University of Indianapolis

College of Health Sciences

CERVICAL PROPRIOCEPTION IN FEMALE COLLEGIATE SOCCER PLAYERS COMPARED TO NON-CONTACT SPORT ATHLETES

Submitted to the Faculty of the
College of Health Sciences
University of Indianapolis

In partial fulfillment of the requirements for the degree
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Cervical Proprioception in Female Collegiate Soccer Players Compared to Non-Contact Sport Athletes

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Abstract

A non-experimental study was conducted to explore whether cervical proprioception was compromised in female collegiate soccer players and to examine what factors may be related to impaired proprioception. Each study participant performed the Head Repositioning Accuracy (HRA) test using active relocation to the original self-selected neutral head position (NHP). Error, in degrees, for repositioning to the NHP was read from a cervical range of motion device. Phase one established cut-off values for classification of impaired cervical proprioception. Phase two compared cervical proprioception between a sample of soccer and non-contact sports athletes. Each phase two group consisted of 24 female participants who were 18-24 years of age.

Comparisons between soccer players and non-contact athletes were conducted to determine if there were statistically significant differences in history of cervical injuries and history of concussions. Demographic data between groups lacked statistical significance. Absolute error (AE), constant error (CE), and variable error (VE) were calculated and compared between groups. A significant difference was found for AE left. Absolute error right, CE left and right, and VE left and right lacked statistically significant differences between groups. Within the soccer group a report of a previous concussion, a history of a cervical injury, and field position were compared for players with and without impaired cervical proprioception. Each lacked statistical significance. A higher percentage of soccer players with a history of a cervical injury had impaired cervical proprioception overall. The statistically significant difference in AE left may lead to consideration of proprioceptive preseason screening for injury prevention and post-injury rehabilitation.

Keywords: cervical proprioception, head repositioning accuracy, soccer

Acknowledgements

As I approach the end of this doctoral program, I feel grateful for the opportunity for professional advancement and personal challenge. I would like to take this opportunity to thank the people who have supported and encouraged me throughout the program.

First, I would like to thank my husband, Curt, and my sons, Ben and Alex. Your love, support, and understanding throughout the process of earning the DHSc has meant more to me than words can express. You have been my central focus throughout this endeavor. To my mom and entire family, the interest and encouragement along the way contributed to my motivation to see the project through to completion.

Next, I would like to thank my committee members, Dr. Emily Slaven, Dr. Elizabeth Moore, and Dr. Ed Jones. I have sincerely valued your expertise. Every piece of advice that was offered greatly improved this project, and it has been deeply appreciated. I would also like to expressly thank the entire faculty in the Interprofessional Health and Aging Studies at University of Indianapolis. I have truly enjoyed the journey over the past three years. I have great respect for everything that I have learned. Each faculty member has been a role model for adherence to high standards and academic excellence.

I would like to acknowledge Michael Cibulka for providing the cervical range of motion device that was used for data collection. I would also like to thank the entire faculty of the Maryville University Physical Therapy Program, particularly Sandy Ross, Michael Cibulka, and Jack Bennett who teach alongside of me. Thank you for your encouragement, mentorship, and moral support. You have been excellent examples of professionalism and friendship.

With gratitude,

Michelle Schneider

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Cervical Proprioception in Female Collegiate Soccer Players Compared to Non-Contact Sport Athletes

Soccer is the most popular sport in the world which accounts for the diversity of its participants not only in age, gender, and ethnicity but also in skill level ranging from amateur to professional (Hulteen, 2017). Concussions and cervical spine injuries are known to occur in recreational, collegiate, and professional soccer players (Rechel, Yard, & Comstock, 2008) and account for approximately 19.1% of injuries seen in emergency departments among high school and collegiate soccer players (Kerr, Pierpoint, Currie, Comstock, & Wasserman, 2017). High velocity collisions (Tsoumpos et al., 2013) and head balls, in which the player impacts the ball with the forehead to alter the trajectory or win possession of the ball (Janda, Bir, & Cheney, 2002), are two mechanisms of soccer-related head and neck injuries that create the potential for cervical injuries, such as whiplash associated disorders (WAD) (Tsoumpos et al., 2013).

Cervical proprioception, position sense of the cervical spine, has been reported to be altered in individuals who experience concussion and cervical injuries such as WAD (Poorbaugh, Brismée, Phelps, & Sizer, 2008; Tsoumpos et al., 2013) and with cervical spine pain of traumatic or atraumatic onset (De Vries, et al., 2015; De Zoete, Osmotherly, Rivett, Farrell, & Snodgrass, 2017; Dugailly et al., 2015). A decrease in cervical proprioception presents an individual with an increased risk for an additional cervical spine injury and concussions by limiting the ability to accurately position the head to avoid injury or set the head in a specific position for anticipatory stabilization. (Armstrong, McNair, & Taylor, 2008; Hides et al., 2017). Therefore, the restoration of proprioception is integral in the rehabilitation after cervical injury (Zech et al., 2009). While it is known that concussions and cervical spine injuries occur among soccer players, it is unknown whether soccer players have an increased-risk of developing cervical proprioception deficits. The purpose of this study was to explore whether cervical proprioception is compromised in female collegiate level soccer players and examine what factors might be related to impaired proprioception. To address this purpose, the study was organized into two phases. In phase one, the criterion for impaired cervical proprioception was established in healthy subjects using the cervical range of motion (CROM) device for the Head Repositioning Accuracy (HRA) test. In phase two, cervical proprioception and risk of cervical proprioception deficits in in female collegiate level soccer players were compared to that of female collegiate athletes who participated in non-contact sports.

In phase one, the objective was to establish a cutoff value for identifying impaired cervical proprioception as assessed by the maximal error in HRA of healthy female collegiate non-athletes.

In phase two, the following primary objectives were addressed:

1. To determine if there were significant differences in the proportions of female collegiate soccer players with (a) a history of a concussion and (b) a history of cervical injury compared to female collegiate athletes who participated in non-contact sports.
2. To determine if there was a significant difference in cervical proprioception assessed using absolute error (AE), constant error (CE), and variable error (VE) in degrees measured with a CROM device during the HRA test between female collegiate soccer players and female collegiate athletes who participated in non-contact sports.
3. To determine if there was a significant difference in impairment in cervical proprioception as assessed with maximal error between female collegiate soccer players and female collegiate athletes who participated in non-contact sports.

In addition, the following secondary objectives were addressed:

1. To determine if there were significant differences in player demographics including history of concussion, history of cervical injury, soccer field position, number of years of participation in competitive soccer, and the number of years with unrestricted head balls between female collegiate soccer players with and without impaired cervical proprioception.
2. To determine if a correlation existed between HRA absolute error measures and the number of years competing in soccer and the number of years of unrestricted head balls between female collegiate soccer players with and without impaired cervical proprioception.

The significance of this study is that it attempts to determine whether female collegiate soccer players have impaired cervical proprioception and which factors that may be associated with impaired proprioception if it exists. This could provide evidence to clinicians regarding the appropriate utilization of proprioceptive tests for preseason screening, training and conditioning for injury prevention, and therapeutic intervention in the rehabilitation of acute and chronic cervical spine injuries in collegiate soccer players.

Literature Review

Head and neck injuries incurred through soccer participation, specifically concussions, neck contusions, and sprains, have been reported in the medical literature ranging from 2.6% - 22.0% depending on the study sample under investigation (Armstrong et al., 2008; Mehnert, Agesen, & Malanga, 2005). While some injuries are reported to athletic trainers and/or are treated in emergency departments, some athletes may not seek treatment; therefore, the prevalence of these injuries may not be fully reported (Kerr et al., 2017). Authors of a 2005 injury surveillance study that included data from 100 high schools in the United States reported that head, face, and neck injuries accounted for 14.6% of total injuries and also indicated that a higher proportion of these of injuries occurred during competition rather than during practice sessions, 17.7% compared to 11.0% (Rechel et al., 2008). Concussions in competition were higher for females than males at 18.8% and 15.6% respectively (Rechel et al., 2008) with a higher percentage of females compared to males being seen in emergency departments for concussions incurred during soccer (Kerr et al., 2017). Most head injuries were due to contact of the head with another player's head or body part, the ground, or the ball (Rodrigues, Lasmar, & Caramelli, 2016). In addition, a 2005 literature review by Mehnert et al. (2005) noted that several studies provided evidence of increased incidence and earlier onset of cervical degenerative changes in soccer players, which may be related to injuries incurred during soccer participation. Such injuries could be sub-traumatic in the form of head balls or traumatic in the form of high speed collisions (Janda et al., 2002; Tsoumpos et al., 2013).

Collisions may be anticipated or unforeseen by an athlete and vary in magnitude based on the nature of the collision (Kerr et al., 2017; Rodrigues et al., 2016). Like collisions, there are several factors reported to influence the quantity and effects of head balls on the cervical spine. These factors include practice versus competition and frequency, technique, and types of head balls, which varied by field position (Erkmen, 2009; Mehnert et al., 2005). There may be various effects on the neck with different types of head balls. Head balls can be performed with the intentions of lightly redirecting a ball away from an opponent, maximally redirecting a ball to "clear" it away from the goal, or utilizing a lateral snap of the head and neck to alter the trajectory of the ball toward the goal (Mehnert et al., 2005). The various effects may be attributed to responses to ball impact during a head ball. It has been reported that the neck is loaded in compression, posterior shear, and extension with 20% of the force being transmitted to the neck as shear and 80% being resisted by head inertia (Funk, Cormier, Bain, & Manoogian, 2011). Head balls result in a skull downward acceleration followed by a skull acceleration in the upward direction. The neck stiffness, which was conceptualized as the strength of the neck muscles (Taha, Hansun, Hassan, & Hasanuddin, 2015) and the resistance of the cervical joints and surrounding soft tissue to deformation (Needle et al., 2014), attenuates skull accelerations and, therefore, brain accelerations during head balls (Taha et al., 2015). Higher accelerations are noted in females soccer athletes compared to males (Needle et al., 2014; Taha et al., 2015, Tierney et al., 2008). This has been attributed, in part, to biomechanical differences in females, such as decreased neck muscle strength, decreased total head and neck mass, and a decreased ratio in size of the head to the size of ball in females as opposed to males (Kerr et al., 2017). This may be a factor in the significantly higher concussion rates from 2009 –2010 to 2013-2014 reported in women's versus men's National Collegiate Athletic Association (NCAA) soccer at 136 and 55 respectively (Zuckerman et al., 2015). In addition, annual national estimates of reported sports-related concussions NCAA women's soccer during the same time frame were the second highest among NCAA sports at 1113, behind men's football at 3417 (Zuckerman et al., 2015).

Concussion in soccer has been widely studied (Maher, Hutchison, Cusimano, Comper, & Schweizer, 2014; Taha et al., 2015; Zuckerman et al, 2015), but the effects on the cervical spine, particularly baseline and potential alterations of cervical proprioception of soccer players has not been studied. In rugby and Australian football players, Hides et al. (2017) presented impaired cervical proprioception as a risk factor for predicting in-season concussions due to the resulting deficiency in the ability to accurately position and set the head during sports participation to avoid injury. Identifying impaired cervical proprioception in soccer players could inform intervention programs consisting of sensorimotor and stabilization exercises to improve proprioception and, thus, mitigate this injury risk factor (Stanton, Leake, Chalmers, & Moseley, 2016). Cervical stabilization and sensorimotor exercises have been effective for improving proprioception (Jull, Falla, Treleaven, Hodges, & Vicenzino, 2007; Lee, Kim, & Lee, 2016). Furthermore, a randomized controlled clinical trial has been proposed to examine the efficacy of specific sensorimotor and balance exercises used along with joint mobilization and therapeutic exercise to improve joint position sense and balance for participants with impaired cervical proprioception and neck pain (Sremakaew et al., 2018). Therefore, due to the evidence that cervical proprioceptive training reduces injury risk and that targeted intervention programs have been effective, cervical proprioception should be a consideration for injury prevention and rehabilitation after injury, and the potential benefits to soccer players should be examined.

Proprioception

Proprioception is the position sense which allows one to determine the position of a body part in space (Armstrong et al., 2008; Proske & Gandevia, 2012) as well as the sense of motion, tissue tension, muscular effort, and balance (Proske & Gandevia, 2012). Proprioception is achieved through the detection of mechanical change during movement, or changes of joint position, that occur due to the deformation of tissues that are innervated by receptors. The quantity of receptors varies throughout muscles and body regions. The primary receptor for proprioception is the muscle spindle, which detects changes in muscle length as well as changes of velocity. Secondary receptors are joint mechanoreceptors, Golgi tendon organs, and skin receptors (Armstrong et al., 2008; Proske & Gandevia, 2012). Proprioception is achieved through a feedback mechanism. The afferent fibers from the muscles, tendons, joints, joint capsules, and skin detect changes in joint position and initiate reflexive muscle contractions for stability. Feed-forward mechanisms also exist, which provide anticipatory stabilization of joints in preparation of motion or action (Armstrong et al., 2008; Artz, Adams & Dolan, 2015; Kristjansson & Treleaven, 2009; Strimpakos, 2011; Treleaven, 2008).

Reflexive muscle contractions and anticipatory stabilization may be critical in the cervical spine for soccer players. The upper cervical spine, in particular, has a unique structure for which ligamentous stability is crucial, specifically at the atlanto-occipital and atlanto-axial joints. The left and right alar ligaments attach the superior lateral aspects of the dens to the occipital condyles and restrain excessive rotation, lateral flexion and flexion. This restraint of rotation protects the nerves and arteries in the upper cervical spine, particularly the vertebral artery. The transverse ligament and tectorial membrane provide restraint for anterior translation of the atlas on the axis, which would directly compress the spinal cord if unstable (Bodon et al., 2017; Levangie, & Norkin, 2011; Neumann et al., 2017; Poorbaugh et al., 2008; Siegmund et al., 2009).

Cervical proprioception. In the cervical region, particularly high densities of muscle spindles are located in the suboccipital muscles, the longus colli and the cervical multifidi of the deep posterior middle layer. Mechanoreceptors exist in smaller quantities in the cervical facet joints, which may indicate that the joint receptors, along with skin receptors, might play a lesser role in proprioception compared with the muscle spindles in this region. (Armstrong et al., 2008; Kristjansson & Treleaven, 2009; Treleaven, 2008). In addition to the high quantity of muscle spindles present in the upper cervical spine, many connections exist among the cervical, vestibular, and visual afferents, which indicate a potentially greater contribution to cervical proprioception of the upper cervical spine verses the lower cervical spine (Kristjansson &

Treleaven, 2009). Cervical proprioception functions with the visual and vestibular system to allow an individual to accurately sense the head position and ultimately contribute to postural control, stabilization of joints, and control of head motion (Armstrong et al., 2008; Kristjansson & Treleaven, 2009; Proske & Gandevia, 2012; Treleaven, 2008).

Cervical proprioception assessment. Clinically, one method of testing proprioception is to assess an individual's ability to perceive the position in which a limb was placed and accurately reposition a limb to this predetermined position. Proprioception measures and interventions are widely used for assessment after knee and ankle injuries and have been shown to be effective for injury prevention and rehabilitation for joint stability and function (Hübscher et al., 2010; Needle et al., 2014; Treleaven, 2008; Zech et al., 2009). Proprioceptive training aims to improve functional joint stability and postural control by means of improving receptor sensitivity, integrating sensory and motor systems, and enhancing neuromuscular control (Kristjansson, & Treleaven, 2009; Needle et al., 2014; Zech et al., 2009). Position sense in the cervical spine has been assessed with position matching tests that allow the assessment of absolute, constant and variable errors in cervical positioning. These methods have been shown to be reliable (Armstrong et al., 2008; Dugailly et al., 2015; Hill et al., 2009; Pinsault et al., 2008) with normal errors that are relatively low (two to five degrees) (Armstrong et al., 2008). One specific cervical proprioception test is the HRA test. It has been measured using a variety of measurement instruments, including a laser-tracking device, electromagnetic tracking devices, electronic systems that measure kinematics, ultrasound trackers, and a CROM device (Performance Attainment Associates, Lindstrom, MN). Specific benefits that have been cited regarding utilization of the CROM device include its convenience in clinical environments, affordability, ease of use, intra-rater reliability for cervical range of motion (Fletcher & Bandy, 2008), test-retest reliability, and validity for the HRA test (Audette, Dumas, Côté, & De Serres, 2010; Tousignant, Smeesters, Breton, Breton, & Corriveau, 2006; Wibault, Vaillant, Vuillerme, Dedering, & Peolsson, 2013).

Cervical proprioception impairment. Any conflict among the afferent input from the proprioceptive, vestibular or visual systems has been associated with impaired cervical proprioception. It can be due to many factors including inflammation as well as changes in the sensitivity of the muscle spindles brought about by local muscle fatigue, trauma, or mechanical disruption of the spindles (Armstrong et al., 2008; Kristjansson & Treleaven, 2009; Pinsault, & Vuillerme, 2010; Treleaven, 2008). Impaired proprioception can also occur due to declines in peripheral muscle function as a result of aging (Artz et al., 2015). Impairment may also be associated with factors such as prolonged soft tissue elongation associated with poor posture while using mobile devices (Mousavi-Khatir, Talebian, Toosizadeh, Olyaei, & Maroufi, 2018; Reid & Portelli, 2016) and structural problems such as adolescent idiopathic scoliosis (Guyot et al., 2016).

Impairments in position sense are observed in individuals who have experienced WAD as well as those with chronic neck pain of a non-traumatic origin, such as arthritis (Armstrong et al., 2008; Poorbaugh et al., 2008; Sjölander, Michaelson, Jaric, & Djupsjöbacka, 2008; Treleaven, 2008). Individuals with idiopathic neck pain and traumatic onsets of neck pain demonstrate impaired cervical proprioception with head-to-neutral repositioning tests compared with asymptomatic controls (De Vries et al., 2015; Stanton, et al, 2016) with recommendations for further research to determine clinical relevance (De Zoete et al., 2017). In addition, greater impairments in cervical proprioception may exist with upper cervical spine pain conditions that are of traumatic origin as opposed to lower cervical spine conditions of traumatic or atraumatic onset (Treleaven, Clamaron-Cheers, & Jull, 2011). In contrast, a lack of impairment with no significant differences in joint repositioning tests were found for a group of those with cervicogenic headache compared with a control group (De Hertogh, 2008). To classify proprioception as impaired, a cut-off value greater than the 90^{th} percentile of the mean of the maximal error of three trials of the HRA test have been utilized (Wibault et al., 2013). The left and right proprioception impairments may be considered separately due to the nature of unilateral physical impairments in craniocervical dysfunctions and apophyseal joint -mediated pain that is atraumatic and associated with WAD (Dumas et al., 2001; Ita, Zhang, Holsgrove, Kartha, & Winkelstein, 2017; Rubio-Ochoa et al., 2016).

Clinical Considerations

If cervical proprioception is found to be impaired for soccer players, whether due to the effects of collisions or head balls, interventions may include musculoskeletal treatment to the cervical spine as well as individualized proprioceptive training as recommended for the management of neck pain (Treleaven, 2008; Treleaven, Peterson, Ludvigsson, Kammerlind, & Peolsson, 2016). Proprioceptive training is considered important for lower extremity rehabilitation after knee and ankle injuries (Hübscher et al., 2010; Needle et al., 2014; Treleaven, 2008; Zech et al., 2009), but it is not often included in rehabilitation programs or screening exams for the cervical spine (Armstrong et al., 2008; Treleaven, 2008). The benefits of assessment and intervention for impaired cervical proprioception include the prevention of injuries from becoming chronic conditions (Armstrong et al., 2008; Kristjansson & Treleaven, 2009) and a decrease in time for return to sports participation following head and associated neck injury (Treleaven, 2017).

Severe head and neck injuries have been reported, which include injuries reported by the athletes to athletic trainers and reports of emergency department visits (Kerr et al., 2017). Additionally, the potential exists that minor and asymptomatic injuries associated with collisions and head balls in soccer could contribute to the cervical proprioception impairments that increase the risk for future injury (Pinsault, Anxionnaz, & Vuillerme, 2010). Impaired cervical proprioception has been reported as a risk factor for head injury in rugby and Australian football (Hides et al., 2017). Although impaired cervical proprioception is a risk factor for rugby, it has not been studied in soccer players. This presents the need to determine impairments that might exist for cervical proprioception among soccer players. Preseason screening and preseason conditioning programs that include cervical proprioception could be used to identify these impairments and address this modifiable risk factor for sport-related concussion and cervical injury (Armstrong et al., 2008; Hides et al., 2017). This study will provide data that is currently lacking regarding the cervical proprioception in a sample of soccer players compared to non-contact sports athletes to determine the need for consideration for screening of cervical proprioception deficits with subsequent conditioning and intervention as indicated.

Method

Study Design

A non-experimental study using a cross-sectional design was conducted. The study took place between January and June 2019. Prior to participant recruitment, the study was approved by the University of Indianapolis Human Research Protections Program with a reliance agreement with the Maryville University Institutional Review Board (IRB).

Participants

Phase one. A convenience sample of 32 healthy non-athlete participants was recruited at a university setting for the establishment of left and right maximal error for the HRA test using the CROM device. The inclusion criteria were females between the ages of 18-24 years. The exclusion criteria were current cervical pain or diagnosis of cervical spine pathology at the time of recruitment, a history of neck or head surgery, a diagnosis of vestibular dysfunction, or a rheumatic condition, with each of the conditions having been diagnosed by a medical doctor. (See Appendix A for the inclusion/exclusion screening form).

Phase two. A convenience sample of female athletes was recruited from two universities that were within a single athletic conference. Inclusion criteria for the soccer group were females who participate in the NCAA Division II soccer with an age range of 18-24 years. Inclusion criteria for the non-contact sports group were females who participate in the NCAA Division II non-contact sports, such as track, cross country, swimming, diving, and tennis, with an age range of 18-24 years. The exclusion criteria were current cervical pain or diagnosed cervical spine pathology, a history of neck or head surgery, a diagnosed vestibular dysfunction, or diagnosed rheumatic conditions, with each of the conditions having been diagnosed by a physician. (See Appendix B for the inclusion/exclusion screening form).

A minimum sample size for phase two was calculated using G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007). The calculation was based on comparing means between two independent groups and the following parameters: two-tailed tests, alpha of .05, power of .80, one-to-one allocation ratio for the two groups, and an effect size of 1.89. This effect size was based on a similar study that compared cervical proprioception of rugby players verses non-contact sport athletes (Pinsault et al., 2010). The calculation resulted in a minimum sample size of six participants per group. To account for a possible smaller effect due to the nature of the contact and collisions involved in soccer being less intense than that in rugby, 24 participants per group were recruited. In addition, the increased sample size was useful in the event that any data needed to be excluded or if a non-parametric test needed to be utilized.

Data Collection

Demographic and outcome data were collected on all phase one and phase two participants by the primary researcher (M. S.) and occurred in lab space designated for physical therapist education and research data collection. All data were recorded on a data collection form (see Appendices C, D, and E for data collection forms). Demographic data collected for phase one were the ages of each participant. For phase two, the following demographic data were collected for the soccer group: age, field position, history of cervical injury, history of concussion, number of years spent playing competitive soccer, and number of years with unrestricted head balls. Demographic data collected for the non-contact athlete group were age, sport, history of cervical injury, history of concussion, and years spent participating in the sport. Outcome data for cervical proprioception consisted of repositioning errors read by the primary researcher directly from the CROM device and recorded in degrees.

Operationalization of variables and definitions. For this study, non-contact sports were defined as competitive physical activities in which the participants either competed with a physical separation from the opponent or with the expectation that physical contact, such as collisions, was not normally experienced or allowed based on the rules of the sport. Examples of non-contact sports that were considered for recruitment were cross country, track, swimming, diving, and tennis. Cervical proprioception was defined as an individual's position sense (Armstrong et al., 2008; Proske & Gandevia, 2012) from the atlanto-occipital through the second thoracic vertebra (Levangie, & Norkin, 2011; Neumann et al., 2017). The HRA for the NHP test assesses the participants' ability to accurately replicate the self-selected neutral position after active movement in the transverse plane (Dugailly et al., 2015). The repositioning error is the difference between the neutral head position (NHP) and the retargeted positon, which was recorded for three trials to the left and three trials to the right for all phase one and two participants. Repositioning error was operationalized as the following error measures: AE, CE, and VE measured with the CROM device during the HRA test for phase two participants (Hill et al., 2009). Absolute error measured the overall accuracy of a participant's repositioning without respect to whether the individual overshot or undershot the neutral position. Constant error measured the overall accuracy of a participant's repositioning including consideration of whether the individual overshot or undershot the neutral position. Variable error measured the overall consistency of the attempts at repositioning to neutral for each participant (Hill et al., 2009). Impaired cervical proprioception was defined as a value at or greater than the 90th percentile of phase one participants' left and right mean maximal errors (Wibault et al., 2013).

Instruments

Head Repositioning Accuracy test. Based on the reliability and validity values, the HRA test is an appropriate test to assess cervical proprioception. The HRA test has established test-retest reliability with intraclass correlation coefficients (ICC) that ranged from .39 to .78, which included vertical, horizontal, and global errors, for a mean of eight trials measured using a laser pointer device (Pinsault et al., 2008). The HRA test has good discriminant validity for patients with WAD and healthy control subjects (Michiels et al., 2013). Regarding the impact of the vestibular system, Pinsault, Vuillerme, and Pavan (2008) reported that while head repositioning errors were greater for patients with non-traumatic neck pain compared to healthy controls, there was no difference for patents with vestibular loss compared to healthy controls.

The authors suggested that the vestibular system was likely not involved in repositioning to the NHP when the HRA was used as a test of cervical proprioception; however, the repositioning was done without instructions regarding speed of motion.

Cervical range of motion device. The CROM device uses inclinometers to measure motion in the sagittal, frontal, and transverse planes. It is a lightweight device that rests on an individual's nose and ears similar to eyeglasses and is fastened at the posterior aspect of the head with a Velcro closure. It includes a magnet that is worn at the upper trunk to function with the magnetic inclinometer that measures transverse plane cervical rotation (Tousignant et al., 2006). Separate gravity inclinometers measure flexion and extension in the sagittal plane and lateral flexion in the frontal plane. A magnetic compass meter measures rotation in the transverse plane (Tousignant et al., 2006), which is the plane tested in the HRA test proposed for this study. The CROM has established reliability and validity for measuring cervical range of motion (Williams, McCarthy, Chorti, Cooke, & Gates, 2010). The CROM device has excellent intra-rater reliability with ICCs from .87 to .94 for asymptomatic subjects and .88 to .96 for subject with neck pain (Fletcher & Bandy, 2008). The CROM has strong test-retest reliability for measuring cervical range of motion with ICC ranging from .89 and .98 for healthy subjects (Audette et al., 2010). Regarding validity, the CROM has good concurrent validity with the FASTRAK, an electromagnetic tracking device, with Pearson correlation coefficients ranging from $r = .93$ for flexion to $r = .98$ for cervical rotation to each direction and cervical extension (Audette et al., 2010). The CROM was found to have excellent criterion validity with the OptoTrak device, an electronic system for measurement of kinematics including spinal motions, with Pearson correlation coefficients of $r = .89$ to .94 (Tousignant et al., 2006).

Cervical range of motion device for Head Repositioning Accuracy. Specific to HRA testing, the CROM has been found to be a reliable and valid instrument. The CROM has test-retest reliability established for three trials each to the left and right and a one-hour interval between trials with ICCs ranging from .79 to .85 for subjects with cervical disc disease (Wibault et al., 2013). The CROM for HRA has inter-rater reliability with ICCs ranging from .72 to .77 (Burke et al., 2016). Wibault et al. (2013) reported criterion validity of the CROM with the laser tracking device with ICCs ranging from .43 to .91 for the assessment of HRA of healthy participants.

Procedures

Recruitment.

Phase one. The primary researcher presented the phase one study to a group of female college students. During the recruitment meeting, the primary researcher described the study, stated the inclusion and exclusion criteria, and answered questions about the study. All of the potential participants were informed of the voluntary nature of participation. Interested individuals were asked to meet briefly with the primary researcher.

Phase two. The primary researcher initially contacted athletic directors, coaches, and athletic trainers at the various universities regarding this study, and letters of agreement for recruitment were signed by the athletic directors. Following letters of agreement and IRB approval, contact was made again with the athletic directors and coaches as appropriate, regarding setting a date and time to present the study to soccer and non-contact sports teams to recruit study participants. During the recruitment meeting, the primary researcher described the study, stated the inclusion and exclusion criteria, and answered questions about the study. All of the potential participants were informed of the voluntary nature of participation. Interested individuals were asked to meet briefly with the primary researcher.

Screening phase one and phase two. At the information session, the interested individuals were verbally screened for inclusion and exclusion criteria by the primary researcher. For eligible participants, a date and time was scheduled with the primary researcher for going through the informed consent process and formal review of the inclusion and exclusion criteria. There was a written script that was used for inclusion and exclusion screening (See Appendix A and B for the inclusion/exclusion screening form).

Informed consent phase one and phase two. Before the scheduled data collection session began, informed consent was obtained by the primary researcher in the form of each participant's verbal agreement to participate in the study after being fully informed of the risks and benefits of participation prior to testing. Participants were given the opportunity to read the informed consent document and indicated agreement by checking the box on the informed consent document pertaining to agreement to participate in the study. No signatures were collected on the informed consent document. Participants were given time to ask questions about the study, and formal screening, data collection, and testing did not begin until all of the participant's questions were answered.

Testing.

Phase one and phase two. After familiarization of the test and instrumentation by explanation and demonstration, participants were seated upright in a standard height chair with a backrest. Each participant's feet rested on the floor, their back rested on the backrest of the chair, and arms rested at the participant's sides. Head repositioning errors were measured using a CROM device that was placed on the individual's head. Participants were permitted to wear any type of shirt but removed any scarves, hoods, hats, eyewear, or facial and neck jewelry. During the HRA test, each participant was blindfolded to eliminate visual contribution and self-selected a NHP, at which point the CROM was set to zero degrees in the transverse plane. Each participant was instructed to actively move the head to the left and return to the self-selected NHP using his or her preferred speed of movement. The participant verbally indicated when he or she perceived that the position had been replicated, and that position was documented in degrees. The error was recorded as the difference in degrees between the NHP and the replicated position. Three trials to the left followed by three trials to the right were performed (Dugailly et al., 2015). The data collection process for each participant took 10 minutes to complete. All of the data collection was performed by the primary researcher, a physical therapist with experience and training in the performance of the test and the use of the CROM.

Data management. Data were collected by the primary researcher using data collection forms (see Appendices C, D, and E). No individual identifiers were used on the data collection forms. Each participant was assigned a unique study identification number by the researcher after she met the inclusion/ exclusion criteria, which was used on the data collection form and in the electronic spreadsheets. Once data were input by the primary researcher into an Excel spreadsheet, the data collection forms were shredded. After all data were collected, they were exported into a statistical program for analysis. Both electronic data files were stored on a password-protected laptop.

Absolute error was calculated as the mean of the three HRA values, referred to as raw errors, for each side without regard for the positive or negative values. Constant error was calculated as the mean of the three raw errors for each side utilizing the positive and negative values. Variable error was calculated as the square root of the mean of the squared differences between each of the three raw errors and the CE (Hill et al., 2009). Maximal error for the left was the greatest absolute repositioning error of the three head repositioning trials on the left. Maximal error for the right was the greatest absolute repositioning error of the three head repositioning trials on the right. The mean of the maximal error for left and right was calculated for phase one participants. The cut-off value was the 90th percentile of the mean value (Wibault et al., 2013). The resulting cut-off values were used to classify phase two participants as having impaired cervical proprioception left and impaired cervical proprioception right. Participants were classified as having impaired cervical proprioception overall if they were impaired on one or both sides.

Data Analysis

All statistical data analyses were performed using IBM SPSS Statistics for Windows, Version 24.0 (IBM Corp., Armonk, NY). Normality of the data was determined using the Shapiro-Wilk test and when appropriate, the Levene's test was used to determine if there was homogeneity of the variables. All comparisons were two-tailed and an alpha level less than .05 was considered statistically significant.

Phase One. The left, right, and overall maximal error for each participant was determined as described above. The 90th percentile of the mean left and right maximal error served as the criterion for identification of impaired left, right, and overall cervical proprioception for phase two participants.

Phase Two. Descriptive statistics were used to describe the sample. Nominal data are presented as frequencies and percentages. Normally distributed interval and ratio data are reported as means and standard deviations, and data that were not normally distributed are reported as medians and interquartile ranges. To determine if participants in the two groups (soccer players and non-contact sports athletes) were similar in demographic characteristics, comparisons were conducted using Fisher's exact test for nominal data and either an Independent *t*-test or non-parametric Mann-Whitney *U* test for interval and ratio data, dependent on whether the data were normally distributed. The Shapiro-Wilk test was used to assess the normality of data. For normally distributed interval or ratio data, equality of variance between groups was determined using Levene's test.

Fisher's exact tests were used to determine if statistically significant differences were present for the proportions of female collegiate soccer players (a) with a history of a concussion, (b) a history of cervical injury, and (c) with impaired cervical proprioception overall compared to female collegiate athletes who participated in non-contact sports. To determine if a statistically significant difference for HRA was present between groups, AE, CE, and VE values were compared between soccer players and non-soccer athletes using an Independent *t*-test or Mann-Whitney *U* test, as appropriate.

Fisher's exact tests were used to determine if statistically significant differences existed between soccer players with and without impaired cervical proprioception by (a) history of concussion, (b) history of a cervical injury, and (c) soccer field position. Independent *t*-tests were conducted to determine the difference in the number of years of participation in competitive soccer and the number of years with unrestricted head balls for soccer players with and without impaired proprioception. Correlation analyses were conducted to identify the relationship between AE and the number of years competing in soccer and the number of years of unrestricted head balls. The interpretation of correlation coefficients was r = 0 - .25 represented little or no relationship, r = 25 - .50 represented a fair degree of relationship, r = .50 - .75

represented a moderate to good relationship, and $r > .75$ represented a good to excellent relationship (Portney & Watkins, 2009).

Results

Phase One

Thirty-two participants completed phase one of the study. Their median age (interquartile range) was 22.00 (0) years. As describe above, the mean (standard deviation) maximal error for the left side was 2.63 (2.37) and 2.19 (1.57) for the right side. The 90th percentile of the mean was used to determine the cut-off value for impaired cervical proprioception for both the left and right side which was ≥ 5.66 for the left and ≥ 4.21 for the right. Impaired cervical proprioception overall was determined for each participant if the maximal error was above the cut-off value for one or both sides.

Phase Two

Forty eight participants were enrolled in phase two of the study with 24 in the soccer group and 24 in the non-contact sports group. Their median (interquartile range) age was 19.98 (2.00). Participant characteristics by athletic group are represented in Table 1. As can be seen in the table, the only statistically significant difference ($p < .001$) in participant characteristics between the soccer group and the non-contact sports group was years of competition with the soccer group having more years of competitive play. Field positions represented by the soccer players were seven (29.17%) forwards, nine (37.50%) midfielders, and eight (33.33%) defenders. The non-contact sports group included 12 (50.00%) track & field athletes, five (20.83%) tennis players, six (25.00%) swimmers, and one (4.17%) diver.

To address objective 1, the history of concussion and history of cervical spine injury were compared between the two athlete groups. Results are found in Table 1 which show that despite the soccer player group having a higher incidence in both history of concussion and history of cervical injury, the difference was not statistically significant ($p > .05$).

To address objective 2, repositioning errors, AE, CE, and VE, were compared for both the left side and right sides between the two athlete groups. Results are found in Table 2. Absolute error left had a statistically significant difference ($p = .006$) between the soccer and non-contact sports group. There was not a statistically significant difference ($p > .05$) in all the other repositioning errors between the groups.

For objective 3, proportions of impaired cervical proprioception left, impaired cervical proprioception right, and impaired cervical proprioception overall were compared between female collegiate soccer players and female collegiate non-contact sports athletes. Results are found in Table 2. Each of these lacked a statistically significant difference ($p > .05$) between groups.

To address the first secondary objective, player demographics including history of concussion, history of cervical injury, soccer field position, number of years of participation in competitive soccer, and the number of years with unrestricted head balls were compared between female collegiate soccer players with and without overall impaired cervical proprioception. Results are found in Table 3. There was not a statistically significant difference ($p > .05$) for any of the player demographics.

The secondary objective, number two, was addressed through correlation analyses between absolute error measures and the number of years competing in soccer and the number of years of unrestricted head balls. All of the correlations had little to no relationship, $r = .22$ ($p = .299$) and $r = .08$ ($p = .704$) for years of competition with absolute error left and right respectively and $r = .18$ ($p = .395$) and $r = .04$ ($p = .858$) for years of unrestricted head balls with absolute error left and right respectively.

Discussion

To explore whether cervical proprioception is compromised in female collegiate level soccer players and to examine what factors may be related to impaired proprioception, multiple objectives were utilized in this study. The objectives aimed to: (a) compare the frequencies of histories of a concussions and a histories of cervical injuries between female collegiate soccer athletes and non-contact sports athletes, (b) determine if a differences exist in cervical proprioception between female collegiate soccer payers compared to non-contact sports athletes using repositioning error values AE, CE, and VE, (c) examine the proportions of athletes classified as having impaired proprioception using maximal error established in phase one, (d) determine if there were differences in cervical spine injuries, concussions, field positions, number of years played, and number of years with unrestricted head balls between soccer players with and without impaired proprioception, and (e) determine if there were relationships between years of competition and years of performance of head balls with repositioning errors.

Cervical Injury and Concussions between Groups

Phase two participant characteristics between groups were not significantly different with the exception of the number of years of competition, with the soccer group having more years than the non-contact group. Concussions and cervical spine injuries were not reported at a rate that was statistically significant between groups. This is in contrast to Zuckerman et al. (2015) who reported that women's NCAA soccer had annual national estimates of reported sports-related concussions that were second behind football and greater than other contact and non-contact women's sports. The data for that study was collected from multiple divisions of the

NCAA as opposed to the small division II, single conference sample that was utilized for this study. The current study results also differ from that of Tsoumpos et al. (2013), who reported high rates of WAD in indoor soccer players, particularly among defenders. The increased rates were attributed to collisions and based on injuries reported in an orthopedic injury clinic that was not limited by gender, level of competition, or age. One possible explanation for the difference between in results between that study and the present study is that the wall that surrounds the indoor soccer field represents an additional structure into which players can collide. The present study's sample consisted of teams that compete outdoors with the potential for collisions to occur with other players, the ground, or goal posts (Rodrigues, 2016). While data regarding a history of cervical injury was collected for this study, a history of indoor soccer competition was not collected. Regarding the unexpected similarity in reported concussion and cervical injury rates between groups, it is possible that a larger sample size among different athletic conferences and divisions could be more representative of the populations of female collegiate soccer players and non-contact sport athletes.

Error Calculations

A statistically significant difference existed for the AE left between the soccer and non-contact sports group (p = .006). This result was consistent with a study conducted with a sample of male rugby athletes that compared rugby forward and backs to non-contact sports athletes, and a significant difference was found between the rugby and non-contact group using absolute error (Pinsault et al., 2010). That study was similar to the present study in the use of AE and VE to compare contact sport athletes to non-contact sport athletes, but it differed in the utilization of ten repositioning trials from each side, the sample of male athletes, and the specific sport (Pinsault et al., 2010). It was considered that the differences between the present study and that of Pinsault et al. (2010) might be due to the nature of the collisions in rugby being more intense and more frequent that those incurred in female division II collegiate soccer.

The significance found in AE left in spite of the small sample of athletes indicated that female collegiate soccer players might have impaired cervical proprioception compared to non-contact sport athletes as evidenced by greater repositioning errors following left rotation. This may provide justification for the consideration of head repositioning accuracy testing for female collegiate soccer players because impaired cervical proprioception has been identified as a risk factor for concussions (Hides et al., 2017), and soccer players may benefit from intact proprioception to accurately position the head for head balls and for feed-forward stabilization prior to anticipated collisions (Armstrong et al., 2008; Hides e al., 2017). Given the evidence that specific sensorimotor training improves repositioning errors and that intact proprioception decreases injury risk (Hübscher et al., 2010; Jull et al., 2007; Lee et al., 2016), an impairment in cervical proprioception can be considered a modifiable risk factor. This information may be useful for the consideration of HRA testing during preseason screening to guide intervention programs designed to mitigate injury risk and for rehabilitation after concussions and cervical spine injuries for a safe return to sport.

In contrast to AE left, AE right lacked a statistically significant difference between the soccer and noncontact athlete groups. Evidence of asymmetrical results exist in previous studies (Hides et al., 2017; Jull et al., 2017; Rix & Bagust, 2001; Treleaven et al., 2011). For example, asymmetric repositioning errors have been reported for participants with non-traumatic neck pain and controls (Rix & Bagust, 2001). Treleaven et al. (2011) studied AE using three trials of joint reposition error testing using the Fastrack device along with the smooth pursuit neck torsion tests and standing balance tests for four subgroups of participants with neck pain: upper traumatic, upper non-traumatic, lower traumatic, and lower non-traumatic. It was reported that participants with upper cervical pain of traumatic onset had greater errors with repositioning trials following right rotation, but not for left rotation or extension. Hides et al. (2017), in a study of rugby and Australian football players, reported that the athletes that sustained a head or neck injury during the season had higher repositioning errors in the preseason for repositioning from relative right cervical rotation. This was tested with the head stationary and with trunk active rotation to the left for the elimination vestibular input with six trials each from the left and right used for calculation of absolute error, and then a mean of the 12 trials was used to calculate an overall mean error. In an intervention study, Jull et al. (2017), reported improvement in right joint position error, but not the left, after a conventional proprioceptive training intervention. This was done using the AE of three trials to the left, right, and extension and compared AE pre- and post-intervention.

Based on the previously cited research, it may be suggested that asymmetry in repositioning for impaired individuals is not an uncommon finding, although the mechanism for the asymmetry has not been examined. In this study, it was noted that the outliers for AE right were participants that had a self-reported history of a cervical injury. Interpretation of this finding was limited by the lack of data collection regarding the specifics of the reported cervical injuries and the presence of impairments in posture, range of motion, muscle strength, flexibility, or handedness patterns. Regarding the potential relevance of posture, previous studies contained results of higher repositioning errors with forward head postures, flexed postures, and scoliosis (Guyot et al., 2016; Mousavi-Khatir et al., 2018; Reid & Portelli, 2016).

Impaired Proprioception Based on Maximal Error

The phase one results for healthy non-athletes included the mean (standard deviation) maximal error, which was 2.63 (2.37) for the left side and 2.19 (1.57) for the right side. These results are consistent with previous studies in which normal AE and CE were less than 5 degrees for healthy subjects (Armstrong et al., 2008) with normal repositioning errors of 3.3 degrees for asymptomatic subjects and a clinical cut-off of 4.5 degrees for proprioception to be classified as impaired (Dugailly, e al,. 2017; Revel, Andre-Deshays, & Minguet, 1991). However, these are to be interpreted with caution due to a different methodology used in the present study. Dugailly, et al. (2017) set the threshold for impaired proprioception so that 100% of the healthy participants fell within the threshold, and 68% of the neck pain participants were outside of the clinical cut-off value. Revel et al. (1991) performed an analysis of sensitivity and specificity for 10 trials of repositioning from maximal left rotation, right rotation, flexion, and extension, and established a threshold of 4.5 degrees.

Normative values have not been established specifically for this age group of 18-24 years of age. Controversy exists as studies have been conducted with results that lacked significant differences in repositioning based on age (Alahmari et al., 2017; Chen & Treleaven, 2013), while others have demonstrated significant effects of age on repositioning errors (Artz et al., 2015; Teng, Chai, Lai, & Wang, 2007; Vuillerme, Pinsault, & Bouvier, 2008). For this study that targeted females aged 18-24 years with a median age of 22 years, the cut-off for classification of impaired proprioception, 90th percentile of the mean maximal error, was $\geq$ 5.66 for the left and $\geq$ 4 .21 for the right. In comparison, Wibault et al. (2013) found a median maximal error of 2.7 with a standard deviation of 2.8 degrees for healthy participants with a cut-off value of 6.7 degrees for classification on impaired proprioception. The sample differed in demographics from the present study with 173 men and women with a mean age of 44 years and standard deviation of 12 years. This result supports the above-cited findings that repositioning errors are greater with increased age (Teng et al., 2007; Vuillerme et al., 2008) and may support the need for the determination of age-specific norms.

Phase two results lacked statistically significant differences in impaired cervical proprioception left, right, and overall between soccer and non-contact sports athletes. In this study 58% of the athletes in both the soccer group and the non-contact group were classified as having impaired cervical proprioception overall. One study was identified that used a similar methodology to classify participants with cervical radiculopathy due to disc disease as impaired verses unimpaired (Wibault et al., 2013), but no previous studies were identified that examined proportions of athletes with impaired proprioception comparing soccer and non-contact sports athletes.

Demographic data and Correlation Analysis

There were no statistically significant differences ($p < .05$) between soccer players with and without impairment for any of the demographic data. The lack of a statistically significant relationship between the field position and the impairment of proprioception was consistent with Pinsault et al. (2010) who reported no difference in repositioning errors between rugby forwards and backs. Although field position was not significant for proprioception in this study, it has been shown to be significant in studies of concussions with defenders and goalkeepers sustaining higher rates of concussion based on a systemic review (Maher et al, 2014). No goalkeepers volunteered for participation in this present study. While this small sample did not show statistical significance, it was noted that each of the three soccer players who reported a history of a cervical injury had impaired cervical proprioception overall. Of the three, two were forwards, and one was a defender. Although it was a small sample, this is consistent with higher rates of head and neck injuries that were reported in central defenders and forwards compared to other field positions in a retrospective study (Onaka, et al., 2017).

In this study, a history of a concussion was reported at similar frequencies for soccer players with and without impaired proprioception. Hides et al. (2017) reported that among rugby and Australian football players, a history of a sport-related concussion was not associated with preseason impairment in proprioception, but an impairment in proprioception in right cervical rotation at baseline increased the odds of sustaining a head or neck injury during the season. Furthermore, it was found that impaired proprioception was an independent predictor of a head or neck injury for athletes with or without a history of a concussion (Hides et al., 2017). The results from the present study, along with other published evidence, strengthens the recommendation that athletes not only be screened for impaired proprioception preseason but also after a concussion with appropriate intervention in an effort to prevent further injury (Jull et al., 2007; Lee et al., 2016).

It was observed that each soccer player with a cervical injury was classified as having impaired cervical proprioception overall. Previous studies have been conducted with participants who are symptomatic, particularly with chronic neck pain, osteoarthritis, WAD, cervical radiculopathy caused by disc disease, and traumatic neck pain (Alahmari et al., 2017; De Vries et al., 2015; De Zoete et al., 2017; Stanton et al., 2016; Treleaven et al., 2017; Uremovic et al., 2007; Wibault et al., 2013). However, no studies have been published exploring cervical proprioception impairment for individuals with a history of a cervical injury. In contrast to the consideration of pain symptoms, Sjölander et al. (2008) recommended that an objective examination be conducted because impairments in motor control and accessory mobility as well as the presence of pathophysiology may be associated with the impaired proprioception.

In the present study, there were no statistically significant correlations between years of competition and years of unrestricted head balls with absolute error ($p < .05$). There are no published studies that have examined such relationships. The authors of previous studies have examined the long-term effects of heading and the effects of frequent heading on neuro-cognition (Maher et al., 2014), but none have examined the relationship of these factors to cervical proprioception.

Limitations

One of the study limitations is the non-random convenience sample consisting of a relatively homogeneous group of division II female collegiate athletes. Although it was a strategy to achieve internal validity, the relative homogeneity of the sample was a limitation for the generalizability of the results to a larger population.

The small sample size was also considered a limitation of this study. The sample size estimate of six participants in each group was based on the results of a study of rugby players who most likely had higher rates of impairment. The sample of this study was increased to 24 per group in anticipation that the collisions incurred in female collegiate soccer were less intense and less frequent than those incurred in rugby. However, the sample of 24 per groups possibly left the study underpowered; therefore, that limited in the ability to have statistical significance.

The HRA test was conducted as described in previously published studies, with the left side being tested first and the right side being tested second. While this contributed to the standardization of the data collection, the lack of randomization of the side that is initially tested during data collection could be considered a limitation due to the potential effects of learning the test, loss of attention span during the test loss of motivation, or fatigue (Chen & Treleaven, 2013; Dugailly et al, 2015).

A potential limitation was the lack of control for athlete fatigue. There were athletes in both groups that arrived at the data collection sessions immediately following practices or after general strengthening workouts that occurred the same day, and the details of that day's workout was not part of the data collection. Armstrong et al., (2008) and Pinsault and Vuillerme (2010) reported that local fatigue specifically of cervical muscles resulted in higher repositioning errors foe AE and VE. However, regarding generalized fatigue, Pinsault et al. (2010) reported no difference in AE and VE for rugby forward and backs tested before and after a training session.

The present study was conducted with three trials each to the left and right as conducted by Treleevan et al., (2016) and Wibault et al (2013). A potential weakness of the study could be a decreased sensitivity with three trials as opposed to six to 10 trials to each side (Pinsault et al., 2008). In a systemic review, Devries et al. (2015) noted that although only four out of 14 studies used more than six repositioning trials, those that used six or more had improved discrimination between participants with and without neck pan due to higher repositioning errors for subjects with neck pain. This may not pose a significant limitation to this study as soccer and non-contact sports athletes reported a history of cervical injury at similar frequencies, and none had current neck pathology per the exclusion criteria. However, De Vries et al. (2015) also suggested that higher repetitions could serve to lessen the influence of the outliers in the data set.

Regarding demographic data, the histories of concussion and cervical injury were self-reported by the participants. The nature of self-reporting of data may lead to a limitation in the accuracy of the information. Additionally, information regarding whether or not there were interventions and what the interventions were for the past injuries was not collected. In spite of past injuries, no participants had a diagnosis of a current cervical pathology per the exclusion criteria.

Implications for Practice and Future Research

Even with the stated limitations, this study serves as an initial step in the examination of cervical proprioception between soccer and non-contact sports athletes, and it provides a set of age-specific norms among the non-athlete healthy sample of females, from which a criterion for impaired proprioception was established. Future research into cervical proprioception among athletes could expand on the findings of this study. A cross-sectional design with a larger sample may be useful for generalizability, for statistical significance, and for the ability to overcome outliers in the data set (De Vries et al., 2015; De Zoette et al., 2017). Testing among a variety of athletic conferences and divisions would be the strategy to improve the generalizability of the study results. Randomization regarding initiating the data collection on the left or right would be beneficial to mitigate issues of learning the test, loss of attention span, and fatigue (Chen & Treleaven, 2013; Dugailly et al, 2015).

Further research may be useful to determine what objective impairments, such as posture, range of motion, strength, and flexibility in addition to details regarding histories of cervical injuries, might be associated with impaired cervical proprioception. Future studies could be designed to further investigate the relationships between proprioception and injury to examine whether cervical injury results in impaired cervical proprioception and whether impaired proprioception increases the risk of concussion for female collegiate soccer players. The ultimate goal is to identify those who may benefit from cervical sensorimotor training for injury mitigation and as part of rehabilitation following head and neck injuries to facilitate a safe return to sport.

Conclusion

This study provides clinical cut-off values that may be useful for the identification of impaired cervical proprioception for females aged 18-24 and utilized for preseason screening for injury prevention. Phase two results of this study indicate that there was a statistically significant difference in the repositioning errors of female collegiate soccer players verses non-contact sports athletes for AE left. The other error measures: AE right, CE left and right, and VE left and right lacked statistical significance. A history of cervical spine injury, history of concussion, field position, number of years in competitive soccer and number of years of unrestricted head balls lacked statistical significance between soccer players with and without impairment of cervical proprioception. There were no correlations between repositioning error values and the number of years of participation and the number of years of unrestricted head balls for soccer players. Further research with a larger and more heterogeneous sample may be beneficial to determine if differences between groups exist. Based on the statistical significance of AE left, routine screening for impaired cervical proprioception may be recommended for female soccer players. Sensorimotor training, which has been shown to be effective in improving cervical proprioception can be utilized during the preseason period for impaired individuals in an effort to prevent injury and incorporated into rehabilitation programs to facilitate a safe return to competition.

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Table 1

Participant Characteristics by Sports Group

	Soccer *N* = 24	Non-Contact Sports *N* = 24	
	N (%)	*N* (%)	*p*
History of Cervical Injury			1.000
No	21 (87.50)	22 (91.67)	
Yes	3 (12.50)	2 (8.33)	
History of Concussion			.125
No	13 (54.17)	19 (79.17)	
Yes	11 (45.83)	5 (20.83)	
	M (SD)	*M* (SD)	
Age*	20.00 (2.00)	19.00 (2.00)	.437
Years of Competition	12.88 (2.38)	9.54 (3.51)	< .001
Years of Unrestricted Head Balls	12.83 (2.33)		

Note. *Age is reported as a median (interquartile range).

Table 2

Comparisons of Error Calculations and Impaired Proprioception between Soccer and Non-Contact Sport Athletes

	Soccer *N* = 24	Non-Contact Sports *N* = 24	
	Mdn (IQR)	*Mdn* (IQR)	*p*
AE left	4.00 (5.42)	1.33 (3.08)	.006
AE right	2.33 (4.91)	3.00 (2.92)	.788
CE left	-3.17 (5.33)	-1.00 (3.75)	.334
CE right	-0.17 (6.58)	-2.83 (4.50)	.363
VE left	1.41 (1.72)	0.94 (1.21)	.068
VE right	0.94 (1.95)	1.41 (1.07)	.090
	N (%)	*N* (%)	
Impaired Cervical Proprioception Left	9 (37.50)	5 (20.83)	.341
Impaired Cervical Proprioception Right	11 (45.83)	12 (50.00)	1.000
Impaired Cervical Proprioception Overall	14 (58.33)	14 (58.33)	1.000

Note. IQR = interquartile range; AE = absolute error; CE = constant error; VE = variable error

Table 3

Comparison of Soccer Athlete Characteristics with Cervical Proprioception Status

	Impaired (N = 14)	Not Impaired (N = 10)	
	N (%)	N (%)	p
History of concussion			.697
No	7 (53.85)	6 (46.15)	
Yes	7 (63.64)	4 (36.36)	
History of cervical injury			.239
No	11 (52.38)	10 (47.62)	
Yes	3 (100.00)	0 (0.00)	
Field position			.591
Forward	5 (71.42)	2 (28.57)	
Midfield	4 (44.44)	5 (55.56)	
Defense	5 (62.50)	3 (37.50)	
	Mdn (IQR)	*Mdn* (IQR)	p
Participation years	13.00 (5.00)	13.00 (2.75)	.900
Head ball years	13.00 (5.00)	13.00 (3.00)	.954

Note. IQR = interquartile range

Appendix A

Inclusion and Exclusion Screening Form Phase One

Cervical Proprioception in Female Collegiate Soccer Players Compared to Non-Contact Sport Athletes

Inclusion Criteria

To be included in the study, the participant must:

1.	Be female.	Yes	No
2.	Be 18-24 years of age.	Yes	No

All Inclusion Criteria must be answered yes, to be included in study.

Exclusion Criteria

Based on the criteria for this study, the participant must not have:

1.	Current cervical pain (occiput to second thoracic vertebra).	Yes	No
2.	Current cervical pathology diagnosed by a medical Doctor (MD).	Yes	No
3.	A history of head or neck surgery.	Yes	No
4.	A vestibular dysfunction diagnosed by a MD	Yes	No
5.	A rheumatic condition diagnosed by a MD.	Yes	No

All Exclusion Criteria must be answered no, to be included in study.

Did the participant meet the eligibility requirements for this study? Yes No

Investigator Signature: Date:

Appendix B

Inclusion and Exclusion Screening Form Phase Two

Cervical Proprioception in Female Collegiate Soccer Players Compared to Non-Contact Sport Athletes

Inclusion Criteria

To be included in the study, the participant must:

1.	Be female.	Yes	No
2.	Be 18-24 years of age.	Yes	No
4.	Participate in NCAA Division II soccer or non-contact sport.	Yes	No

All Inclusion Criteria must be answered yes, to be included in study.

Exclusion Criteria

Based on the criteria for this study, the participant must not have:

3.	Current cervical pain (occiput to second thoracic vertebra).	Yes	No
4.	Current cervical pathology diagnosed by a medical Doctor (MD).	Yes	No
3.	A history of head or neck surgery.	Yes	No
4.	A vestibular dysfunction diagnosed by a MD	Yes	No
5.	A rheumatic condition diagnosed by a MD.	Yes	No

All Exclusion Criteria must be answered no, to be included in study.

Did the participant meet the eligibility requirements for this study? Yes No

Investigator Signature: Date:

Appendix C

Phase One Data Collection Form

ID#	Age	HRA #1/2/3 Left (errors in degrees)	HRA #1/2/3 Right (errors in degrees)

Appendix D

Phase Two Soccer Athletes Data Collection Form

ID #	Age	Soccer Field Position	History of Cervical Injury	History of Concussion	Number of years in competitive participation/ Number of years with unrestricted head balls	HRA #1/2/3 Left (errors in degrees)	Absolute Error Left (in degrees)	HRA #1/2/3 Right (errors in degrees)	Absolute Error Right (in degrees)

Appendix E

Phase Two Non-Contact Sport Athletes Data Collection Form

ID#	Age	Non-Contact Sport	History of Cervical Injury	History of Concussion	Years spent in sport	HRA #1/2/3 Left (errors in degrees)	Absolute Error Left (in degrees)	HRA #1/2/3 Right (errors in degrees)	Absolute Error Right (in degrees)
