4.0)</td>
<td>0.823</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control</td>
<td>2.1 (2.4)</td>
<td></td>
<td></td>
<td>-3.2 (3.3)</td>
<td></td>
<td></td>
<td>1.8 (8.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sitting</td>
<td>Prism</td>
<td>Symptomatic</td>
<td>1.9 (3.5)</td>
<td>0.313</td>
<td></td>
<td>0.0 (2.6)</td>
<td>0.835</td>
<td></td>
<td>2.5 (4.3)</td>
<td>0.055</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control</td>
<td>-0.8 (1.5)</td>
<td></td>
<td></td>
<td>0.2 (2.9)</td>
<td></td>
<td></td>
<td>-1.5 (5.0)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 3.4.2 Direct View vs. Prism View

As table 9 shows, in standing the control group, over time, showed a change (an increase) in neck flexion in the direct view (3.8° ± 2.0°) that was significantly different than the one in prism view (-0.6° ± 2.4°) (paired t-test, p < 0.001). Interestingly, also during standing the control group, over time, showed a change of head tilt (towards greater downward orientation) in the direct view (-3.9° ± 4.8°) which was also significantly different from the change during the prism view (which was essentially 0, meaning no difference between head tilt during minutes 3 and 9). Other than those, there
were no other significant differences found between prism view and direct view (paired t-test, all \( p > 0.05 \)).

<table>
<thead>
<tr>
<th>Posture</th>
<th>Method</th>
<th>Symptom</th>
<th>Neck Flexion difference, in degree (°)</th>
<th>Head Tilt difference, in degree (°)</th>
<th>Phone Tilt difference, in degree (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean (SD)</td>
<td>p</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Standing</td>
<td>Direct</td>
<td>Symptomatic</td>
<td>2.5 (4.8)</td>
<td>0.430</td>
<td>-2.4 (5.9)</td>
</tr>
<tr>
<td></td>
<td>Prism</td>
<td></td>
<td>1.5 (3.7)</td>
<td></td>
<td>-0.2 (4.1)</td>
</tr>
<tr>
<td>Standing</td>
<td>Direct</td>
<td>Control</td>
<td>3.8 (2.0)</td>
<td>&lt;0.001</td>
<td>-3.9 (4.8)</td>
</tr>
<tr>
<td></td>
<td>Prism</td>
<td></td>
<td>-0.6 (2.4)</td>
<td></td>
<td>-0.1 (2.9)</td>
</tr>
<tr>
<td>Sitting</td>
<td>Direct</td>
<td>Symptomatic</td>
<td>1.1 (6.2)</td>
<td>0.473</td>
<td>-2.4 (5.4)</td>
</tr>
<tr>
<td></td>
<td>Prism</td>
<td></td>
<td>1.9 (3.5)</td>
<td></td>
<td>0.0 (2.6)</td>
</tr>
<tr>
<td>Sitting</td>
<td>Direct</td>
<td>Control</td>
<td>2.1 (2.4)</td>
<td>0.135</td>
<td>-3.2 (3.3)</td>
</tr>
<tr>
<td></td>
<td>Prism</td>
<td></td>
<td>-0.8 (1.5)</td>
<td></td>
<td>0.2 (2.9)</td>
</tr>
</tbody>
</table>

Table 9: Comparison of the change of neck flexion, head tilt and phone tilt angles over time \((\text{angle}_{\text{minute9}} - \text{angle}_{\text{minute3}})\) between viewing methods.

### 3.4.3 Standing vs. Sitting

As table 10 shows, in the control group with the direct view, over time, the change of neck flexion in standing \((3.8° \pm 2.0°)\) was significantly higher than the change during sitting \((2.1° \pm 2.4°)\) (paired t-test, \( p = 0.026 \)). In the control group with the direct view, over time, the change in phone tilt in standing \((2.7° \pm 3.6°)\) was significantly higher than the change during sitting \((-1.5° \pm 5.0°)\) (paired t-test, \( p = 0.042 \)). Other than those, there were no other significant differences found (paired t-test, all \( p > 0.05 \)).
<table>
<thead>
<tr>
<th>Posture</th>
<th>Method</th>
<th>Symptom</th>
<th>Neck Flexion difference, in degree (°)</th>
<th>Head Tilt difference, in degree (°)</th>
<th>Phone Tilt difference, in degree (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean (SD)</td>
<td>p</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Standing</td>
<td>Direct</td>
<td>Symptomatic</td>
<td>2.5 (4.8)</td>
<td>0.454</td>
<td>-2.4 (5.9)</td>
</tr>
<tr>
<td>Sitting</td>
<td></td>
<td></td>
<td>1.1 (6.2)</td>
<td></td>
<td>-2.4 (5.4)</td>
</tr>
<tr>
<td>Standing</td>
<td>Direct</td>
<td>Control</td>
<td>3.8 (2.0)</td>
<td>0.026</td>
<td>-3.9 (4.8)</td>
</tr>
<tr>
<td>Sitting</td>
<td></td>
<td></td>
<td>2.1 (2.4)</td>
<td></td>
<td>-3.2 (3.3)</td>
</tr>
<tr>
<td>Standing</td>
<td>Prism</td>
<td>Symptomatic</td>
<td>1.5 (3.7)</td>
<td>0.614</td>
<td>-0.2 (4.1)</td>
</tr>
<tr>
<td>Sitting</td>
<td></td>
<td></td>
<td>1.9 (3.5)</td>
<td></td>
<td>0.0 (2.6)</td>
</tr>
<tr>
<td>Standing</td>
<td>Prism</td>
<td>Control</td>
<td>-0.6 (2.4)</td>
<td>0.106</td>
<td>-0.1 (2.9)</td>
</tr>
<tr>
<td>Sitting</td>
<td></td>
<td></td>
<td>-0.8 (1.5)</td>
<td></td>
<td>0.2 (2.9)</td>
</tr>
</tbody>
</table>

Table 10: Comparison of the change in neck flexion, head tilt, and phone tilt angles over time (angle<sub>minute9</sub> – angle<sub>minute3</sub>) between task postures.

### 3.5 The change of discomfort level comparisons between groups over time

Table 11 shows the mean reported neck and shoulder discomfort levels before and after each test condition. Figures 8 - 15 show the neck and shoulder discomfort ratings before and after each test condition for each study participant. In those figures, control subjects are labeled C01 – C10 and symptomatic subjects are labeled P01-P15.
<table>
<thead>
<tr>
<th></th>
<th>Standing</th>
<th></th>
<th>Sitting</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Direct</td>
<td>Prism</td>
<td>Direct</td>
<td>Prism</td>
</tr>
<tr>
<td>Symptomatic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before</td>
<td>Neck</td>
<td>1.1 (1.0)</td>
<td>Neck</td>
<td>1.2 (1.1)</td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>1.0 (1.0)</td>
<td>Mean (SD)</td>
<td>1.0 (1.2)</td>
</tr>
<tr>
<td></td>
<td>Shoulder</td>
<td>1.1 (1.0)</td>
<td>Shoulder</td>
<td>1.1 (1.2)</td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>1.0 (1.0)</td>
<td>Mean (SD)</td>
<td>1.0 (1.2)</td>
</tr>
<tr>
<td>Control</td>
<td>Neck</td>
<td>0.2 (0.3)</td>
<td>Neck</td>
<td>0.3 (0.3)</td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>0.1 (0.2)</td>
<td>Mean (SD)</td>
<td>0.5 (0.2)</td>
</tr>
<tr>
<td></td>
<td>Shoulder</td>
<td>0.0 (0.0)</td>
<td>Shoulder</td>
<td>0.0 (0.0)</td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>0.1 (0.2)</td>
<td>Mean (SD)</td>
<td>0.5 (0.2)</td>
</tr>
<tr>
<td>Symptomatic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>After</td>
<td>Neck</td>
<td>2.3 (1.0)</td>
<td>Neck</td>
<td>2.3 (1.0)</td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>2.0 (1.6)</td>
<td>Mean (SD)</td>
<td>1.9 (1.3)</td>
</tr>
<tr>
<td></td>
<td>Shoulder</td>
<td>1.5 (1.4)</td>
<td>Shoulder</td>
<td>1.3 (1.4)</td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>1.3 (1.2)</td>
<td>Mean (SD)</td>
<td>1.3 (1.4)</td>
</tr>
<tr>
<td>Control</td>
<td>Neck</td>
<td>1.6 (1.4)</td>
<td>Neck</td>
<td>1.4 (1.2)</td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>1.1 (0.8)</td>
<td>Mean (SD)</td>
<td>0.9 (1.1)</td>
</tr>
<tr>
<td></td>
<td>Shoulder</td>
<td>0.7 (0.7)</td>
<td>Shoulder</td>
<td>0.6 (0.8)</td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>1.1 (0.8)</td>
<td>Mean (SD)</td>
<td>0.7 (0.7)</td>
</tr>
</tbody>
</table>

Table 11: Mean neck and shoulder discomfort levels before and after each test condition; possible range was 0 to 10.
Figure 8: Neck Discomfort: Pre- and Post-Task: Sitting – Direct View (C01-C10: Control group; P01 – P15: Symptomatic group)
Figure 9: Neck Discomfort: Pre- and Post-Task: Sitting – Prism View (C01-C10: Control group; P01 – P15: Symptomatic group)
Figure 10: Neck Discomfort: Pre- and Post-Task: Standing – Direct View (C01-C10: Control group; P01 – P15: Symptomatic group)
Figure 11: Neck Discomfort: Pre- and Post-Task: Standing – Prism View (C01-C10: Control group; P01 – P15: Symptomatic group)
Figure 12: Shoulder Discomfort: Pre- and Post-Task: Sitting – Direct View (C01-C10: Control group; P01 – P15: Symptomatic group)
Figure 13: Shoulder Discomfort: Pre- and Post-Task: Sitting – Prism View (C01-C10: Control group; P01 – P15: Symptomatic group)
Figure 14: Shoulder Discomfort: Pre- and Post-Task: Standing – Direct View (C01-C10: Control group; P01 – P15: Symptomatic group)
Tables 12, 13, and 14 show the changes in neck and shoulder discomfort levels from the start to the end of each task (i.e. each test condition). Comparisons were provided for standing vs. sitting, direct view vs. prism view, and symptomatic vs. control groups. The values used in the comparison were obtained by subtracting the discomfort level at the start of the task from the discomfort level at completion of the 10 min task.
3.5.1 Symptomatic vs. Control

As table 12 shows, in the tasks, irrespective of posture (standing or sitting) or viewing method (direct view or prism view), the change of neck and shoulder discomfort levels were not significantly different in the symptomatic group as compared to the control group (independent t-test, all $p > 0.05$).

<table>
<thead>
<tr>
<th>Posture</th>
<th>Method</th>
<th>Symptom</th>
<th>Change in Neck Discomfort</th>
<th>Change in Shoulder Discomfort</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean (SD)</td>
<td>p-value</td>
</tr>
<tr>
<td>Standing</td>
<td>Direct</td>
<td>Symptomatic</td>
<td>1.2 (0.6)</td>
<td>0.691</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control</td>
<td>1.4 (1.5)</td>
<td></td>
</tr>
<tr>
<td>Standing</td>
<td>Prism</td>
<td>Symptomatic</td>
<td>0.3 (0.8)</td>
<td>0.158</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control</td>
<td>0.8 (1.0)</td>
<td></td>
</tr>
<tr>
<td>Sitting</td>
<td>Direct</td>
<td>Symptomatic</td>
<td>1.1 (0.6)</td>
<td>0.649</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control</td>
<td>1.1 (1.3)</td>
<td></td>
</tr>
<tr>
<td>Sitting</td>
<td>Prism</td>
<td>Symptomatic</td>
<td>0.3 (0.7)</td>
<td>0.976</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control</td>
<td>0.5 (1.3)</td>
<td></td>
</tr>
</tbody>
</table>

Table 12: Comparison of the change of neck and shoulder discomfort levels over time ($\text{discomfort}_{\text{minute 10}} - \text{discomfort}_{\text{minute 0}}$) between the symptomatic group and control group.

3.5.2 Direct View vs. Prism View

As table 13 shows, in standing for the symptomatic group, over time, the change in neck discomfort during the direct view ($1.2 \pm 0.6$) was significantly higher than the increase during the prism view ($0.3 \pm 0.8$) (paired t-test, $p = 0.008$). In the same condition
(standing-symptomatic group), over time, the change in shoulder discomfort during the direct view (1.0 ± 1.0) was significantly higher than during the prism view (0.3 ± 0.6) (paired t-test, p = 0.017).

In sitting for the symptomatic group, over time, the change in neck discomfort level during the direct view (1.1 ± 0.6) was significantly higher than during the prism view (0.3 ± 0.7) (paired t-test, p = 0.009). For the same condition (sitting-symptomatic group), over time, the change in shoulder discomfort level during the direct view (0.9 ± 0.7) was significantly higher than during the prism view (0.2 ± 0.5) (paired t-test, p = 0.003).

There were no significant differences in neck or shoulder discomfort found between prism view and direct view for the control group (paired t-test, all p > 0.05).

<table>
<thead>
<tr>
<th>Posture</th>
<th>Method</th>
<th>Symptom</th>
<th>Change in Neck Discomfort</th>
<th>p-value</th>
<th>Change in Shoulder Discomfort</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean (SD)</td>
<td>p-value</td>
<td>Mean (SD)</td>
<td>p-value</td>
</tr>
<tr>
<td>Standing</td>
<td>Direct</td>
<td>Symptomatic</td>
<td>1.2 (0.6)</td>
<td>0.008</td>
<td>1.0 (1.0)</td>
<td>0.017</td>
</tr>
<tr>
<td></td>
<td>Prism</td>
<td></td>
<td>0.3 (0.8)</td>
<td></td>
<td>0.3 (0.6)</td>
<td></td>
</tr>
<tr>
<td>Standing</td>
<td>Direct</td>
<td>Control</td>
<td>1.4 (1.5)</td>
<td>0.174</td>
<td>1.0 (0.8)</td>
<td>0.066</td>
</tr>
<tr>
<td></td>
<td>Prism</td>
<td></td>
<td>0.8 (1.0)</td>
<td></td>
<td>0.6 (0.6)</td>
<td></td>
</tr>
<tr>
<td>Sitting</td>
<td>Direct</td>
<td>Symptomatic</td>
<td>1.1 (0.6)</td>
<td>0.009</td>
<td>0.9 (0.7)</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>Prism</td>
<td></td>
<td>0.3 (0.7)</td>
<td></td>
<td>0.2 (0.5)</td>
<td></td>
</tr>
<tr>
<td>Sitting</td>
<td>Direct</td>
<td>Control</td>
<td>1.1 (1.3)</td>
<td>0.236</td>
<td>0.9 (1.1)</td>
<td>0.500</td>
</tr>
<tr>
<td></td>
<td>Prism</td>
<td></td>
<td>0.5 (1.3)</td>
<td></td>
<td>0.5 (0.8)</td>
<td></td>
</tr>
</tbody>
</table>

Table 13: Comparison of the change in neck and shoulder discomfort levels over time (discomfort$_{\text{minute}10} - \text{discomfort}_{\text{minute}0}$) between viewing methods.
3.5.3 Standing vs. Sitting

As table 14 shows, there was no significant difference found between standing and sitting conditions on the change of neck and shoulder discomfort levels over time (paired t-test, all p > 0.05).

<table>
<thead>
<tr>
<th>Posture</th>
<th>Method</th>
<th>Symptom</th>
<th>Change in Neck Discomfort</th>
<th>Change in Shoulder Discomfort</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean (SD)</td>
<td>p-value</td>
</tr>
<tr>
<td>Standing</td>
<td>Direct</td>
<td>Symptomatic</td>
<td>1.2 (0.6)</td>
<td>0.715</td>
</tr>
<tr>
<td>Sitting</td>
<td>Direct</td>
<td>Control</td>
<td>1.1 (0.6)</td>
<td></td>
</tr>
<tr>
<td>Standing</td>
<td>Direct</td>
<td>Control</td>
<td>1.4 (1.5)</td>
<td>0.357</td>
</tr>
<tr>
<td>Sitting</td>
<td>Direct</td>
<td>Control</td>
<td>1.1 (1.3)</td>
<td></td>
</tr>
<tr>
<td>Standing</td>
<td>Prism</td>
<td>Symptomatic</td>
<td>0.3 (0.8)</td>
<td>0.951</td>
</tr>
<tr>
<td>Sitting</td>
<td>Prism</td>
<td>Symptomatic</td>
<td>0.3 (0.7)</td>
<td></td>
</tr>
<tr>
<td>Standing</td>
<td>Prism</td>
<td>Control</td>
<td>0.8 (1.0)</td>
<td>0.257</td>
</tr>
<tr>
<td>Sitting</td>
<td>Prism</td>
<td>Control</td>
<td>0.5 (1.3)</td>
<td></td>
</tr>
</tbody>
</table>

Table 14: Comparison of the change in neck and shoulder discomfort levels over time (discomfort_{minute10} – discomfort_{minute0}) between postures.

3.6 Head motion activity comparisons between groups.

Tables 15, 16, and 17 compared the head motion activity between subject groups and due to test conditions (standing vs. sitting, direct view vs. prism view), respectively. The data used in the comparison were the standard deviations of the values from the ActivPal accelerometer that was taped on subject’s forehead. The greater the standard
deviation, the greater the head motion activity; conversely, the smaller the standard
deviation, the more fixed the head posture.

The data from standing-direct view-symptomatic group, sitting-prism view-
symptomatic group, and sitting-prism view-control group were not normal until one or
two subject’s data were removed. Tables 15-17 show comparisons using the whole data
set and with the outliers removed.

3.6.1 Symptomatic vs. Control

As table 15 shows, during the tasks, the head motion activity during standing-
prism view for the symptomatic group (2.8 ± 0.9) was significantly higher than in the
control group (1.9 ± 0.6) (independent t-test, p = 0.004)). Other than that, there were no
differences found between symptomatic and control groups (independent t-test, all p >
0.05).
Table 15: Comparison of the head motion activity between symptomatic group and control group.

<table>
<thead>
<tr>
<th>Posture</th>
<th>Method</th>
<th>Symptom</th>
<th>n</th>
<th>Mean (SD)</th>
<th>p</th>
<th>n</th>
<th>Mean (SD)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing</td>
<td>Direct</td>
<td>Symptomatic</td>
<td>15</td>
<td>3.7 (2.2)</td>
<td>0.778</td>
<td>13</td>
<td>2.9 (0.8)</td>
<td>0.136</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control</td>
<td>10</td>
<td>3.9 (1.7)</td>
<td></td>
<td>10</td>
<td>3.9 (1.7)</td>
<td></td>
</tr>
<tr>
<td>Standing</td>
<td>Prism</td>
<td>Symptomatic</td>
<td>15</td>
<td>2.8 (0.9)</td>
<td>0.004</td>
<td>15</td>
<td>2.8 (0.9)</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control</td>
<td>10</td>
<td>1.9 (0.6)</td>
<td></td>
<td>10</td>
<td>1.9 (0.6)</td>
<td></td>
</tr>
<tr>
<td>Sitting</td>
<td>Direct</td>
<td>Symptomatic</td>
<td>15</td>
<td>3.4 (1.6)</td>
<td>0.733</td>
<td>15</td>
<td>3.4 (1.6)</td>
<td>0.733</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control</td>
<td>10</td>
<td>3.2 (1.4)</td>
<td></td>
<td>10</td>
<td>3.2 (1.4)</td>
<td></td>
</tr>
<tr>
<td>Sitting</td>
<td>Prism</td>
<td>Symptomatic</td>
<td>15</td>
<td>2.1 (1.3)</td>
<td>0.766</td>
<td>14</td>
<td>1.8 (0.8)</td>
<td>0.587</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control</td>
<td>10</td>
<td>1.9 (1.3)</td>
<td></td>
<td>9</td>
<td>1.6 (0.9)</td>
<td></td>
</tr>
</tbody>
</table>

3.6.2 Direct view vs. Prism View

As table 16 shows, during the tasks, the head motion activity during standing-direct view for the control group (3.9 ± 1.7) was significantly higher than during the standing-prism view (1.9 ± 0.6) (paired t-test, p = 0.007).

Using the whole data set, the head motion activity during sitting-direct view for the symptomatic group (3.4 ± 1.6) was significantly higher than during sitting-prism view (2.1 ± 1.3) (paired t-test, p = 0.006). With one outlier removed from the symptomatic group in sitting-prism view, the head motion activity during sitting-direct view (3.4 ± 1.6) was still significantly higher than sitting-prism view (1.8 ± 0.8) (paired t-test, p < 0.001) for the symptomatic group. The reason to delete this outlier was 1) the standard deviation of the head motion activity of that subject was 5.8, which was too high as compared to
the mean of the rest of the group, 1.8, and 2) the video footage showed that the subject repeatedly scratched an apparently itchy shoulder and this slightly changed the head posture more than 20 times, whereas, compared to other members of the symptomatic group there were less than 5 slight changes in head postures during the sitting-prism view condition.

Using the whole data set, the head motion activity during sitting-direct view for the control group (3.2 ± 1.4) was not significantly different from sitting-prism view (1.9 ± 1.3) (paired t-test, p = 0.075). With one outlier removed for sitting-prism view, however, the head motion activity during sitting-direct view (3.2 ± 1.4) was significantly higher than during sitting-prism view (1.6 ± 0.9) (paired t-test, p = 0.016) for the control group. The reason to delete this outlier was 1) the head motion activity of that subject was 4.7, which was too high as compared to the mean 1.6, and 2) the video footage showed that the subject changed his arm posture 5 times between lower and upper positions, which increased his head motion activity, whereas there were only 1 or 2 postures changes in sitting-prism view for the other members of the control group.

Other than those, there were no other significant differences found between symptomatic group and control group (pair t-test, all p > 0.05)
### Table 16: Comparison of the head motion activity between viewing methods. Green highlighting signals that the difference became significant after removal of the outlier.

<table>
<thead>
<tr>
<th>Posture</th>
<th>Method</th>
<th>Symptom</th>
<th>n</th>
<th>Mean (SD)</th>
<th>P</th>
<th>n</th>
<th>Mean (SD)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing</td>
<td>Direct</td>
<td>Symptomatic</td>
<td>15</td>
<td>3.7 (2.2)</td>
<td>0.128</td>
<td>13</td>
<td>2.9 (0.8)</td>
<td>0.422</td>
</tr>
<tr>
<td></td>
<td>Prism</td>
<td></td>
<td>15</td>
<td>2.8 (0.9)</td>
<td></td>
<td>15</td>
<td>2.8 (0.9)</td>
<td></td>
</tr>
<tr>
<td>Standing</td>
<td>Direct</td>
<td>Control</td>
<td>10</td>
<td>3.9 (1.7)</td>
<td>0.007</td>
<td>10</td>
<td>3.9 (1.7)</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>Prism</td>
<td></td>
<td>10</td>
<td>1.9 (0.6)</td>
<td></td>
<td>10</td>
<td>1.9 (0.6)</td>
<td></td>
</tr>
<tr>
<td>Sitting</td>
<td>Direct</td>
<td>Symptomatic</td>
<td>15</td>
<td>3.4 (1.6)</td>
<td>0.006</td>
<td>15</td>
<td>3.4 (1.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Prism</td>
<td></td>
<td>15</td>
<td>2.1 (1.3)</td>
<td></td>
<td>14</td>
<td>1.8 (0.8)</td>
<td></td>
</tr>
<tr>
<td>Sitting</td>
<td>Direct</td>
<td>Control</td>
<td>10</td>
<td>3.2 (1.4)</td>
<td>0.075</td>
<td>10</td>
<td>3.2 (1.4)</td>
<td>0.016</td>
</tr>
<tr>
<td></td>
<td>Prism</td>
<td></td>
<td>10</td>
<td>1.9 (1.3)</td>
<td></td>
<td>9</td>
<td>1.6 (0.9)</td>
<td></td>
</tr>
</tbody>
</table>

#### 3.6.3 Standing vs. Sitting

As table 17 shows, during the tasks, with the whole data set, the head motion activity during standing-prism view for the symptomatic group (2.8 ± 0.9) was significantly higher than sitting-prism view (2.1 ± 1.3) (paired t-test, p < 0.017). With the outlier removed from the sitting-prism view, the head motion activity of the standing-prism view (2.8 ± 0.9) was still significantly higher than sitting-prism view (1.8 ± 0.8) (paired t-test, p < 0.001) for the symptomatic group.

Other than that, there were no other significant differences found between standing and sitting conditions on the head motion activity (pair t-test, all p > 0.05).
<table>
<thead>
<tr>
<th>Posture</th>
<th>Method</th>
<th>Symptom</th>
<th>n</th>
<th>Mean (SD)</th>
<th>P</th>
<th>n</th>
<th>Mean (SD)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing</td>
<td>Direct</td>
<td>Symptomatic</td>
<td>15</td>
<td>3.7 (2.2)</td>
<td>0.580</td>
<td>13</td>
<td>2.9 (0.8)</td>
<td>0.559</td>
</tr>
<tr>
<td>Sitting</td>
<td>Direct</td>
<td>Symptomatic</td>
<td>15</td>
<td>3.4 (1.6)</td>
<td></td>
<td>15</td>
<td>3.4 (1.6)</td>
<td></td>
</tr>
<tr>
<td>Standing</td>
<td>Direct</td>
<td>Control</td>
<td>10</td>
<td>3.9 (1.7)</td>
<td>0.184</td>
<td>10</td>
<td>3.9 (1.7)</td>
<td>0.184</td>
</tr>
<tr>
<td>Sitting</td>
<td>Direct</td>
<td>Control</td>
<td>10</td>
<td>3.2 (1.4)</td>
<td></td>
<td>10</td>
<td>3.2 (1.4)</td>
<td></td>
</tr>
<tr>
<td>Standing</td>
<td>Prism</td>
<td>Symptomatic</td>
<td>15</td>
<td>2.8 (0.9)</td>
<td>0.017</td>
<td>15</td>
<td>2.8 (0.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sitting</td>
<td>Prism</td>
<td>Symptomatic</td>
<td>15</td>
<td>2.1 (1.3)</td>
<td></td>
<td>14</td>
<td>1.8 (0.8)</td>
<td></td>
</tr>
<tr>
<td>Standing</td>
<td>Prism</td>
<td>Control</td>
<td>10</td>
<td>1.9 (0.6)</td>
<td>0.943</td>
<td>10</td>
<td>1.9 (0.6)</td>
<td></td>
</tr>
<tr>
<td>Sitting</td>
<td>Prism</td>
<td>Control</td>
<td>10</td>
<td>1.9 (1.3)</td>
<td></td>
<td>9</td>
<td>1.6 (0.9)</td>
<td>0.566</td>
</tr>
</tbody>
</table>

Table 17: Comparison of the head motion activity between postures.

**3.7 Change of performance comparisons between groups.**

In order to reduce the variance that can occur by letting subjects choose between speed and accuracy of performance, at the start of the study all subjects were instructed to focus on the accuracy of their typing rather than speed of entry. Table 18 shows the actual results for speed (number of characters typed in 10 minutes) and accuracy (percent correct).
Table 18: Mean speed (number of characters) and accuracy (%) performance for each condition, by subject group.

Tables 19 and 20 compare differences in performance of the groups due to posture (standing vs. sitting) and mode of viewing (direct view vs. prism view). Speed ratios and accuracy ratios were obtained by one condition’s data divided by another condition’s data. For example, the speed during the standing-direct view for the symptomatic group was divided by speed during standing-prism view, producing a mean speed ratio of 1.3 ± 0.2, which indicates that, on average, the speed during standing-direct view was 1.3 times the speed during standing-prism view for the symptomatic group.

### 3.7.1 Speed comparison

As Table 19 shows, during standing, the speed ratio of direct view and prism view in the symptomatic group (1.3 ± 0.2) was significantly higher than the speed ratio of the control group (1.1 ± 0.1) (paired t-test, p = 0.020).
In the prism view condition, the speed ratio of standing v. sitting for the symptomatic group (1.1 ± 0.2) was significantly different (less than) the speed ratio of the control group (1.2 ± 0.2) (paired t-test, p = 0.033).

Other than those, there were no other significant differences found between the symptomatic and control groups in speed ratio comparisons (paired t-test, p > 0.05). The table also shows, based on the results of the sign test, that subjects in both groups typed significantly faster in the direct view, irrespective of posture.
Table 19: Speed ratio comparisons. A significant sign test means the ratio of the two test conditions is different from 1.0. The p-value column indicates the outcome of the comparison of the ratios from the two subject groups.

### 3.7.2 Accuracy comparison

As table 20 shows, there were no significant differences found in accuracy comparisons between the symptomatic and control groups (paired t-test, all \( p > 0.05 \)). There were also no effects on accuracy due to posture or viewing mode, based on results of the sign test that show that none of the ratios are different from 1.0.
### Table 20: Accuracy ratio comparisons.

A significant sign test means the ratio of the two test conditions is different from 1.0. The p-value column indicates the outcome of the comparison of the ratios from the two subject groups.

<table>
<thead>
<tr>
<th>Accuracy Ratio</th>
<th>Symptomatic Mean (SD)</th>
<th>Sign test</th>
<th>Control Mean (SD)</th>
<th>Sign test</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing Direct</td>
<td>1.0 (0.0)</td>
<td>0.469</td>
<td>1.0 (0.0)</td>
<td>0.603</td>
<td>0.998</td>
</tr>
<tr>
<td>Standing Prism</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sitting Direct</td>
<td>1.0 (0.0)</td>
<td>0.354</td>
<td>1.0 (0.0)</td>
<td>0.273</td>
<td>0.542</td>
</tr>
<tr>
<td>Sitting Prism</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standing Direct</td>
<td>1.0 (0.0)</td>
<td>0.591</td>
<td>1.0 (0.0)</td>
<td>0.247</td>
<td>0.336</td>
</tr>
<tr>
<td>Standing Direct</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sitting Direct</td>
<td>1.0 (0.0)</td>
<td>0.292</td>
<td>1.0 (0.0)</td>
<td>0.979</td>
<td>0.521</td>
</tr>
<tr>
<td>Sitting Prism</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 3.7 Preference

Table 21 shows preference results for the viewing methods, for the symptomatic and control groups. In terms of neck comfort, 14 out of 15 from the symptomatic group preferred the prism view, which was preferred by 8 out of 10 from the control group. However, in terms of visual comfort, 14 out of 15 from the symptomatic group preferred the direct view, which was preferred by 9 out of 10 from the control group.

In terms of speed, 14 out of 15 from the symptomatic group believed they typed faster during the direct view, in comparison to 10 out of 10 from the control group. This
preference, based on speed, corresponded with the results that speed during the direct view was faster than during the prism view (Table 19).

In terms of accuracy, 14 out of 15 from the symptomatic group believed they typed more accurately in the direct view, in comparison to 10 out of 10 from the control group. However, as described in the section just above, there were no significant differences found in measured accuracy due to test conditions (Table 20).

<table>
<thead>
<tr>
<th></th>
<th>Symptomatic Total: 15 subjects</th>
<th>Control Total: 10 subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Direct</td>
<td>Prism</td>
</tr>
<tr>
<td>Preference in terms of NECK comfort?</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Preference in terms of VISUAL comfort?</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Preference in terms of productivity (speed)?</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Preference in terms of accuracy?</td>
<td>13</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 21: Preferences between viewing methods.

3.8 Comments

Tables 22 and 23 showed the positive and negative comments from the 15 symptomatic and control subjects about the prism view. From positive impressions, in the symptomatic group, 13 out of 15 felt that their neck was more comfortable during the prism view, whereas only 3 out of 10 from the control group felt that way.

From negative impressions, 9 out of 15 from the symptomatic group felt the prism glasses worn during the study were too heavy, whereas only 3 out of 10 from the control group felt that way.
Positive Impressions

<table>
<thead>
<tr>
<th></th>
<th>Symptomatic Total: 15 subjects</th>
<th>Control Total: 10 subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck was more comfortable</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>Promotes Focus on Task</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 22: Subjects’ positive comments about the prism view method.

Negative Impressions

<table>
<thead>
<tr>
<th></th>
<th>Symptomatic Total: 15 subjects</th>
<th>Control Total: 10 subjects</th>
<th>Design Related</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glasses too heavy</td>
<td>9</td>
<td>3</td>
<td>Y</td>
</tr>
<tr>
<td>Small viewing area/window</td>
<td>4</td>
<td>3</td>
<td>Y</td>
</tr>
<tr>
<td>Hard to get accustomed</td>
<td>4</td>
<td>3</td>
<td>N</td>
</tr>
<tr>
<td>Glasses too loose</td>
<td>2</td>
<td>1</td>
<td>Y</td>
</tr>
<tr>
<td>Fonts turned smaller</td>
<td>1</td>
<td>1</td>
<td>Y</td>
</tr>
<tr>
<td>Lost reference point</td>
<td>1</td>
<td>1</td>
<td>N</td>
</tr>
<tr>
<td>Glasses not convenient</td>
<td>1</td>
<td>1</td>
<td>N</td>
</tr>
<tr>
<td>Dry eye</td>
<td>1</td>
<td>1</td>
<td>N</td>
</tr>
<tr>
<td>Nose pad too stiff</td>
<td>1</td>
<td>1</td>
<td>Y</td>
</tr>
<tr>
<td>Head was locked</td>
<td>0</td>
<td>1</td>
<td>N</td>
</tr>
<tr>
<td>Caused motion sickness</td>
<td>0</td>
<td>1</td>
<td>N</td>
</tr>
<tr>
<td>Caused neck extension</td>
<td>0</td>
<td>1</td>
<td>N</td>
</tr>
</tbody>
</table>

Table 23: Subjects’ negative comments about the prism view method.
Chapter 4: Discussion

In this study, the direct view typically adopted in smartphone use, while sitting or standing, generated higher levels of muscle activity in the neck and greater non-neutral postures as compared to the prism viewing method. The statistical results in the current study show that use of the ergonomic intervention (prism glasses) improved neck postures in both groups of subjects (symptomatic and control) and produced less of an increase in neck discomfort in the symptomatic group.

4.1 Posture

It has been found in this study that the neck flexion and head tilt changes from baseline (neutral posture) to prism view were significantly less than the ones in direct view irrespective of symptomatic or control groups, suggesting that the use of prism glasses enabled subjects to view their smartphone with a posture closer to their neutral postures, and thus improved neck postures. This result is supported by Smith et al. (2002), which found the use of the prism glasses generated more neutral neck posture as compared to direct view during simulated dental hygienists’ work.
Prior studies (Hashimoto et al. 2015, Kim 2015) have shown that neck posture worsened with smartphone use as time elapsed. The current study did not specifically assess whether or not a change over time occurred, but did test for a difference in posture change over time between test conditions. A significant difference was found for the control group in the standing condition between direct view and prism view. Neck flexion increased by 3.8 deg (sd=2.0) over time in the direct view, in comparison to a change of -0.6 deg (2.4) in the prism view; head tilt became more pronounced by 3.9 deg (4.8) in the direct view, but was essentially unchanged in the prism view (-0.1 deg (2.9)). This result suggests that the use of prism glasses showed some promise for reducing the increasing downward position of the head over time in the control group, so could possibly be an effective intervention in advance of smartphone users developing neck pain.

4.2 Muscle activity

In this study, it was hypothesized that the use of prism glasses would significantly lower activity in the neck muscles, because the prism view diverted the view downward requiring less neck flexion to view the smartphone. Less muscle activity is required to support the head when the center of mass of the head remains closer to a balanced position over the spine (small load moment to be supported by the muscles), rather than the head being out in front of the spine producing a larger load moment for the cervical extensor muscles to support (Figure 3). This result is consistent with a previous study by Smith et al. (2002), which found the use of the prism glasses generated more neutral neck
posture as compared to the direct view during a simulation of dental hygienists’ work. This result also corresponds with the result found in neck flexion and head tilt, which showed less neck flexion and head tilt when prism glasses were used in the current study.

It was found that in sitting-direct view, the trapezius muscle activity was significantly lower than standing-direct view. This result was expected as the chair’s arm rests were used so that the subject’s arms were supported, which required less shoulder muscle exertion. The result of this study is aligned with the recommendation of the forearm being supported (e.g. against the thighs, or a table, or an arm rest) in order to reduce the risk of MSDs when using a smartphone for texting (Gustafsson et al. 2011).

Further, in the symptomatic group, the trapezius muscle activity in standing-direct view was significantly higher than standing-prism view, whereas, there was no such difference in the control group. This result cannot be explained but may be a possible contribution to their symptoms.

4.3 Discomfort

It was found in the symptomatic group that, the use of the prism glasses resulted in a significantly lower increase in neck and shoulder discomfort at the conclusion of the task when compared to the direct view, irrespective of posture. This is consistent with the finding of less neck muscle activity, and less neck flexion and head tilt found during the use of the prism glasses. The control group displayed a similar trend, though the results were not statistically significant. Similar results were also found in another smartphone study (Xie et al. 2016), which compared the discomfort changes after a 10 minute task
from 40 participants (20 neck pain participants and 20 healthy participants) who used a smartphone or a computer to type in three sitting conditions ((A) bilateral texting, (B) unilateral texting, and (C) computer typing.). The results indicated that the changes in discomfort level after each task in the symptomatic group were significantly higher as compared to the control group (Xie et al. 2016). With regards to the current study, Figures 8-11, which depict self-reported neck discomfort, reveal that several subjects in the symptomatic group began each condition with some level of mild to moderate discomfort, while only a few control subjects reported even the mildest discomfort at the outset. Yet, at the end of the direct view trials only 1 or 2 subjects in either group reported no neck discomfort or experienced no increase in discomfort. A substantial majority of subjects in each group experienced an increase in neck discomfort by the conclusion of the direct view condition, in both standing and sitting postures. In contrast, after using the prism glasses most subjects in both groups did not experience an increase in neck discomfort, with one marked exception being one of the control subjects; at the conclusion of the standing-prism view, only a small number of control subjects and one symptomatic subject were shown to have noticeable increases in neck discomfort. As seen in Figures 12-15, development of shoulder discomfort was less consistent across subjects in comparison to neck discomfort. The eight figures together (Fig. 8-15) show that after only 10 minutes on the direct view tasks most subjects in each group were susceptible to developing some level of neck discomfort, with some subjects in both groups also developing some shoulder discomfort, and that most subjects in both groups benefited from the use of the prism glasses, as revealed in less discomfort at task end.
4.3 Head motion activity

Head motion activity tended to be greater during direct viewing than when using the prism glasses. For the control group, when standing head motion activity was greater with the direct view than the prism view \((p = 0.007)\). For the symptomatic group, when sitting head motion activity was greater with direct view than with the prism view \((p = 0.006)\). Without wearing the prism glasses participants were free to move their head as usual. While wearing the prism glasses, however, due to the limited viewing area of the prism, which was mentioned by nearly 1/3 of the participants, participants tended to maintain fixed postures, which resulted in less head motion activity. Epidemiological research (Bridger 2009) has shown that health risks increase in either of two directions: when movement is too static or too frequent (Figure 8). It is believed that less head motion activity with the use of the prism glasses found in this study may further make a static posture even more static, and hence pose more health risk to people when the prism glasses are used. This suggests that a modification of the design to provide a larger viewing area could be beneficial. However, this would have to be accomplished without adding weight to the glasses, because the weight of the glasses was already a concern of some of the subjects.
4.4 Performance

It was found that the typing speeds with direct viewing method were significantly higher than with the prism viewing method, irrespective of standing or sitting, and for both groups, symptomatic and control. However, there was no difference in terms of accuracy. Although the majority of the participants in this study felt comfortable with the prism glasses after a few minutes of practice at the beginning of the experiment, nearly 1/3 of the participants reported difficulty getting accustomed to them during the interview after the experiment. It is believed that, for all the participants, this was the first time they had experience with the prism glasses, and more time might be needed to overcome the inevitable learning curve and achieve similar productivity. Additionally, if the prism
glasses were used interchangeably with the direct view, speed may not change or may even increase due to reduced discomfort once people became proficient with the prism glasses (Smith et al. 2002).

4.5 Subjective preference

The majority of the participants preferred the prism glasses in terms of neck comfort. However, the majority of the participants preferred the direct view in terms of visual comfort, productivity and accuracy. The subjective preference for neck comfort corresponded with muscle activity, posture, and discomfort results. The subjective preference for productivity corresponded with the speed result, which indicated the direct view was faster. However the majority felt the direct view was more accurate, but in fact, there were no significant difference in terms of accuracy. It is believed that if the participants were given more time and chance to practice, productivity would be similar.

4.6 Comments for improvement of the intervention

The majority of the symptomatic participants preferred the prism glasses, because at the end of the typing task they felt less discomfort in their neck when the prism glasses were used as compared to direct view. However, only 1/3 of the control group felt that way. This can be explained as follows: those with neck pain were more receptive to an intervention that offered the possibility of preventing their neck pain from being exacerbated when typing on the phone. Once the glasses were used, non-neutral postures
were minimized, which provided them a more comfortable posture when using the
smartphone. Those without neck pain, on the other hand, experienced little pain or no
pain at the outset of the task, so the small increase in discomfort while using the phone
was not consequential to them. Although the glasses provided some reduction in
discomfort, which was indicated by their preference, the effects on the control group
were limited.

The sensitivity of the symptomatic group could also be seen from the impression
of 9 out of 15 from that group that the glasses were too heavy versus only 3 out of 10
from the control group reporting that perception. The prototype prism glasses used in this
study were lighter than models on the market, weighting only 128 grams as compared to
other models which weigh around 180 grams. The glasses frame was made from light-
weight aluminum to minimize weight. In order to achieve convenient portability, and a
stylish and ordinary appearance of the glasses, the majority of the weight was supported
by the bridge of the nose, which may also have caused discomfort. The prism glasses
used in Smith et al. (2002), however, were fixed around the participant’s head by an
adjustable band, so the weight of the glasses was evenly distributed, which resulted in
less percentage (1/4) of the participants reporting discomfort during wearing. A lighter
version should be developed. It is noticed that the majority of the weight of the glasses
was from the two prisms. It is unknown if the prisms could be made with a lighter
weight material. As those who recognized the benefits of the reduced discomfort were
the symptomatic group and that is the group more likely to purchase the glasses to reduce
neck discomfort, weight reduction deserves further attention. Another potential
alternative that might reduce the weight of the prisms could be a smaller angled prism, one that does not bend the view 90 deg, but something less than that. Lindegard et al. (2012) conducted a small intervention study in dentists and dental hygienists, using glasses with a 5 deg prism. There were some positive effects on head posture, but not on neck posture or perceived discomfort. This may indicate that a more pronounced prism angle is needed to realize effects on posture and discomfort, but possibly not as large as the one in the current study.

Additionally, around 1/3 of the participants in the current study had an impression that viewing area or windows of the prism glasses were too small. It is believed that the small viewing area may have restricted the head motion activity found in this study. Enlarging the area without sacrificing the requirement for light weight could be a solution to this issue.

Interestingly, there was one participant in the control group who reported motion sickness from the use of the prism glasses. He told the researcher that he was not able view objects through sun glasses and any 3D glasses would lead to motion sickness. It raises the concern that the prism glasses may not be suitable for some sensitive people, or use in moving vehicles or in the air or train, where use may exacerbate the symptoms of motion sickness.

4.7 Administrative control on the intervention

Some suggestions have been made to prevent MSDs when using smartphones in the direct view, such as supporting the forearms, using both thumbs when typing, and
sitting with head in an upright position (Gustafsson 2012). The current study shows that the use of prism glasses provides another solution to lower the risk of MSDs. However, it is recommended that if smartphones are to be used for a long period of time, using the prism glasses and direct view interchangeably may further lower the risk of MSDs.

4.8 Study strengths and limitations

The current study examined the biomechanical efficacy, as well as the usability, desirability, and performance outcomes of wearing prism glasses during smartphone use. To eliminate the possibility of unequal familiarity with smartphone use, all subjects involved had at least 2 years of experience on smartphone use. Second, in order to minimize the biased preference that symptomatic subjects might have on the intervention study, a control group was included. Finally, the study collected multiple types of data, including objective and subjective to ensure holistic assessment of the intervention.

However, the duration of each task was short, there was no way to predict if the benefit of prism persists beyond 10 minutes. Further, subjects were all younger adults, future studies are recommended to expand age range to see if similar results are seen in children, teens, and older adults. Finally, the study was conducted in a controlled setting, further usability assessment is recommended to determine feasibility and usefulness in practice.
Chapter 5: Conclusion

Prior research showed promising benefits of prism glasses as an engineering control-type intervention that could possibly reduce neck pain and MSDs in simulated dental hygiene work (Smith et al. 2002). The current study examined the biomechanical efficacy, as well as the usability, desirability, and performance outcomes of wearing prism glasses during smartphone use. Results showed that the prism view generated lower neck muscle activity, more neutral postures, and less neck discomfort, compared to the direct view in both a symptomatic and a control group. Although the typing speed in prism view was significantly lower than in the direct view, the accuracy was the same. It is believed the speed difference would decline if more time working with the prism glasses were provided. However, the intervention would need to be further developed to address the two major concerns found in this study: 1) glasses being too heavy, and 2) viewing area being too small. As the majority of the weight is from the 90 deg prisms, it would be interesting to test the effects of using glasses with a 5 deg prism in Lindegard et al. (2012) or remodeled glasses with less than 90 deg prism in future similar studies.
References


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Khalaf, S., 2014. Mobile to television: We interrupt this broadcast (again). FLURRY.


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Appendix A: Flyer
Do you see yourself in these pictures? Is there a better way to interact with a smartphone?

The Ohio State University

You may be able to help OSU researchers investigate a new way to interact with smartphones.

If you are a smartphone user with neck pain or a smartphone user without neck pain you may be eligible to participate in this study.

Qualifications for participation include:

- Being 18 years of age or older, AND
- Having at least 1 year of experience using a touchscreen Android smartphone or iPhone, AND
- Not needing eye glasses to read your smartphone (contact lenses are ok), AND
- Ability to stand unassisted for 10 minutes while using your smartphone, AND
- Having no history of neck surgery, neck trauma, or debilitating neck pain.

Where: The study takes place in Baker Systems Engineering Bldg.

What you’ll do: The study will require about 90 minutes of your time. You will send email messages using your smartphone while sitting and standing and while using a new way of looking at your smartphone. While you perform these tasks, we will record your muscle activity and make a video recording.

Study participants will receive a $15 gift card for participating in this study.

Taking part in this study is voluntary. Would you like more information? Please contact Steven Tang by phone at (614) 397-1721 or email at tang.750@osu.edu.

The researcher who will evaluate your data is Steven Tang, Ph.D., Research Assistant Professor in the Department of Biomedical Engineering.

Please note: This study is being conducted in accordance with the institutional review board (IRB) at The Ohio State University. If you have questions or concerns about your rights as a research participant, contact the OSU Office of Responsible Research Practices at (614) 292-3211.

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<tr>
<th>Study</th>
<th>Contact Information</th>
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Appendix B: Screen form
Smartphone Intervention Study - Screening Form

Directions: Begin by thanking the potential participant for contacting us. Indicate that we are conducting a research study that will examine the effects of a different way to view a smartphone, and that we would like to ask a few questions to see if they qualify for the study. This screening will take about 10 minutes. If this is not a good time, when can we arrange to speak with you to go through these questions? __________

What is your age? __________ Sex: M F
(if age <18 or does not qualify)

Do you have at least 1 year of experience using a touchscreen Android smartphone or iPhone? Android iPhone (if "neither", does not qualify)

Do you need to wear glasses to read your smartphone? Yes No (If "Yes", does not qualify)

Can you stand unassisted for 10 minutes while typing on your smartphone? Yes No (If "No", does not qualify)

Is your skin easily irritated by adhesive tape (band-aids or first aid tape) or rubbing alcohol? Yes No (If "Yes", does not qualify)

Do you have a history of neck surgery, neck trauma, or debilitating neck pain? Yes No (If "Yes", does not qualify)

Do you have fibromyalgia, cervical radiculopathy, or headaches brought on by reading? Yes No (If "Yes", does not qualify)

Next, I have a set of 10 questions about neck pain that I will read to you, along with the responses. Please answer each question for the time period covering the past 3 months, including today.
(if response for any item is >3, does not qualify)

Determine the person's score: __________

If the potential participant does NOT qualify:
- Inform them that they do not qualify for the current study and state reason
- Answer any questions they might have
- Thank them for their time and end the call

If the potential participant qualifies for inclusion in the study:
- Inform them that they qualify and ask if they may describe the study to them (use script on next page).
- Ask if they have any questions.
- Ask if they can book them for a data collection session.
- Set up an appointment for the testing (remind about what they should wear (neck and shoulders should be accessible; top should not be baggy)); and to bring their charged smartphone and charger

Collect contact information for the participant:
Name: ___________________________ best Phone Number for contact: (____)______________
Email: ____________________________

Action Taken:
__ Participant qualified, was scheduled for the session on ___/___/___ at ____ am/pm
__ Participant qualified, but was not interested in participating
__ Participant did not qualify because (give reason): ____________________________

Version date: 2019/02/27
Smartphone Intervention Study - Description Script

In this study we are interested in exploring a different way of viewing a smartphone.

The study will require about 90 minutes of your time. During the study the tasks you will be performing will be typing email messages using your smartphone. You will do this while sitting and standing and while using a new way of looking at your smartphone. While you perform these tasks, we will record your muscle activity and make a video recording. Each task is 10 minutes long, and you will do 4 tasks altogether, with a 5 minute break in between tasks.

When you arrive for your session, we will give you a chance to first practice working with the intervention, so that you can become comfortable using it while you are typing on your phone.

We are interested in your perceptions of any neck discomfort you experience when performing any of the tasks.

Additionally, we are going to record the activity level from some of the muscles in your neck and shoulders as you perform the tasks. These measurements are made with surface electrodes, which are attached with adhesive tape.

We will also be recording the tasks on video.

Your name will not be associated with your data. We assign you a subject ID number and that is how we label all of your data. No one sees the data or images that we collect, outside of the people involved in the study. The researchers are a graduate student at The Ohio State University and two faculty members.

We will provide you with a written consent form when you come for the study. It will provide you with essentially the same information I have just provided to you.

→ Do you have any questions about the study?

I also want to mention that each participant will receive a $15 gift card for participating in the study.

Return to screening form →
Appendix C: Consent from
The Ohio State University Consent to Participate in Research

Study Title: An Investigation of an Ergonomic Intervention for Neck Pain During Smartphone Use

Principal Investigator: Carolyn M. Sommerich, PhD

Sponsor: None

- **This is a consent form for research participation.** It contains important information about this study and what to expect if you decide to participate. Please consider the information carefully. Feel free to discuss the study with your friends and family and to ask questions before making your decision whether or not to participate.

- **Your participation is voluntary.** You may refuse to participate in this study. If you decide to take part in the study, you may leave the study at any time. No matter what decision you make, there will be no penalty to you and you will not lose any of your usual benefits. Your decision will not affect your future relationship with The Ohio State University. If you are a student or employee at Ohio State, your decision will not affect your grades or employment status.

- **You may or may not benefit as a result of participating in this study.** Also, as explained below, your participation may result in unintended or harmful effects for you that may be minor or may be serious depending on the nature of the research.

- **You will be provided with any new information that develops during the study that may affect your decision whether or not to continue to participate.** If you decide to participate, you will be asked to sign this form and will receive a copy of the form. You are being asked to consider participating in this study for the reasons explained below.

1. **Why is this study being done?**

   The purpose of this project is to obtain information that could be used to examine the efficacy, usability, desirability, and efficiency of the intervention of prism glasses worn by users with and without neck pain during smartphone use.

2. **How many people will take part in this study?**

   25 people
3. What will happen if I take part in this study?

During this study, you will be asked to use your smartphone to type an assigned paragraph of text into an email that will be sent to the researcher after each task condition. You will experience four task conditions during the study. The four task conditions include two different postures and two ways of viewing your smartphone. These are the four conditions that you will experience during this study:

- Standing | not using prism glasses
- Standing | using prism glasses
- Sitting | not using prism glasses
- Sitting | using prism glasses

Each task condition will last for 10 minutes and you will be given a break between conditions.

Before you begin the tasks, small surface EMG (electromyography) electrodes will be taped on your skin over your neck/shoulder muscles to record the activity of these muscles. An ActivPal™ (accelerometer) will be taped on your forehead. Initial here to indicate that you do not have any known skin sensitivities to rubbing alcohol or adhesive tape (such as that on band-aids): _________.

Video will be recorded during the whole process. The recording will only be used for research purposes. Any still images that may be made from the video for publication purposes will have your face masked to ensure your anonymity and privacy. Initial here to indicate that you are ok with having your image recorded during this study: _________.

Several times during the study you will be asked to describe any neck discomfort that you may be experiencing. When all task conditions are finished, you will complete a final assessment of your preferences and opinions concerning the use of the prism glasses for neck comfort, productivity, and accuracy.

4. How long will I be in the study?

The whole session will take about 90 minutes.

5. Can I stop being in the study?

You may leave the study at any time. If you decide to stop participating in the study, there will be no penalty to you, and you will not lose any benefits to which you are otherwise entitled. Your decision will not affect your future relationship with The Ohio State University.

6. What risks, side effects or discomforts can I expect from being in the study?
The risks are listed below:

- Skin irritation to people with sensitive skin.
  - To reduce the risk of this, we use hypoallergenic adhesives.

- Some level of soreness or discomfort may develop in your neck or shoulders while performing the tasks.
  - To reduce the risk of this, you will be provided a 5 minute break after each 10 minute task.

- Some level of visual strain (eye discomfort) may develop while performing the tasks.
  - To reduce the risk of this, you will be provided a 5 minute break after each 10 minute task.

7. What benefits can I expect from being in the study?

Through participation in this study, you will be introduced to a new method of viewing your smartphone. You may or may not find that this makes viewing your phone more comfortable. As such, there may or may not be a direct benefit to you as a result of your participation in this study. The results of the study could potentially benefit other people. If any benefits are found to using the prism glasses.

8. What other choices do I have if I do not take part in the study?

You may choose not to participate without penalty or loss of benefits to which you are otherwise entitled.

9. Will my study-related information be kept confidential?

Efforts will be made to keep your study-related information confidential. However, there may be circumstances where this information must be released. For example, personal information regarding your participation in this study may be disclosed if required by state law.

Also, your records may be reviewed by the following groups (as applicable to the research):

- Office for Human Research Protections or other federal, state, or international regulatory agencies;
- U.S. Food and Drug Administration;
• The Ohio State University Institutional Review Board or Office of Responsible Research Practices;
• The sponsor supporting the study, their agents or study monitors; and
• Your insurance company (if charges are billed to insurance).

If this study is related to your medical care, your study-related information may be placed in your permanent hospital, clinic, or physician’s office records. Authorized Ohio State University staff not involved in the study may be aware that you are participating in a research study and have access to your information.

A description of this clinical trial will be available on http://www.ClinicalTrials.gov as required by U.S. law. This website will not include information that can identify you. At most, the website will include a summary of the results. You can search the website at any time.

You may also be asked to sign a separate Health Insurance Portability and Accountability Act (HIPAA) research authorization form if the study involves the use of your protected health information.

10. What are the costs of taking part in this study?

None

11. Will I be paid for taking part in this study?

To show our appreciation for your participation in this study, you will receive a $10 Kroger gift card.

By law, payments to subjects are considered taxable income.

12. What happens if I am injured because I took part in this study?

If you suffer an injury from participating in this study, you should notify the researcher or study doctor immediately, who will determine if you should obtain medical treatment at The Ohio State University Wexner Medical Center.

The cost for this treatment will be billed to you or your medical or hospital insurance. The Ohio State University has no funds set aside for the payment of health care expenses for this study.
13. What are my rights if I take part in this study?

If you choose to participate in the study, you may discontinue participation at any time without penalty or loss of benefits. By signing this form, you do not give up any personal legal rights you may have as a participant in this study.

You will be provided with any new information that develops during the course of the research that may affect your decision whether or not to continue participation in the study.

You may refuse to participate in this study without penalty or loss of benefits to which you are otherwise entitled.

An Institutional Review Board responsible for human subjects research at The Ohio State University reviewed this research project and found it to be acceptable, according to applicable state and federal regulations and University policies designed to protect the rights and welfare of participants in research.

14. Who can answer my questions about the study?

For questions, concerns, or complaints about the study you may contact Dr. Carolyn M. Sommerich, (614) 292-9965.

For questions about your rights as a participant in this study or to discuss other study-related concerns or complaints with someone who is not part of the research team, you may contact Ms. Sandra Meadows in the Office of Responsible Research Practices at 1-800-678-6251.

If you are injured as a result of participating in this study or for questions about a study-related injury, you may contact Dr. Carolyn M. Sommerich, (614) 292-9965.
Signing the consent form

I have read (or someone has read to me) this form and I am aware that I am being asked to participate in a research study. I have had the opportunity to ask questions and have had them answered to my satisfaction. I voluntarily agree to participate in this study.

I am not giving up any legal rights by signing this form. I will be given a copy of this form.

Printed name of subject

Signature of subject

Date and time

Printed name of person authorized to consent for subject

Signature of person authorized to consent for subject

Date and time

Relationship to the subject

AM/PM

Investigator/Research Staff

I have explained the research to the participant or his/her representative before requesting the signature(s) above. There are no blanks in this document. A copy of this form has been given to the participant or his/her representative.

Printed name of person obtaining consent

Signature of person obtaining consent

Date and time

Witness(es) - May be left blank if not required by the IRB

Printed name of witness

Signature of witness

Date and time

Printed name of witness

Signature of witness

Date and time

Printed name of witness

Signature of witness

Date and time