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Assessment of Antebrachial and Carpal Muscle Activity During Smartphone Use: is “Selfie Wrist” a Real Phenomenon?

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ASSESSMENT OF ANTEBRACHIAL AND CARPAL MUSCLE ACTIVITY DURING SMARTPHONE USE: IS “SELFIE WRIST” A REAL PHENOMENON?

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ABSTRACT

Monica E. Stacy: ASSESSMENT OF ANTEBRACHIAL AND CARPAL MUSCLE ACTIVITY DURING SMARTPHONE USE: IS "SELFIE WRIST" A REAL PHENOMENON?
(Under the direction of Dr. Carol Britson)

Reports in the media by celebrities have sparked an interest in a phenomenon being called "selfie-wrist," in which smartphone users develop symptoms traditionally associated with carpal tunnel syndrome (CTS). CTS is a compression neuropathy characterized by pain, numbness and tingling occurring over the first three and a half digits, as well as over the radial portion of the palm. While many studies have investigated the potential ill effects of texting on musculoskeletal health, there has been no research to date which investigates the claims of "selfie wrist." The primary aim of this study was to address the validity of "selfie wrist" claims and to determine if individuals could be at risk as a result of their smartphone usage. The secondary aim of this study was to further investigate the effects of texting on musculoskeletal health, taking into account the differences between texting one-handed versus two-handed, as well as to investigate the potential effect of using a grip device such as the PopSocket while texting.

The experiment consisted of an intake survey component, a selfie-taking component, and a texting component. Subjects who, for various reasons, were unable to participate in the in-person experiment completed an online alternate survey. The surveys assessed smartphone usage habits and any pain subjects experienced which was associated with smartphone usage. During the experiment, photos of the flexion angles of the thumb, wrist, and elbow were taken of participating subjects during flexion without holding a smartphone, which created their baseline flexion angle data, as well as during selfie-taking and group selfie-taking for each joint. Surface electromyography (sEMG) was used to assess the muscle activity of the trapezius, flexor carpi ulnaris (FCU), flexor carpi radialis (FCR), and abductor pollicis longus (APL) muscles during texting tasks performed one-handed, two-handed, and with and without a grip device. Joint angle data and muscle activity data were analyzed with a two-way analysis of variance (ANOVA), with the two factors being joint and number of hands used during texting, and grip device in use and number of hands used during texting, respectively.

A significant increase was found in the elbow joint angle during selfie-taking and group selfie-taking, with the average baseline flexion of the elbow being 27.8 degrees, and increasing by 609% and 707% during single selfie and group selfie-taking, respectively. Joint angles of the thumb and wrist did not show significant changes with any form of selfie-taking. The significant increase that occurred in the elbow joint was expected since the baseline data reflected flexion of the elbow, and the anatomy of the joint results in extension with the performance of any activity, including selfie-taking. These results indicate that a detrimental angle of flexion was not achieved with any selfie-taking task, and that "selfie wrist" is not a real phenomenon. Further research is needed to determine the potential effects of selfie-taking when viewed as a repetitive strain injury (RSI). All muscles except for the FCR showed a significant increase in muscular output during texting one-handed as compared to two-handed. These results support existing data which reported the same result. There was no significant difference found in the use of a grip device during texting one-handed nor two-handed. These results indicate that a grip device neither aids in relaxing the muscles during texting, nor does it increase muscular output during texting. The results of this study indicate that neither texting nor selfie-taking result in the development of musculoskeletal disorders (MSDs). Further research is warranted which continues to investigate the cause of musculoskeletal pain experienced by subjects during smartphone usage. It is possible that the significant increase in muscular activity during one-handed texting could result in muscular fatigue or perceived pain during one-handed texting.

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INTRODUCTION

While cellphones have been around for several decades, improved models with capabilities beyond calling and texting have seen an increased prevalence only within the last decade or so. These improved models have created what is known as the smartphone, and with it, an overwhelming wave of its usage. According to Pew Research Center (2019), nearly 96% of Americans now own a cellphone, with 81% specifically owning a smartphone. While these statistics seem to indicate that the American population is "plugged in" and up to date with technology, with increased smartphone occurrence also comes increased smartphone usage, which can potentially be detrimental to one's health.

Before the era of smartphones, the most common mobile technology in use was the laptop computer. Musculoskeletal symptoms seen with excessive smartphone usage bear striking similarities to those which arose due to the similar over-usage of laptops. Although the postures for using a laptop are not identical to smartphone usage, the same general repetitive movements and hand positions deriving from daily computer use of several hours or more could contribute to increased risk for musculoskeletal disorders (MSDs) such as neck pain, shoulder strain, forearm tenosynovitis, carpal tunnel syndrome (CTS) and De Quervain's tenosynovitis (So et al., 2017). Other reports have also suggested that there is a correlation between computer usage and upper extremity MSDs. Contrarily, Waersted et al., (2017) concluded that there is insignificant evidence to be able to declare a causal relationship between computer usage and the development of CTS. Enhanced computer technology also paved the way for videogames and the increase in time spent by adolescents playing videogames coupled with their continued computer usage. In a study which investigated Brazilian adolescent videogame usage and the effects of this usage on musculoskeletal symptoms and disorders by Zapata et al., (2006), it was found that painful MSDs and repetitive strain injuries (RSIs) were common in the school-aged adolescents, and were most commonly found in female students. Despite this data, a clinical significance was not able to be established at the time which specifically correlated excessive videogame activity with MSDs (Zapata et al., 2006). The concerns surrounding computer and videogame usage have recently become secondary to the concerns which plague the excessive smartphone usage of today.

Preliminary research has begun to investigate the effects that smartphones can have on one's health: from eyestrain, to hearing loss, potentially-reduced fertility, and even the much-feared conclusion that smartphone usage could correlate with the occurrence of some brain tumors, there has been no shortage of fear surrounding the negative effects of smartphones on the human body (Fowler and Noyes 2017). Canillas et al. (2014) even determined that cellular phone abuse was an aggravating agent in two cases of early-onset trapeziometacarpal osteoarthritis, indicating another MSD becoming more prevalent in younger populations as a result of smartphone usage. The issue that seems to have gained the most momentum in research and the media for its common occurrence and seemingly mild nature is that of an overuse injury of the muscles of the hand and wrist specific to using smartphones. Overuse injuries can be described as long-standing or recurrent musculoskeletal problems which are generally unrelated to an acute incident. While they are most commonly seen in competitive athletes (Banks et al., 2005), with increased cellphone usage have come injuries that increasingly bear similarities to traditional overuse injuries. In a study by Fowler and Noyes (2017), several 8-11-year-old participants described the way in which texting too much hurts their thumbs, and that in some instances, they even preferred to make phone calls rather than text because of the pain associated with texting. Before the availability of Apple’s iPhone, “Blackberry thumb” was dubbed as the unofficial name of the condition in which texting with a Blackberry phone caused pain at the base of the thumb or in the muscles of the thumb or wrist (Fowler and Noyes 2017). Studies have shown that such RSIs as “Blackberry thumb” are ever-increasing due to the increased usage of such devices, which require sustained and prolonged gripping, repetitive pushing, and other movements of the thumb and fingers that have been identified as risk factors for various MSDs (Sharan and Ajeesh 2012). Additionally, it was reported that 84% of participants in another study expressed pain of some sort due to texting, and that the most common pain occurred in the base of the right thumb (Berolo et al., 2011). In a study which focused on the many variables related to young adolescent’s well-being and their usage of wireless phones, the symptoms most consistent with usage were headache and having a painful thumb as a result of texting (Redmayne et al., 2013). These results indicate the fairly common incidence of pain associated with texting which continues to pose a problem in the population for smartphone users.

In addition to the increased usage of smartphones and the subsequent potential health defects associated with their usage, smartphones themselves continue to evolve. It has been investigated, that, as the size of smartphone touchscreens has become increasingly larger over the years, single hand usage has become increasingly difficult, especially for female users (Guo et al., 2016). It was argued that without a change in the smartphone screen interface which would allow for a greater accessibility to all parts of the screen, users will continue to experience pain from overuse in the hands and thumb as a result of straining to reach all parts of the screen (Guo et al., 2016). Additionally, smartphones have transitioned in recent years from being keypads, such as the Blackberry described above, to being touchscreens. Although touchscreen phones have become far more popular, phones with physical keypads are still commercially available, indicating the presence of populations that still use keypad phones (Gustaffson et al., 2018). In an earlier study, electromyography was used to analyze the muscular loads of six muscles while participants completed texting tasks using a Nokia Model 3310 keypad smartphone (Gustaffson et al., 2010). Findings revealed several key differences in muscular activity between males and females, namely that females had higher muscle activity levels and greater thumb abduction, allowing them to move their thumbs with higher velocities and to have fewer pauses in the thumb movements (Gustaffson et al., 2010). This study also noted that subjects with existing MSDs had lower muscle activity levels in the abductor pollicis longus (APL), tended to move their thumb at higher velocities, and had fewer pauses in their thumb movements compared to those without symptoms of MSDs (Gustaffson et al., 2010).

These findings lay the basis for recent studies which focus on both the comparison between muscular loads using keypad versus touchscreen smartphones, and also studies which solely focus on the impact of touchscreen smartphones today. Comparisons made between keypad and touchscreen smartphones found lower muscle activity occurred while using the touchscreen phone in comparison with keypad phones (Gustaffson et al., 2018). These results suggest that current touchscreen smartphones may be an ergonomic improvement from the initial keypad smartphones that are now being phased out. In a study which investigated a cohort of touchscreen smartphone users both with and without existing MSDs, a follow-up was performed on the individuals both one year and five years after the initial study (Gustaffson et al., 2017). While the results seemed to indicate an association between texting and MSDs, the analysis revealed mostly short-term effects of MSDs in the neck and upper extremities, which were seen to a lesser extent when considered on a long-term time scale (Gustaffson et al., 2017).

Although touchscreen smartphones have thus been shown to reduce the muscular output that occurs during texting in comparison to older models of keypad smartphones, newer-model touchscreen smartphones may still result in MSDs on the short-term, and possibly even long-term, scale. These results also may be exacerbated by the fact that current touchscreen smartphones' screens continue to increase in size, making accessibility to the entire screen increasingly difficult without strain on the thumb and wrist. It has been reported that, although available evidence does suggest that mobile touchscreen device use and aspects of its use, such as long duration, awkward postures, larger screen size and gaming tasks, may be associated with musculoskeletal symptoms, concrete evidence suggesting a direct correlation between MSDs and smartphone use is limited with mainly low quality studies (Toh et al., 2017).

Existing studies investigating a correlation between MSDs and smartphone usage so far tend to focus explicitly on texting. However, recent media reports have surfaced which suggest that "selfies" may also now be responsible for creating musculoskeletal symptoms from overuse. Selfies, or self-portrait digital photographs, have become increasingly popular for their usage through various social media sharing sites, and are especially used for communication through SnapChat. The only existing literature investigating the effects of selfie-taking have to do with the secondary injuries that occur as a result of accidents such as tripping and falling due to being distracted while taking selfies (Lyons et al., 2017). Few studies have investigated the role that selfie-taking may have on musculoskeletal symptoms through smartphone usage, although there has been a call to do so following celebrity reports. Today show host Hoda Kotb brought the issue to light following reports with celebrity magazines where she cited speaking to an orthopedist about pain in her elbow and being subsequently diagnosed with "selfie elbow," a supposed overuse injury occurring from excessive selfie-taking (Mirchandani 2016). Orthopedic surgeon Dr. Levi Harrison then weighed in on the issue, explaining that "selfie elbow" as well as "selfie wrist" cases are on the rise, and that "selfie wrist" is a form of CTS (Bharanidharan 2018). These reports are preliminary speculation as a result of media publicity on the subject, and lack substantial research and evidence such as what is already underway in regard to texting. Nevertheless, work tasks of long duration with flexed wrists have been reported as risk factors for CTS during extended use of a computer and mouse (Hagberg 1996). It is then possible that movements occurring during selfie-taking which mimic long durations of wrist flexion may have the same effect in putting the subject at risk for CTS, and the characteristic symptoms of pain, numbness and tingling over the digits and radial portion of the palm (Woo et al., 2016).

To understand the implications of overuse injuries potentially derived from texting and selfie-taking requires a more general understanding of the anatomy that can be affected through smartphone usage in general. Various MSDs affecting the upper limb traditionally caused by sports overuse injuries or trauma are now being increasingly reported as a result of smartphone usage. As described above, tendon overuse injuries seem to be the most common form of injury in association with smartphone use. Overuse injuries as a result of sports injury tend to occur in endurance sports as a result of cumulative microtrauma, which leads to mechanical fatigue of the tendon, rendering it unable to withstand further stress (Selvanetti et al., 1997). This type of injury then relates to excessive smartphone use to result in similar tendon damage in and around the thumb and wrist. The incidence of RSIs occurring through smartphone overuse have also been investigated, and often present in the form of De Quervain's tenosynovitis, or similarly, extensor pollicis longus tenosynovitis (Eapen et al. 2014). De Quervain's tenosynovitis occurs as the result of shear microtrauma due to repetitive gliding of the first dorsal compartment tendons, and is the most common form of wrist tendinitis, found most often in athletes (Rettig 2004). Ultrasound imaging can detect subclinical changes in the tendons of the thumb in subjects experiencing thumb pain during text messaging, and that excessive text messaging causes damage to the third and first compartments of the wrist extensors (Eapen et al., 2014). Arthritis of the first carpometacarpal joint has also been sustained as a consequence of excessive texting in several reports, and general wrist, hand, and elbow discomfort were found to be more common on the right side of the body (So et al., 2017). In a study regarding the incidence of arthritis in the population, women were more likely to be diagnosed with hand arthritis compared to men and to be more physically impaired as a result of their hand symptoms (Cole et al., 2011). The debilitating nature of all of the above-described MSDs has led to the necessity of understanding the impact that the overuse of smartphones can have.

Research has increasingly shown the effect that excessive texting can have on musculoskeletal health of the hand and wrist. Although there have been studies which take into account smartphone screen size and the potential for creating a more accessible interface to reach all parts of the screen with greater ease, there have not as of yet been any reports which take into account the effect that a phone grip device could have on muscular load activity. I hypothesize that the use of a phone grip, such as the PopSocket or ring grip, will reduce the muscular load required while texting by allowing relaxion of the muscles of the hand and wrist. I also hypothesize that larger smartphone screens will result in greater muscular load and strain, as will texting with only one thumb in comparison to two. In regard to the argument surrounding the possibility of "selfie wrist," I hypothesize that the taking of selfies will result in a potentially detrimental flexion angle of the wrist, and that group selfies will result in an even greater wrist flexion, and therefore strain, than taking traditional selfies of oneself.

METHODS AND MATERIALS

Participant information

Participants were recruited from the Fall 2019 class of Human Anatomy and Physiology I, BISC 206, at the University of Mississippi via a Blackboard announcement. Of the total number of students enrolled in the class, 80 students reached out by email to participate in the study, and data were collected from 53 of them. All participants were over the age of 18 and had no pre-existing MSDs. Of the participants who appeared in person for data collection, 6 participants were male and 47 were female. Additionally, five participants were left-handed and 48 were right-handed. Volunteers were informed by email that they were only required to attend a single meeting which was expected to last around 30 minutes. Data collection took place throughout the Fall 2019 semester beginning on 20 September 2019 and ending on 6 December 2019.

Equipment and software

Two, 26T PowerLabs were connected in tandem to a computer running LabChart Version 8.1.8 software, licensed to the University of Mississippi. Two electrodes were placed on either side of the belly of each muscle and were connected to the PowerLab unit via a BioAmp cable. A ground electrode was placed on the upper back. Muscular activity data were collected at a rate of 2000 readings/second within a range of 2mV. ACPP Core2 posture application for iPhone by Jinnyu Technology Co., LTD was used to take pictures of the subjects performing various flexion angles and taking selfies. Angles in Photos application for iPhone was used in conjunction with the pictures taken using ACPP Core2 posture application to obtain the angles of flexion on the pictures of the subjects.

Experimental procedure

This experiment, IRB protocol #19x-306, was approved as exempt under 45 CFR 46.101(b)(#3). Each subject was given a unique six-digit identification number that was kept separate from their name in all files except for the master sheet. This six-digit number was made up of a two-digit month, two-digit day, and a two-digit number identifying in what order the subjects were seen each day. Upon arrival, the protocol of the experiment was explained to the subject in detail, and their ability to withdraw from the study at any time was emphasized. After signing the consent form, the volunteer then completed an intake questionnaire regarding their sex, hand dominance, smartphone model, smartphone habits, videogame habits, and any pain they may have associated with smartphone or videogame usage.

The subject was then asked to perform flexion of their thumb, wrist, and elbow of their dominant hand. Pictures were then taken of the subject's hand, wrist, and elbow, first in a neutral position, followed by each flexed without holding a smartphone (Figure 1). These flexion angles comprised the subject's baseline data upon which the rest of the flexion angle data during selfie-taking and group selfie-taking would later be calculated as relative to. The subject was instructed to open either their camera on their personal smartphone or their SnapChat account, and to position themselves how they normally would to take a selfie. Pictures were taken of the flexion angles of the thumb, wrist, and elbow of the subject while they held their selfie position (Figure 2). The subject was then asked to position themselves how they would if they were trying to take a group selfie to include multiple people. The subject held this position while pictures were again taken of the flexion angles of their thumb, wrist, and elbow. Pictures of the subject were taken using my personal iPhone 8 plus smartphone using the ACPP Core2 Posture application. The subject's face was blurred out of any pictures in which it appeared. The Angle in Photos application for iPhone was used to measure the subject's flexion angles.

The location of the APL, flexor carpi ulnaris (FCU), flexor carpi radialis (FCR), and trapezius muscles and their potential functions in relation to texting were explained to the subject to prepare them for the surface electromyography (sEMG) portion of the experiment. The subject was then shown pictures which demonstrated the general locations of the eight disposable electrodes which would be attached to their aforementioned muscles to record data regarding their muscular electrical output while they performed several texting tasks (Figure 3). The subject was instructed to flex their thumb and wrist, and to raise and lower their dominant arm in sequence to allow palpation of the four muscles to allow for proper electrode placement (Figure 4). Two electrodes were attached near the ends of each muscle in order to reduce noise within the data collected using a PowerLab Data Acquisition Unit while the subject completed several tasks.

Tasks consisted of: performing a maximum voluntary contraction (MVC) of each muscle being measured; texting one-handed using their dominant hand (Figure 5); texting one-handed using their dominant hand while using a PopSocket grip device; texting two-handed (Figure 6); and texting two-handed while using a PopSocket grip device. Data were recorded throughout the entire length of time it took the subject to complete all four texting tasks without breaking between tasks. Subjects who did not have a PopSocket or similar grip device on their personal smartphone used a sample iPhone 8 plus with PopSocket to complete the texting tasks using the PopSocket. This was noted in the data.

During data collection the subject was positioned so that he/she could not easily view the screen as it was recording their results in order to reduce subject bias that could affect the data. The subject first flexed their thumb and wrist, and raised and lowered their dominant arm in sequence to obtain their MVC data. These data were recorded in order to create baseline data before introducing other variables such as a texting, whether texting was done with one hand or two, and whether or not a grip device was used. All subsequent data were calculated as a percentage of the MVC.

Next, the subject was instructed to go to the Notes section of their phone where they would be typing to simulate texting. To ensure the subject texted for a long enough period of time per texting task to collect substantial data, the subject was instructed to answer a different question per texting task, and it was requested that they type out at least a one or two-sentence response. The prompt questions were "Why did you choose Ole Miss?" "What are your career goals or general goals for the future" "What is your favorite class you are taking this semester and why" and "What are you most looking forward to about this year?" As each question was asked, the subject was instructed which texting task to perform as they responded to the question, following the order of single thumb texting, single thumb texting using a grip device, two hand texting, and two hand texting using a grip device.

After completion of all texting tasks, the Lab Chart recording software was stopped and checked to make sure that the data from each texting task were recorded properly. If all the data were sufficient, the electrodes were removed from the subject who was offered lotion to apply to the electrode attachment sites if desired. The subject was thanked for their participation, and it was reiterated that the subject would receive a small amount of extra credit toward their BISC 206 grade for their participation in the experiment.

Without the subject present, data were collected from their file. Using the Waveform cursor feature on Lab Chart, I collected data on the peak values in millivolts times seconds (mV*s) for each texting task of each muscle for the integral data. This was done by scrolling through the subject's data to determine the location of the greatest peak in muscular electrical output for each muscle during each texting task.

Data analysis

Joint angle data were analyzed with a two-way analysis of variance (ANOVA) with the two factors being joint and number of hands used during texting. Muscle activity data were also analyzed with a two-way analysis of variance (ANOVA) with the two factors of grip device in use and number of hands used during texting. The level of significance was set at alpha = 0.05 for all analyses. Descriptive statistics were calculated for the alternate survey data to develop a background profile of typical smartphone use in college students.

RESULTS

Intake survey data

The majority (81%) of subjects investigated identified as right-handed females. Only 5 subjects were left-handed, with one male and one female left-handed subject showing mixed left and right-handed smartphone usage, and predominantly right-handed smartphone usage, respectively. Forty-eight out of 53 subjects owned a model of Apple's iPhone. The remaining five subjects owned a Samsung Galaxy (Figure 7). The most common smartphone used by subjects was the iPhone 8 Plus, owned by 11 out of 53 subjects. Only one subject owned the iPhone 11 Pro Max, which boasts the largest screen of any iPhone (Table 1).

Fifty percent of subjects reported an average of 3-4 hours of smartphone screen time daily (Figure 8). Of the 5 subjects who did have a grip device attached to their smartphone, only one subject reported regularly using their grip device to take selfies. Several subjects used their grip device to complete other smartphone tasks (Figure 9). Of the 44 subjects who reported that they most often texted using two hands, 23 subjects reported that they found it difficult to text using only one hand (Figure 10). Nine subjects reported regularly texting using one hand only, and only two of those subjects reported having difficulty texting using one hand (Figure 11). Subjects estimated the number of text messages sent per day, number of selfies taken per month, and what percentage of those selfies are group selfies (Table 2). Data were taken to determine how many subjects used alternative buttons to take selfies, such as the up and down volume buttons. All but three subjects knew there was an alternative button to push to take a selfie, however, only 4 subjects reported regular use of an alternative button (Figure 12).

Fifteen subjects expressed varying degrees of soreness or discomfort as a direct result of different smartphone activities. Seven subjects complained of pain after holding their smartphone for less than 30 minutes, and six subjects complained of pain while texting (Table 3). Only one subject complained of pain while taking selfies. Eleven out of 53 subjects reported neck pain after looking down at their smartphone for less than thirty minutes. An additional 11 subjects reported that the pain began after looking at their smartphone for nearly an hour (Table 4). Five out of 53 subjects reported feeling shoulder pain in the form of soreness or discomfort when taking group selfies of themselves with several other people.

The eight subjects who reported playing videogames regularly showed varying lengths of playtime, with four subjects reporting a sitting lasting 1-2 hours long (Table 5). None of the subjects expressed that they experienced pain or discomfort of the hand or wrist after playing videogames for an extended period of time (Table 5).

Flexion angles

Subjects' flexion angles were reported in three categories: baseline flexion of each joint (thumb, wrist, and elbow), flexion of each joint during single selfie-taking, and flexion of each joint during group selfie-taking (Figure 13).

A significant increase in joint angle of the elbow as compared to the baseline flexion angle was found when subjects took selfies of just themselves in a comfortable position ($F=32.95$, $df=2,5$, $p< 0.001$, Figure 14). A significant difference was not found when comparing subjects who text one-handed versus two-handed during selfie-taking

(F=0.998, df=1,5, p=0.321, Figure 14). There was also no significant difference found when comparing subjects who text one-handed versus two-handed in conjunction with their joint angles during selfie-taking (F=0.906. df=2,5, p=0.409, Figure 14). A significant increase in joint angle of the elbow as compared to baseline flexion angle was also found during group selfie-taking (F=51.443, df=2,5, p<0.001, Figure 15). A significant change was not found when comparing subjects who text one-handed versus two-handed during group selfie-taking (F=1.401, df=1,5, p=0.241, Figure 15). There was also no significant change found when comparing subjects who text one-handed versus two-handed in conjunction with their joint angles during group selfie-taking (F=1.209, df=2,5, p=0.305, Figure 15).

sEMG Data

There was no significant change found in any of the four muscles measured when texting with a grip device was compared with texting without the use of one (trapezius: F=0.457, df=1,3, p=0.50; FCU: F=0.644, df=1,3, p=0.423; FCR: F=2.582, df=1,3, p=0.110; APL: F=0.937, df=1,3, p=0.334) (Figure 16). A significant increase in muscular activity was found when subjects texted using one hand versus two in three out of the four muscles measured (trapezius: F=9.029, df=1,3, p=0.03; FCU: F=5.990, df=1,3, p=0.015; APL: F=9.963, df=1,3, p=0.02). A significant change regarding one-handed texting as compared with two-handed texting was not found for the FCR (F=2.297, df=1,3, p=0.131). While the interaction of one-handed versus two-handed texting with and without a grip device came close to showing significance in the FCR (F=3.245, df=1,3, p=0.073), no muscle showed a significant change in regard to these variables (trapezius: F=0.382, df=1,3, p=0.537; FCU: F=0.188, df=1,3, p=0.665; APL: F=0.001, df=1,3, p=0.973) (Figure 16).

Alternate survey data

Subjects choosing to participate in the alternate survey came from the same pool of subjects who participated in the full in-person experiment. Of 81 total subjects, 57 subjects reported they most often text using both of their thumbs. Thirty-two of the 81 subjects reported finding it difficult or uncomfortable to text using only one hand. Thirty-four subjects reported using their smartphone for 3-4 hours per day. Ten of 81 subjects reported using a grip device to regularly hold their smartphone. Twenty-two subjects reported sending approximately 20-30 text messages in a day, while 21 subjects reported sending 50 or more text messages per day. Thirty-three subjects estimated taking 1-10 selfies in a month, while 19 subjects reported taking 50 or more selfies per month (Table 6). Thirty-seven of 81 subjects reported experiencing pain of soreness of the hand or wrist following smartphone usage of more than one hour. Only five of 81 subjects reported regularly playing videogames (Table 6).

DISCUSSION

Conclusions on "selfie wrist"

Given the results on the angles of the thumb, wrist, and elbow joints during selfie-taking and group-selfie taking and the significance found in the angles compared to the baseline angle for only the elbow joint, I reject my hypothesis that the angle of flexion of the wrist during selfie-taking is one that would be detrimental to carpal tunnel health. While it still is possible that repetitive strain may play a role in carpal tunnel health in regard to selfie-taking, the results of this study show that the angle of wrist flexion is not to blame for any pain or discomfort that may result from taking selfies.

I also reject my hypothesis that taking group selfies would result in a greater and more detrimental angle of wrist flexion than that which occurs during selfie-taking of oneself. While the angle of wrist flexion during group selfie-taking was greater than that of traditional selfie-taking (102% of baseline angle compared to 94% of baseline angle, respectively), neither angle was significantly different from that which was found in the baseline flexion angles. For these reasons, I reject my hypothesis that group selfies would be more detrimental to carpal tunnel health than regular selfies, because neither position results in an angle of wrist flexion that is abnormal as compared with the baseline angle.

The significant increase from the baseline flexion angle of the elbow to that which occurred during selfie-taking was to be expected considering the average angle of baseline elbow flexion was a small, acute angle of 27.81 degrees across all participating subjects. Conversely, when the subject performed any activity which required extension of the elbow joint, such as taking a selfie of themselves or in a group, the joint angle increased drastically to an obtuse angle, and resulted in nearly a full extension of the elbow during group selfie-taking. The average angle achieved by the elbow during selfie-taking was therefore 609% of the baseline angle and 707% of the baseline angle during selfie-taking and group selfie-taking, respectively. These changes were significant, presenting a logical difference between the joint angles when considering the activities that were being performed. Despite this significant result, the premise of measuring joint changes during selfie-taking was to determine if the positioning one held in order to take a selfie was one in which extreme and potentially harmful joint angles were required and sustained throughout the selfie-taking process. Given that the joint angle achieved by the elbow during selfie-taking was still within normal limits of the capacity of the elbow joint itself, this significant increase is not a cause for concern. Had the significant increase been found within the thumb and/or the wrist instead, the concern would be greater due to the anatomy of these joints and the extreme and potentially harmful angle that would be occurring during selfie-taking and group selfie-taking as compared with that achieved in the baseline data.

Conclusions on effectiveness of using a grip device

I reject my hypothesis that the use of a grip device during texting would lessen the muscular output of the muscles measured in this experiment. No muscle of the four that were measured for this experiment showed any significant change in muscular output between using the grip device to text and not using a grip device to text. Although the interaction of one-handed and two-handed texting with and without a grip device came close to having a significant change in the FCR, no muscle showed a truly significant change that would allow acceptance of the hypothesis regarding grip device usage during texting.

While I hypothesized that the use of a grip device would allow subjects' muscles to relax during texting, resulting in less contraction of each of the four muscles, several subjects during the experiment expressed how difficult they found it to text using the grip device. This brought into question if the final results would display a significant change in the other direction, displaying that the use of the grip device would result in greater muscular contraction during texting. Both claims, however, proved to be incorrect, as the grip device had no effect on muscular contraction during texting.

Conclusions on texting thumb

I accept my hypothesis that texting using only one hand would increase the muscular load required to complete the texting task when compared with two-handed texting, which could in turn result in muscular strain. For the six subjects who reported pain during texting, texting with two hands would lessen the muscular output of the muscles of the hand and wrist, which could potentially see a reduction in pain while texting.

A significant increase in muscular activity was found in three out of the four muscles measured in regard to texting while using just one hand as compared to using two. The trapezius, FCU, and APL muscles all exhibited a significant increase in muscular output during texting one-handed compared to texting two-handed. The FCR muscle did not show a significant change between texting one-handed and texting with both hands. Similarly, although focusing on different muscles than those highlighted in this experiment, Gustaffson et al. (2011) found higher muscle activity in the wrist extensors during one-handed texting when compared with two-handed texting. Toh et al. (2017) also reported significantly higher upper trapezius, wrist extensor, wrist flexor, finger and thumb muscle activity during one-handed holding and usage of a tablet as compared with a two-handed grip and usage. Contrarily, Kietrys et al. (2015) did not find significantly greater thumb muscle activity during one-handed texting as compared with two-handed texting, speaking to the uncertainty that still surrounds results regarding texting and musculoskeletal health of the upper extremity.

Conclusions on smartphone screen size

The most common smartphone used by subjects in this experiment was the iPhone 8 plus. This phone, while sporting a fairly large screen at a 13.97 cm display, is now considered to be a mid-sized phone by iPhone standards, whose newest model, the iPhone 11 Pro Max, has a 16.51 cm display. While this phone size could contribute to muscular strain of the hand and wrist during texting, I am unable to accept or reject my hypothesis that larger phones would result in muscular strain due to the lack of subjects owning smaller smartphones as well as the fact that hand size was not taken into account. Toh et al., (2017) reportedly found higher muscular activity with the use of larger screen sizes. Their study incorporated the usage of tablets in addition to smartphones, so it is difficult to discern if their results would still show significant differences based on screen size if only smartphones were studied (Toh et al., 2017).

Subjects' pre-existing pains reported

Eighty-three percent of subjects reported in their intake survey that they most often used both of their hands to text. Of the 44 subjects who reported texting with both hands, 23 of them also reported that they found it difficult or uncomfortable to text using only one hand. While these subjects were not prompted to indicate if this discomfort also resulted in pain, it is possible that the significant increases found in muscular contraction when subjects used only one hand to text were responsible for this feeling of discomfort. Fifteen subjects expressed varying degrees of pain or discomfort that they believed to come as a direct result of smartphone usage. Several subjects reported pain of the hand or wrist resulting from holding their smartphone for an extended period of time or from texting. Several subjects reported neck pain as a result of looking down at their smartphone for varying degrees of time. Guan et al., (2015) found significant forward head postures when subjects viewed their mobile phone in contrast to standing neutrally, and cited previous studies which determined that the dramatic use of mobile phones was causing adverse effects, including neck and shoulder pain. Only one subject reported pain of the wrist as a result of taking selfies, and five subjects reported pain in the shoulder as a result of taking group selfies. These results are in accordance with those found in other studies, which stated that there were clear associations linking texting to musculoskeletal pain of the neck and shoulder, as well as some reports of numbness and tingling of the hand and fingers for both male and female participants (Gustaffson et al., 2017). Lin and Peper (2009) reported that 83% of their participants experienced some degree of hand and neck pain during texting, leading them to believe texting could contribute to developing pain, MSDs, or RSIs. Gustaffson et al., (2017), on the other hand, also noted that their results suggest that musculoskeletal pain as a result of texting is likely a short-term effect, and that long-term effects were less likely a direct result of intensive texting.

Videogame usage

Contrary to the findings of Berolo et al., (2011), who found significant associations between the time spent playing videogames in a given day and pain reported in the thumb, none of the eight subjects who reported playing videogames with varying degrees of regularity in this experiment reported experiencing pain or discomfort of the hand or wrist following an extended period of time playing videogames, although some reported pain and discomfort from smartphone usage. Zapata et al., (2006) found that the students in their study who played videogames more than three times a week actually reported a lower frequency of musculoskeletal pain syndromes compared to those students who did not play videogames upwards of three times per week. Additionally, they reported that pain and discomfort of the wrist was not associated with computer or videogame usage in their study, indicating the need for further research to determine the relation between hand/wrist pain and videogame usage (Zapata et al., 2006).

Suggestions for future studies to include variables unaccounted for in this study

Hand size was a variable brought to my attention more than midway through the experimental process, when nearly three-fourths of the subjects had already been evaluated. The idea behind including this variable in future studies is that it is likely that individuals with larger hands would have an easier time reaching the entirety of the keyboard while texting. This would in turn likely allow for a lesser muscular output than for individuals with smaller hands who would have to strain themselves more to text one-handed. Similarly, while subjects' smartphone model and size were recorded as part of their intake demographic data, this information was not used in conjunction with their hand size. This information would have helped to determine the potential ill effects of a smaller hand size with a larger phone size, as compared with a smaller phone size and larger hand size, as compared to an average hand size with a mid-sized smartphone. In a study which investigated the variable of hand size in relation to levels of muscular activity, the focus was on comparing the effects of different hand sizes on texting on keypad versus touchscreen smartphones (Gustaffson et al., 2018). The study found that individuals with wider hands exhibited lower muscle activity in the abductor pollicis brevis muscle than those individuals with shorter hands when they texted on a touchscreen smartphone, an iPhone 3 GS model (Gustaffson et al., 2018). A previous study also found that an increase in screen width forced the subject to open their palm wider and extend their fingers more to accommodate the increase in smartphone size (Xiong and Muraki 2016). These changes in turn resulted in a need for the thumb to extend more to be able to achieve proper coverage of the screen to text normally, a need which was hindered by the increased smartphone size itself (Xiong and Muraki 2016). Increases in finger flexor, wrist extensor, and upper trapezius muscle activity with increasing screen size have also been reported (Kietrys et al. 2015). This extra exertion needed to further extend the thumb while using a larger smartphone could certainly result in strain of the muscles of the thumb responsible during texting, further necessitating the need to include this variable in future studies.

Along with hand size, sex was another variable that was not taken into consideration throughout this experiment. While I recorded the sex of each subject, these data were used only to obtain a demographic of the type of subject I was working with. I believe that a consideration of sex as a variable in relation to hand size and smartphone screen size could yield significant results when considering muscular output during texting. Significant differences in the muscular activity of the APL muscle have been found between the sexes, with females having higher activity of this muscle while texting using a Nokia model 3310 as the standard smartphone for subject usage, which is a keypad phone (Gustaffson et al., 2010). Without replicating this experiment on exclusively touchscreen smartphones, it would be difficult to discern if the same results would occur.

The APL muscle was the only muscle used in both Gustaffson's study and this experiment which exhibited these results. The inclusion of this variable would be particularly interesting to study because other studies, namely Toh et al., (2017), actually cited lower muscle activity of the wrist, elbow, fingers and thumb during touchscreen smartphone usage as compared to traditional electronic devices, a category which included keypad smartphones. For this reason, a future study's inclusion of sex differences as a variable as well as the comparison between touchscreen and keypad smartphones would allow for more concrete data to explain the relationship between these variables.

In this study, subjects were all between the ages of 18 and 22 years old, with two non-traditional students serving as subjects who were in their early thirties. Because of this, no comparisons were made based upon age and the effect that smartphone usage could have on the elderly who now regularly use smartphones as well. While this constraint lowered the probability of having to turn subjects away who have diagnosed MSDs, it also hindered the potential results of having a wider range of subjects' age. A study which investigated the relationship among smartphone screen size, thumb length, and the age of the smartphone users, found no significant differences in the area of thumb coverage of the smartphone screen between the young and the elderly subjects (Xiong and Muraki 2016). It was cited that the elderly would be more likely to have decreased muscle strength and motor function when compared with the younger cohort, an assumption that would have important implications for future studies on texting using sEMG (Xiong and Muraki 2016).

When Apple made iOS 13 available for iPhone users on 19 September 2019, it unveiled a new feature known as QuickPath, in which users could text entire words without ever lifting their finger from the screen. Users would simply begin by touching the first letter of the word they wished to type, and from there would swipe across the screen, reaching each letter in turn necessary to form a word before lifting their finger and watching the full word appear. As this software was very new for iPhone users at the time this experiment began, few subjects knew about the feature, and even fewer used it regularly. While this feature has existed for several years for Android smartphones, none of the five subjects who used a Samsung Galaxy smartphone reported using this feature. The addition of this variable in future studies would determine if the use of this feature could reduce the muscular output necessary to text by the motion of sustained swiping instead of tapping.

Additionally, future studies could include selfie-taking research from the perspective of it causing an RSI. This study focused on selfie-taking strictly as a detriment to musculoskeletal health based on joint angles. It is possible that the pain reported by subjects occurring in the wrist and shoulder during selfie-taking and group selfie-taking, respectively, was instead a result of the posture required to take many consecutive selfies. Therefore, it could be useful for future studies to investigate the variable of sEMG data during repetitive selfie-taking for muscles of the hand and wrist to determine if that could be the cause of the reported pain and discomfort that accompanies selfie-taking for some subjects. Although overuse injuries are most commonly diagnosed in athletes, similar movements such as gripping and thumb flexion may occur during smartphone usage and selfie-taking as well, resulting in inflammation that could lead to De Quervain's syndrome, CTS, FCR tendinitis, FCU tendinitis, among other syndromes that often arise as a result of repetitive strain (Banks et al. 2005).

Overall conclusion

In accepting the hypothesis that texting with one hand results in greater muscular output and potential muscular strain as compared to texting with two hands, this experiment's results are in accord with several other studies which have found the same results. Future studies might investigate exactly what these results could mean in the long-term for smartphone users, and determine ways to minimize possible ill effects that could arise from excessive texting, especially with one hand. While all hypotheses regarding the potential harmful effects on the carpal tunnel region that could arise through selfie-taking were rejected in this experiment, further research is warranted which takes into account the variables and the changes in methods detailed above. This further research would help to ascertain that smartphone users are definitively not at risk for early-onset CTS symptoms or any other musculoskeletal symptoms as a result of excessive selfie-taking.

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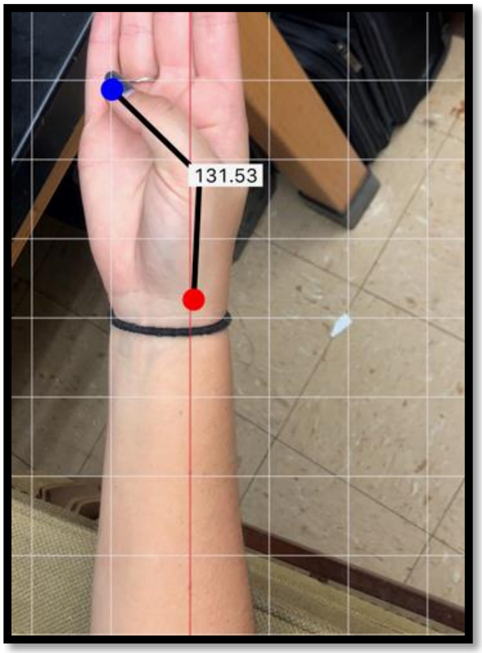
A)



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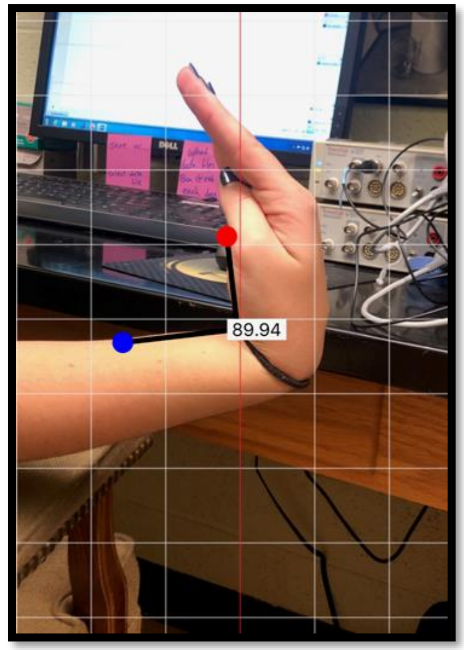

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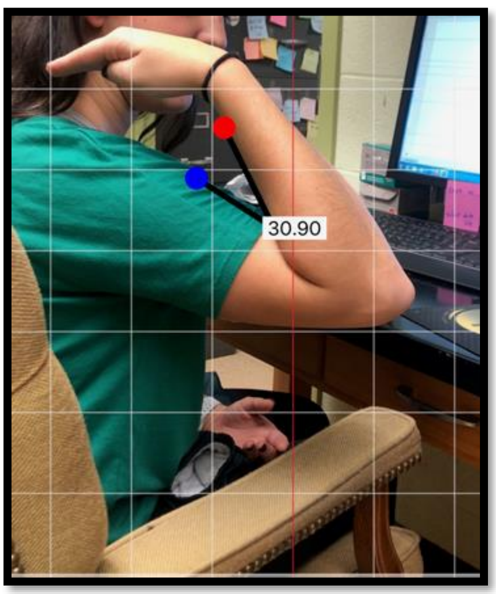

FIGURE 1: A) Subject performing a baseline flexion of the dominant thumb with measurement. B) Subject performing a baseline flexion of the dominant wrist with measurement. C) Subject performing a baseline flexion of the dominant elbow with measurement

A)

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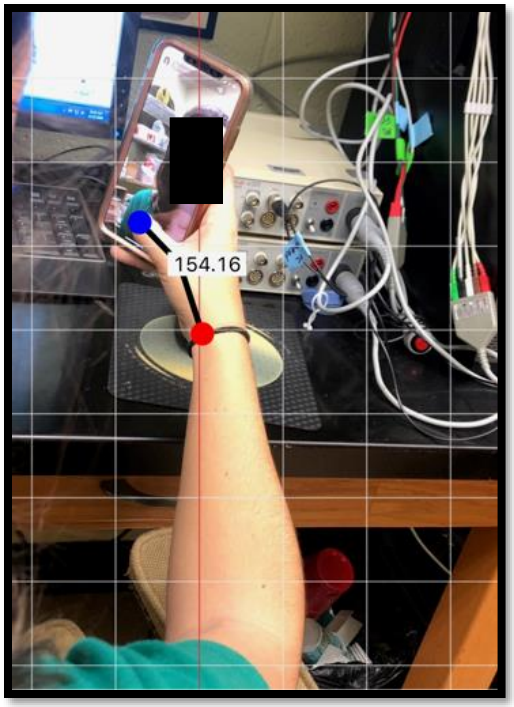

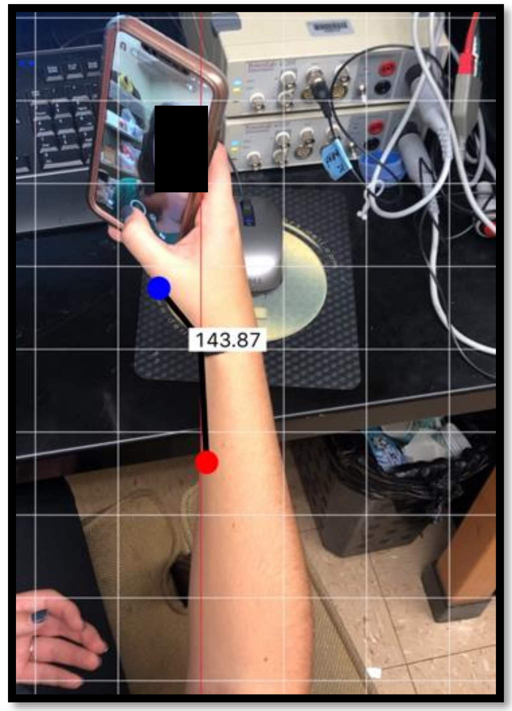

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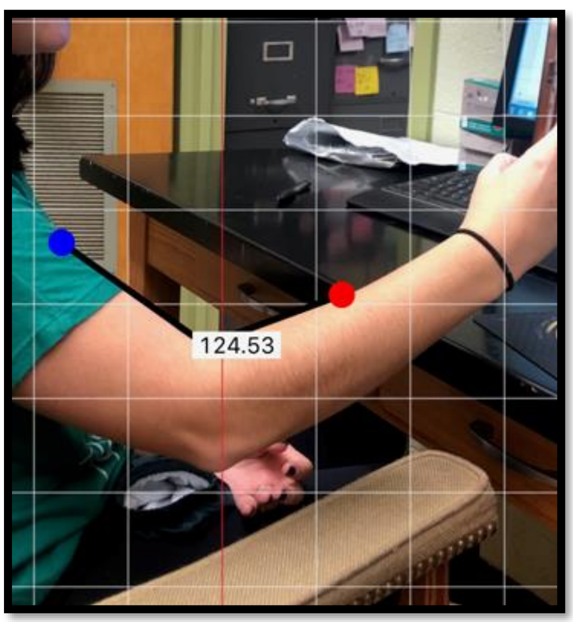

FIGURE 2: A) Measurement of the subject's dominant thumb flexion during selfie-taking. B) Measurement of the subject's dominant wrist flexion during selfie-taking. C) Measurement of the subject's dominant elbow flexion during selfie-taking.

FIGURE 3: Subject attached to all 8 electrodes: two electrodes attached to each the dominant APL, dominant FCU, dominant FCR, and trapezius muscles of the dominant arm.

A)

B)

C)

FIGURE 4: A) Subject performing dominant thumb flexion to aid in placement of electrodes over the APL muscle by allowing palpation. B) Subject performing dominant wrist flexion to allow placement of electrodes over the FCU and FCR muscles by allowing palpation. C) Subject raising their dominant arm to allow palpation of the trapezius muscle to attach electrodes.

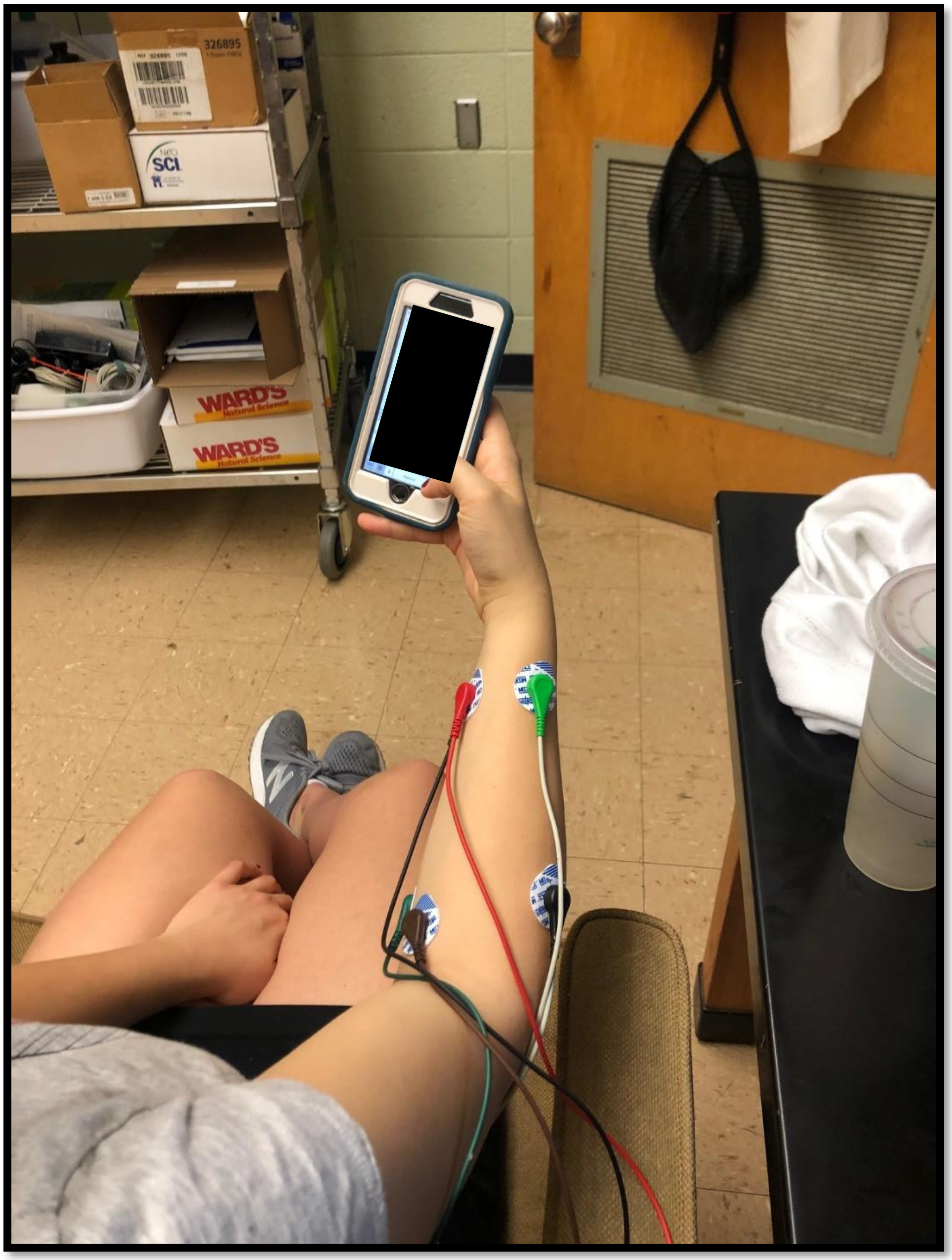

FIGURE 5: Subject texting with their dominant hand without a grip device while attached to the electrodes and being recorded through LabChart.

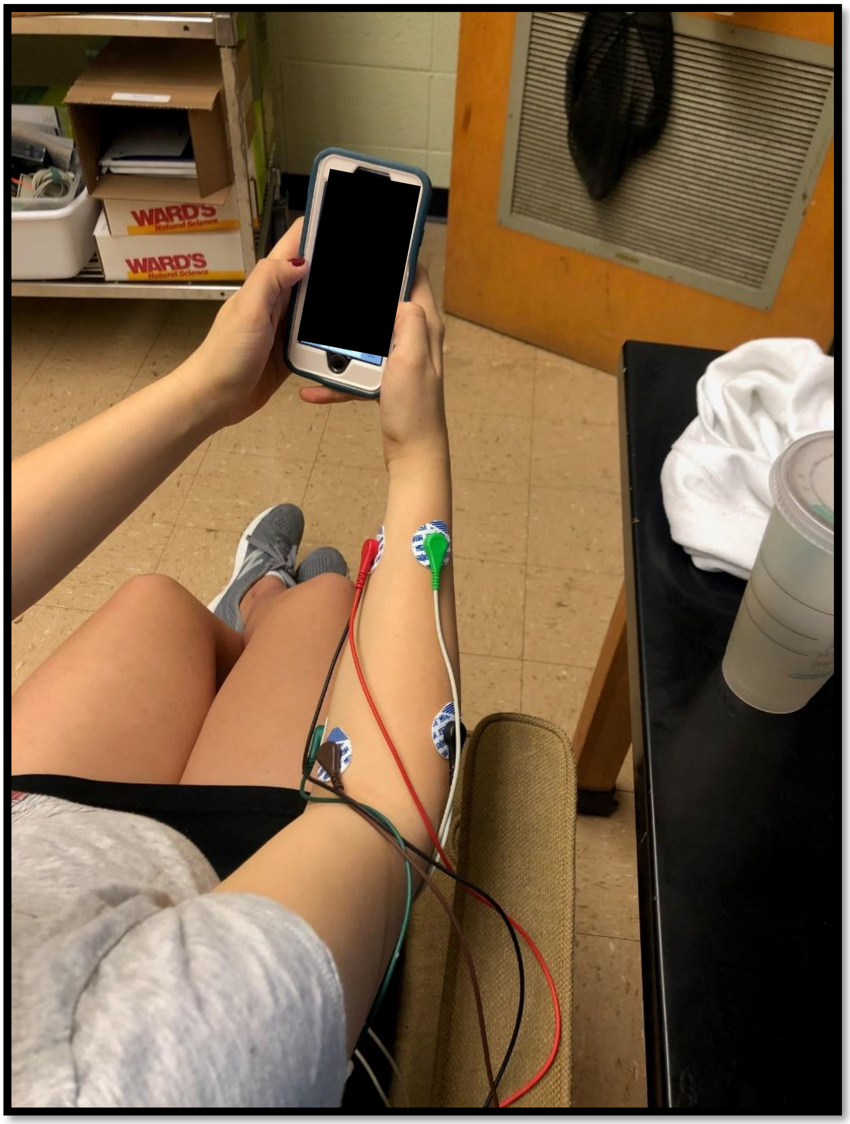

FIGURE 6: Subject texting with both hands without a grip device while attached to the electrodes and being recorded through LabChart.

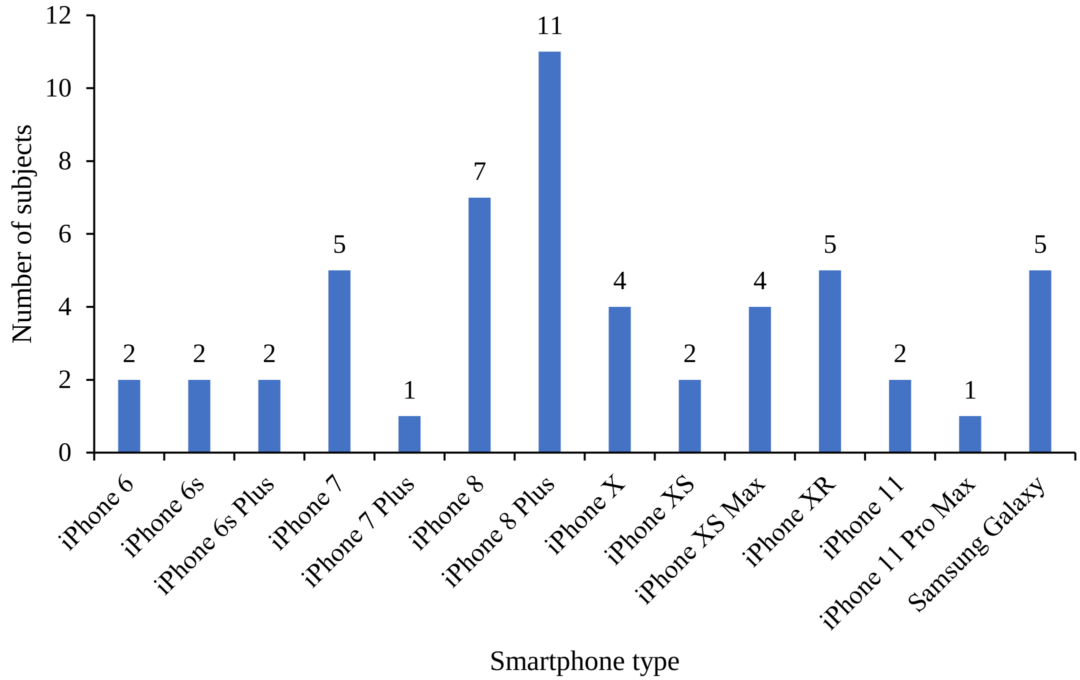

Figure 7: Distribution of smartphone type among subjects.

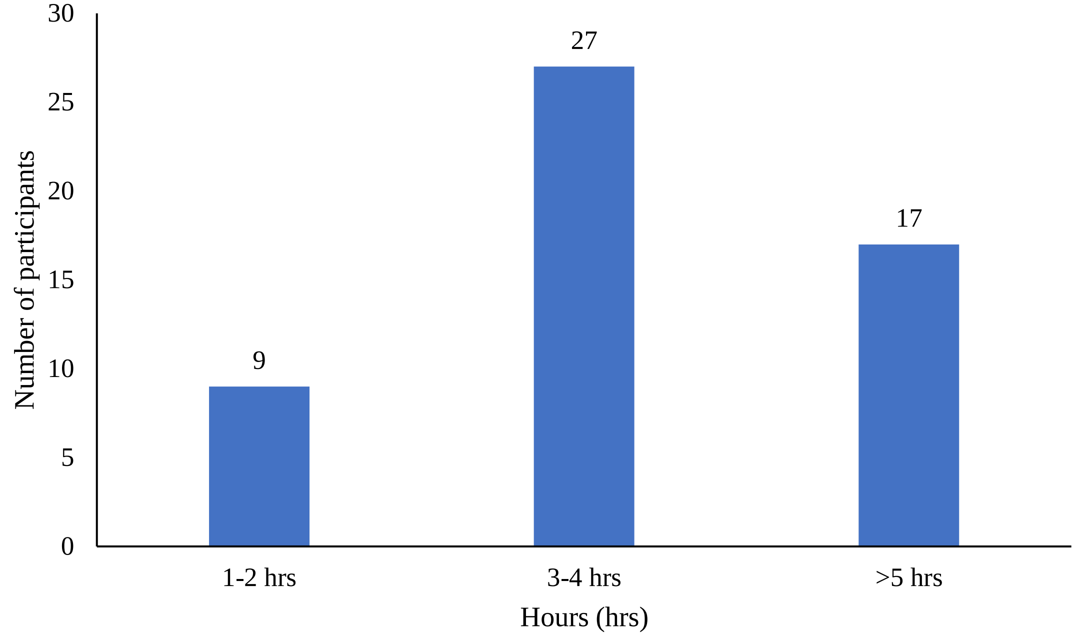

Figure 8: Distribution of the number of reporting subjects for each bracket of time representing the amount of time spent daily on a smartphone.

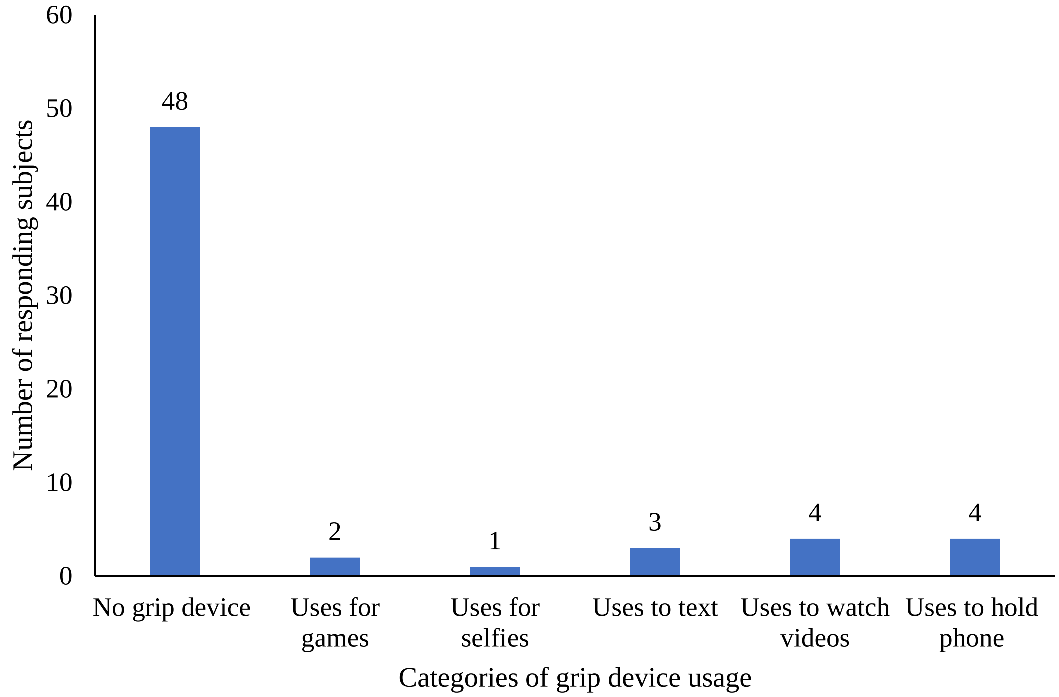

Figure 9: Distribution of subjects' grip device usage. Of those subjects who used a grip device, responses were divided into which activities they used their PopSocket or similar grip device to complete. Totals add up to exceed the number of participants because subjects were counted once for each activity in which they used their grip device.

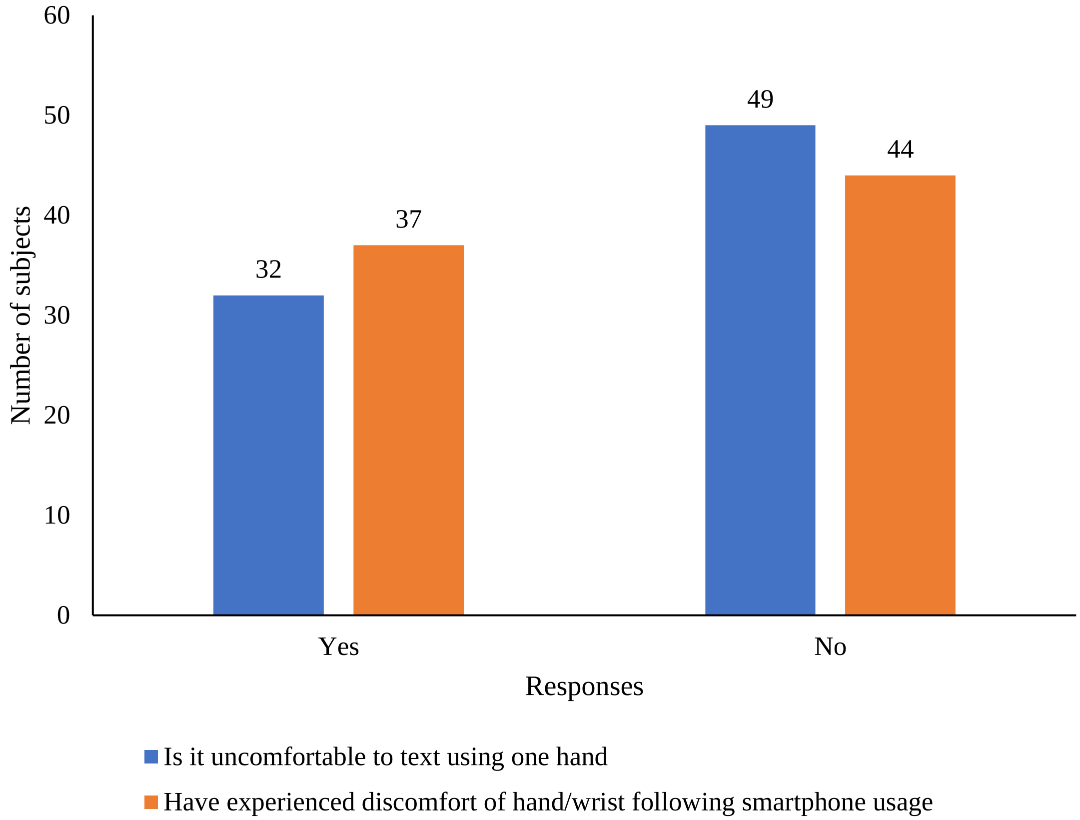

Figure 10: Subjects reported whether they used one hand to text or two, if they found it difficult or uncomfortable to text using only one hand, and if they experienced any pain or discomfort of the hand and/or wrist following smartphone usage.

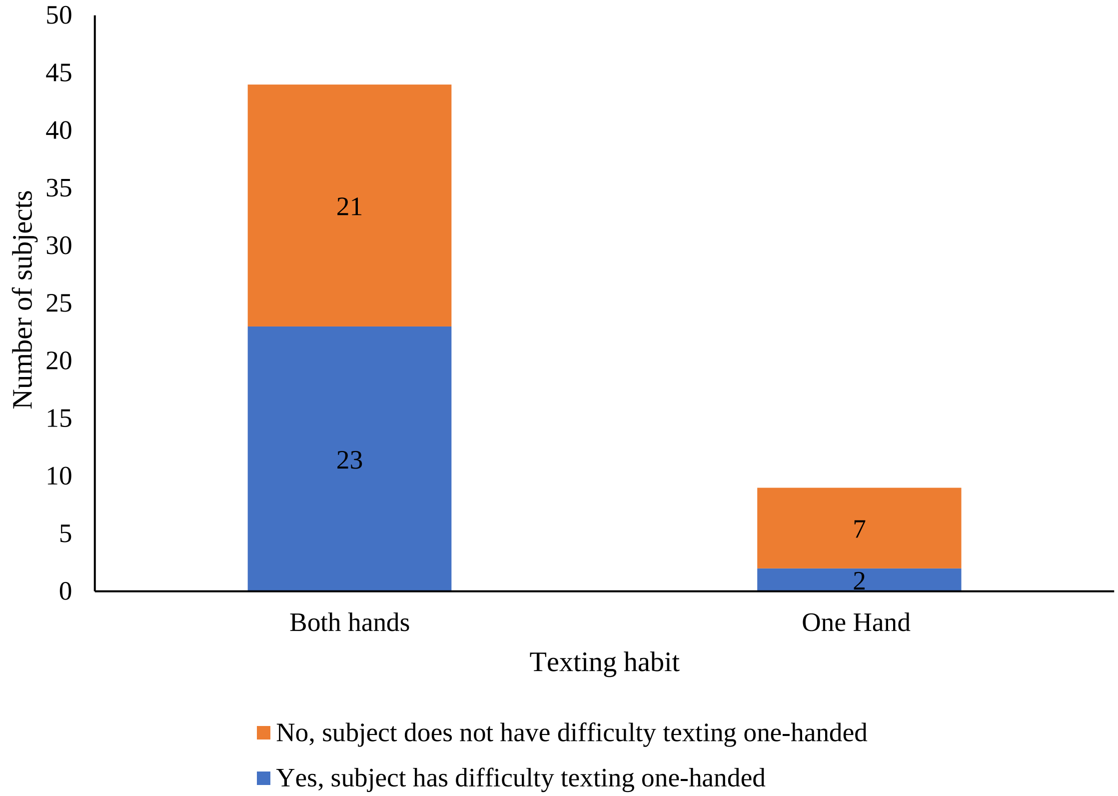

Figure 11: Distribution of subjects' texting habits broken down into whether they text most often using one hand or two. Within each subgroup, the subjects answered whether or not they found it difficult to text using only one hand.

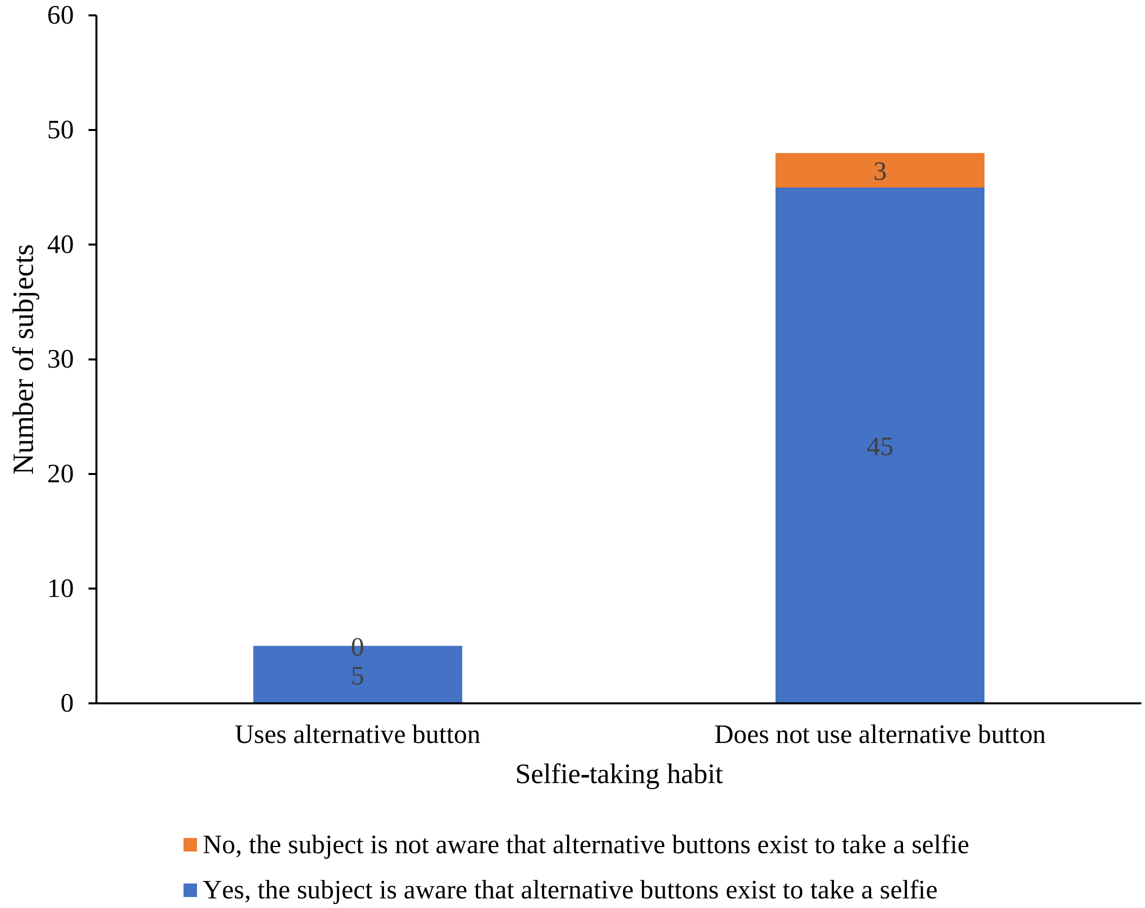

Figure 12: Subjects reported their awareness of the existence of the alternative buttons that can be used to take selfies, namely the up and down volume buttons, and whether or not they used their alternative buttons regularly.

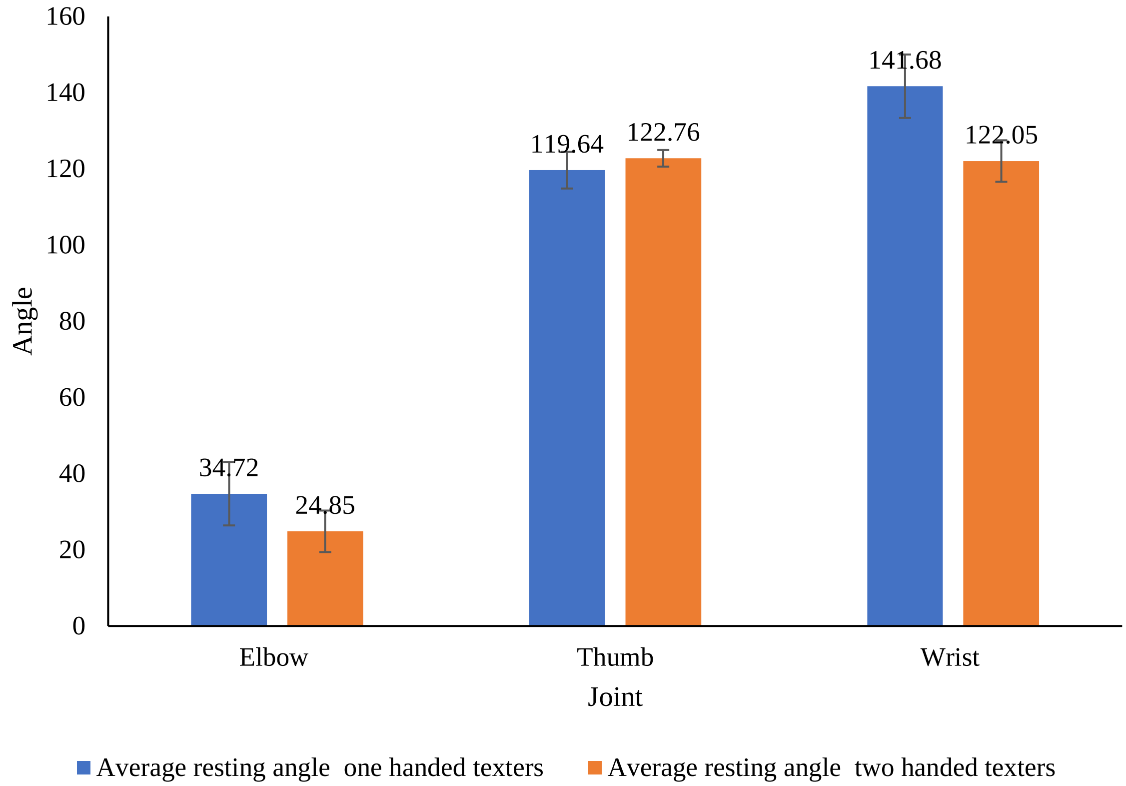

Figure 13: Average baseline joint angles recorded for each the elbow, thumb, and wrist joints, with results further divided into those subjects who reported texting one-handed as compared with those who reported texting two-handed. Error bars represent 1 standard error +/- around the mean.

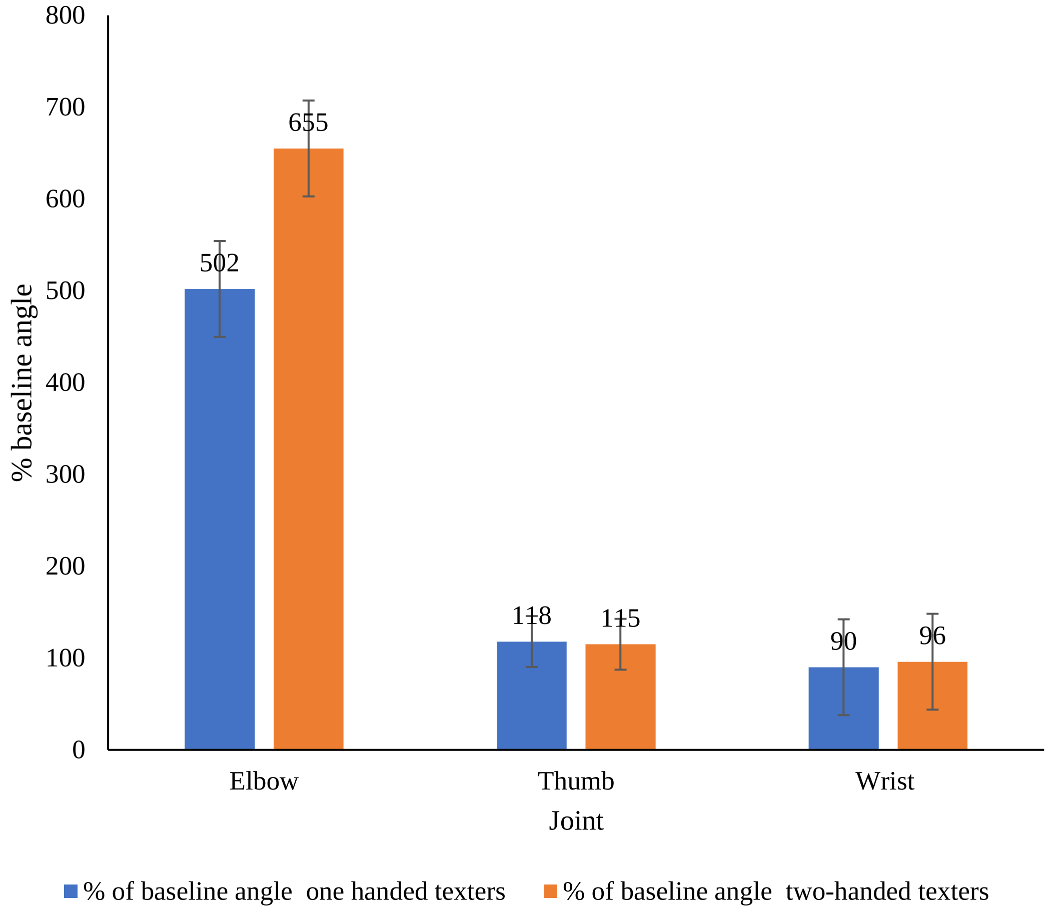

Figure 14: The average joint angles during selfie-taking were calculated as a percentage out of the average baseline angle, with results separated into one-handed texters and two-handed texters. Two-way ANOVA results found an increase in joint angle. Post-hoc comparison found a significant increase in elbow joint angle for selfie-taking. Error bars represent 1 standard error +/- around the mean.

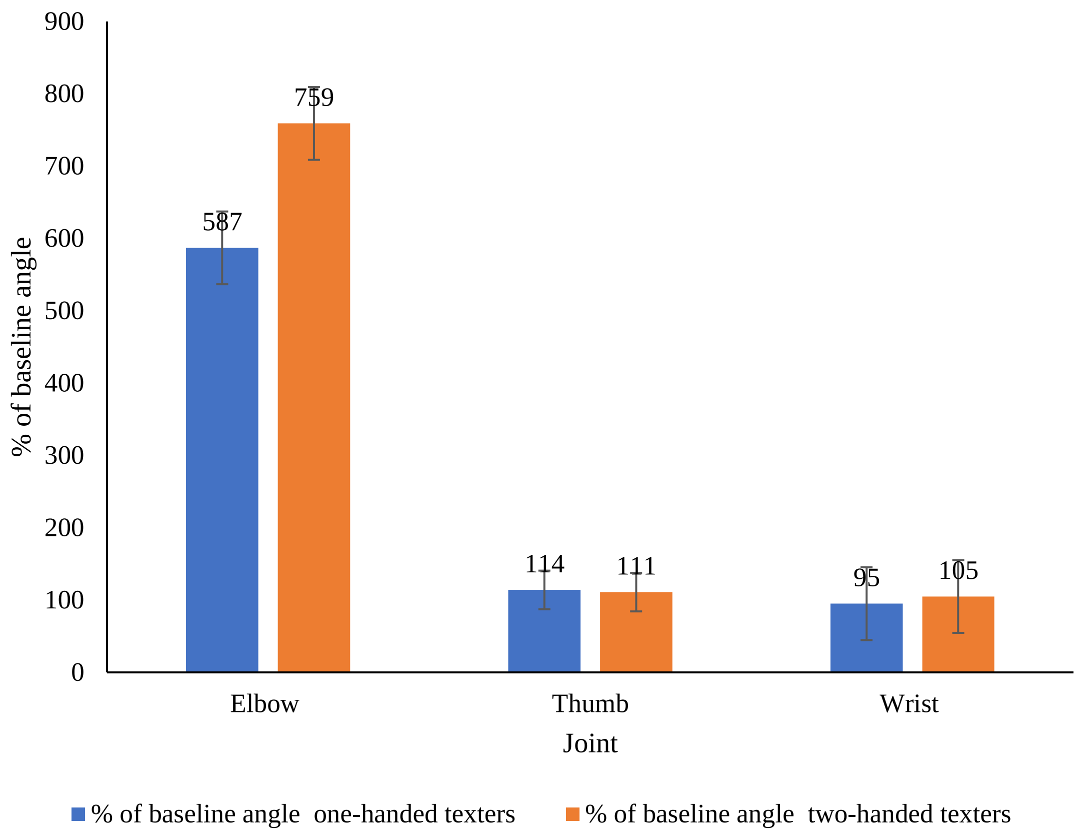

Figure 15: The average angles during group selfie-taking were calculated as a percentage out of the average baseline angle, with results separated one-handed texters and two-handed texters. Two-way ANOVA results found an increase in joint angle. Post-hoc comparison found a significant increase in elbow joint angle for selfie-taking. Error bars represent 1 standard error +/- around the mean.

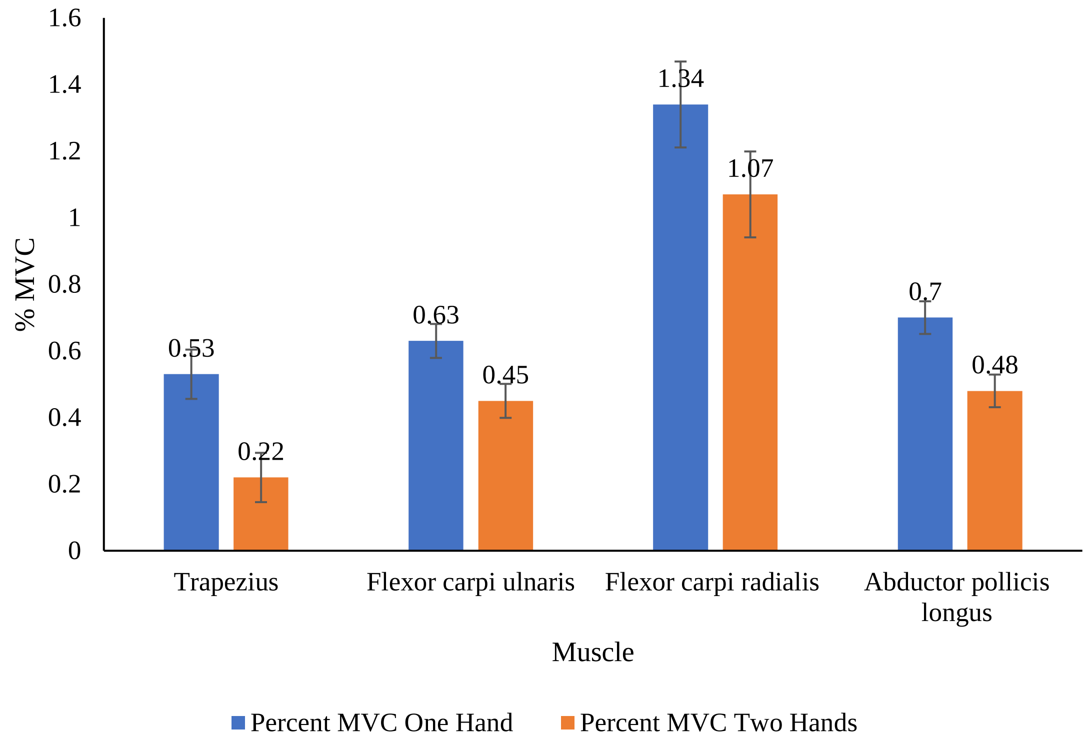

Figure 16: Mean percent maximum voluntary contraction (% MVC) for each of four muscles measured comparing texting one-handed and two-handed texting. Error bars represent 1 standard error +/- around the mean.

Table 1: Smartphone size distribution chart showing the increasing size of iPhone screens beginning with the iPhone SE in this chart, and ending at the top with the newest and largest iPhone yet, the iPhone 11 Pro Max.

Smartphone	**Display (cm)**	**Height (cm)**	**Width (cm)**
iPhone 11 Pro Max	16.51	15.80	7.77
iPhone XS Max	16.51	15.75	7.75
iPhone 11	15.49	15.09	7.57
iPhone XR	15.49	15.09	7.57
iPhone 11 Pro	14.73	14.40	7.14
iPhone XS	14.73	14.35	7.09
iPhone X	14.73	14.35	7.09
iPhone 8 Plus	13.97	15.85	7.80
iPhone 7 Plus	13.97	15.82	7.80
iPhone 6s Plus	13.97	15.82	7.80
iPhone 6 Plus	13.97	15.80	7.77
iPhone 8	11.94	13.84	6.73
iPhone 7	11.94	13.82	6.71
iPhone 6s	11.94	13.82	6.71
iPhone 6	11.94	13.82	6.71
iPhone SE	10.16	12.37	5.87
Samsung Galaxy S8	14.73	14.88	6.81

Table 2: Responses from the intake survey completed by subjects upon arrival to the lab regarding their smartphone usage habits, specifically texting and selfie-taking.

Question	<10	<25	<50	50 or more
How many text messages do you send in a typical day?	7	18	14	14
How many selfies do you take in a month? (Please take into account camera roll selfies as well as those taken on SnapChat)	8	11	7	27
What percent of selfies taken are of you and one or more persons? (Group shots)	8	16	20	9

Table 3: Assessment of subjects' perceived pain or discomfort of the hand or wrist during various activities of smartphone usage with data received from the intake survey.

Question	**No**	**While texting**	**While taking selfies**	**While holding phone for <5 minutes**	**While holding phone for <30 minutes**	**While holding phone for <1 hour**	**While holding phone for >1 hour**
Do you experience soreness or discomfort of the hand or wrist when using your phone?	38	6	1	1	7	2	3

Table 4: Subjects' responses regarding neck pain due to smartphone usage.

Question	**No, I don't experience any pain or discomfort of the neck**	**Yes, after looking down for <5 minutes**	**Yes, after looking down for <30 minutes**	**Yes, after looking down for <1 hour**	**Yes, after looking down for >1 hour**
Do you experience any soreness or discomfort of the neck when looking down at your phone?	25	1	11	11	5

Table 5: Subject responses to questions regarding their videogame habits.

Table 5a

Question	No	Yes, several times a month	Yes, once a week	Yes, daily	Yes, for more than 1 hour per day
Do you regularly play videogames?	45	0	5	3	0

Table 5b

Question	< 1 hour	1-2 hours	3-4 hours	>4 hours
How long do you normally play videogames for in a sitting?	2	4	2	0

Table 5c

Question	Yes	No
Do you ever experience soreness or discomfort of the hand or wrist after playing videogames for a prolonged period of time?	0	8

Table 6: Results from the alternate survey regarding smartphone usage and associated pain.

Table 6a

Question	Yes	No
Do you use a PopSocket, ring, or similar grip device to hold your smartphone regularly?	10	71
Do you find it uncomfortable or difficult to text using only one hand?	32	49
Do you regularly play videogames?	5	76
Have you ever experienced any soreness or discomfort of the hand or wrist following smartphone usage of more than one hour?	37	44

Table 6b

Question	1-2 hours	2-3 hours	3-4 hours	5 or more hours
Please provide an estimate for how many hours per day you are on your phone:	8	21	34	18

Table 6c

Question	1-10	10-20	20-30	30-40	40-50	50 or more
Please estimate how many text messages you send in a day:	3	13	22	9	13	21
How many “selfies” do you estimate taking in a month?	33	15	4	8	2	19

Table 6d

Question	One hand	Both hands
Are you more likely to text using one hand (thumb) or both?	24	57

APPENDIX A

INTAKE SURVEY

1. How often are you on your phone in a day? (iPhone users may use new screen-time feature to assist in estimation)
   - <1 hr. 1-2 hrs. 3-4 hrs. >5 hrs.

2. What model cell phone do you use?
   - iPhone Samsung Galaxy Google Pixel other (please list)________

3. (iPhone users) Which model do you have? ___________

4. Do you have a PopSocket (or ring) currently attached to your device?
   - Yes No (proceed to question 6)

   - If yes, do you regularly use a PopSocket (or ring) to: (check all that apply)
     - Take selfies ___
     - Text ___
     - Watch videos ___
     - Hold your phone when not in use ___
     - Other activity (please list) ____________________

5. If you regularly use your PopSocket, do you have difficulty texting without use of a PopSocket?
   - Yes No

6. How many text messages do you send in a typical day?
   - <10 <25 <50 50 or more

7. Do you text more often using one hand or both?

   - One hand Both

8. Do you find it difficult or uncomfortable to text with one hand?

   - Yes No

9. How many selfies do you take in a month? (Please take into account camera roll selfies as well as those taken on SnapChat)
    - <10 <25 <50 50 or more

10. What percent of selfies taken are of you and one or more persons? (Group shots)
    - <10% <25% <50% >50%

11. Are you aware that there is more than one button that can be pushed to take a picture? (iPhone)
        - Yes No (proceed to question 12)

    - If yes, do you still most often use the camera button?
        - Yes No

    - If no, do you use the "up volume" or "down volume" more often?
        - Up volume button Down volume button

12. Do you experience any soreness or discomfort of the hand or wrist when using your phone?
        - Yes No (proceed to question 13)

    - If yes, please circle the activities that cause the pain or discomfort:
        - Texting
        - Taking selfies
        - Holding phone for certain periods of time
          <5 min. <30 min. <1 hr. >1 hr.
        - Other (please list) _______________

13. Do you experience any soreness or discomfort of the neck when looking down at your phone?
        - Yes No (proceed to question 14)

    If yes, after how long of looking down do you notice this pain/discomfort?
    <5 min. <30 min. <1 hr. >1 hr.

14. Do you experience any soreness or discomfort of the shoulder when taking selfies of yourself with several other people?
        - Yes No

15. Do you regularly play videogames?
        - Yes No (proceed to question 16)

- If yes, how often?

Several times a month Once a week Daily For more than 1 hour per day

- How long do you normally play videogames for in a sitting?
  - <1 hr. 1-2 hrs. 3-4 hrs. >4 hrs. at a time

- Do you ever experience soreness or discomfort of the hand or wrist after playing videogames for a prolonged period of time?
  - Yes No

16. Which hand is your dominant?
    - Left Right

17. What gender do you identify as?
    - Male Female Other: ________ Prefer not to respond

APPENDIX B

ALTERNATE SURVEY

1. Please provide an estimate for how many hours per day you are on your phone:

   <1 hr. 1-2 hrs. 2-3 hrs. 3-4 hrs. 5 hrs. or more

2. Do you use a PopSocket, ring, or similar grip to hold your smartphone regularly?

   Yes No

3. Please estimate how many text messages you send in a day:

   1-10 10-20 20-30 30-40 50 or more

4. How many "selfies" do you estimate taking in a month?

   1-10 10-20 20-30 30-40 50 or more

5. Are you more likely to text using one hand (thumb) or both?

   One hand Both hands

6. Do you find it uncomfortable or difficult to text using only one hand?

   Yes No

7. Do you regularly play videogames?

   Yes No

8. Have you ever experienced any soreness or discomfort of the hand or wrist following smartphone usage of more than one hour?

   Yes No