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Assessing the Repeatability of Clinical Tests in People with and without Flexion-induced Neck Pain

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Assessing the Repeatability of Clinical Tests in
People with and without Flexion-induced Neck Pain

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Abstract

The accessibility of mobile technology has improved productivity but can contribute to musculoskeletal disorders due to the posture associated with using such devices. Neck flexion, a posture assumed by smartphone users, has been shown as a risk factor for the development of clinical neck pain if sustained for prolonged periods. Determining the individuals who are naturally more predisposed to develop flexion-induced neck pain can aid in the prevention and treatment of musculoskeletal disorders. The purpose of this thesis is to assess the repeatability of clinical tests between trials over the course of two days in young adults who do and do not develop neck pain after 30 minutes of smartphone use. Healthy participants (n=41) ages 18- 29 (21.6 ±2.12) underwent a battery of clinical tests used in populations with chronic neck pain. Tests included pain pressure threshold (PPT) testing, cervical and craniocervical flexion, and a cervical extensor (CE) fatigue assessment. Afterwards, each participant spent 30 minutes using their personal smartphone for a series of predetermined tasks. During the 30 minutes, participants completed 5 visual analog scales (VAS) that helped categorize them into 2 separate pain groups: pain developers (PD) or non-pain developers (NDP). Clinical tests were repeated after the smartphone use intervention and participants returned for a second data collection 1 to 2 weeks later. Intraclass correlation coefficients (ICC) were calculated for pre- and post-smartphone use variables between days 1 and 2 to determine repeatability of the clinical tests in this population. A McNemar chi-square test was used to determine the number of participants who remained in their initial pain groups on day 2 of data collection. NPD had greater between day reliability for PPT measurements taken before the intervention, while PD had higher ICC values after 30 minutes of smartphone use. The cervical extensor fatigue assessment and cervical flexion protocols had higher reliability before and after the smartphone use intervention in the

PD group. An assessment of the pain response to pressure stimulus, cervical flexion, and CE fatigue are recommended as protocols to differentiate individuals who do and do not develop pain after 30 minutes of smartphone use.

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Introduction

Neck pain is the fourth ranked condition contributing to years lived with a disability in the United States (Murray, 2013). The average annual prevalence rate for the occurrence of a new episode of neck pain for all age groups is 37.2% and is between 15.8% and 22.1% for adolescents (Fejer, Ohm Kyvik, & Hartvigsen, 2006). A risk factor for neck pain development is prolonged neck flexion (Andersen et al., 2003; Ariens et al., 2001), which is a posture assumed by more than 90% of smartphone users (Gold et al., 2012) that involves the decrease of the angle between the chin and chest. The accessibility of mobile technology has improved productivity has given individuals the freedom to work on-the-go; however, it may also contribute to musculoskeletal disorders of the neck and upper back, especially in younger adults (Cuellar & Lanman, 2017).

Understanding neck and upper back pain that results from prolonged smartphone use is an important step in determining preventative measures, and the performance of clinical tests to evaluate or diagnose musculoskeletal disorders such as neck pain is an important tool for treatment. However, it is important that the results of these tests are reliable, thus the purpose of this study is to assess the repeatability of clinical tests between trials over the course of two days in young adults who do and do not develop neck pain after 30 minutes of smartphone use.

To the knowledge of the researchers, this will be the first study to assess differences between clinical tests performed before and after smartphone use in young adults. Identifying these differences will aid in future efforts to develop interventions and rehabilitation strategies, and to promote practices that reduce pain development. In order to understand if an intervention results in a true change, we must ensure that our tests are repeatable between days. The aim of the thesis is to assess the between-day repeatability of cervical range of motion (CROM) device

measurements of cervical flexion and craniocervical flexion, pain pressure threshold, and cervical extensor fatigue assessments after 30-minutes of smartphone usage. It was hypothesized that (1) each clinical test will have good to excellent between- day reliability, and (2) the between- day reliability of each clinical test would be more variable after 30 minutes of smartphone use. Each of these assessments are used discretely to evaluate and predict the extent of a musculoskeletal disorder of the neck. This was assessed using data collected in a lab-based study that consisted of performing clinical tests before and after 30 minutes of standardized smartphone use on two separate lab visits. Neck and upper-back pain development was be determined through the use of a visual analog scale, and a benchmark of a difference of 12mm (Kelly, 2001) between pre- and post- measurement to differentiate between those who did and did not develop pain. Participants came into the lab on two occasions, with their visits separated by at least one week, which allowed us to assess the between-day repeatability of the outcome measures.

Literature

Prevalence of Neck Pain

Neck pain is the fourth-ranked disease and injury contributing to years living with a disability in the United States (Murray, 2013). According to a systematic review performed by Fejer and colleagues, the annual prevalence of a new episode of neck pain for adults age 17 to 70 years ranged from 16.7% to 75.1%, with an average of 37.2%, and the annual prevalence of a new episode of neck pain for adolescents is 15.8% and 22.1% (Fejer et al., 2006). The large range in prevalence is due to differences in protocol design, outcome measures, and participant recruitment. In individuals who have been free from neck pain for 6 months, there is an incidence rate of 14.6% for a new episode of neck pain, and it is estimated that 54% of adults suffer from neck pain during any 6-month period, while 4.6% experience activity limitations due to neck pain (Cote et al., 1998).

The annual medical expenditure for an individual suffering from spinal complications exceeds $6,000 (Martin et al., 2008). Clinicians have noticed a recent increase of patients complaining of neck pain, especially in younger age groups (Cuellar and Lanman, 2017) and 72% of American undergraduate students reported symptoms of neck pain (Jenkins et al., 2007). A cohort study of adults between the ages of 30 and 46 years reported that 37.3% of individuals had persistent neck pain and 22.8% of individuals had recurrent neck pain. 32.7% of individuals who reported neck pain experienced improvement in neck pain within 6 months (Cote, David Cassidy, Carroll, & Kristman, 2004).

Neck Flexion Induced Pain

Neck flexion refers to forward bending of the neck resulting in reduction of the angle between the chin and chest. Poor posture is a leading cause of neck pain (Mayo Clinic, 2018). Epidemiological studies have shown that a neck angle greater than 20° for more than two-thirds of an eight-hour work day increases the risk for developing clinical neck pain (Andersen et al., 2003, Ariens, 2001). Neck flexion of any angle increases the gravitational moment of the head (Harms-Ringdahl, Ekholm, Schuldt, Nemeth, & Arborelius, 1986) requiring greater activation of neck extensor muscles than when in neutral posture (Schuldt, Ekholm, Harms-Ringdahl, Nemeth, & Arborelius, 1986). When the neck is flexed, the gravitational moment of the head is around 3.52 Nm compared to 1.22 Nm when in a neutral position (Vasavada, Nevins, Monda, Hughes, & Lin, 2015). During tablet usage, typing with the device low in the lap creates a greater gravitational moment than when the device is propped on a desk (Vasavada et al., 2015). These results would be similar during smartphone use, since many people utilize their mobile devices in their lap (Young, Trudeau, Odell, Marinelli, & Dennerlein, 2012).

Smartphone Use, Neck Flexion, and Neck Pain Development

Ninety-six percent of Americans ages 18 to 29 years old own a smartphone (Pew Research Center, 2019). Smartphone owners spend an average of 5 hours per day looking at its screen (Andrews, Ellis, Shaw, & Piwek, 2015) which could be problematic because research has shown that total time spent looking at a smartphone is significantly associated with reported neck pain (Berolo, Wells, & Amick III, 2011). The most common posture assumed when using a smartphone is neck flexion (Gold et al., 2012). In a recent study, investigators attached inertial measurement units (IMUs) to the foreheads of participants to measure neck angle. Over the

course of eight hours, the average neck angle assumed during smartphone use is 32.3° (Han, Lee, & Shin, 2019)

Repetitive behaviors can accumulate into clinical health issues over time. Tissues that undergo repetitive stresses like repeated neck flexion often follow a dose-response relationship (Kumar, 2001). Most tissues adapt to and recover from stress. However, repeated exposure over a prolonged time period can result in incomplete recovery and residual strain within the tissue (Kumar, 2001). Residual strain contributes to reduced stress tolerance of the tissue, and can ultimately lead to injury or disorder (Kumar, 2001)

Previous research has indicated that 52.9% of individuals who developed transient low back pain during a standing protocol reported clinical low back pain during a 3-year follow-up (Nelson- Wong & Callaghan, 2014). The same study also found that individuals who developed pain during standing were greater than 3 times more likely than non-pain-developers to experience at least 1 episode of clinical low back pain within the following 24 months (Nelson-Wong & Callaghan, 2014). Future research should investigate the application of this outcome to individuals who experience transient neck or upper back pain during prolonged smartphone usage.

Clinical Measures of Neck Pain and Measurement Reliability

Clinical tests are often used by clinicians to determine treatment plans and to evaluate the severity of neck pain. Three tests that can assist in quantifying neck dysfunction are the deep cervical extensor test, pain pressure thresholds, the cervical range of motion tests, and visual analog scales.

The deep cervical extensor test is used to determine the point at which the multifidus, semispinalis cervicis, and the cervical extensors fatigue (Jorgensen, Ris, Falla, & Juul-Kristensen, 2014). The subject lies in a prone position with arms resting at their side, and the head and neck suspended over the edge of a treatment table. A laser is affixed to a headband that is placed around the subject's head. A target is placed on the ground, and the subject is instructed to maintain the laser beam's position in the target for as long as possible. A stopwatch is used to record the time until the participant deviates from the target. Jorgensen and colleagues demonstrated that a lower score or time was correlated with neck pain reported from a neck disability index ($p=.047$) in subjects with clinical neck pain (Jorgensen et al., 2014). The same study also found the cervical extensor test to have an intraclass correlation coefficient (ICC) for intra- and inter- rater reliability ranging from 0.75 to 0.90 (Jorgensen et al., 2014).

Pain pressure threshold (PPT) is often used to predict short and long-term outcomes for individuals with acute whiplash-associated disorder; however, PPT has shown to be a reliable clinical test regardless of whether or not the individual is experiencing symptomatic pain (Walton et al., 2011). Because musculoskeletal pain is the largest complaint for those with musculoskeletal disorders, PPT has a broad clinical application in treatment and diagnosis (Walton et al., 2011). Previous research in clinical populations has indicated that there is a significant relationship between pain reported and PPT ($p=<0.01$) (Jorgensen et al., 2014). The Wagner Force Ten FDX (Wagner Instruments, Greenwich, CT) handheld algometer, the most common instrument used for PPT measurements, has an accuracy of ±0.3%. PPT measurements are taken in units of force and are often the average of 3 measurements for each landmark used during the protocol.

Active cervical range of motion (ROM) is considered a clinical standard of practice and is frequently used as an outcome measure when assessing neck- pain- related conditions. Normal ROM for the cervical spine is about 80° to 90°(Swartz, Floyed, & Cendoma, 2005), and a reduction in cervical ROM is often seen in individuals with cervical dysfunction who are seeking therapy (Audette, Dumas, Cote, & De Serres, 2010). A cervical range of motion (CROM) device is a tool used by clinicians to measure cervical ROM and entails a plastic frame attached to two inclinometers that determine the position of the head in the sagittal and frontal plane with respect to gravity. The frame is placed on the head and worn like glasses across the ears and nose. The CROM can be used to measure cervical ROM in all directions, is affordable, and simple to use (Audette et al., 2010). The CROM device yields results that are comparable with motion capture technology (Audette et al., 2010). When compared to Fastrak technology, correlation coefficients were found to be 0.93 for flexion. ICC values for all directions ranged between 0.89 and 0.98, providing evidence that the test-retest reliability is "excellent". The CROM device has a higher level of reliability when compared to a standard bubble inclinometer and is more cost efficient that other sophisticated research tools (Audette et al., 2010).

A visual analog scale (VAS) is a 100mm continuum where individuals can mark their level of pain from no pain at all (0mm) to worst pain imaginable (100mm). They are the most commonly used tool for evaluating pain severity (Kelly, 2001) and were used during this protocol to monitor pain development. The minimal clinically significant difference (MCSD) can be defined as the mean difference between current and preceding scores when a test subject reported pain to be either "a little worse" or "a little better" (Kelly, 2001). Previous research has demonstrated that the MCSD in individuals experiencing mild pain was 11mm (Kelly, 2001).

Measurement of Sub-clinical Neck Pain

A test must display validity and between-day reliability in order to be clinically relevant (Audette et al., 2010). The studies in the previous section that assessed reliability compared measurements amongst a specific population. Participants were either healthy (Audette et al., 2010) or were experiencing clinical neck pain (Audette et al., 2010; Jorgensen et al., 2014; Kelly, 2001; Walton et al., 2011). The young adults recruited for this study were considered to be healthy. However, this population spends around 5 hours per day in neck flexion looking at a smartphone (Andrews et al., 2015). Evidence suggests that individuals who spend 2/3, or about 60%, of the working day with the neck flexed more than 20 degrees are at an increased risk for developing neck pain (Andersen et al., 2003; Ariens et al., 2001). Preliminary analysis of data collected for this thesis indicated that participants who developed pain showed a decreased time in the cervical extensor assessment that was performed after 30 minutes of smartphone use. Research has shown that exercise interventions can be administered to strengthen the neck extensors and can provide relief for transient neck pain (Bertozzi et al., 2013; Sihawong, Janwantanakul, Sitthipornvorkul, & Pensri, 2011). In order to investigate the impact of such interventions on clinical neck pain, we must quantify the repeatability of our clinical tests in this specific population.

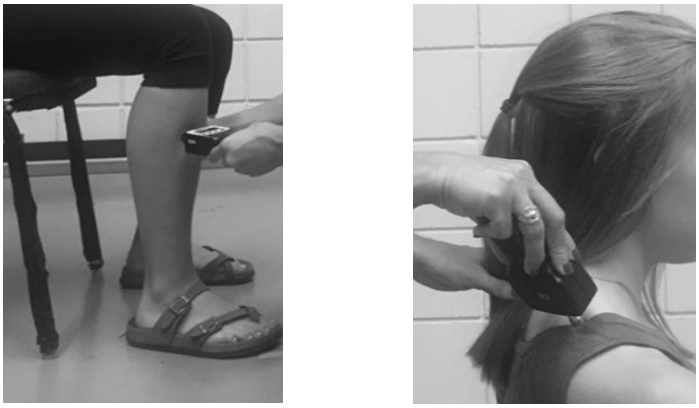
Methods

Participants

Participants between the ages of 18 and 29 years were recruited from Northwest Arkansas between October 2018 and June 2019. Exclusion criteria included a previous history of chronic headaches or migraines, dizziness or fainting, a history of neck pain that required more than 3 days off from regular activities, and a previous history of neck injury, surgery whiplash, or concussion. It was required for participants to own a touchscreen smartphone. Protocol approval was granted by the Institutional Review Boards of the University of Arkansas and the University of Arkansas for Medical Sciences (UAMS). All participants provided written informed consent prior to the study. Participants completed two data collections that were at least one, and no more than four, weeks apart. The same protocol was followed for both collections.

Clinical Tests

Pain Pressure Threshold (Walton et al., 2011; Jorgensen et al., 2014). While seated in a padded banquet chair without arms, 7 bilateral landmarks were identified by a single, trained investigator (See Table 1) and marked using a water-based pen. An algometer (Wagner Force Ten FDX) was used to apply pressure to each of the landmarks (Figure 1). All participants were given the following instructions: “Pressure will be applied to each of these landmarks. Tell the investigator when the sensation felt transitions from comfortable pressure to slightly unpleasant pain. This should not be the point of extreme pain but should be uncomfortable.” To measure the pain pressure threshold of the landmark at T4, the participant was instructed to lie prone on a treatment table. Pain pressure threshold of the 14 landmarks was cycled through 3 times to allow investigators to obtain a mean measurement for each landmark.



Source: Author

Figure 1: PPT of Tibialis Anterior (Left) and Upper Trap (Right)

Table 1: Bilateral PPT Landmarks

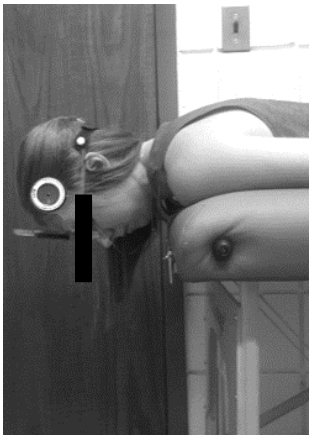
Tibialis Anterior	~8 cm below lateral condyle of tibia
Splenius Capitis	~4 cm lateral of C3
Splenius Cervicis	~5 cm lateral of C5
Upper Trapezius	Midway between C7 and acromion process
Levator Scapulae	Midway between C7 and inferior angle of scapula
Thoracic Spine (T4)	~6 cm lateral of T4
Sternocleidomastoid	1/3 distance between mastoid and sternoclavicular joint

Cervical Range of Motion. The chair was positioned so that the left side was flush against a wall, and the participant sat with their back against the wall. A Cervical Range of Motion (C-ROM) device was placed on the head of the participant. The participant was instructed to flex the neck as far as possible while keeping the back and shoulders against the wall (Figure 2). Once the C-ROM measurement was taken, the participant relaxed. The participant was then instructed to keep the back, shoulders, and the back of the head against the wall and perform a chin tuck so the investigator could measure craniocervical flexion (Figure 2). Once the measurement was taken with the C-ROM the participant relaxed. These measurements were taken three times each allowing researchers to obtain a mean measurement.

Source: Author

Figure 2: Cervical Flexion (Left) and Craniocervical Flexion (Right)

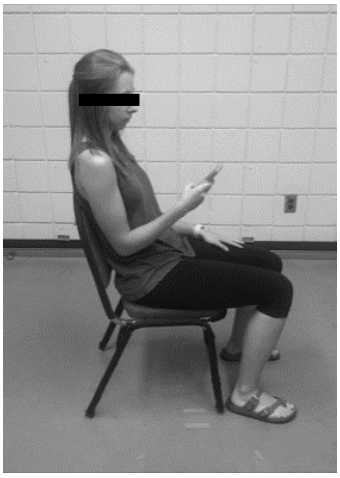
Cervical Extensor Fatigue Assessment. While wearing the C-ROM device, the participant was instructed to lie prone on a treatment table with the head and neck hanging off of the edge unsupported and in a neutral position according to the CROM device (Figure 3). When a stopwatch began, the participant was instructed to hold this position for as long as possible. Termination of the assessment occurred if the participant felt pain at the base of the skull or between the scapulae, if the angle of the head changed by 5°, or if the duration of the test exceeded 120 seconds. Termination time was recorded, and the participant removed the C-ROM and returned to a seated position in the chair.



Source: Author

Figure 3: Cervical Extensor Fatigue Assessment

Experimental protocol. Clinical tests were performed on the participants before and after thirty minutes of smartphone use. Participants were instructed to sit in a banquet-style chair and use their smartphone as they normally would (Figure 3). The only instruction participants received on their posture was to refrain from leaning forward and resting their elbows on their knees. The thirty minutes of smartphone use consisted of the following three activities administered in a random order: a free-response questionnaire, an online scavenger hunt, and a list of videos to watch. Each of the activities was performed for ten minutes. A visual analog scale was taken from participants at 0, 10, 20, and 30 minutes of smartphone usage. Because a healthy population was assessed in this protocol, an MCSD of 12mm (Kelly, 2001) was used to differentiate pain developers (PD) from non-pain developers (NPD).



Source: Author

Figure 4: Participant Position during Smartphone Use

Clinical Tests. Pain pressure threshold, cervical and craniocervical range of motion, and the cervical extensor fatigue assessment were administered a second time following 30 minutes of smartphone usage.

Statistical Analyses

To assess between day (day 1 vs. day 2) repeatability for a single rater, interclass correlation coefficients (ICCs) were computed using SPSS software and a two-way mixed-effects model (Table 2). Because we were interested in assessing interrater reliability, "single rater" type was chosen (Koo & Li, 2016). Absolute agreement was used due to the assessment of values between days one and two. ICC values less than 0.5 indicate poor reliability, values between 0.5 and 0.75 are indicative of moderate reliability, values between 0.75 and 0.9 indicate good reliability, and values greater than 0.90 are indicative of excellent reliability (Koo & Li, 2016). A confidence interval of 95% was used to evaluate the level of reliability of the ICC value for each variable. For example, if the confidence interval of an ICC estimate is between .86 and .95, the level of reliability is considered to be between good and excellent (Koo & Li, 2016). A McNemar Chi Square test was used to determine the number of participants who remained in their initial pain groups on day 2 of data collection.

Table 2: Variables Compared for ICC

Day 1 vs. Day 2

1. *Pre- Smartphone Usage PPT*
2. *Pre- Smartphone Usage Cervical Flexion*
3. *Pre- Smartphone Usage Craniocervical Flexion*
4. *Pre- Smartphone Usage Cervical Extensor Fatigue Assessment*
5. *Post- Smartphone Usage PPT*
6. *Post- Smartphone Usage Cervical Flexion*
7. *Post- Smartphone Usage Craniocervical Flexion*
8. *Post- Smartphone Usage Cervical Extensor Fatigue Assessment*

Results

Pain Group. Participants were separated into pain groups (NPD, PD) based on their day 1 responses to VAS administered at baseline, before smartphone use, and at 10, 20, and 30 minutes into smartphone use. Eighty percent (33/41) (p= 0.4795) of participants remained in their initial pain groups after the second data collection (Table 3).

Table 6: Pain Group Total for Day 1 vs. Day 2

		Day 1		
		NPD	***PD***	***Total***
Day 2	***NPD***	17	3	20
	PD	5	16	21
	Total	22	19	41

Pain Pressure Threshold. There were differences in reliability between pain groups for clinical assessment measures between days 1 and 2 (Table 4). Before 30 minutes of smartphone use, PD demonstrated moderate to excellent reliability (95% CI= 0.508- 0.939) for right and left tibialis anterior (TA) right splenius capitis, right upper trap, left thorax, and left sternocleidomastoid (SCM) PPT values. Right and left splenius cervicis, left upper trap, and left and right levator scapulae exhibited poor to good reliability (95% CI= 0.371-0.893) for PPT values. The reliability of the PPT measurement of the left splenius capitis was moderate to good (95% CI= 0.519- 0.898), and right thorax and right SCM demonstrated poor to excellent reliability (95% CI= .0451- 0.937).

After 30 minutes of smartphone use (Table 4), PD presented moderate to excellent reliability (95% CI= 0.508- 0.952) for most PPT measurements. Left splenius cervicis demonstrated poor to good reliability (95% CI= 0.456- 0.881), and reliability for right upper trap PPT measurements was poor to moderate (95% CI= -0.156-0.642).

Reliability of PPT measurement values for NPD differed from those of the PD group. Good to excellent reliability (95% CI= 0.574- 0.971) was exhibited by the PPT values of the left TA, left spenius cervicis, right and left upper trap, right and left levator scapulae, and right and left thorax (Table 5). The right TA, right splenius capitis, and right and left SCM presented moderate to excellent reliability (95% CI= 0.519- 0.954). Reliability of the PPT measurements of the right and left splenius cervicis was poor to good (95% CI= 0.339- 0.870).

NPD demonstrated moderate to excellent reliability (95% CI= 0.540- 0.964) for a majority of PPT measurements after 30 minutes of smartphone use (Table 5). Poor to good reliability (95% CI= -.028-0.896) was exhibited by left splenius capitis, left splenius cervicis, left thorax, and right SCM PPT measurements. Left TA PPT values displayed good to excellent reliability (95% CI= 0.811- 0.969), and poor to moderate reliability (95% CI= 0.055- 0.737) was seen in left SCM measurements.

Table 4: ICC Values for PPT Measurements in Pain Developers

	Pre- Smartphone Use			Post- Smartphone Use		
	ICC	**95% Confidence Interval**	**ICC Classification**	**ICC**	**95% Confidence Interval**	**ICC Classification**
Right Tibialis Anterior	0.836	(0.643- 0.930)	Moderate to Excellent	0.835	(0.639- 0.929)	Moderate to Excellent
Left Tibialis Anterior	0.855	(0.676- 0.938)	Moderate to Excellent	0.881	(0.731- 0.950)	Moderate to Excellent
Right Splenius Capitis	0.774	(0.528- 0.901)	Moderate to Excellent	0.813	(0.591- 0.920)	Moderate to Excellent
Left Splenius Capitis	0.769	(0.519- 0.898)	Moderate to Good	0.792	(0.553- 0.910)	Moderate to Excellent
Right Splenius Cervicis	0.705	(0.400- 0.869)	Poor to Good	0.83	(0.572- 0.932)	Moderate to Excellent
Left Splenius Cervicis	0.681	(0.371- 0.856)	Poor to Good	0.732	(0.456- 0.881)	Poor to Good
Right Upper Trap	0.847	(0.656- 0.936)	Moderate to Excellent	0.292	(-0.156- 0.642)	Poor to Moderate
Left Upper Trap	0.751	(0.479- 0.893)	Poor to Good	0.851	(0.667- 0.938)	Moderate to Excellent
Right Levator Scapulae	0.722	(0.436- 0.876)	Poor to Good	0.818	(0.580- 0.924)	Moderate to Excellent
Left Levator Scapulae	0.735	(0.416- 0.887)	Poor to Good	0.819	(0.508- 0.930)	Moderate to Excellent
Right Thorax	0.807	(0.482- 0.937)	Poor to Excellent	0.852	(0.587- 0.952)	Moderate to Excellent
Left Thorax	0.814	(0.508- 0.939)	Moderate to Excellent	0.846	(0.576- 0.950)	Moderate to Excellent
Right Sternocleidomastoid	0.782	(0.451- 0.913)	Poor to Excellent	0.853	(0.675- 0.937)	Moderate to Excellent
Left Sternocleidomastoid	0.887	(0.744- 0.952)	Good to Excellent	0.861	(0.687- 0.941)	Moderate to Excellent

Table 5: ICC Values for PPT Measurements in Non- Pain Developers

	Pre- Smartphone Use			Post- Smartphone Use		
	ICC	**95% Confidence Interval**	**ICC Classification**	**ICC**	**95% Confidence Interval**	**ICC Classification**
Right Tibialis Anterior	0.887	(0.736- 0.954)	Moderate to Excellent	0.892	(0.700- 0.959)	Moderate to Excellent
Left Tibialis Anterior	0.904	(0.768- 0.961)	Good to Excellent	0.922	(0.811- 0.969)	Good to Excellent
Right Splenius Capitis	0.802	(0.571- 0.916)	Moderate to Excellent	0.786	(0.540- 0.909)	Moderate to Excellent
Left Splenius Capitis	0.849	(0.662- 0.937)	Good to Excellent	0.731	(0.438- 0.884)	Poor to Good
Right Splenius Cervicis	0.7	(0.374- 0.870)	Poor to Good	0.87	(0.706- 0.946)	Moderate to Excellent
Left Splenius Cervicis	0.683	(0.339- 0.863)	Poor to Good	0.757	(0.488- 0.896)	Poor to Good
Right Upper Trap	0.821	(0.574- 0.927)	Good to Excellent	0.863	(0.678- 0.945)	Moderate to Excellent
Left Upper Trap	0.858	(0.678- 0.941)	Good to Excellent	0.836	(0.630- 0.933)	Moderate to Excellent
Right Levator Scapulae	0.881	(0.729- 0.951)	Good to Excellent	0.836	(0.632- 0.932)	Moderate to Excellent
Left Levator Scapulae	0.882	(0.731- 0.951)	Good to Excellent	0.88	(0.726- 0.951)	Moderate to Excellent
Right Thorax	0.907	(0.731- 0.971)	Good to Excellent	0.888	(0.671- 0.964)	Moderate to Excellent
Left Thorax	0.9	(0.710- 0.968)	Good to Excellent	0.51	(-.028- 0.820)	Poor to Good
Right Sternocleidomastoid	0.793	(0.519- 0.915)	Moderate to Excellent	0.57	(0.199- 0.802)	Poor to Good
Left Sternocleidomastoid	0.864	(0.659- 0.946)	Moderate to Excellent	0.456	(0.055- 0.737)	Poor to Moderate

Cervical Extensor Fatigue Assessment. Before and after 30 minutes of smartphone use, PD demonstrated poor to good reliability (Table 6). For the cervical extensor fatigue assessment. NPD presented poor to moderate reliability (95% CI = -0.181- 0.645) for the cervical extensor fatigue assessment prior to 30 minutes of smartphone use, and poor to good reliability (95% CI= 0. 108- 0.766) afterwards.

CROM Measurements. Cervical flexion measurements were similar between pain groups pre- and post- 30 minutes of smartphone use (Table 6). Before smartphone use, both PD and NPD demonstrated poor to good reliability (95% CI= 0.108- 0.887) for cervical flexion, and moderate to excellent reliability (95% CI= 0.595- 0.924) afterwards.

ICC values for craniocervical flexion measurements differed between pain groups (Table 6). Prior to smartphone use, PD exhibited moderate to excellent reliability (95% CI= 0.536- 0.906), and poor to good reliability (95% CI= 0.446- 0.879) afterwards. NPD displayed poor to good reliability (95% CI= 0.233- 0.827) before smartphone use and poor to moderate reliability (95% CI= -0.317- 0.507) after the intervention.

Table 6: ICC Values for Cervical Extensor Fatigue Assessment Time and CROM Measurements

		Pain Developers		
		ICC	**95% Confidence Interval**	**Classification**
Cervical Extensor Fatigue Assessment Time	Pre Smartphone Use	0.741	(0.482-0.89)	Poor to Good
	Post Smartphone Use	0.602	(0.254- 0.815)	Poor to Good
CROM Device Cervical Flexion	Pre Smartphone Use	0.743	(0.466- 0.887)	Poor to Good
	Post Smartphone Use	0.847	(0.663- 0.935)	Moderate to Excellent
CROM Device Craniocervical Flexion	Pre Smartphone Use	0.783	(0.536- 0.906)	Moderate to Excellent
	Post Smartphone Use	0.727	(0.446- 0.879)	Poor to Good
		Non-Pain Developers		
		ICC	**95% Confidence Interval**	**Classification**
Cervical Extensor Fatigue Assessment Time	Pre Smartphone Use	0.289	(-0.181- 0.645)	Poor to Moderate
	Post Smartphone Use	0.503	(0.108- 0.766)	Poor to Good
CROM Device Cervical Flexion	Pre Smartphone Use	0.741	(0.451- 0.889)	Poor to Good
	Post Smartphone Use	0.818	(0.595- 0.924)	Moderate to Excellent
CROM Device Craniocervical Flexion	Pre Smartphone Use	0.611	(0.233- 0.827)	Poor to Good
	Post Smartphone Use	0.107	(-0.317- 0.507)	Poor to Moderate

Discussion

This study evaluated the between day reliability of clinical tests that are typically used as diagnostic tools for musculoskeletal disorders of the neck in a population of healthy young adults. The participants were separated into pain groups (NPD, PD) based on their responses to VAS administered during 30 minutes of smartphone usage. The between-day reliability of participants for the clinical tests was different between pain groups and between collections before and after the 30- minute smartphone use intervention. NPD showed greater reliability for PPT measurements taken before the smartphone use intervention, while PD showed higher reliability for PPT measurements taken afterwards. Although researchers consider the measurement of craniocervical flexion unreliable, PD displayed higher reliability for those measurements before and after smartphone use. PD also showed higher reliability than NPD for cervical flexion measurements and the cervical extensor fatigue assessment before and after the smartphone use intervention. It is possible that the development of neck pain effected the reliability of these clinical tests.

Pain Classification. Eighty percent of participants remained in their initial pain groups for the second data collection which could have affected the between-day reliability of the results. For the first day, PD had a mean of 19.35mm ±10.99mm for maximum VAS values for the neck and 20.70mm ± 12.38mm for the upper back. NPD had a first day mean of 4.35mm ± 4.91mm maximum neck VAS values and 3mm ± 4.74mm for the upper back. There was a clear difference between the VAS values of pain groups and the 12mm threshold that classified NPD and PD (Figure 5). A similar intervention study that assessed the repeatability of low-back pain during standing found that 83% of participants remained in their initial pain groups upon the

second day of testing (Nelson- Wong & Callaghan, 2014), which represents the variation present in human research participants. Participants who change pain groups could negatively impact the reliability of clinical tests and could be mistakenly categorized into the incorrect pain group. It is possible that if the smartphone use intervention was longer, the participants who changed pain groups on day 2 would have remained in their initial groups from day 1. Six of the eight participants who changed pain groups on day 2 had a change in VAS of ±5mm of the 12mm threshold that separated the two pain groups. These participants who are close to the threshold criteria could have movement patterns that fluctuate from day to day impacting the reliability of the clinical tests performed (Vogt, Segieth, Banzer, & Himmelreich, 2007) .

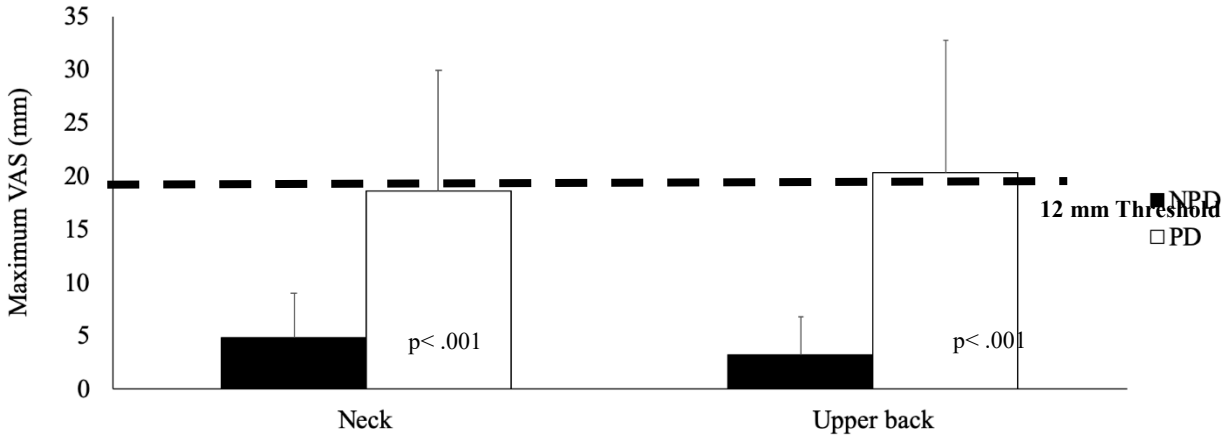


Figure 5: Max VAS Values for the Neck and Upper Back between Pain Groups

Pain Pressure Threshold. Repeatability of PPT measurements for PD varied before 30 minutes of smartphone use, with ICC values from poor to excellent (95% CI= 0.371- 0.952). The landmarks with the lowest reliability were right and left splenius cervicis and left and right levator scapulae. These muscles are smaller, which could lead to error when marking landmarks

for PPT testing. Other sources of error in these measurements could lie in inconsistent marking of landmarks between days or muscle soreness resulting from physical activity (Lau, 2013).

For PD, the highest ICC values were seen for PPT measurements taken after 30 minutes of smartphone use (0.508- 0.950). This contradicted our hypothesis that reliability would be more variable after the intervention. These participants did not have a history of chronic neck pain and varied from each other before the 30-minute smartphone use intervention; however, exposure to sustained neck flexion led the participants in this pain group to react similarly.

Prior to 30 minutes of smartphone usage, NPD had the highest reliability for PPT, which agrees with the hypothesis. For this pain group, the splenius cervicis had the lowest between day reliability. This could be caused by difficulty accessing the muscle due to its location under the splenius capitis. In general, PPT reliability was lower after the smartphone use intervention. Further investigation of the collected motion capture and electromyography data could provide greater explanation for these results.

A strength of our study was the assessment of several more PPT landmarks compared to previous literature. The upper trap (UT) and tibialis anterior (TA) are the most common landmarks measured. In a previous study, healthy, uninjured participants had ICC values of 0.97 (95% CI =0.94- 0.98) for the UT and 0.94 (95% CI =0.91- 0.97) for the TA (Walton et al., 2011). Jorgensen and colleagues (2014) found and ICC value of 0.86 (95% CI =0.71- 0.91) for the TA (Jorgensen et al., 2014). Our ICC values differed by 0.03 (left TA) and 0.06 (right TA). Previous work has looked at the PPT of the infraspinatus and C3-C4 vertebrae (Jorgensen et al., 2014). Jorgensen and colleagues (2014) found ICC values of 0.89 (95% CI= 0.79- 0.95) for C3-C4 PPT measurments (Jorgensen et al., 2014). Our current study used the splenius capitis which is located at the level of the third and fourth vertebrae of the cervical spine for PPT measurement

(Table 3, Table 4). The values for NPD before and after the smartphone use intervention are similar to those of Jorgensen (2014) which shows congruency among PPT measurements taken in the neck and upper back area.

Because this study was the first to evaluate several pre- and post- smartphone usage measurements in a healthy population, researchers were unsure which variables would be significant and as a result did not want to control variables that could be important at determining the differences between the two groups. Previous research that investigated the reliability of the clinical tests mentioned did not control for specific variables; however, it is important to note variables that could impact width of the reliability confidence intervals. For example, vigorous physical activity can often lead to muscle soreness (Cheung, Hume, & Maxwell, 2003), which could influence PPT measurements (Lau, 2013) and affect the between- day reliability of those values. In female participants, research has shown that the highest pain pressure thresholds are seen during the follicular phase of the menstrual cycle (Amodei & Nelson- Gray, 1989; Kuczmierczyk & Adams, 1986). There were 1 to 2 weeks between participant visits. Therefore, females were in different phases of the menstrual cycle for each visit which could impact the between-day reliability of PPT measurements. Unlike previous studies, we did not take the average of measurements between the right and left sides for PPT values. Averaging the values would not impact the reliability of the particular PPT landmarks, but would not allow researchers to compare bilateral differences that could be the result of posture and different muscle activation patterns.

One variable that was not evaluated in this study was perceived stress level. 98% (40/41) participants were college students. College can be a stressful time due to exams, maintaining grades, balancing coursework with social obligations, and learning to live independently (Ross,

Niebling, & Heckert, 1999). Research shows that individuals with higher perceived stress levels have a lower PPT (Ballegaard, Petersen, Gyntelberg, & Faber, 2012; Hven, Frost, & Ellekilde, 2017). Researchers also found that the PPT protocol could act as a trigger point release that made some participants feel better. A different measurement, such as a pressure sensitivity assay (Kostek et al., 2016), should be tested for reliability under the conditions used for this study to aid in determining the best protocol to use for the assessment of musculoskeletal pain. Pressure sensitivity assay uses similar methodology as pain pressure threshold testing, but determines the intensity of the participant pain sensation by using a VAS. These factors could have impacted PPT measurements, resulting in lower between-day reliability.

Cervical Extensor Fatigue Assessment. Before and after 30 minutes of smartphone use, PD displayed poor to good between- day reliability for the cervical extensor fatigue assessment. In NPD, ICC values for this assessment were poor to moderate before the intervention and poor to good afterwards. Previous research found an ICC of 0.77 (0.55- 0.89) for the cervical extensor fatigue assessment for one rater and 0.90 (0.79- 0.95) for a second (Jorgensen et al., 2014). The values from the first rater are similar for the pre- smartphone use values for the PD pain group from this study but differ greatly from the results of the NPD.

Differences in ICC values between the two studies could be due to different methodology. Jorgensen and colleagues had participants lie prone with a laser attached to the head (Jorgensen et al., 2014). While maintaining cervical extension, participants were required to maintain the laser beam inside of a target placed on the floor (Jorgensen et al., 2014). Jorgensen's method is more sensitive to small changes in neck position and allows researchers to easily see when subjects deviate from the required position. The method used in this study used

the inclinometer on the side of a C-ROM device, and the protocol ended when the participant exceeded a change in 5° of neck angle. A narrower range could have improved the reliability for this protocol. Researchers chose this protocol over the laser and target method because of the sensitivity of the test. During piloting, participants were able to hold the laser in the target perimeter for long durations of time. Perhaps this was because participants were recruited from a healthy population, and this particular protocol was designed for those with clinical diagnoses. Jorgensen and colleagues did not compare ICC values between healthy (control) participants and clinical participants. Doing so would allow researchers to see differences between the groups that would help determine the applicability of this testing protocol.

CROM Measurements. Between-day reliability of cervical flexion measurements before smartphone use was poor to good for both NPD and PD, and both pain groups had moderate to excellent reliability after the intervention. ICC values in the literature range between 0.81- 0.86 (95%CI = 0.62- 0.93) (Jorgensen et al., 2014) and 0.89 (95% CI=0.73- 0.96) (Audette et al., 2010). These are similar to flexion values for PD after 30 minutes of smartphone use. Half of the participant population in the study conducted by Jorgensen and colleagues (2014) was clinical neck pain patients. Perhaps these participants could be compared to the PD group from this study. However, it is difficult to draw conclusions because the ICC values for neck flexion are unknown for only the clinical population. Participants in the study conducted by Audette and colleagues (2010) were healthy adults without chronic pain. Results and participant population are comparable to our study. Therefore, the assessment of cervical flexion can be used to evaluate healthy populations that develop transient neck and upper back pain during prolonged flexion.

Craniocervical flexion ICC values were higher in PD for pre- and post- intervention measurements than in NPD. Reliability for PD before the intervention was moderate to excellent (95% CI= .536- 0.906) and was poor to good (95% CI= 0.446- 0.879) after. Protocol reliability for NPD was poor to good (95% CI= 0.233- 0.827) before 30 minutes of smartphone use and poor to moderate (95% CI= -0.317- 0.501) after. Previous research has found limited cervical range of motion in individuals with chronic pain (Vogt et al., 2007). Though all participants in this study were healthy and asymptomatic, those who developed pain share similar range of motion characteristics with chronic neck pain patients. Motion capture and electromyography data were collected but have not been reported in this thesis. Further evaluation of such data can provide greater insight to the differences between PD and NPD groups.

There are no reliability values for craniocervical flexion in the literature. Therefore, researchers do not have a precedent for the comparison of results. This was a difficult motion for participants to perform. Researchers feel this protocol was unreliable because of the variability in ICC values among pain groups. Due to discomfort when performing the motion, researchers do not recommend this as a valid method for distinguishing differences between those who do and do not develop neck pain during smartphone use. Perhaps a different protocol could better measure craniocervical flexion. Previous research has used a craniocervical flexion test (CCFT) in which the participant lies supine on a treatment table with a pressure biofeedback device placed suboccipitally, and the participant performs craniocervical flexion through 5 stages of progression (Jorgensen et al., 2014). This protocol assesses cervical flexor endurance rather than range of motion; however, cervical flexors are necessary for performing this motion. A pilot study assessing the correlation between cervical flexor endurance and craniocervical range of motion should be conducted to determine if the CCFT could replace the assessment

craniocervical range of motion in this population. This particular protocol has a between day reliability ranging from 0.7 (95% CI= 0.43- 0.85) to 0.86 (95% CI= 0.72- 0.93) (Jorgensen et al., 2014). Future research should assess this protocol under the conditions and methodology used for this study.

Limitations. Several variables were assessed during this study which led to lengthy data collections. After 30 minutes of smartphone use, participants were often fatigued which could have altered the reliability of results. An additional limitation is learned behavior by participants. Although clinical tests used for this study were not skill-based, participants could improve from multiple exposures to each protocol affecting reliability. Researchers did not control for participant physical activity (Lau, 2013) or female menstrual cycle (Amodei & Nelson- Gray, 1989; Kuczmierczyk & Adams, 1986), and participant perceived stress level was not measured (Ross et al., 1999). Each of these could impact the reliability of clinical tests or widen the confidence intervals of ICC values.

Conclusions and Future Research

The purpose of this study was to assess the repeatability of clinical tests over the course of two days in young adults who do and do not develop neck pain after 30 minutes of smartphone use. It was important for researchers to evaluate several tests usually used in clinical populations for the investigation healthy individuals who are more likely to develop flexion-induced neck pain. NPD had greater between day reliability for PPT measurements taken before the intervention, while PD had higher ICC values after 30 minutes of smartphone use. Although unreliable, ICC values for the protocol used to assess craniocervical flexion were higher in PD than in NPD before and after intervention, and the cervical extensor fatigue assessment and cervical flexion protocols had higher reliability before and after the smartphone use intervention in the PD group.

Understanding the reliability of the researched clinical tests will impact the efficacy of interventions aimed at reducing flexion-induced neck pain development. Future studies should include the following protocols as part of a testing battery that aids in determining individuals with a potential predisposition for developing flexion- induced neck pain, and to assess changes that arise following exposure to neck flexion:

- Pain pressure testing of the upper trapezius (UT), splenius capitis, and the T4 thoracic vertebrae
- Cervical Extensor Fatigue Assessment
- Cervical Flexion Test

Future work must also examine additional methods for measuring pain pressure responses of participants by comparting PPT with other methods such as pain pressure sensitivity assay (Kostek et al., 2016), and should compare craniocervical flexion with a CCFT protocol.

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Appendix

UNIVERSITY OF ARKANSAS

To:	Kaitlin Gallagher HPER 308-R
From:	Douglas James Adams, Chair IRB Committee
Date:	08/17/2018
Action:	**Expedited Approval**
Action Date:	08/15/2018
Protocol #:	1808135367
Study Title:	Determining risk factors of neck pain development due to smartphone use
Expiration Date:	08/14/2019
Last Approval Date:	

The above-referenced protocol has been approved following expedited review by the IRB Committee that oversees research with human subjects.

If the research involves collaboration with another institution then the research cannot commence until the Committee receives written notification of approval from the collaborating institution's IRB.

It is the Principal Investigator's responsibility to obtain review and continued approval before the expiration date.

Protocols are approved for a maximum period of one year. You may not continue any research activity beyond the expiration date without Committee approval. Please submit continuation requests early enough to allow sufficient time for review. Failure to receive approval for continuation before the expiration date will result in the automatic suspension of the approval of this protocol. Information collected following suspension is unapproved research and cannot be reported or published as research data. If you do not wish continued approval, please notify the Committee of the study closure.

Adverse Events: Any serious or unexpected adverse event must be reported to the IRB Committee within 48 hours. All other adverse events should be reported within 10 working days.

Amendments: If you wish to change any aspect of this study, such as the procedures, the consent forms, study personnel, or number of participants, please submit an amendment to the IRB. All changes must be approved by the IRB Committee before they can be initiated.

You must maintain a research file for at least 3 years after completion of the study. This file should include all correspondence with the IRB Committee, original signed consent forms, and study data.

cc: Madison Rose Hotelling, Key Personnel
Cameron Reid Bruner, Key Personnel
Ashton Matson, Key Personnel
Caleb Charles Burruss, Key Personnel
Madison Marie Boule, Key Personnel
Molly Ann Bolton, Key Personnel
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