Intrasession Test-Retest Reliability of the Cervicocephalic Kinesthetic Sensibility Test used to Measure Cervical Joint Position Sense

by

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INTRODUCTION: Cervical spine injuries and concussion present with similar mechanisms and nearly identical symptoms. Reliable measures of cervical proprioception could help determine if deficits exist. The aim of this study was to determine the intrasession reliability of the Cervicocephalic Kinesthetic Sensibility (CKS) test. Previous literature has only addressed Left and Right Axial Rotation, where this study addresses 3 planes of motion. **METHODS:** A descriptive, observational design was used to assess intrasession reliability. Seventeen subjects were included in this study (4 males, 13 females), 18-25 years old avg. Age (yrs.) (23.12±1.36), avg. Weight (kgs) (66.89±12.59), avg. Height (cm) (171±11.44). The dependent variables for this study included cervical joint position sense (JPS) error of the cervical spine in degrees (°). Cervical Flexion (CF), Cervical Extension (CE), Right Axial Rotation (RAR), Left Axial Rotation (LAR), Right Side-Bending (RSB) and Left Side-Bending (RSB) were assessed for JPS error. A chair was placed 90cm from the wall. A 40cm target was placed on the wall. The subject wore a helmet with a laser attached and Head Neutral (HN) was established prior to testing. The rater instructed the subject to position themselves in HN, close their eyes and flex their neck to end range of motion, then had them return to HN. The rater marked on the target where the laser landed. This was performed in the same manner for all 6 cervical motions. The intrasession test retest reliability was estimated calculating ICC(2,1) and ICC(2,3), 95% CI and P-values. Statistical significance was set *a priori* at alpha= 0.05, two-sided. **RESULTS**: The highest reproducibility for single measures ICC and average measures ICC was found in CF and LSB, CF ICC(2,1) = .404, LSB ICC(2,1) = .496, CF ICC(2,3) = .670, LSB ICC(2,3) = .747. Cervical Extension (CE), Right Axial Rotation (RAR), Left Axial Rotation (LAR) showed very low reproducibility for single measures ICC, however showed more acceptable average measures ICC. **CONCLUSION**: These results show a wide variability among reliability of the CKS test in 6 different cervical motions. Further evaluation of test-retest reliability is necessary to determine the usefulness of this tool to measure cervical proprioception.

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1.0 Introduction

It is estimated that 1.6 to 3.8 million people sustain a sport or recreational Traumatic Brain Injury (TBI) each year in the United States.[1] Sports-related concussion (SRC) is defined as a traumatic brain injury induced by biomechanical forces.[2] SRC results in a rapid onset of short-lived impairment of neurological function that typically resolves spontaneously. However, in some cases, signs and symptoms evolve over several minutes to hours.[2] The acute clinical signs associated with SRC are typically functional rather than structural. No structural abnormalities of the brain can be found on standard neuroimaging in association with the neurophysiological changes.[2] SRC may or may not result in a loss of consciousness and involves a range of clinical signs and symptoms. Resolution of these signs and symptoms typically occur in 7-10 days however, in some cases symptoms may be prolonged.[2] Approximately 10-20% of concussion cases do not follow the typical timeline for recovery and in turn have prolonged symptoms known as post-concussion syndrome.[2] Headache is the number one reported symptom of concussion while dizziness is the second. [3] Dizziness is stated to occur in 23-81% of cases.[4] Often these symptoms overlap with symptoms of whiplash or other cervical injury and it can be difficult to differentiate between the two. This is highlighted in a Delphi study by Reneker et al.[5] in which they compiled data from different experts such as physical therapists and athletic trainers to determine the most commonly used cervical tests to differentiate between cervicogenic causes of dizziness and concussion. Reneker et al.[5] found a lack of common ground among professions for differentiating between injury to the cervical spine and concussion alone. The results of this study highlight a need for standardized methods for determining cervicogenic involvement when evaluating concussion. Dizziness occurring after concussion is not well defined. It presents with numerous symptoms and several potential sources and mechanisms. The inner ear, the brain, the cervical spine and the integration of afferent input and tuning within the sensorimotor system has been of recent interest.[5,6] The diagnosis of cervicogenic dizziness can be complicated. It is described as dizziness and disequilibrium that is associated with neck pain in patients with cervical pathology. Wrisley et al.[7] described the incidence, prevalence, and possible pathology of cervicogenic dizziness as well as outlined the diagnostic criteria and treatment. They determined that the occurrence of complaints of dizziness and cervical spine dysfunction most commonly occur in association with a flexion-extension injury, whiplash, as the result of a motor vehicle accident. Cervicogenic diagnosis is a process of exclusion as an ideal and robust clinical diagnostic test has yet to be established. Treatment of cervicogenic dizziness has shown promising results with manual therapies.[7]

Cervical musculature plays a pivotal role in stabilization of the head during contact sport and has been suggested to play a role in the reduction of injury, in particular concussion.[8-10] Linear and angular acceleration of the head upon impact have been shown to be correlated with cervical strength.[11,12] Osteoligamentous structures have been shown to make up approximately 20% of the minimally needed mechanical stability of the cervical spine.[13] This leaves 80% of the responsibility of mechanical load to the cervical musculature.[14] It is thought that when someone contracts their cervical musculature, they have an increased effective mass of the head by more rigidly coupling the head to the neck and thorax. [12,15-17] Therefore, theoretically testing isometric strength would be an appropriate way to determine the strength of the stiffness or rigidity of the cervical spine. Cervical strength has often been proposed as a modifiable risk factor of concussion. Collins et al.[18] reported that for every 1-pound increase in neck strength, the risk of concussion was decreased by 5%. Neck musculature may reduce the risk of concussion by decreasing movement of the head when an external force is applied.

Engelman et al.[19] conducted a study on cervical musculature strength in a pediatric population of athletes with multiple concussions. They used an isokinetic dynamometer to measure maximal isometric voluntary contraction (MVIC) for the following cervical motions: flexion, extension, right lateral flexion and left lateral flexion. The investigators found no significant difference in MVIC in any direction between the concussion and control groups. In a study by Lincoln et al.[20] they examined videos that captured the occurrence of concussion during games and practice. They found that approximately 50% of the concussions occurred due to unanticipated impacts. This may suggest that these concussions occur due to lack of situational awareness and preparation for impact. Strength has been suggested by a few studies as a preparatory mechanism for more anticipated movements and the importance of situational awareness must be emphasized.[20] It is also suggested that other factors like timing of muscle firing, muscle stiffness and neuromuscular control play an important role in reducing the risk of sustaining a concussion. Testing for time to peak force may give greater insight to cervical strength in a more realistic scenario.

The primary focus of this paper is to determine a reliable measure for cervical proprioception. While many have attempted to examine reliability of measures for cervicocephalic kinesthetic sensibility (Cervical Joint Reposition Sense) there is no general consensus on methods. Few studies examine proprioception of the cervical spine in the three cardinal planes: sagittal, frontal and transverse.[21,22] Further investigation is warranted into an original method designed by Revel et al.[23], which is clinically friendly, non-invasive and inexpensive. For this to be a useful tool among clinicians it is necessary to determine the reliability of the measure.

1.1 Epidemiology of Concussion

1.1.1 Concussion in Sport

Sports-related concussion (SRC) is defined as a traumatic brain injury induced by biomechanical forces.[2] It is estimated that 1.6 to 3.8 million people sustain a sport or recreational Traumatic Brain Injury (TBI) each year in the United States.[1] SRC results in a rapid onset of short-lived impairment of neurological function that typically resolves spontaneously. However, in some cases, signs and symptoms evolve over several minutes to hours.[2] The acute clinical signs associated with SRC are typically functional rather than structural. No structural abnormalities of the brain can be found on standard neuroimaging in association with the neurophysiological changes.[2] SRC may or may not result in a loss of consciousness and involves a range of clinical signs and symptoms. Resolution of these signs and symptoms typically occur in 7-10 days however, in some cases symptoms may be prolonged.[2] Approximately 10-20% of concussion cases do not follow the typical timeline for recovery and in turn have prolonged symptoms known as post-concussion syndrome.[2] Headache is the number one reported symptom of concussion while dizziness is the second.[3] Dizziness is stated to occur in 23-81% of cases.[4] Often these symptoms overlap with symptoms of whiplash or other cervical injury and it can be difficult to differentiate between the two.

1.1.2 Sex Considerations for Concussion

Various epidemiology studies report that concussion rates are higher for male athletes than female athletes at the high school and collegiate level[24,25], however, with studies predominantly conducted on high schools that include football, which has the highest occurring rate of concussion[26], it does not take into account the higher rates for concussions in females in sex comparable sports. When you remove the largest culprit for sustaining concussion and focus on sex comparable sports female athletes have higher occurring rates of concussion compared with their male counter parts.[27-31] A study conducted by Marar et al.[29] reported the epidemiology of concussions among high school athletes found that among comparable sports like baseball/softball, basketball, soccer and ice hockey, females had a concussion rate of 1.7 per 10,000 athlete exposures (AE) where males had a rate 1/10,000 AE. Many studies have attempted to identify the risk factors. Previous research has indicated that female student athletes have an increased risk of sports related concussion compared to males in comparable sports.[27-31] A study conducted by O'Conner et al.[30] reported females at the high school level are 1.56 times a greater risk for SRC than male athletes in sex comparable sports.[30] At the collegiate level it has been reported that female athletes sustain a greater number of concussions in basketball, ice hockey, soccer and softball/baseball than their male counter parts.[27,31]

There are several reasons why female athletes may sustain larger numbers of concussion compared to males. Female patients have a decreased head-neck segment mass, neck girth and strength compared with male athletes.[11,12,32] Tierney et al. reported that females have a greater head-neck segment acceleration than males when their heads are subjected to the same load. Females have been found to carry more head mass per unit of cervical musculature than males. Even when adjusted for height and weight females have a smaller neck relative to the proportion of their heads.[33]. These studies are consistent with the literature exploring cervical strength of males and females.[34,35] The study by Garces et al.[35] aimed to collect normative data of isometric cervical strength in a healthy population. Garces and colleagues found a positive correlation between weight and strength, as well as height and strength among males and females. The data determined that males have about 30-40% stronger cervical musculature than females.

Bretzin et al. conducted an epidemiological study describing the sex differences in the incidence of sports related concussion. This was measured in missed school days and time loss for student athletes. A total of 193,757 (116,434 males and 77,323 female) students athletes participating in Michigan high school athletic association that were recorded in the Head Injury Reporting system were included in the study. All reported head injuries were recorded from 2015-2016 academic year. Total concussion injuries, as well as missed school days and time loss for each concussive injury were reported. Overall female high school student-athletes were at a 1.9 times greater risk for a SRC compared with males HS student athletes. Several reasons have been identified to explain why females may be at a greater risk for SRC. Females may have a decreased head-neck segment mass, neck girth, and strength compared with males. These factors may lead to a greater angular and linear velocity during impact. It should be noted that females tend to report symptoms of concussion more frequently than males. This is referred to as reporting bias. Recent literature has suggested that male athletes may not report sports related concussions due to certain athletics factor like pressure from coaches, feelings of letting the team down and not wanting to miss game time.[36] Hormones may play a role in the severity of symptoms in females, effecting not only the risk of concussion but also the time missed from school as well as practices and games. Females in this study had more time lost from concussion than males, which is consistent with previous research.[27,28] There were no significant differences found for days missed of school. On average only one school day was missed for both male and female student athletes with concussions. A few of the limitations of this study were that it was only performed in high schools in Michigan, and some of these high schools did not have an athletic trainer so the administrator would document these injuries. Accurate documentation of the symptoms and severity of symptoms is necessary to paint a complete and accurate picture of the problem at hand. The study was only conducted from the data of one academic school year, so may not be representative of all years. This paper gives good reasoning to believe that females in a high school setting are at a greater risk for sustaining concussion. Similar information is lacking at the collegiate level for both males and females. This study highlights a few reasons speculated as to the increased incidence of concussion in females. More information is needed about the biomechanical deficits like cervical strength, proprioception and range of motion that may leave females at higher risk for concussion.

1.1.3 Concussion Trajectories

Sports related concussion (SRC) is heterogeneous in nature, presenting clinically in different ways. Therefore, it can be a challenging injury for many sports medicine professionals, as a one size fits all approach is not appropriate for concussed patients. Researchers have identified 6 trajectories or clinical profiles of concussed patients. 1) cognitive/ fatigue, 2) vestibular, 3) ocular, 4) posttraumatic migraine, 5) anxiety/mood, and 6) cervical.[37,38] These profiles are not described as exclusionary, and many patients overlap or change profiles throughout treatment.[37] Kontos et al. describes cervical involvement as a modifier of sports related concussion, describing that SCR may involve cervicogenic injury due the role of neck musculature in stabilizing the head. While the cervical spine is not greatly addressed throughout concussion literature, it is noted that if cervicogenic injury is confirmed, a patient should be further evaluated by a physician or physical therapist who specializes in cervical rehabilitation.[37]

Ellis et al.[39] describes cervicogenic post-concussion disorder as persistent concussion symptoms and impairments caused by dysfunction of the cervical spine somatosensory system.

Neck musculature is dense and has a complex structure of mechanoreceptors that are a large source of proprioceptive information that gets translated to multiple levels of the central nervous system. Ellis et al.[39] suggest that when cervicogenic involvement is suspected to be the underlying cause of ongoing concussion symptoms, further evaluation of the cervical spine is necessary to address possible cervical spine deficits. In particular, assessment of cervical joint repositioning in a clinical setting is recommended to investigate proprioception deficits and is also used for cervical proprioceptive retraining. However, with this recommendation, a simple and reliable method to measure joint position sense is not widely known or available to clinicians.

1.2 Diagnostic Tools for the Cervical Spine

It is important to access the cervical spine when concussion or injury to the cervical spine is suspected. However, few tools are available to clinicians for thorough investigation of damage to the cervical spine. The Sports Concussion Assessment Tool- 5th addition (SCAT5) is widely used to assess concussion on- and off-field. . The SCAT5 lays out different subsections to address both physical and cognitive signs and symptoms of concussion.[2] The section for assessing the cervical spine is minimal, only assessing for pain and range of motion. The Neck Disability Index is the most widely used tool to assess for cervical spine pain and function

1.2.1 Concussion Evaluation for the Cervical Spine

The Sports Concussion Assessment Tool-5th Edition (SCAT5) is a sideline evaluation of cognitive function; a brief neurophysiological test that assesses attention and memory function.

The SCAT5 incorporates the Maddocks questionnaire and Standardized Assessment of Concussion (SAC).[2] The SCAT5 currently represents the most robust and widely used concussion assessment tool. The assessment includes a symptom checklist, clinical reaction time, gait/balance assessment, oculomotor screening and a cervical spine evaluation. The cervical spine evaluation is brief and only addresses pain and range of motion function.[2] The Vestibular/Ocular-Motor Screening (VOMS) assessment is used to access the vestibular and ocular motor impairments by provoking patient reported symptoms following each assessment. The VOMS consists of seven domains: 1) smooth pursuit, 2) horizontal saccades, 3) vertical saccades, 4) near point convergence (cm) 5) horizontal vestibular ocular reflex (VOR), 6) vertical VOR, and 7) visual motion sensitivity (VMS). A base line of symptoms is used as a part of the VOMS assessment. A verbal rating of changes in headache, nausea, dizziness and fogginess on a scale of 0-10 is recorded. 0 being none and 10 being the most severe provocation of symptoms. A verbal rating of these symptom changes occurs after each domain is completed. Further evaluation of performance in these tests along with more thorough evaluation of the cervical spine is necessary to understand the complex role the cervical spine may play in the prevention of or recovery from concussion and/or coinciding spinal injury. Proper evaluation and treatment of injuries to the cervical spine is necessary for the best patient outcomes. Evaluation of the cervical spine for pain and function could give insight into functional deficits that exist.

1.2.2 Neck Disability Index

The Neck Disability Index (NDI) displayed in **Error! Reference source not found.**, is a commonly used outcome measure for neck pain and function.[39] A study by MacDermid et al. determined its clinical usefulness and limitations. With the chronic and often episodic nature of neck pain and disfunction and with few concise physiologic objective measures it is important to have a reliable tool to measure neck disability.[39] This measurement is a self-reported outcome. MacDermid and colleagues performed a systematic review of 37 studies that used the NDI as an outcome measure for neck disability. They analyzed both its psychometric properties, like relative difficulty of items; appropriate grouping of items into subscales; reliability; validity; and responsiveness, as well as its “clinical friendliness” or usefulness. They concluded that the NDI has sufficient usability to remain the most commonly used outcome measure of neck disability.

Vernon and Mlor[40] developed the NDI on the frameworks of the Oswestry Low Back Pain Index (OLBPI). The OLBPI includes 6 scored categories: Pain intensity, personal care, lifting, sleep, driving and sex life. Originally 4 more categories were added the for use in the NDI. After review for applicability of use only 5 categories from the OLBPI remained and 5 categories were added to complete the 10 categories scored for the NDI. The NDI categories include: Pain intensity, personal care, lifting, work, headaches, concentration, sleeping, driving, reading and recreation.[40,41]

Miettinen et al.[42] determined that a “normal” score would be between 0 to 20 points. This score would represent “normal to mild disability”. Vernon and Mlor[41] suggest that a score between 0 and 4 represents no disability, 5 and 14 mild disability, 15 and 24 moderate disability, 25 and 34 severe disability, and any score greater than 35 to be complete disability.[41] For use in the current study the NDI was used as an additional measurement to ensure a healthy population was assessed for test-retest reliability of the Cervicocephalic Kinesthetic Sensibility Test.

1.3 Cervical Characteristic Assessments

Whiplash is characterized by a sudden acceleration or deceleration resulting in rapid hyperextension, hyperflexion, or lateral flexion of the cervical spine without necessarily experiencing an external blow to the head[43], not unlike the mechanism of injury resulting in concussion.[2] The symptoms of whiplash include neck pain, headache, vertigo, nausea, blurring of vision, dysacusis (pain or discomfort due to sound), fullness of the ear and various emotional and cognitive disturbances.[44-46] These symptoms overlap with symptoms related to concussion and post-concussion syndrome.[2] Post-concussion syndrome occurs in approximately 10-20%[2] of concussed patients. One of the largest predictive symptoms of post-concussion syndrome is dizziness.[3] Whiplash can cause long term disability, with one study finding that 6% of patients were unable to return to work for one year following injury.[47] Heikkila and colleagues found that patients with complaints of dizziness showed greater repositioning error. With the similarities in symptoms and mechanisms further research is warranted to determine if a relationship exists between cervical deficits in proprioception, strength and ROM resulting from history of concussion. There is no consensus about the appropriate methods used, or if cervical pain, injury or dysfunction of the cervical spine has an effect on cervical characteristics.

1.3.1 Cervical Strength Testing

There are many different ways that isometric strength can be measured including custom made machines, isokinetic equipment, tension scales, and handheld dynamometry (HHD)[48] HHD is more clinically available, portable, inexpensive and relatively quick to use.[48] Fixed-frame dynamometry is the most widely used and recognized tool for measuring cervical muscle isometric strength. This method uses a large wall or framed-mounted machine with a fixed base. This is expensive and often impractical for most clinical settings.[49]

Hand-held dynamometry (HHD) has been found in numerous studies to be a reliable and clinically applicable method of measuring cervical strength. A study done by Geary et al.[50] tested the intra-rater reliability of hand-held dynamometers to test the neck strength of rugby union players. They tested the isometric neck strength of 25 male rugby players. They measured: flexion (F), extension (E), right side flexion (RSF) and left side flexion (LSF). Two sessions were completed using a commercially available HDD and a custom designed neck harness. The sessions were completed on two separate days in the same location. A warm-up was included that involved range of motion exercises of the neck and shoulders as well as three submaximal trials to familiarize subjects with the procedures. Prior to testing, the xiphoid process was identified, a mark was made 4 finger widths above. A tape measure was used to measure the adjacent points at this height on each of their arms and back to be used as a landmark for stabilization against the electronic table. This was to ensure no movement or use of torso or lower body musculature. This allowed for isolation of the neck musculature to be tested. For each test session the participants completed three trials of each cervical motion. Intra-rater reliability intraclass correlation coefficients (ICC) ranged from 0.80 to 0.92: ICC F, 0.85; E, 0.85; F:E, 0.85; LSF, 0.80; RSF, 0.8; LSF:RSF, 0.91; total isometric strength, 0.92. This indicates excellent reliability for use of an HDD to measure cervical strength. These methods provide valuable information about the correct use of a HDD to measure cervical strength and could be easily repeated for reliable measures.

Vannebo, Iverson, Marius and Mork[51] conducted a test-retest reliability study of a handheld dynamometer for measurement of isometric cervical muscle strength. Vannebo et al. focused on repeated test sessions to access learning effect and gender differences. A total of 60 subjects included thirty men and thirty women. They used a HDD to measure isometric cervical muscle strength all performed by the same tester. Neck flexion, extension and right/left lateral flexion was tested. Three trials were completed per session with a one-minute rest between. Three sessions were completed with at least five days in between sessions. On the day of the first session the subject performed 1-2 submaximal warm up trials to become familiarized with the task. During the test trials the subject was asked to build up to maximal isometric force within 3-5 seconds while the tester applied resistance. Immediately following each trial, the subject was asked to rate their effort of maximal contraction on a Borg CR-10 scale with a score of 10 defining maximal effort. Vannebo et al. found that in women there was a systematic reduction in within subject variation between days 2-3 measurements compared to days 1-2, demonstrating a possible learning effect. This was not observed in men. The overall consistency of the repeated measures was relatively similar, and ICCs were high (0.73-0.93). The cervical strength values measured in this study were lower than the study done by Geary et al[50], this may be due to the testing methods. This study used a "make" test, where the test subject simply holds the isometric contraction, while Geary et al. used a "break" test which has been shown to produce higher values of isometric contraction[52,53]. The break test differs in that the subject holds the contraction and the tester forcibly "breaks" the hold by applying over pressure. The difference may also be due to the nature of the subjects, while Vannebo and colleagues used males and females, Geary et al. used male Rugby players.

Versteegh et al.[54] evaluated a method of neck strength assessment using a self-generated resistance with a HHD. This was to reduce the bias of the strength of the tester by removing the need for a tester all together. Thirty healthy subjects were included in this study, fourteen male and sixteen females. A standardized HHD was used to evaluate maximum isometric contraction, measured in kilogram-force (kgf) for each plane. The participants were seated on a stool with feet flat on the floor. The stool had no back or arm rests to prevent from bracing the trunk against them. This method also used a “make” test; however, the participant held the HHD rather than a tester. They found their results to be consistent with reliability findings from studies using large fixed-frame dynamometers.

Krause et al. studied a comparison of various cervical muscle isometric strength testing methods using a HHD. They hypothesized that while all three methods would prove reliable, they would find significantly different force outputs between the methods. The three methods were lying push tests, sitting push tests and sitting pull test. They used a total of 30 participants, 15 males and 15 females. The motions measured were extension, flexion, and right and left side bending. Krause et al. used an ergoFET HHD (Hoggan Scientific, LLC) and either an Adapta ADP 300 adjustable-height treatment table or a standard chair without armrests depending on the method. Prior to testing, a screening was completed involving active cervical flexion, extension and lateral bending and a Spurling test. To ensure pain free cervical motion and meet the criteria for inclusion in the study. Each participant warmed up with 10 repetitions of each cervical motion and a three second hold of submaximal contraction for each motion. The testing order for each method was randomized. No significant difference was found in reliability of the three methods, ICC reliability coefficients from the lying position (ICC, 0.89-0.95) were equal or greater than measurements from the seated push or seated pull test. The minimal detectable error (MDC) was most sensitive for the lying push (range 3.19-4.85 %BW). The lying position presents with a couple of advantages. No strap is required to keep the participant stable, unlike the seated position. The lying position also gives the examiner a mechanical advantage, because the examiner can position themselves to use their body weight to provide resistance. This eliminates the need for the examiner to have to overpower the participant with their own strength.

Almosnino et al.[55] conducted a study to test the retest reliability of force-time variables of neck muscles under isometric conditions. The participants for this study were 26 highly physically active, healthy males. A custom-built testing apparatus was used to measure voluntary isometric contractions of the neck muscles in five directions of cervical motion: Flexion, extension, protraction, left and right lateral flexion. This was measured at least 7-8 days apart to limit fatigue. This study aimed to test isometric neck strength in different conditions where in many studies only peak force was recorded and examined. Almosnino et al[55] claim that peak force alone may not be an adequate measurement for a sport setting. Peak force may not examine the role of the neck musculature for injury prevention. A laboratory or clinical setting does not adequately represent a field setting where injury is likely to occur, such as games or practices. During a game or practice an athlete may not reach maximal force during an impact, this can be explained due to the nature of an often-unanticipated impact that typically causes injury. The variables measured were peak force (PF), rate of force development (RFD) and time to 50% of peak force. No systematic bias was present or detected for the dependent measures across any movement direction, retest differences in measurements were between 1.8% and 2.7% with corresponding 95% confidence interval ranges less than 10% overlapping. The confidence interval was lowest in the peak force range across all the tested directions followed by RDF and time to 50% of peak force the ICC score range for all dependent measures was .90-.99. These findings have possible applications for investigating the role of neck muscle strength-training programs in reducing the risk of injuries in sport settings. Force generating capacities of the neck muscles under isometric conditions can be measured with an acceptable degree of reliability. This study differs in its use of the hockey helmet during testing, it was thought that the participant would be more comfortable giving maximal effort. The helmet does not however allow for cervical rotation. The results of this study cannot be generalized to all populations, as a lot of the justification for a lack of bias was reliant on the population. This study also only used males, exploration of the strength differences between males and females is necessary to gain a full understanding of the role of cervical musculature in injury prevention, as females have a higher incidence of concussion than males.[27-31]

Collins et al.[18] examined neck strength as a protective factor for reducing the risk of concussion in high school sports. Fifty-one high schools in 25 States participated in this study (n=6,704). The purpose of this study was to develop a cost effective and functional way for clinicians to measure strength of cervical musculature. A feasibility study was conducted to determine if the handheld tension scale could be reliable for use by clinicians in high school settings by the athletic trainer to measure cervical neck strength. A pilot study was also conducted to determine if anthropometric measurements taken by the athletic trainers can be used to predict concussion risk amongst high school soccer, basketball and lacrosse players. Overall neck strength and sport were significant indicators of concussion risk. Smaller mean neck circumference, smaller mean neck to head ratio, and weaker mean overall neck strength were significantly associated with concussion. For every 1lb increase in neck strength, the odds of concussion decreased by 5 %.[18] Further research is needed to understand why these differences exist and how they may affect the risk of concussion. It is indicated that these findings should be confirmed in larger and broader pools of athletes, the sample was limited to high school athletes so therefore cannot be generalized for age, sport or level of competition. The athletic trainers were not blinded to the neck strength results, so therefore there may have been a potential for reporting bias. Despite these limitations their findings and methods of reliable and cost-effective measurement of strength are useful for further research.

Smith et al.[56] conducted a study to evaluate the clinical measures of deep cervical flexor endurance and cervical active range of motion (AROM) among highschool football players. Smith and collogues attempted to determine a relationship between these cervical characteristics and a history of concussion. This study had a population of 122 highschool football players. Concussion history was taken, and cervical AROM, and deep neck flexor endurance were measured. Reference values were calculated for AROM and endurance measures: associations were examined between various descriptive variables and concussion. Deep neck flexor endurance was measured using the craniocervical flexion test (CCFT), deep neck flexor of the longus capitus and longus colli were measured. These particular muscles play a key role in stability and normality of cervical motion.[57] There were no statistically significant differences found between athletes with a history of concussion and those without. A modest inverse relationship was found between body mass and AROM in the sagittal and transverse planes. These results indicate that the participants with larger body mass had less cervical AROM in these directions. Limitations to this study include a small sample size. The study was only conducted on high school football players and therefore cannot be generalized to age, sport or sex. The athletes self-reported concussion, underreporting or underdiagnosed healthy subjects may have affected the results. Although these results have value, other measures like muscle quickness, rate of force development, and joint position sense my reveal more information about the variance in concussion outcomes.

Schmidt et al.[14] studied the influence of cervical muscle characteristics on head impact biomechanics in football. The purpose of the study was to determine if stronger, larger, and stiffer neck muscles protect football players from high magnitude impacts to the head. This study consisted of 49 football players, 34 high school, and 15 collegiate athletes. Head impact biomechanics were collected for each participant. Isometric strength measures of peak torque and rate of torque development were taken using the HUMAC NORM Testing & Rehabilitation System. Torque generated by the cervical flexors, extensors and right and left lateral flexors were measured. Three consecutive ultrasound images of the sternocleidomastoid, upper trapezius, and semispinalis capitis were obtained using an M-turbo ultrasound system. Cervical perturbations were taken by applying a load to the head. A median split was used to categorize players as either high or low performers for each of the variables taken: Isometric torque and cervical perturbations. The odds of sustaining moderate and severe head impacts were computed against the reference odds of sustaining mild head impacts across cervical characteristics. Football players with either stronger or weaker cervical muscles were found to have equal odds of sustaining a concussion, with the exception of lineman with greater strength of lateral left and right flexors and overall cervical strength had 1.75 increased odds of a moderate rather than mild head impact. This finding differs from previous research. It is suggested that the inherent and associated risk that football players accept may make be attributable to this finding. Players who developed extensor torque quicker had two times the increased odds of sustaining severe linear impacts rather than mild. However, players with greater cervical stiffness had reduced odds of sustaining both moderate and severe head impacts compared with players with less cervical stiffness. The results of this study suggest that greater cervical stiffness and less angular displacement after perturbation reduced the odds of sustaining higher magnitude head impacts. However, the findings did not show that players with stronger and larger muscles mitigated head impact severity. So, strength and stiffness play a larger role than actual muscle size, measured by neck circumference. The discussion mentions more functional research by incorporating more rotational linear velocity, to mimic the actual sport motion upon impact to the head.

Muscle strength has been explored from a few different angles through these studies, however, there is not a strong consensus between results. Collins and colleagues did find a strong correlation between neck mass as well as strength and an increased risk of concussion. Comparatively, Schmidt and colleagues found that strength and muscular stiffness played a larger role as a protective mechanism against concussion. Smith et al. attempted to investigate several cervical characteristics affecting the risk of concussion but found no significant correlation between healthy and concussed patients. All three studies were conducted on high school aged subjects, with limited data about collegiate athletes. Two were solely focused on football. Information on collegiate level subjects, as well as the significant differences between males and females is lacking. Sex, sport and age comparisons could give greater insight into strength as a protective factor for concussion.

1.3.2 Cervical Range of Motion Testing

In the context of this paper, cervical range of motion refers to the angular range of motion (ROM) which is subdivided into the following motions: flexion, extension, right lateral flexion (RLF) and left lateral flexion (LLF), and right rotation (RR) and left rotation (LR). Cervical ROM referred to active ROM rather than passive ROM. The most widely used methods of evaluating cervical range of motion (ROM) are using a measuring tape, goniometers, inclinometers, and visual estimates.[58]

Siegler et al.[59] conducted a study on the envelope of motion of the cervical spine and its influence on the maximum torque generating capacity of the neck musculature. Measurements of passive ROM and Isometric Maximum Voluntary Contraction (IMVC) of the cervical spine were defined and measured using a six-degree of freedom validated instrument, referred to as the Neck Flexibility Tester (NFT). The NFT measured the subject's ROM via rotational sensors and IMVC via torque sensors at any neck posture. Data from the sensors (position and torque) were collected through an A/D converter at a sampling rate of 20 Hz. The NFT was attached to the subject's head by a helmet. The subject was seated in a chair with torso stabilized to minimize use of trunk musculature. A test-retest was performed on six subjects from the same population to assess the reliability of the NFT in measuring ROM and IMVC between sessions. ICC data showed good repeatability of the NFT in measuring both ROM and IMVC in different neck postures. ICC ranged between .78 and .98 for ROM measurements and between .79 to .98 for IMVC measurements. The further from neutral the neck posture was, the larger the decrease in ROM and IMVC. Head extension and combined two-plane rotations postures, such as extension with lateral bending produced the largest decreases in ROM and IMVC, thus suggesting that these postures pose the highest potential risk for injury.

Bible et al. examined the normal functional ROM of the cervical spine during fifteen activities of daily living. Sixty asymptomatic patients, thirty males and thirty females, were recruited for this study. Electrogoniometer and torsiometer were used to measure range of motion of the cervical spine. Accuracy and reliability of the devices were confirmed by comparing the ROM values acquired from dynamic flexion, extension and lateral bending radiographs. Intra-observer reliability was established by calculating the ICC for repeated measurements on the same subjects by one investigator on consecutive days. Full ROM of the cervical spine was evaluated: flexion, extension, right and left lateral flexion and right and left axial rotation. They also assessed the functional time required to complete 15 simulated activities of daily living. Compared to the radiograph measurements, the electrogoniometer was found to measure within 2.3 degrees. The intra-observer reliabilities for measuring the full ROM active and functional ROM were both excellent. The absolute and percentage of full active cervical spinal ROM used during the fifteen ADLs was 13 to 32 degrees and 15% to 32% (median, 20 degrees/19%) for flexion/extension, 9-21 degrees and 11% to 27% (14 degrees/18%) for lateral bending, 13 to 57 degrees and 12 % to 92% (18 degrees/19%) for rotation. This study provides norms for cervical ROM and reliability for the electrogoniometer and torsiometer.

A universal goniometer (UG) has been found to be a reliable measure of cervical range of motion in a study by Farooq et al.[60] They used the UG to measure active cervical ROM in flexion, extension, right and left lateral flexion and right and left axial rotation. The results revealed excellent reliability between session and between raters. Range of motion was taken three times for each motion. 18 measures in total were taken for each subject. Using fixed landmarks proves to be the most reliable use of a UG.

1.3.3 Cervical Proprioception

The neutral control of the head-neck system depends on cues provided by the proprioceptive, vestibular and visual paths.[61] Cervical proprioception is defined as one's ability to know head position and the head's orientation in space. [62] Cervical muscle fatigue and whiplash injuries can lead to proprioception deficits, which can also be considered a contributing factor to chronic neck pain.[63] Several studies base their measurement of cervical repositioning on an original method designed by Revel et al. in 1991. The test-retest reliability of this method is moderate.[64] Roran et al.[64] compared Revel and colleagues' visual technique and a 3D ultrasound (US) based technique to measure cervical repositioning in healthy and neck pain subjects. They found the test-retest for joint position sense to have moderate reliability (ICC=0.68) for both techniques. The correlation between the visual and US technique was poor (r= 0.32 and 0.46, respectively). However, when performed simultaneously the correlation was excellent (r=0.95 for both). Revel and colleagues developed a cervical repositioning test which consisted of a visual measuring error of head reposition from a targeted head neutral position after active cervical rotation. In the study performed by Roran et al., the measurement of error was calculated in degrees to represent angular displacement; error was measured from a neutral head position (center of the target). The other technique used was a 3D US technique. Both techniques represented moderate test-retest reliability. The US technique may provide more qualitative and quantitative data appropriate for research. However, the visual head repositioning test would be more suitable for daily clinical practice. Rix et al.[21] conducted a study to investigate cervicocephalic kinesthetic sensibility in patients with non-traumatic cervical spine pain. This test is also known as "head repositioning accuracy" to a subjective straight or neutral head.[21,23,64,65] The cervical repositioning test used in Rix and colleagues' study was based on Revels original simple cervical repositioning test. Rix et al.[21] had the subjects blindfolded and measurements of head repositioning accuracy (HRA) were taken in flexion and extension, right and left lateral flexion, and right and left cervical rotation. They used a cycling helmet to fix a laser pointer to the subjects' head. The subject was seated 90cm from the target. The target is a 40cm paper target with a coordinate system designed to measure the over- or undershooting of the subjects cervical repositioning. No significant difference in cervicocephalic kinesthetic sensibility was found between healthy subjects and subjects with non-traumatic cervical spine pain. It was suggested that subjective nature of the measurement, may have attributed to some experimenter bias or geometric inaccuracy. It is noted that in this case comparing absolute values between different studies should be done with caution.

The methods for this study involved having the subject perform near-maximal range of motion (ROM). For the subjects with neck pain this was likely not possible as certain end ROM caused sharp pain. Further investigation is warranted into healthy subjects to determine the appropriate methods of this test.

Lee et al.[22] conducted a study that examined the reliability of a technique for cervical joint repositioning in all three cardinal planes. Although a few studies have explored how to perform the head repositioning test there is not a consensus on the reliability and the methods involved.[23,43,65,66] This study, like Rix and colleagues, examines all three cardinal planes. The study recruited twenty young adults from a local university. They excluded anyone with cervical trauma, cervical pain or treatment for cervical pain, or anyone with neurological and vestibular impairments. The instrumentation for this study differs from the others in its use of an ultra-sound based motion analysis system, CMS 70P (Zebris system, Medizintecknick GmbH, Tubingen Germany).[22] Markers were used on the head and shoulders to detect real-time cervical motion via mini ultrasound transmitters. Cervical motion was automatically recorded by the Win-data 2.11 software. The test was divided into three parts 1) determining Neutral Head Position (NHP) 2) determining the target position and 3) performing the head-to-NHP and head-to-target repositioning. These methods are very similar to the previous studies mentioned aside from the use of ultrasound as the motion detector. The whole procedure was performed in six directions: flexion and extension, left and right rotation, and left and right side-bending. Three trials were completed for each motion. Each trial was performed with eyes closed to eliminate any visual input. Root mean square error (RMSE, total error), constant error (CE, directional bias), variable error (VE, variability), and standard error of measurement (SEM) were calculated from the position data. The results of this study showed fair to excellent reliability of RMSE during head-

NHP (ICC= 0.45-0.80) and head to target tests (0.42-0.90), except during from an extended position (ICC=0.29). Low reliability of VE in left side bending indicated a direction-dependent effect. It is suggested that hand or side dominance may play a role in this discrepancy, however further research is indicated. This study showed acceptable and reliable RSME measurements with the motion analysis system in healthy adults in three cardinal planes. Examining the CE and VE could provide more insight into directional bias and the repositioning variability, respectively.

Alahmari et al.[63] conducted a study to test the intra- and inter-rater reliability of neutral head position (NHP) and target head position tests in patients with and without neck pain. The study consisted of 69 subjects split into two groups, 36 subjects experiencing neck pain and 33 healthy subjects. The intra-rater and inter-rater reliability of NHP and target position sense were assessed in each group. NHP was assessed in cervical extension. Target position sense (TPS) was tested in six directions flexion, extension, right and left lateral flexion and right and left rotation. Motion was detected using an inclinometer. Intra rater reliability ranged from good to very good for both NHP and TPS tests of cervical proprioception. Significant differences were found in the neck pain subjects for joint position error. During NHP test the subject tried to reposition the head to a neutral position after being moved away from the NHP, whereas during a TPS test the subject repositions the head to a target position predetermined by the investigator. Cervical muscle fatigue and whiplash injuries can lead to proprioception deficits, which can also be considered a contributing factor to chronic neck pain. The patients experiencing neck pain were significantly younger (36 ± 14.8) than the healthy subject group (56± 13.2).

Heikkila et al.[43] measured cervicocephalic kinesthetic sensibility, active range of cervical motion, and oculomotor function in patients with whiplash injury. Oculomotor function was tested at 2 months and 2 years after whiplash injury. The ability to appreciate both movement and head position was studied. Active ROM of the cervical spine was measured. Subjective intensity of neck pain and major symptoms were recorded. Active head repositioning was significantly less precise in whiplash subjects than in control group. Failure in oculomotor functions were observed in 62% of subjects after 2 years. Significant correlations occurred between smooth pursuit tests and active cervical ROM. Correlations also were established between the oculomotor test and the kinesthetic sensibility tests. These results suggest that restricted cervical movements and changes in quality of proprioceptive information from cervical spine region affect voluntary eye movements. A flexion/extension injury of the neck may result in dysfunction of the proprioceptive system. Oculomotor dysfunction after neck trauma may be related to cervical afferent input disturbances, leaving someone at risk for further neck or head injury.

A reliable measure of cervical proprioception to detect change in functions of the cervical spine is necessary to measure cervical proprioception in healthy adults. A clinically friendly, non-invasive, and inexpensive method would help widen the use of this measurement in everyday practice.

1.4 Definition of The Problem

Cervical spine injuries and concussion present with similar mechanisms and nearly identical symptoms.[67] This means symptoms and causes alone are insufficient to differentiate between patients with concussion and patients with a cervical injury.[68] Cervical joint repositioning tests, cervical flexion-rotation and assessment of the deep neck flexors and extensors were found in a study by Cheever et al.[68] to be the most helpful tools to differentiate between concussion and cervical spine injury. The results of this study indicate a lack of a well-defined, globally understood clinical tests to diagnose cervical dysfunction in the presence of concussion. Given the similarities described earlier it is crucial to be able to differentiate between concussion, cervical dysfunction, or concomitant injury. Having reliable tools to measure cervical dysfunctions is necessary to identify if this relationship exists.

Cheever et al.[68] conducted a review of the literature on cervical injury assessments for concussion evaluation. Cervical injuries and concussion can share similar mechanisms and nearly identical symptoms or causes. Symptoms, in particular dizziness, and mechanism of injury alone may be insufficient to differentiate between patients with concussion and patients with a cervical injury. Clinical assessments such as cervical joint reposition error test, smooth pursuit neck torsion test, head-neck differentiation test, cervical flexion rotation test, and physical examination of the cervical spine can be perfumed after a head and neck pathomechanical event to identify cervical injury. Differentiation is critical to the timely and appropriate care of injury. Continued research is necessary to determine the clinical utility of the five tests identified in this study. Cheever and colleague's literature review outlined the similarities in causes and symptoms of both injuries, gave injury definitions, explained the physiology of cervical injury, and identified clinical tests to isolate and differentiate cervical injury from concussion. It is hypothesized that clinicians are not incorporating cervicogenic tests into their routine evaluations of head trauma because of a lack of awareness of the appropriate tests and methods. Current athletic training education competencies do not recommend these special tests to differentiate cervical symptoms and concussive symptoms.[69] The treatment for each differ greatly and may be contributing to the prolonged recovery from concussion. Therefore, it is imperative that early recognition of cervicogenic involvement is necessary. Cervical injuries benefit from an active recovery and manual therapies, while concussion may benefit from active rest and recovery. Differentiating between the injuries is vital for the clinicians to understand and to best serve their athlete. Patients that suffer from both injuries may benefit from a combination of therapies. Cheever et al. provide useful background to the clinical problem; however further investigation of clinical techniques is necessary to determine the efficacy of their use.

Reneker et al.[5] conducted a study to identify clinically administered tests and measurements that help to differentiate between cervicogenic and other causes of dizziness after a sports related concussion. They used the Delphi technique to gather the general consensus of opinions from targeted content experts. Experts were systematically gathered through two strategies. The first through PubMed and the second through Google. The clinicians were asked about the clinical utility of 23 tests. Ten of the tests met the 70% criteria of strong clinical utility, while six of the clinical tests met the 70% criteria of weak clinical utility. The other seven tests did not reach a consensus. The results of this study highlight the complete lack of consensus about cervicogenic involvement associated with dizziness in concussed patients. It did however identify ten tests that have strong clinical utility in the differential diagnosis of dizziness after concussion. These tests include Dix-Hallpike Test, Orthostatic Hypotension testing, spontaneous nystagmus, head impulse test, roll test, gaze-hold test, saccade testing, vestibulo-ocular reflex cancellation, headshake test, and smooth pursuits test. No consensus was made about cervical joint position sense, static and dynamic balance tests, convergence, dynamic visual acuity test, reproduction of dizziness through manual passive joint mobility, neck pain and related dizziness, and reproduction of dizziness through palpation of cervical musculature. A consensus of weak clinical utility was found for the following tests, cervical flexion rotation test, smooth pursuit neck torsion test, vibration test, head-neck differentiation test, motor control assessment of the deep cervical flexors and extensors, vibration test II. It is clear that no universal understanding of the appropriate use, and effective clinical use exists across the several medical disciplines questioned in this study. It is unclear if that is a lack of competency or a lack of knowledge of these different clinical tests.

Understanding the cervical deficits related to a history of concussion is necessary to determine if further research is warranted into their relationship. Furthermore, a study in the reliability of the tools used to measure cervical deficits is needed to account for the validity of their measures. A commonly used tool for cervical joint repositioning is the Cervicocephalic Kinesthetic Sensibility test originally developed by Revel et al. [23] This test is easily repeated in most environments and therefore it is clinically friendly and inexpensive. While many studies use this test, or a modification of the test, clear reliability of the tool has not been established for its use for measuring cervical joint repositioning. Therefore, the validity of this measurement is uncertain.

1.5 Purpose of The Study

The purpose of this study was to measure the intrasession test-retest reliability of the Cervicocephalic Kinesthetic Sensibility Test. This study aimed to determine the reliability of a test used to measure cervical proprioception using a cervical joint reposition test.

1.6 Specific Aim and Hypothesis

Specific Aim 1: To measure the intrasession test-retest reliability of the Cervicocephalic Kinesthetic Sensibility Test used to measure cervical joint position error.

Hypothesis 1: It is hypothesized that the Cervicocephalic Kinesthetic Sensibility will have acceptable intrasession test-retest reliability when measuring joint position sense error.

1.7 Study Significance

This study aimed to find a reliable and affordable method of testing cervical proprioception. A reliable tool for measuring cervical proprioception is necessary to expand the knowledge of cervical characteristics relationship to concussion. Previous literature has suggested that prolonged recovery from concussion could be due to an underlying cervical spine injury causing a proprioception deficit. Reliability of this measure has ranged from moderate to excellent in previous literature. Reliability of all 6 motions has not been established in healthy patients in previous literature using this method. Retrospectively it could help determine if reduced cervical proprioception is an underlying risk factor for sustaining a concussion, this would require collecting proprioception performance data prior to injury to the head/neck segment. Without a reliable method, any detectable change in proprioception is unreliable and invalid. This method is affordable, efficient, and easy to replicate. Using this method could be an ideal way to measure cervical proprioception in a clinical setting.

2.0 Methods

2.1 Experimental Design

This study used a descriptive, observational design. The purpose of this study was to measure the test-retest reliability of the Cervicocephalic Kinesthetic Sensibility Test previously used to measure cervical joint position sense error. This study aimed to find a reliable tool to measure cervical joint proprioception through a method of joint reposition sense. Subjects completed 1 session at the Neuromuscular Research Laboratory. Within the session there were 3 trials of each cervical motion.

2.1.1 Dependent Variables

The dependent variables for this study included cervical joint position sense (JPS) error of the cervical spine. Joint position sense (JPS) was measured in six motions, flexion and extension left and right axial rotation, and right and left side bending. JPS was assessed using a helmet with a laser and target and measured in centimeters (cm) of error from the center, which was then converted into degrees (°) (angle = tan-1[error distance(cm)/90 cm]).

2.2 Subjects

2.2.1 Subject Recruitment

This study was approved by the Institutional Review Board of the University of Pittsburgh prior to implementing any of the following research procedures. Subjects were recruited from the University of Pittsburgh School of Health and Rehabilitation Sciences. Emails were sent out to faculty within the department and asked that the recruitment form be forwarded to students. Review of the inclusion and exclusion criteria was done prior to including individuals in the study. Testing was performed at the Neuromuscular Research Laboratory (NMRL).

2.2.2 Subject Consent

Participants were asked to reach out to the Principal investigator directly if they were interested in participating in the study. Upon arrival subjects were provided instructions on how to perform the cervical proprioception test, an explanation of risk and an opportunity to ask questions about participation requirements, the participants were asked to sign an informed consent form prior to implementing any testing procedures or data collection.

2.2.3 Power Analysis

A sample size of 15 subjects with 3 observations per subject achieves 80% power to detect an intraclass correlation of 0.8 under the alternative hypothesis when the intraclass correlation under the null hypothesis is 0.4 using an F-test with a significance level of 0.05. To account for data loss, 20% more subjects (total of 18 subjects) were included in the study.

2.2.4 Inclusion Criteria

Individuals were included in the study if they were:

- University of Pittsburgh Students,
- 18-25 years of age,
- male or female, and had
- pain free cervical range of motion.

2.2.5 Exclusion Criteria

Individuals were excluded from the study for any of the following:

- history of spinal injury,
- current upper extremity injury including head and/or neck,
- neck pain at the time of testing,
- history of migraines, or
- headache at the time of testing,

2.3 Instrumentation

2.3.1 Related History Survey

A history of the subject's demographics was collected using a customized Qualtrics survey. The survey included age (yr.), height (cm), weight (kg), sex (M/F), as well as questions from the Neck Disability Index (NDI) [41] developed by Vernon in 1991.[40] The NDI is a widely used and valid tool to measure neck pain and dysfunction.

2.3.2 Laser/Target

Cervical joint reposition error testing was measured using a test originally designed and described by Revel et al.[65] Revel and colleagues designed the Cervicocephalic Kinesthetic Sensibility Test, a method that uses a helmet with a laser and a target. The laser was firmly attached using tape, to the top of the helmet.[65] A bicycle helmet was used in this study for comfort and security of the laser on the helmet. The target for joint position sense error is based on Heikkila et al.[43] A paper target was placed on the wall 90 cm from the subject. The target is 40 cm in diameter, with concentric circles every centimeter.[43] Two axes split the circle into quadrants to create a bullseyes reference for Head Neutral (HN) position.[43]

2.4 Testing Procedures

2.4.1 Cervical Joint Position Sense

Joint position sense of the cervical spine was taken in an active-active method, the subject actively performed each cervical motion through complete ROM from a Head Neutral (HN) position where the laser hits the center of the target and then were instructed to bring their head back to what they feel repositions their cervical spine into HN. The target was placed on the wall 90cm in front of the seated participant.[43] The participant was seated on a chair with hips and knees at approximately 90 degrees and was instructed to find a comfortable erect seated position, with arms by their side. The target was placed of the wall after the participant was in the seated position, and was adjusted up or down on the wall so that the laser attached to the helmet hit the bullseye on the target, this then determined the participants HN.[43,65] The researcher instructed every participant on each cervical motion. Each participant was instructed on the movement before performing the test and was allowed one trial with their eyes open to familiarize themselves with these instructions. The participant completed six cervical motions, flexion and extension, left and right axial rotation, and left and right-side bending.[43,63,65,70] They completed three trials with their eyes closed after being allotted one practice trial with eyes open. Beginning with cervical flexion, the participant was instructed to close their eyes and flex their neck forward until end range of motion was reached, then they were instructed to come back to their perceived HN. All participants completed each movement at their desired speed.[65] The subjects reposition accuracy was measured in centimeters from where the laser beam landed on the target. The participant was not be given any feedback about the success or failure of the trial.[65] The eyes closed trial was repeated two more times, between each trial the participant was instructed to open their eyes to realign to accurate

HN.[65] The same instructions were provided for each cervical motion. For each cervical motion three trials were completed not including the eyes open trial.

2.5 Data Reduction

2.5.1 Cervical Joint Position Sense

Cervical Joint Position Sense (JPS) error was measured in centimeters (cm) at the time of data collection. JPS error was converted to degrees (°)of error to represent angular displacement of the head/neck segment for each subject, (angle = tan-1[error distance(cm)/90 cm]). Mean and standard deviation (SD) was calculated for all 3 trials of the 6 cervical motions.

2.6 Statistical Analysis

Descriptive statistics (Mean and SD) were calculated for all outcome variables. The intrasession test-retest reliability was estimated by calculating ICC(2,1) and ICC(2,3), 95 % confidence intervals and corresponding *p* values. Data analysis was conducted using SPSS Version 25 (IBM Corp). Statistical significance was set *a priori* at alpha= 0.05, two-sided.[71,72]

3.0 Results and Analysis

3.1 Results

3.1.1 Demographics

Demographics and Neck Disability Index (NDI) Score are presented in Table 1. Seventeen subjects 18-25 years old, 4 males and 13 females. The Neck Disability Index (NDI) scores ranged from 0-4. Scores between 0 and 4 represents no disability.[40] The subjects scores indicate these were healthy individuals with “normal” cervical spine function, according to the NDI definition and score analysis.[40,42]

Table 1: Demographics and Neck Disability Index (NDI) Score

	N	**Mean ± SD**
Age (yrs.)	17	23.12 ± 1.36
Height (cm)	17	171.00 ± 11.44
Weight (kgs)	17	66.89 ± 12.59
NDI (Score 0-50)	17	.88 ± 1.27

3.1.2 Cervicocephalic Kinesthetic Sensibility Intrasession Test-Retest Reliability

The intrasession test-retest reliability was estimated by calculating ICC(2,1) and ICC(2,3), 95 % confidence intervals and corresponding *p* values. A variable degree of reproducibility was found among the 6 cervical motions.

The highest reproducibility for single measures ICC was found in Cervical Flexion (CF) and Left Side-Bending (LSB). ICC(2,1) was .404 with a 95% Confidence Interval (CI) of .105, .692, $p <.004$ for CF and ICC(2,1) was .496 with a 95% CI of .198, .753, $p < .001$ for LSB. Cervical Extension (CE), Right Axial Rotation (RAR), Left Axial Rotation (LAR) showed very low reproducibility. CE ICC(2,1) was .264 with a 95% CI of -.007, .58, $p < .030$. RAR ICC(2,1) was .244 with a 95% CI of -.040, .572, $p < .050$. LAR ICC(2,1) was .299 with a 95% CI of .001, .618, $p < .025$. Right Side-Bending (RSB) showed the lowest reproducibility for single measures ICC. RSB ICC(2,1) was .174 with a 95% CI of -.112, .520, $p < .125$. The results are summarized in Table 2.

Table 2: Single Measures ICC for the Cervicopephalic Kinesthetic Sensibility Test

Cervical Motion	N	Mean and SD (°)			Single Measures ICC	
		Trial 1	Trial 2	Trial 3	ICC(2,1), 95% CI	*p*-Value
Cervical Flexion	17	4.56± 3.47	5.32±3.97	5.79±4.27	.404, (.105, .692)	.004*
Cervical Extension	17	6.72±3.76	5.38±2.38	4.73±3.04	.264, (-.007, .581)	.030
Right Axial Rotation	17	5.27±3.72	4.36±2.39	4.19±1.74	.244, (-.040, .572)	.050
Left Axial Rotation	17	4.47±2.85	4.21±3.28	5.05±3.03	.299, (.001, .618)	.025
Right Side-bending	17	3.50±1.70	3.47±2.24	3.17±2.33	.174, (-.112, .520)	.125
Left Side-bending	17	4.52±2.63	4.93±2.98	4.67±2.38	.496, (.198, .753)	.001*

* Indicates a significant p-value, Statistical significance was set *a priori* at alpha= 0.05, two-sided.

Average measures ICC showed improved reproducibility among all cervical motions. Similarly, CF and LSB showed the highest reproducibility, CF ICC(2,3) was 0.670 with a confidence interval of 0.260, .871, $p < 0.004$, and LSB ICC(2,3) was .747 with a 95% CI of .425, .902, $p < .001$. CE, RAR, and LAR showed acceptable reproducibility for average measures ICC. CE ICC(2,3) was 0.519 with a 95% CI of -.020, .806, p < 0.030. RAR ICC (2,3) was .492 with a 95% CI of -.131, .800, $p < 0.050$. LAR ICC(2,3) was .562 with a 95% CI of .003, .829, $p < 0.025$.

RSB had the lowest reproducibility of average measures ICC. RSB ICC(2,3) was .388. with a 95% CI of -.431, .765, $p < .125$. The results are summarized in

Table 3.

Table 3: Average Measures ICC for the Cervicocephalic Kinesthetic Sensibility Test

Cervical Motion	N	Mean and SD (°)			Average Measures ICC	
		Trial 1	Trial 2	Trial 3	ICC(2,3), 95% CI	*p*-Value
Cervical Flexion	17	4.56± 3.47	5.32±3.97	5.79±4.27	.670, (.260, .871)	.004*
Cervical Extension	17	6.72±3.76	5.38±2.38	4.73±3.04	.519, (-.020, .806)	.030
Right Axial Rotation	17	5.27±3.72	4.36±2.39	4.19±1.74	.492, (-.131, .800)	.050
Left Axial Rotation	17	4.47±2.85	4.21±3.28	5.05±3.03	.562, (.003, .829)	.025
Right Side-bending	17	3.50±1.70	3.47±2.24	3.17±2.33	.388, (-.431, .765)	.125
Left Side-bending	17	4.52±2.63	4.93±2.98	4.67±2.38	.747, (.425, .902)	.001*

* Indicates a significant p-value, Statistical significance was set *a priori* at alpha= 0.05, two-sided.

4.0 Discussion

4.1 Study Aim and Hypothesis

The primary aim of this study was to determine the intrasession test-retest reliability of the Cervicocephalic Kinesthetic Sensibility (CKS) Test used to measure cervical joint position sense. It was hypothesized that the CKS Test would prove to have a good level of reproducibility within the rater to measure cervical joint position error.

4.2 Study Significance

This study aimed to find a reliable and affordable method of testing cervical proprioception. A reliable tool for measuring cervical proprioception is necessary to expand the knowledge of cervical characteristics relationship to concussion. Previous literature has suggested that prolonged recovery from concussion could be due to an underlying cervical spine injury causing a proprioception deficit. Reliability of this measure has ranged from moderate to excellent in previous literature. Reliability of all 6 motions has not been established in healthy patients in previous literature using this method. Retrospectively it could help determine if reduced cervical proprioception is an underlying risk factor for sustaining a concussion, this would require collecting proprioception performance data prior to injury to the head/neck segment. Without a reliable method, any detectable change in proprioception is unreliable and invalid. This method is affordable, efficient, and easy to replicate. Using a reliable test is an ideal way to measure cervical proprioception in a clinical setting. While this study had limitations, it provides valuable information pertaining to the reliability of this method which has been used in numerous previous studies.[21-23,43]

4.3 Cervicocephalic Kinesthetic Sensibility Intrasession Test-retest Reliability

Intrasession test-retest reliability was calculated using Single Measures ICC(2,1) and Average Measures ICC(2,3). The Cervicocephalic Kinesthetic Sensibility (CKS) test showed wide variability in the results. The highest reproducibility for single measures ICC was found in Cervical Flexion (CF) and Left Side-Bending (LSB). Cervical Extension (CE), Right Axial Rotation (RAR), Left Axial Rotation (LAR) showed very low reproducibility. Right Side-Bending (RSB) showed the lowest reproducibility. The values for single measures were fairly low. The highest reproducibility for average measures ICC was found in CF and LSB and would be considered moderate reliability.[73] CE, RAR, LAR acceptable reproducibility. RSB showed the lowest reproducibility. The results indicate that the average of multiple trials produces higher reproducibility. Taking one measure using the Cervicocephalic Sensibility test would not prove a reliable measure of joint reposition sense.

The original use of this test for cervicocephalic kinesthesia by Revel et al.[23] completed 3 sessions, 10 trials with 2 raters, among 11 of their 30 healthy subjects to estimate reproducibility. No data analysis for test-retest or inter-rater reliability was reported, just that between session data was consistent within subjects and that there was no significant difference between raters. Roren et al.[64] compared the reliability of Revels technique and a 3D ultrasound and found comparable test-retest reliability. For Revels technique the ICC= .68, where the 3D ultrasound was .62. This study however only assessed for reliability among patients suffering from neck pain and only axial rotation of the cervical spine. With such variable results between the present study and previous literature, it has yet to be determined if this method is reproducible among different clinicians, settings, and healthy populations.

Revels original study of this method found that in the 30 healthy subjects an average of trials fell within 4.5° of error.[23] This contradicts the findings within the this study. The present study found Cervical flexion had an average of 4.56± 3.47° for trial one, 5.32±3.97° for trial two, and 5.79±4.27° for trial three. Cervical extension had an average of 6.72±3.76° for trial one, 5.38±2.38° for trial two and 4.73±3.04° for trial three. Right axial rotation had an average of 5.27±3.72° for trial one, 4.36±2.39° for trial two and 4.19±1.74° for trial three. Left axial rotation had an average of 4.47±2.85° for trial one, 4.21±3.28° for trial two, and 5.05±3.03° for trial three. Side bending has not been assessed in this method in previous literature. In the present study this it appears Right side-bending had the fewest errors and most consistency between trials, 3.50±1.70 for trial one, 3.47±2.24 for trial two, and 3.17±2.33 for trial three. Left Side-bending had an average of 4.52±2.63 for trial one, 4.93±2.98 for trial two, and 4.67±2.38 for trial three. Confirming an average baseline is important for clinical significance. Normal measures of cervical proprioception are necessary to understand where a deficit may exist in an individual. The lack of consistency among research indicates a larger sample size is needed to understand cervical proprioception norms. Since previous research indicates that cervical range of motion may play a role in performance on cervical proprioception tests, this relationship would need to be established in order to find normative data.[21]

4.4 Limitations

While this study addresses some gaps in knowledge about a frequently used method of measuring joint position sense, it is not without its limitations. Due to time restraints, a sample of convenience was used. A pool of students in the University of Pittsburgh's School of Health and Rehabilitation Sciences may not be representative of the general population of healthy eighteen to twenty-five-year-old males and females. The subjects recruited may have had a greater understanding of cervical characteristics, as well as research methods. This population has a background knowledge of musculoskeletal anatomy, strength testing, measuring range of motion, and the concept of proprioception. The subjects were familiar with the motions performed and were easy to instruct. While this may not have affected the outcome of these results, it is worth noting.

The time restraints did not allow for an adequate number of testing sessions. Hopkins[74] published an article defining measures of reliability in sports medicine and science, suggesting that preferably no less than four sessions, separated by at least a week and held under exact circumstances, would be necessary to determine test-retest reliability of this method. Each session should consist of at least three trials in order to detect meaningful change.[74] Multiple sessions are necessary to analyze test-retest reliability. Intrasession reliability provides some insight into the reproducibility of the CKS test, however without multiple test sessions and inter-rater reliability assessment this tool cannot be confidently used among other clinicians wishing to measure joint position sense of the cervical spine.

4.5 Future Research

In order to understand the clinical implications for the CKS test future research needs to address the following topics. Cervical characteristics like strength, range of motion (ROM) and proprioception have previously been observed in literature; however, no research addresses their relationship to one another. It was observed by Rix et al.[21] that patients experiencing neck pain may have had reduced performance on the proprioception test due to limited ROM. It is unknown if limited cervical ROM affects cervical proprioception. Normative data of cervical strength, proprioception and ROM of a healthy population is necessary to recognize deficits. A larger sample would help to reduce random error and systematic bias within the results. Future research is necessary to determine the reliability of the CKS test, if a learning effect is present, and to determine if the measure is translatable among clinicians. Test-retest reliability needs to be assessed across multiple sessions. Poor performance may be an indication of a proprioception deficit, or that a session is needed to become familiar with testing procedures before determining and true measure of cervical proprioception. Inter-rater reliability assessment could help determine the clinical applicability of the tool. Further analysis of hand or eye dominance and under or over shooting of the axes of the target could provide greater insight into joint position error. Research observing a correlation between cervical proprioception and performance of the Vestibular/Ocular-Motor Screening (VOMs) and the Modified Balance Error Scoring System (mBESS).

A correlation between cervical ROM, cervical strength and cervical proprioception is unknown. All three factors play a part in prevention of musculoskeletal injuries. Further evaluation of these cervical characteristics is necessary to determine if a relationship exists between a deficit in one or all three can lead to an increased risk of sustaining a concussion.

Unrecognized deficits have been suggested to prolong recovery from concussion. Further evaluation of the cervical spine in suspected head/neck injury could begin to close this gap. Cervical strength has been frequently analyzed and is thought by previous researchers to provide a protective mechanism against concussion.[18] Collins et al.[18] examined neck strength as a protective factor for reducing the risk of concussion. They concluded that for every 1lb increase in neck strength, the odds of concussion decreased by 5%.[18] Reduced range of motion or hindered mobility of the cervical spine has been suggested as a precursor to many injuries. Reduced cervical ROM could leave one to a multitude of risks related to neck and head injuries. Rix et al.[21] compared proprioception performance among healthy subjects and subjects with neck pain. They did not notice substantial difference between the two populations; however, they noted that those suffering from neck pain could not complete full ROM. Further investigation is warranted into healthy subjects to determine how ROM affects performance on joint position sense.

Collecting a larger sample size would provide enough information to compile normative data. In order to understand if a deficit exists, it is necessary to have a baseline. A larger sample of a healthy population is needed to further evaluate what a true "normal" score would be considered baseline for joint position sense. Greater insight into a healthy population in all 3 cardinal planes of motion: sagittal, transverse, and frontal, could make strides to understand proprioception performance of the cervical spine. This information helps clinicians to recognize when deficits are present.

Cervical proprioception has not sufficiently been studied in relation to a history of concussion. No previous literature has been successful in determining whether injury to the cervical spine and or head lead to deficits in cervical proprioception. Further research needs to address whether preexisting cervical proprioception deficits lead to a greater risk in certain populations. Sports and sex as a specific population need to be addressed. Previous research has indicated that female student athletes have an increased risk of sports related concussion compared to male athletes in comparable sports.[27-31] A study conducted by O'Conner et al.[30] reported female athletes at the high school level are 1.56 times a greater risk for SRC than male athletes in sex comparable sports.[30] At the collegiate level it has been reported that female athletes sustain a greater number of concussions in basketball, ice hockey, soccer and softball/baseball than their male counter parts.[27,31] Most literature assessing cervical characteristics in relation to concussion focus on strength. Research should compare performance on proprioception assessment to determine if differences among sexes is present.

Throughout data collection its was observed in several of the subjects a preference of quadrants. The 40cm target is split into four quadrants with the abscissa or horizontal axis and the ordinate or vertical axis. For the current study only measures degrees of error were measured from the bullseye and over or undershooting of the axes was not addressed. Revel et al.[23] used the axes and assigned either a positive or negative sign to represent whether the laser fell above or below the axis, respectively. For each trial in the in the current study a pen mark was made where the laser landed, while the axis error was not analyzed for this study it was observed that for several subjects a large number of pen marks fell within a particular quadrant. Further evaluation of hand dominance or eye dominance could give greater insight into this joint position error phenomenon.

Vestibular input, ocular motor function, and balance in relation to cervical proprioception is under studied. Performance on the Vestibular/Ocular-Motor Screening (VOMS) assessment in relation to cervical proprioception is an area lacking in research. A flexion/extension injury of the neck may result in dysfunction of the proprioceptive system. Oculomotor dysfunction after neck trauma may be related to cervical afferent input disturbances, leaving someone at risk for further neck or head injury.[43] Balance is a component of spatial awareness and proprioception. Both the modified Balance Error Scoring System (mBESS) and VOMs are commonly used tools for accessing concussion. The neutral control of the head-neck system depends on cues provided by the proprioceptive, vestibular and visual paths.[61] Injury to neck musculature can cause damage to proprioceptors and potentially affect performance on concussive evaluation tests such as the mBESS and VOMs. The Cervicocephalic Kinesthetic Sensibility test has been used in previous literature to access whiplash injury, in order to assess deficits in cervical proprioception. It is hard to differentiate between concussion, cervical spine injury, or a coinciding injury. Injury to the cervical spine and concussion often present with the same mechanism of injury and identical symptoms. Identifying and diagnosing an injury is imperative to the patient outcome. While the Sport Concussion Assessment Tool 5th edition.[2] includes a section for cervical assessment, it only addresses cervical spine pain and range of motion. Additional information about both proprioception and strength may lead to greater insight into the nature of the injury and lead to better patient outcomes.

4.6 Conclusion

These results show a wide variability among reliability of the Cervicocephalic Kinesthetic Sensibility test in 6 different cervical motions. The results indicate that the average of multiple trials produces higher reproducibility. Taking one measure using the Cervicocephalic Sensibility test would not prove a reliable measure of joint reposition sense. Further evaluation of test-retest reliability is necessary to determine the usefulness of this tool to measure cervical proprioception. A larger sample size more representative of a young healthy population is needed. Overall further assessment is needed to determine the reliability of this tool. It has proven feasible for the nature of this study; however, the suggested future research is necessary to fill in some glaring gaps in the literature.

Neck Disability Index

THIS QUESTIONNAIRE IS DESIGNED TO HELP US BETTER UNDERSTAND HOW YOUR **NECK PAIN** AFFECTS YOUR ABILITY TO MANAGE EVERYDAY -LIFE ACTIVITIES. PLEASE MARK IN EACH SECTION THE **ONE BOX** THAT APPLIES TO YOU.
ALTHOUGH YOU MAY CONSIDER THAT TWO OF THE STATEMENTS IN ANY ONE SECTION RELATE TO YOU, PLEASE MARK THE BOX THAT **MOST CLOSELY** DESCRIBES YOUR PRESENT -DAY SITUATION.

SECTION 1 - PAIN INTENSITY

- ☐ I have no neck pain at the moment.
- ☐ The pain is very mild at the moment.
- ☐ The pain is moderate at the moment.
- ☐ The pain is fairly severe at the moment.
- ☐ The pain is very severe at the moment.
- ☐ The pain is the worst imaginable at the moment.

SECTION 2 - PERSONAL CARE

- ☐ I can look after myself normally without causing extra neck pain.
- ☐ I can look after myself normally, but it causes extra neck pain.
- ☐ It is painful to look after myself, and I am slow and careful
- ☐ I need some help but manage most of my personal care.
- ☐ I need help every day in most aspects of self -care.
- ☐ I do not get dressed. I wash with difficulty and stay in bed.

SECTION 3 – LIFTING

- ☐ I can lift heavy weights without causing extra neck pain.
- ☐ I can lift heavy weights, but it gives me extra neck pain.
- ☐ Neck pain prevents me from lifting heavy weights off the floor but I can manage if items are conveniently positioned, ie. on a table.
- ☐ Neck pain prevents me from lifting heavy weights, but I can manage light weights if they are conveniently positioned
- ☐ I can lift only very light weights.
- ☐ I cannot lift or carry anything at all.

SECTION 4 – READING

- ☐ I can read as much as I want with no neck pain.
- ☐ I can read as much as I want with slight neck pain.
- ☐ I can read as much as I want with moderate neck pain.
- ☐ I can't read as much as I want because of moderate neck pain.
- ☐ I can't read as much as I want because of severe neck pain.
- ☐ I can't read at all.

SECTION 5 – HEADACHES

- ☐ I have no headaches at all.
- ☐ I have slight headaches that come infrequently.
- ☐ I have moderate headaches that come infrequently.
- ☐ I have moderate headaches that come frequently.
- ☐ I have severe headaches that come frequently.
- ☐ I have headaches almost all the time.

SECTION 6 – CONCENTRATION

- ☐ I can concentrate fully without difficulty.
- ☐ I can concentrate fully with slight difficulty.
- ☐ I have a fair degree of difficulty concentrating.
- ☐ I have a lot of difficulty concentrating.
- ☐ I have a great deal of difficulty concentrating.
- ☐ I can't concentrate at all.

SECTION 7 – WORK

- ☐ I can do as much work as I want.
- ☐ I can only do my usual work, but no more.
- ☐ I can do most of my usual work, but no more.
- ☐ I can't do my usual work.
- ☐ I can hardly do any work at all.
- ☐ I can't do any work at all.

SECTION 8 – DRIVING

- ☐ I can drive my car without neck pain.
- ☐ I can drive my car with only slight neck pain.
- ☐ I can drive as long as I want with moderate neck pain.
- ☐ I can't drive as long as I want because of moderate neck pain.
- ☐ I can hardly drive at all because of severe neck pain.
- ☐ I can't drive my care at all because of neck pain.

SECTION 9 – SLEEPING

- ☐ I have no trouble sleeping.
- ☐ My sleep is slightly disturbed for less than 1 hour.
- ☐ My sleep is mildly disturbed for up to 1-2 hours.
- ☐ My sleep is moderately disturbed for up to 2-3 hours.
- ☐ My sleep is greatly disturbed for up to 3-5 hours.
- ☐ My sleep is completely disturbed for up to 5-7 hours.

SECTION 10 – RECREATION

- ☐ I am able to engage in all my recreational activities with no neck pain at all.
- ☐ I am able to engage in all my recreational activities with some neck pain.
- ☐ I am able to engage in most, but not all of my recreational activities because of pain in my neck.
- ☐ I am able to engage in a few of my recreational activities because of neck pain.
- ☐ I can hardly do recreational activities due to neck pain.
- ☐ I can't do any recreational activities due to neck pain.

PATIENT NAME ______________________________ DATE ____________

SCORE ________ [50]

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Figure 1: Neck Disability Index

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