Does Physical Therapy Presentation differ according to Mechanism of Injury in Adolescents after Concussion

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

In partial fulfillment of the requirements for the degree
Doctor of Health Science
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Does Physical Therapy Presentation Differ according to Mechanism of Injury in Adolescents after Concussion

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Abstract

There is a high incidence of concussion in adolescents, regardless of sport participation, and may require evaluation by a physical therapist or other qualified healthcare provider. A retrospective study was performed to identify clinical differences between adolescent patients who sustained a sport-related concussion (SRC) and non-sport-related concussion (nSRC) at the time of their physical therapy evaluation. More specifically, measures of cervical spine function, post-concussion symptom severity, and quality of life measures were examined. There were 257 patients in the SRC group and 248 patients in the nSRC group between the ages of 10 and 18 years of age with mean age at the time of physical therapy being 14.75 and 15.07 years, respectively.

Comparisons between the SRC and nSRC group were conducted to determine if there were statistically significant differences in cervical range of motion, headache response with cervical spine palpation, post-concussion symptom inventory (PCSI) reports, Pediatric Quality of Life scores, and other patient-specific characteristics between the groups. Demographic data between the groups did not demonstrate significant differences. Statistically significant differences were found as patients after nSRC had greater cervical spine impairments, worse scores on both PCSI and PedsQL™, and had greater likelihood of presence of headache at the time of physical therapy evaluation as compared to patients with an SRC.

Physical therapists can utilize this information to anticipate the examination and evaluation needs of a patient coming in for physical therapy following concussion.

Keywords: concussion, adolescents, physical therapy

Acknowledgements

The opportunity to pursue my doctorate from the University of Indianapolis was a great opportunity and challenge for my personal and professional life. The completion of this entire process would not have been possible without several people in my corner that supported me throughout this process.

Table of Contents

List of Figures and Tables

Does Physical Therapy Presentation differ according to Mechanism of Injury in Adolescents after Concussion

The Centers for Disease Control (CDC) estimates that between 1.6 and 3.8 million concussions occur with sports and recreation-related activities annually (Langlois et al., 2006). Concussion has been described as a traumatic brain injury induced by biomechanical forces that can be caused by a direct blow to the head or other area (McCrory et al., 2009, 2013, 2017). After experiencing a concussion, patients may present to their healthcare provider with reports of a rapid onset of short-lived impairments and functional disturbances of the neurologic system and a variety of persistent clinical signs and symptoms that can range in severity and duration (McCrory et al., 2009, 2013, 2017; Quatman-Yates et al., 2020). A majority of the literature surrounding concussion has been published on older athletes and patients (Duhaime et al., 2012; Hänninen et al., 2016; (McCrory et al., 2009, 2013, 2017; Resch et al., 2015) and only recently has more attention been given to younger patients (Büttner et al., 2020; Emery et al., 2021; Gunter et al., 2018; Harper et al., 2021; Quatman-Yates et al., 2020; Schneider et al., 2018).

Due to the mechanism of injury associated with concussion, the cervical spine can be injured and can contribute to a myriad of symptoms common after concussion including headache, neck pain, and visual problems (Duhaime et al., 2012; Ellis et al., 2019; Emery et al., 2021; Guskiewicz & Register-Mihalik, 2011; Harper et al., 2021; Kennedy et al., 2019; Kennedy et al., 2017; Quatman-Yates et al., 2020; Schneider et al., 2018; Tiwari et al., 2019). Physical therapists are well-equipped to evaluate and treat patients with cervical impairments using treatment-based clinical practice guidelines (Blanpied et al., 2017) and additional impairment-based strategies for management following concussion. (Ellis et al., 2015; Gunter et al., 2018; McCrory et al., 2017; Quatman-Yates et al., 2020; Schneider et al., 2014). In recent years, particular attention has been given to cervical spine impairments in youth athletes following concussion (Ellis et al., 2019; Schneider et al., 2013, 2018; Tiwari et al., 2019) despite having no evidence-based guidelines for management of youth cervical injuries that accompany concussion. Impairment-based treatment guidelines require thorough evaluations of the patient population in question to therefore help guide appropriate treatments.

Mechanism of injury (MOI) is an important piece of information and possible contributor to these impairments. It may provide insight into the various impairments found at the time of physical therapy evaluation and subsequent treatments needed to reduce these symptoms and impairments. The Berlin Consensus statement on Concussion in Sport defines sport-related concussion (SRC) as a traumatic brain injury induced by traumatic forces such as a blow to the head, face, or body causing short-lived impairments of neurological function McCrory et al., 2017) which can occur within organized sport (Daneshvar et al., 2011) and not explained by other injuries or comorbidities (McCrory et al., 2017).

While SRC and non-SRC (nSRC) may present similarly, there may be important differences between the two regarding the mechanism of injury and circumstances or environment surrounding that mechanism of injury. Individuals who suffer nSRC include injuries related to falls, motor vehicle accidents, recreational activities, and other accidents that are not inherently part of what the patient may expect to happen. A prior study found no relationship between MOI and prolonged recovery amongst their cohort of patients after collision, falls, MVA and sport (Eisenberg et al., 2013). However, another study did acknowledge there may be a protracted recovery in a young cohort after MVA-related concussion as compared to SRC (Seiger et al., 2014). The Berlin Consensus statement and its authors (McCrory et al., 2017) acknowledge the challenge in concussion management whereby "this consensus document reflects the current state of knowledge and will need to be modified as new knowledge develops" (p. 838) and that "the term concussion, while useful, is imprecise, and because disparate author groups define the term differently, comparison between studies is problematic" (p. 839). While the term concussion is considered imprecise, so is the understanding of the relationship of mechanism of injury on patients after concussion. "More research is needed to examine the relationship between non-sport MOI and concussion recovery" (Aggarwal et al., 2019, p. 2).

Athletes are provided with numerous resources surrounding the injury prior to being eligible to compete in their sport and perhaps may have additional factors related to recovery from an SRC that could influence their initial presentation. Both groups, SRC and nSRC, may exhibit deficits that warrant a referral to physical therapy and their presentation to physical therapy may be different. Therefore, the purpose of this study is to examine the relationship between mechanism of injury (nSRC and SRC) and common impairments of the cervical spine, patient-reported outcomes, and symptom presentation at the time of physical therapy assessment.

Research Question

To address the study purpose, the following research question will be answered:

Among adolescents presenting to physical therapy after a concussive injury, are there differences in quality of life and musculoskeletal function at their initial physical therapy visit between those injured during sport and those injured during other activities?

Objectives

The following study objectives will be met to answer the research question.

1. Identify if there is a significant difference in cervical spine impairments between those who had a sports-related mechanism of injury and those that did not.
2. Identify if there is a significant difference in quality of life between those who had a sports-related mechanism of injury and those that did not.
3. Determine if the mechanism of injury sustained by a participant is able to predict the cervical spine impairment, headache severity, total concussion symptom severity, or quality of life measure.

Significance of the Study

This study would contribute to the paucity of research studies currently available which describe cervical spine impairments in youth following concussion and help to develop impairment-based guidelines to inform treatment. The information gleaned from this study could optimize outcomes in this population by providing greater insight into common cervical spine impairments in young patients after concussion and aligning them with age-appropriate treatments.

Literature Review

Concussions are a "traumatic brain injury induced by biomechanical forces" that can cause a myriad of symptoms and disruption of neurologic function for a short period of time (McCrory et al., 2017, p. 2). It is estimated that millions of SRC and recreation-related concussions occur annually (Daneshvar et al., 2011; Langlois et al., 2006) with recent data suggesting there has been a nearly three-fold increase in the number of concussions reported in the National Electronic Injury Surveillance System between the years of 1997 and 2019 (Reid et al., 2020). This increase is likely due to the campaigns over the last 10-15 years that have sought to increase public awareness about the diagnosis (Sarmiento et al., 2014). These efforts are geared to alert parents, coaches, and players to the importance of recognizing concussions and highlight potential strategies to improve management and curb the potential long-term consequences associated with concussion (Daneshvar et al., 2011; Sarmiento et al., 2014). Medical care estimates have been reported to be nearly $17 billion each year in the United States (Centers for Disease Control and Prevention, 2003) for these mild traumatic brain injuries.

Concussion can be caused by a blow to the head, face, neck or body which allows the force to be transmitted to the head (Duhaime et al., 2012; McCrory et al., 2009, 2013, 2017; Quatman-Yates et al., 2020; Zemek et al., 2016). These traumatic forces can cause significant harm to the musculoskeletal structures in the cervical spine that are responsible for an individual's ability to turn their head, sit for prolonged periods of time, participate in school, and other functions that require static positions or dynamic head movements.

For the very young (less than 5 years old) and very old (greater than 65 years), fall-related mechanisms of injury appear to be the most common (Reid et al., 2020). For those individuals between the ages of 5 and 24 years of age, sports-related injuries are the most common and males between the ages of 5 and 14 years of age appear to be at the most risk (Reid et al., 2020). Another study of those presenting with concussion to the emergency department (ED) found similar results and demonstrated that a majority of adolescent concussion injuries were sustained by sport or recreational play (67.2%) followed by non-sports injury or fall (24.7%) and the remaining subjects were by motor vehicle collision, assault or other means not classified (Zemek et al., 2016). A study by Marar et al. (2012), however, noted that in 15- to 24-year-olds concussion sustained in sport was second only to motor vehicle crashes as far as highest injury mechanism.

Across the number of sports that are reported to have the highest incidence in concussion, these numbers appear to vary greatly by region due to popularity and access to certain sports including action sports such as snowboarding (Feletti & Bonato, 2020) and usual sports such as football (Marar et al., 2012; Reid et al., 2020; Zemek et al., 2016). Across most sports and activities, there was a tendency for males to have a greater risk of concussion, especially in sports such as football (Feletti & Bonato, 2020; Reid et al., 2020; Zemek et al., 2016). There are a number of sports, however, such as soccer, basketball, (Daneshvar et al., 2011) and hockey (Daneshvar et al., 2011; Duhaime et al., 2012) reporting females having a higher incidence compared to their male counterparts. Overall, it is noted that females tend to have higher rates of concussions than males in similar sports (Daneshvar et al., 2011).

Concussion is recognized as one of the more difficult injuries to manage due to the evolving nature of the acute signs after concussion and having no definitive test available to diagnose the injury (Kazl & Torres, 2019). As noted above, the symptoms after a concussion can be short-lived, especially in the older athlete, with a majority of patients after concussion recovering within 7-10 days (McCrory et al., 2009, 2013, 2017; Quatman-Yates et al., 2020). However, there is evidence that up to one-third of adolescents after concussion can have persistent symptoms after 4 weeks (Zemek et al., 2016).

After a concussion, individuals may experience a wide range of symptoms and impairments. The impairments after concussions are commonly put into domains of physiologic impairments, cervicogenic impairments, and vestibulo-ocular impairments (Ellis et al., 2015; Grabowski et al., 2017). The physiologic post-concussion deficits may include impairments and symptoms such as headache worsened by physical or cognitive activity, elevated resting heart rate, and graded exercise testing difficulties due to worsening symptoms (Ellis et al., 2015).

Researchers studying management strategies for impairments in the physiologic domain have shown improvements can be made if these strategies are implemented early (Leddy et al., 2019) or later (Kurowski et al., 2017).

In addition to the physiologic domain described above, cervicogenic and vestibulo-ocular impairments are also part of a comprehensive assessment. Cervicogenic post-concussion impairments may include neck pain, increased neck stiffness, cervical muscle tenderness to palpation, loss of cervical range of motion, occipital headaches, and impaired position sense of the head-neck segment (Ellis et al., 2015). Vestibulo-ocular post-concussion deficits may include symptom reports of dizziness, vertigo, or lightheadedness, blurred vision, motion sensitivity, photophobia, difficulty reading, impaired balance or gait testing, and impaired vestibular and ocular examinations (Ellis et al., 2015). Two retrospective studies of patients presenting for management of their concussion noted that most patients experienced symptoms and impairments within multiple domains (Grabowski et al., 2017; Lennon et al., 2018). These two specific domains, cervicogenic and vestibulo-ocular, have overlapping symptom reports and impairments that may be related to the cervical spine and are important to tease out early in the evaluation process (Quatman-Yates et al., 2020).

Beginning around 2017, studies emerged that increasingly considered the involvement of the cervical spine as a concomitant injury along with concussion (Ellis et al., 2019; Emery et al., 2021; Kennedy et al., 2017; Schneider et al., 2018; Tiwari et al., 2019). Ellis et al. (2019) highlighted that cervical spine impairments may serve as a possible contributing source of symptoms in a cohort of pediatric patients. The authors highlighted that a majority of patients were still considered to have neck problems contributing to their symptoms despite the cohort being an average of 7.5 weeks from their concussive event (Ellis et al., 2019). Early randomized controlled trials have shown that neck exercise, particularly with emphasis on muscular endurance and strength training, are effective in the treatment of cervicogenic headaches (Ylinen et al., 2010). One randomized controlled trial noted that a multimodal treatment approach combining cervical and vestibular exercise was effective in reducing symptoms and return to activity following concussion (Schneider et al., 2014). While it is promising to see these studies emerge, little progress has been made to align these efforts with the clinical practice guideline (Blanpied et al., 2017) to guide treatment of neck pain and provide evidence-based management strategies for patients after concussion.

Impairment-based strategies for management of concussion have been proposed (Ellis et al., 2015) and these strategies are viewed as part of a comprehensive program across various populations (Gunter et al., 2018; Haider et al., 2021; McCrory et al., 2009, 2013, 2017; Quatman-Yates et al., 2020; Schneider et al., 2014). Impairments related to neck pain following concussion have been reported (Kennedy et al., 2019) and have been the focus of more recent studies in youth treated for concussion (Ellis et al., 2019; Schneider et al., 2013, 2018; Tiwari et al., 2019). With similar impairments noted in youth (Tiwari et al., 2019) as adults (Blanpied et al., 2017), there is the potential that similar strategies could be utilized across ages for this common impairment (neck pain) after concussion (Kennedy et al., 2019). Resch et al. (2015) aimed to predict the duration of persistent symptoms after concussion and found that self-report of neck pain was one of the factors that contributed to the formula for recovery. Previous, unpublished work has found that neck pain at the time of injury within a similar cohort of patients exhibited cervical impairments and worse patient-reported outcomes (Kanetzke et al., 2022). With those with neck pain at the time of injury demonstrating a worse presentation to physical therapy, it would be worthwhile to continue to examine what factors, including mechanism of injury, could be related to these impairments.

Details uncovered during the subjective portion of the examination are paramount for determining areas for further examination, potential for additional referrals, and prognosis (Quatman-Yates et al., 2020). There is a gap, however, linking what is known about cervical spine impairments in youth athletes after concussion and if potential relationships exist based on their mechanism of injury. This study will seek to examine the differences in those post-concussion injury symptoms and impairments between those who suffered a sport-related mechanism of injury and those that did not.

Methods

Study Type and Design

This is a non-experimental study using a retrospective study design examining differences in clinical presentation and outcomes between groups of participants following concussion with different mechanisms of concussive injury. This study used data collected between January 1, 2017, and December 31, 2021.

Participants

Participants for this study included adolescents, age ranges of 10 to 18 years, who presented to physical therapy clinics at a major metropolitan children's hospital in the Midwestern United States. To be included in the study, the individual must have suffered a concussion injury between the ages of 10 to 18 years and be referred to physical therapy for management. Exclusion criteria included diagnosis of a more severe traumatic brain injury as evident by positive imaging findings indicating TBI versus concussion, concomitant injury (e.g. fracture), or incomplete or missing data for analysis.

Data

The following demographics and patient characteristics were collected from patient charts via the electronic medical record:

- Sex (male/female)
- Age (years)
- Time from injury date to physical therapy (PT) evaluation (days)
- Headache with cervical muscle palpation (positive or negative)
- Neck pain at the time of injury

Independent Variable

- Mechanism of Injury (MOI)
    - Sport related or non-sport related (MVA, fall, etc.)

Outcome Variables

- Cervical range of motion (CROM)
    - Cervical flexion, extension, lateral flexion to the left and right, rotation to the left and right (degrees)
    - Limited or Within Functional Limits (WFL)

- Post-Concussion Symptom Inventory (PCSI) total score will be the severity of the participant’s symptoms (total from 0 to 126) with higher scores being worse
    - PCSI sub score Headache severity of symptom (total from 0 to 6)
- Pediatric Quality of Life (PedsQL™)
    - Physical Functioning (8 items)

Instruments

Cervical Range of Motion (CROM)

The cervical range of motion of participants was measured utilizing a CROM device. This device has demonstrated good test-retest reliability and validity (Audette et al., 2010). For cervical range of motion, the degrees measured were examined both as a continuous variable and as a dichotomous variable classified as “within functional limits” (WFL) or not. Smith et al. (2016) examined a healthy, adolescent cohort as part of baseline testing preseason and was utilized to determine the ROM cut points for values that would be considered WFL or limited for the current study. The authors (Smith et al., 2016) aimed to develop normative values for cervical ROM and suggested that scores at or below the 40th percentile may be abnormal. For example, their reference values from Table 2 of their study for the 40th percentile for cervical extension was 70 degrees (Smith et al., 2016). Therefore, those individuals in our study with less than or equal to 70 degrees of cervical extension was considered “limited” and the 40th percentile was used for all cervical ranges of motion. The dichotomization of these variables may be more clinically relevant to providers.

Patient Reported Outcome Measures

For this study, two patient-reported measurement tools, the PedsQL™ and PCSI, were utilized. These tools are free to use; however, the PedsQL™ requires licensing rights which was provided through the primary researcher's (J. H.) institution.

Post-Concussion Symptom Inventory

A critical component to the assessment and management of concussion is the tracking of patient symptoms. The Post-Concussion Symptom Inventory (PCSI) is a symptom-reporting tool that can be used in youth after concussion. The 21-item scale measures the severity of symptoms after concussion on a Likert scale with scores that range from 0 (no symptoms at all) to a maximum score of 124. The scale has been shown to be reliable and valid for determining concussed versus non-concussed individuals in the younger population (Gioia et al., 2009; Sady et al., 2014). The most common reported symptom following a concussion is headache (Duhaime et al., 2012; Ellis et al., 2015; Emery et al., 2021; Grabowski et al., 2017; Marar et al., 2012; Quatman-Yates et al., 2020). In a study by Büttner et al. (2020), nearly 25% of patients perceived that headache and dizziness had an adverse effect on their quality-of-life scores. In a large, longitudinal study of youth hockey players after concussion, authors noted that several factors, including greater symptom severity and headache severity, were significant predictors of longer clinical recovery (Emery et al., 2021).

The PCSI includes unique self-reports for children ages 5-7 (5 items), 8-12 (17 items) and 13-18 (21 items) years of age (Sady et al., 2014). Symptom checklists, like the PCSI, have been recommended for monitoring recovery and should be age-appropriate (Quatman-Yates et al., 2020). Responses for the scale for those age 8 years and above utilizes a 7-point Likert scale measuring the severity of the symptom being reported with 0 being "not a problem" and 6 being "severe problem" and are totalled to provide a total PCSI score; the final question is ranked on a

5-point Likert scale with 0 being "no different" and 4 being "very different" for the patient's overall difference since their injury. The scale has been shown to be reliable and valid for determining concussed versus non-concussed youth patients (Gioia et al., 2009; Sady et al., 2014). There are some limitations to the total PCSI score's ability to provide reliable change measures as some symptoms that are not endorsed (e.g. loss of consciousness, vomiting) are recommended to still be included due to potential for more severe injury assessment (Sady et al., 2014). The total post-concussion symptom score has previously been associated with prolonged recovery (Meehan et al., 2014) and may advise clinical decision-making. Test-retest reliability of the PCSI total score over a 2-week interval was shown to be moderately high (ICCs = 0.65 – 0.89) and the internal consistency was strong between post-concussion symptom scales (α = 0.8-0.9) (Sady et al., 2014).

Pediatric Quality of Life

The PedsQL™ includes a physical functioning subscale which contains eight items examining the patient's ability to perform various physical activities. Participants rate their ability or inability to perform an activity from "Never" to "Almost Always" which provides a raw score from 0 to 4. These items are reverse scored from the sum of the items over the number of items answered and then converted into a 0 to 100 scale. The total scale score (23 items) has been found to be reliable and valid in distinguishing between healthy children and children with chronic conditions (Varni, 2021). In a sample examining healthy children and acutely or chronically ill children, participants considered healthy scored an average of 84.41, acutely ill 78.88, and chronically ill 77.36 on the physical health portion of the PedsQL™ (Varni et al., 2001). Prior work on a large, populated-based survey of children from the state of California demonstrated that QOL scores less than or equal to 72.98 on the PedsQL™ were impaired (Varni et al., 2003). A change in the PedsQL™ physical functional score of 4.4 with other musculoskeletal conditions (Grigoriou et al, 2015) to 6.66 represents a clinically important difference (Varni et al., 2003).

Procedures

Informed Consent

Informed consent was not needed for this study. All subjects enrolled in Cincinnati Childrens Hospital OTPT registry as part of the parent study (IRB 2014-6879) which permits information in their medical record to be included in a retrospective observational study. All subjects agreed to have their patient data included in a division wide registry at the time of their physical therapy evaluation as part of a patient registry process, thus allowing inclusion of their medical data absent a unique, study specific informed consent. As a result, additional consent is not required since the research presents no greater than minimal risk.

Data Collection

Following IRB approval and in accordance with OT/PT Divisional Patient Registry (IRB 2014-6879), patient background data and clinical data outlined above was obtained for the period of January 1, 2017, and December 31, 2021. Beginning in 2014, the institution's OT/PT/TR division formalized the development of a patient data registry by creating an infrastructure and extraction processes to support high-quality data capture and analysis for patient visits. Specific to patients with concussion, all physical therapists were trained to perform a systematic and reliable approach for management from evaluation to treatment.

For this retrospective study, use of the electronic medical record system served as the source for data collection. Patients were identified via selection of an outcome tracking tool, "Concussion", within the electronic medical record chart by the physical therapist. Additional checks for missing participants were used by cross-checking referrals to physical therapy with "concussion" as the diagnosis. These records and corresponding descriptive and outcome variables were exported into a Microsoft Excel document by the primary researcher. For missing or incomplete data, a manual review of the record for non-discreet documentation of the data was completed when appropriate (e.g., pain not reported in intake/pain section, however typed into subjective history "pain is 3/10"). All other decisions regarding missing or incomplete data that could not be sourced from the electronic medical record system, whether discreet or not, was discussed amongst the research team to come to a consensus.

Patient records were de-identified and the electronic file was kept on password-protected network drive only available to research staff and the primary researcher. Participants whose records were ineligible for use in this study were removed and the process for documenting this procedure was followed and reported to the IRB as necessary.

One limitation of all studies involving electronic medical records data is the extent to which the data can be trusted. As mentioned previously, all clinicians complete competency training for reliable and valid measures taken across sites. In addition, education is provided twice annually to ensure management strategies for various populations, including concussion, are enhanced or maintained. Finally, the electronic medical record system was designed to maximize the utility of the data being entered by the clinicians who received this training.

Data Management

Several continuous variables were utilized within this study and were treated as such for the analysis. In addition to analysis as continuous variables, categorization of the variables was conducted to analyse differences between dichotomous or categorical variables. For cervical range of motion, the degrees measured were examined as a continuous variable, and were also examined as a dichotomous variable of "within functional limits" (WFL) or not. Smith et al. (2016) was utilized to determine the ROM cut points for values that would be considered WFL or not within the patient dataset. The independent variable of mechanism of injury was categorized as sport-related concussion (SRC) and non-sport-related concussion (nSRC). Sport-related concussions were injuries that occurred during organized sports. Patients classified as nSRC included individuals with mechanisms of injury documented within the electronic medical record (EMR) including motor vehicle accident (MVA), recreational activities (e.g., playground injury), or other (e.g. fall or hitting head on furniture).

Demographic and clinical data of interest listed above were exported from the EMR to Microsoft Excel for ease of quality check and analysis. Data was extracted and maintained according to the registry protocol in a password-protected, access-controlled drive to which only study staff had access.

Statistical Analysis

Descriptive statistics were used to describe the following demographic and participant characteristics: sex, age, average time from injury date to physical therapy, and mechanism of injury. All comparisons were two-tailed and an alpha level of less than .05 was considered statistically significant.

To achieve study objective one, independent *t* tests were used to determine if differences exist in the cervical range of motion values measured in degrees between patients with SRC and nSRC. In addition, chi-square tests were conducted to determine differences in the presence of each dichotomous variable between SRC and nSRC. Those dichotomous musculoskeletal components include neck pain at time of injury, presence of "limited" cervical range of motion in all planes, and change (yes or no) in headache symptoms with palpation.

To achieve study objective two, independent t tests were used to determine if differences exist in the patient reported outcome variables of PCSI and PedsQL™ total scores. In addition, Chi-square tests were conducted to determine differences in the presence of each symptom (dizziness and headache) between SRC and nSRC.

To achieve study objective three, linear and logistic regression analyses were used to determine if mechanism of injury predicted any one of the dependent variables. Linear regression was utilized to examine the ability of MOI to predict the continuous dependent variables. Binomial logistic regression was conducted for those categorical dependent variables. In addition, for the continuous dependent variables, separate linear regression was analyzed to evaluate the interaction of demographic variables with each of the continuous dependent variables.

To indirectly assess clinical relevance, effect sizes were calculated and interpreted based on recommendations of Cohen (1992). Guidelines from Laerd Statistics were used to address test assumptions (Laerd Statistics, n.d.). For large datasets, it has been argued that normality of the data should be considered but does not have to be satisfied to choose between parametric or non-parametric tests, specifically with the use of independent t-tests (le Cessie et al., 2020). Equality of variance between groups was determined utilizing Levene's test for normality. Data was analysed using IBM SPSS Statistics for Windows, Version 28.0 (IBM Corp., Armonk, NY).

Results

Out of 665 records collected, 505 met the criteria for analysis. Figure 1 demonstrates the flowchart for criteria exclusion and Table 1 represents the demographic breakdown amongst the patient records examined. There were 256 patients in the SRC group with a mean age of 14.75 years (SD = 2.07), average time to PT 42.73 days (47.15), and 58% of the group being female. There were 249 patients in the nSRC group with a mean age of 15.07 years (SD = 2.18), average time to PT 45.69 days (SD = 61.38), and 68% of the group being female.

Objective 1 Results

For study objective one, differences in cervical ROM between nSRC and SRC were examined. Results can be found in Table 2. All patients who had cervical ROM recorded as a continuous variable were included in the analysis. Patients with nSRC had significantly less cervical extension (p = .010), cervical lateral flexion left (p = .043), cervical lateral flexion right (p = .009), and cervical rotation left (p = .039) than patients with SRC. Cervical rotation to the right trended towards statistical significance (p = .053). Cervical flexion (p = .846) was the only cervical range of motion value that was not significantly different between the two groups.

In addition, for study objective one, a chi-square test was performed to examine relationships between MOI (nSRC vs SRC) and each dichotomous variable inclusive of cervical ROM values listed as “within functional limits” (WFL) or “limited”, neck pain at the time of injury (yes or no), and palpation change in headache (yes or no).” See Table 3 for results. There are a greater proportion of patients after nSRC with “limited” cervical extension ($\chi^2(1)$ = 4.530, p = .033) and cervical rotation left ($\chi^2(1)$ = 4.013, p = .045). There are a greater proportion of patients after nSRC with neck pain at the time of injury ($\chi^2(1)$ = 5.094, p = .024). In addition, there was a trend toward significance for cervical rotation to the right ($\chi^2(1)$ = 3.338, p = .068).

Objective 2 Results

For study objective two, differences in the patient-reported outcomes measures of PCSI and PedsQL™ were examined between patients with SRC and nSRC . Results can be found in Table 4. When examining PCSI score, 198 patients in the SRC group and 173 patients in the nSRC group successfully completed the PCSI and were included in the analysis. For differences in PCSI between groups, the assumption of homogeneity of variances was violated, as assessed by Levene's test for equality of variances (p <.001). Patients in the SRC group had significantly lower (better) scores (p < .001) than those in the nSRC group. The PCSI scores were lower (better) in the SRC group (mean 28.75) than those in the nSRC group (mean 43.02).

There were 233 patients in the SRC group and 221 patients in the nSRC group for examination of PedsQL™ scores. For differences in PedsQL™ scores between groups, there was homogeneity of variances, as assessed by Levene's test for equality of variances (p = .677). The PedsQL™ scores were significantly higher (better) in the SRC group (p <.001). The mean PedsQL™ score for patients after nSRC was 56.16 and for patients after SRC was 64.90.

A chi-square test was performed to examine relationships between MOI (nSRC vs SRC) and the presence of headache or dizziness symptoms. See Table 5 for results. There were a greater proportion of patients after nSRC with the presence of headache than those who suffered a SRC ($\chi2(1) = 9.496$, p = .002). Patients who suffered a nSRC were more likely to present with a headache at the time of physical therapy evaluation.

Objective 3 Results

For study objective three, mechanism of injury (SRC and nSRC) was independently examined to see if it was able to predict the measures of cervical ROM, PedsQL™ score, and

PCSI total score at the time of initial physical therapy evaluation. Results can be found in Tables 6 and 7. The mechanism of injury predicted cervical extension ROM, $F(1, 399) = 6.78$, $p = .010$, left cervical lateral flexion ROM, $F(1, 410) = 4.12$, $p = .043$, right cervical lateral flexion ROM, $F(1, 410) = 6.99$, $p = .009$, and left cervical rotation ROM, $F(1, 360) = 4.28$, $p = .039$, with patients after nSRC demonstrating less cervical motion for each variable than patients after SRC. Despite statistical significance, the mechanism of injury accounted for a low percentage of variability, specifically 1.7% of cervical extension, 1% of left cervical lateral flexion, 1.7% of right cervical lateral flexion, and 1.2% of left cervical rotation. The mechanism of injury did not significantly predict cervical rotation right ROM, $F(1, 360) = 3.76$, $p = .053$. The mechanism of injury significantly predicted PCSI, $F(1, 369) = 26.54$, $p < .001$, accounting for 6.7% of the explained variability in PCSI. The mechanism of injury significantly predicted PedsQL™, $F(1, 452) = 17.88$, $p < .001$, and accounted for 3.8% of the explained variability in PedsQL™.

A multiple linear regression was constructed to determine if mechanism of injury predicted continuous cervical range of motion values while considering sex, age, and time to physical therapy. Results can be found in Table 8. The multiple regression model significantly predicted total cervical extension ROM, $F(4, 396) = 4.710$, $p = .001$, adjusted $r^2 = .036$. Only age and time to PT added to the statistical significance of the model ($p < .05$). The multiple regression model significantly predicted right cervical lateral flexion ROM, $F(4, 407) = 2.546$, $p = .039$, adjusted $r^2 = .015$. Only mechanism of injury was found to significantly contribute to the model, ($p < .05$) for right cervical lateral flexion ROM.

A multiple linear regression was additionally constructed to determine if mechanism of injury was able to predict the PedsQL™ and PCSI scores while considering sex, age, and time to physical therapy. Results can be found in Table 9. The multiple regression model significantly predicted PCSI, $F(4, 366) = 11.084$, $p < .001$, adjusted $r^2 = .098$. Only sex and age contributed significantly to the model ($p < .05$) for PCSI. In addition, the multiple regression model significantly predicted PedsQL™ score, $F(4, 449) = 5.616$, $p < .001$, adjusted $r^2 = .039$. Only mechanism of injury contributed significantly to the model ($p < .05$) for PedsQL™ score.

Additionally, for objective three, separate and independent binomial logistic regression analyses were used to examine the predictive ability of mechanism of injury on the presence of impairments or symptoms that patients with nSRC and SRC may exhibit. Dichotomous variables included limited ROM, reproduction of headache with palpation, and neck pain at the time of injury. These results can be found in Table 9. The logistic regression model for presence of limited cervical extension was statistically significant, $\chi2(1) = 4.492$, $p = .034$. The model explained only 1.7% (Nagelkerke R2) of the variance in the presence of limited cervical extension ROM and correctly classified 73.8% of cases. Similarly, the logistic regression model for presence of limited cervical left rotation was statistically significant, $\chi2(1) = 4.000$, $p = .046$. The model explained only 1.2% (Nagelkerke R2) of the variance in the presence of limited cervical left rotation ROM and correctly classified 60% of cases. Lastly, the logistic regression model for neck pain present at the time of injury was statistically significant, $\chi2(1) = 5.077$, $p = .024$. The model explained only 1.4% (Nagelkerke R2) of the variance in the those presenting with neck pain at the time of injury and correctly classified 55% of cases. The odds of having the presence of headache are 2.5 times greater for patients with nSRC than SRC. The odds of having limited cervical extension ROM were 1.6 times greater for patients with nSRC than SRC. The odds of having limited left cervical rotation ROM were only 1 time greater for patients with nSRC than SRC. Lastly, the odds of having neck pain at the time of injury were 1.1 times greater for patients with nSRC than SRC.

A binomial logistic regression was used to ascertain the effects of mechanism of injury (SRC vs nSRC) on the likelihood that participants have the presence of each headache or dizziness symptom. Results can be found in Table 10. The logistic regression model for presence of headache was statistically significant, $\chi2(1) = 9.074$, $p = .003$. The model explained only 4.4% (Nagelkerke R2) of the variance in the presence of headache and correctly classified 83.9% of cases. The odds of having the presence of headache symptoms are 2.5 times greater for patients with nSRC than SRC.

Discussion

This retrospective study aimed to determine if common physical therapy objective values and patient-reported outcomes were different based on mechanism of injury (SRC compared to nSRC) among adolescents after concussion. There were 256 patients represented in the SRC group and 249 patients in the nSRC group. The present study was able to determine that there does appear to be significant differences in cervical spine impairments and patient-reported outcome measures between patients with SRC and nSRC. In addition, the mechanism of injury was able to predict four of the six cervical spine ROM measurements, PCSI score, and PedsQL™ score. Similarly, mechanism of injury was able to predict the presence of range of motion limitations for most cervical spine motions as well as predict the likelihood of neck pain at the time of injury and the presence of headache at the time of physical therapy evaluation.

Cervical Spine Range of Motion Impairments

The American Physical Therapy Association's Clinical Practice Guideline on Concussion highlighted the importance of a thorough cervical spine exam as a crucial, initial step in a comprehensive concussion examination (Quatman-Yates et al., 2020). The findings for cervical spine impairments after a concussion have been well-documented (Duhaime et al., 2012; Ellis et al., 2019; Kennedy et al., 2019; Kennedy et al., 2017; Quatman-Yates et al., 2020; Schneider et al., 2018; Schneider et al., 2014; Tiwari et al., 2019)). The results of the current study indicate that patients with nSRC have statistically significant differences in ROM than those with SRC. Patients after an nSRC appear to have statistically significant reductions in their ROM for cervical extension, cervical lateral flexion to the left and right, and cervical rotation to the left with a trend towards significance for cervical right rotation. The current study appears to be the first to examine these differences based on classifying adolescents by SRC and nSRC. Tiwari et al. (2019) characterized their findings of cervical spine impairments in a young cohort of patients after concussion as limitations being present or not present. In their study it was reported that over 70% of patients had upper cervical mobility impairments which is known to contribute to much of the available cervical rotation in patients (Tiwari et al., 2019). Their study also examined a young cohort of individuals after concussion and found similar results to the current study for deficits in cervical rotation ROM.

Ellis et al. (2015) described impairment-based groups for patients after concussion and included cervicogenic post-concussion disorders as one of those groups. The APTA's Neck Pain Revision Clinical Practice Guideline (CPG) (Blanpied et al, 2017) also highlighted common findings for patients who may fit into the categories of neck pain with headache (cervicogenic). The highlights from the CPG include having a mechanism of injury linked to trauma, presence of headache and/or dizziness, and limited cervical ROM (Blanpied et al., 2017). The current study examined patients after a traumatic, concussive event and demonstrated that those with nSRC had limited cervical ROM as well, with both cervical extension and cervical rotation to the left being the only two cervical variables that were statistically significant when examined as a continuous (degrees of motion) and dichotomous (limited or WFL) variable.

In addition, those patients after nSRC were more likely to have neck pain at the time of injury. If we included analysis performed in our current study that also demonstrated presence of headache to be statistically significant between the two groups, it would appear that the nSRC group fit much of the criteria outlined by the APTA's Clinical Practice Guideline for cervicogenic headache. Further, a study by Jull et al (2007) discussed the major loss of motion to be primarily in the sagittal plan (cervical extension), followed by horizontal planes (axial rotation). This was featured as part of their clinical prediction rule (CPR) for cervicogenic headache with a reported sensitivity of 100% and specificity of 94% by clustering cervical ROM, manual examination of the upper cervical spine, and the cranio-cervical flexion test (Rubio-Ochoa et al., 2016). In the present study, cervical extension and rotation to the left were both found to be significantly different for the presence of the respective impairment and for the degrees of range of motion between the SRC and nSRC groups. While the results of the current study appear to demonstrate that the nSRC group demonstrates common characteristics outlined in the CPG and CPR for cervicogenic headache in the literature, the specific cervical ROM values and impairments for patients after concussion, especially younger patients, warrant further investigation.

Despite small differences between the groups, this study highlights that clinicians could expect differences between those with SRC and nSRC and careful examination of range of motion values with reliable tools (e.g., CROM). Smith et al. (2016) noted that when evaluating an athlete with reduced cervical motion (notably the 40th percentile or lower) clinicians should probe further into those factors contributing to the decreased motion. While the cervical ROM values presented in this study were statistically significant and different between the groups (SRC and nSRC), these values may not be clinically meaningful as their mean differences (Table 2) of approximately 3 and 4 degrees do not exceed suggested MCID's for cervical extension or rotation. (Jørgensen et al., 2017).

Patient-Reported Outcomes

Post-Concussion Symptom Inventory

The use of post-concussion symptom scales has been the hallmark of concussion management strategies and is supported by a number of consensus statements (McCrory et al., 2017; McCrory et al., 2013) and clinical practice guidelines following concussion and mild traumatic brain injury (Quatman-Yates et al. 2020; Marshall et al., 2012). The present study found a significant difference between mechanism of injury and PCSI total score with those individuals suffering an nSRC having worse total PCSI scores as compared to those with SRC. The mean PCSI for individuals suffering from a SRC was 28.75 as compared to those with a mechanism of nSRC at 43.02. The current study's' differences between the nSRC and SRC groups exceed the reported MCID's found in the literature of between 7 and 10 points on the PCSI (Cheever et al., 2019; Johnston et al., 2015; Sufrinko et al., 2018). It is well-established that high symptom severity reports have been shown to have poor prognostic indicators of recovery (Emery et al., 2021, Zemek et al., 2016). In our study, having an nSRC versus a SRC suggests the patient could present with higher/worse symptom reporting at the time of physical therapy evaluation. These high symptoms reports may lead to their episode of physical therapy care taking longer to recover. While outside the scope of the current study, future work could examine differences in recovery trajectories between these groups based on initial total symptom reports.

The most common reported symptom following a concussion is headache (Duhaime et al., 2012; Ellis et al., 2015; Emery et al., 2021; Grabowski et al., 2017; Marar et al., 2012; Quatman-Yates et al., 2020). Headache was also the most common symptom reported at the time of physical therapy evaluation for young patients after concussion (Tiwari et al., 2019). The present study would suggest that if you suffered an nSRC that you were more likely to present with a headache at the time of physical therapy evaluation as compared to those with SRC. The presence of this symptom has previously been shown to be one of a few factors related to protracted recovery in younger patients (Zemek et al., 2016).

Both groups in the present study had a large percentage of patients that reported the presence of headache upon physical therapy evaluation, with nSRC being at 90.2% and SRC at 78.4%. These findings are similar to a prior study which noted "high occurrence of headaches (84%) and dizziness (57%) among the patients in this study" (Tiwari et al., 2019, p. 291). The authors of the prior study also commented on the percentage of these symptoms and relationship to the cervical spine impairments (most notably the upper cervical spine), as an additional reason to thoroughly examine the cervical spine in a population of adolescents after concussion. While the presence of dizziness was not significant between SRC and nSRC, our study also noted similar reports of dizziness, 64.7% and 58.8%, for nSRC and SRC. Both studies highlight the high symptom reports of both headache and dizziness in young patients after concussion and support the challenges associated with the cervical spine and these confounding symptom reports common after concussion.

Pediatric Quality of Life (PedsQL™)

In a study by Büttner et al. (2020), nearly 25% of patients perceived that headache and dizziness had an adverse effect on their quality-of-life scores. Pieper & Garvan (2013), however, found that health-related quality of life scores for children after mild traumatic brain injury (mTBI), or concussion, were not significantly different between times points of 1-, 3-, 6-, and 12-months post-injury and that children tended to rate themselves lower than their parents on the Physical Health Functioning Score post-injury. Our present study looked at the Physical Health Functioning Score reported as PedsQL™ and found that there was a significant difference between nSRC and SRC on PedsQL™ scores. Those patients suffering an nSRC had lower/worse scores than those with SRC.

In addition, the mechanism of injury was significantly able to predict PedsQL™ scores. Clinically it is important to note the myriad of challenges patients face after concussion, not just with those deficits and impairments discovered during a physical therapy evaluation. PedsQL™ measures can help ensure a more robust examination of how the child's overall well-being, including the Physical Health Functioning Score, is impacting their initial present and subsequent recovery after concussion. A study by Houston et al. (2016), demonstrated average measures of PedsQL™ Physical Health Functioning Scores at Day 10 returned to mean baseline scores in a cohort of young patients after concussion.

Mechanism of Injury as a Predictor

Cnossen et al. (2018) looked at factors related to prediction of persistent post-concussion symptoms. The authors found that presence of neck pain and headache at the time of injury significantly improved their model at predicting who would and would not go on to have persistent post-concussion symptoms and only neck pain was significantly associated with persistent post-concussion symptoms at 6 months (Cnossen et al., 2018). Since their model used data taken at the emergency department (ED), this study's findings could be viewed similarly to our documented findings of neck pain at the time of injury. The current study found neck pain at time of injury to be significantly associated with mechanism of injury for those sustaining an nSRC. The current study also found that mechanism of injury was able to able to predict the presence of neck pain as patients with a nSRC were more likely to have neck pain at the time of physical therapy evaluation (p = .024).

When examining the ability of mechanism of injury, nSRC vs SRC, to predict other variables associated with the cervical spine, our data would also suggest lower ranges of cervical motion in degrees for all motions (p < .05) will be found for those with nSRC except for cervical rotation right, which trended towards significance (p = .053). When examining if mechanism of injury, nSRC or SRC, was able to predict if ROM was limited or WFL, our results indicated that if a patient suffered an nSRC only cervical extension (p = .034) and cervical rotation left (p = .046) were significantly different (more likely to be impaired) compared to the SRC group.

While the current study chose to focus on mechanism of injury and its ability to predict dependent variables, examination of the interaction of some of the demographic variables was also performed for those continuous variables (cervical motion and patient-reported outcomes). When examining the interaction of sex, age, time to PT (days), and mechanism of injury for cervical variables (Table 8), mechanism of injury was consistently the strongest predictors for all cervical ROM values, highlighting patients after nSRC were more likely to have reduced or limited cervical ROM. The exception was for cervical extension, with age (p = .038) and time to PT (p = .048) also contributing significantly to the model. As the age of the patient increases, they tend to have less cervical extension ROM. If the patient is closer to their time of injury, their cervical extension ROM is likely to be less as well. Surprisingly sex did not contribute to the model for cervical extension (p = .081) despite other studies demonstrating a higher incidence in females. Prior studies have pointed out the potential reason for a higher likelihood of concussive injuries in females versus males in similar sports and would suggest neck strength and the inability to attenuate forces about the head and neck as potential contributors (Collins et al., 2014; Covassin et al., 2018). In addition, neck strengthening programs have been proposed to help mitigate risk of concussive injuries (Streifer et al., 2019), especially in females, because of the strong association of the female sex with concussive risk (Zemek et al.,). Recent systematic reviews indicates that the female sex and prior history of neck pain are the strongest and most consistent risk factors for new-onset neck pain in office workers and the general population (Blanpied et al., 2017). Future studies could examine neck strength and its influence on the dependent variables.

When the interaction of sex, age, and time to PT (days) were examined to determine the ability of mechanism of injury to predict patient-reported outcomes (PCSI and PedsQL™), only some of the factors examined demonstrated a significant interaction. Specifically, with PCSI scores, sex ($p = .010$), age ($p = .004$) and mechanism of injury ($p < .001$) contributed significantly to the predictive model. Zemek et al. (2016) also found several variables as part of a prediction model to determine persistent post-concussive symptoms (PPCS) at 28 days in younger children presenting to the emergency department. Some of the variables of interest related to our study, consistent with Zemek, included older age, specifically 13-18 years old, female, and headache at the time of presentation. For PedsQL™, only mechanism of injury contributed to the model ($p < .001$). Clinicians could therefore expect that older females (closer to 18) who suffered an nSRC and are presenting more recently after their concussive injury may report higher PCSI values. A study by Russel et al. (2019) found that those young patients after concussion who went on to have delayed recovery (>28 days) had clinically meaningful lower initial assessment PedsQL™ Physical Functioning scores as compared to those with normal recovery after SRC. Future studies could examine more closely other factors within the female population subsets and other potential confounding variables (history of depression or anxiety) which have also been noted to likely contribute to higher PCSI reports at the time of injury (Tator et al., 2016).

Overall, the regression models for nSRC and SRC predicting outcome variables explained extremely low percentages of the variance for any given variable. For example, the model explained only 1.7% (Nagelkerke R2) of the variance in the presence of limited cervical extension ROM. Ultimately, there were significant differences in the variables we examined between those patients after nSRC versus SRC at the time of physical therapy assessment. However, it appears these differences may lack significant clinical relevance and demonstrate small effect sizes overall. While the current study would suggest that there is a difference at the time of physical therapy presentation between patients, based on mechanism of injury, there is still more work to be done on identifying those contributing factors for cervical musculoskeletal deficits and poor patient-reported outcome scores.

Limitations

It is important to acknowledge the limitations of the current study. This was a retrospective chart review of concussion patients presenting to a metropolitan pediatric hospital for physical therapy examination and therefore results of this study may not be generalizable to populations outside of the pediatric population. In addition, it is difficult to control for many of the factors that can contribute to a patient's initial presentation to physical therapy which includes family history, personal medical history or comorbidities, and prior management strategies which may include treatments aimed at musculoskeletal and post-concussive symptom complaints; each of these could have profound effects and would be difficult to discern what, if any, effect that would have had on their presentation.

There may be other differences whose influence we are unable to measure or gauge for those who suffered their injury through sport versus non sport including intrinsic and extrinsic factors related to recovery from any injury. It is important that a thorough subjective history of the events, personal and familial medical history, patient's prior recovery trajectories from musculoskeletal or prior concussions, and patient primary complaints are elicited as they may advise much of the physical therapy assessment, regardless of diagnosis. These details and factors are sometimes challenging to capture within the electronic medical record and could have a significant influence on the findings of the current study. Therefore, these variables should remain a mainstay for the clinician to inform evaluation and prognostic decisions on an individual basis. Neck pain at the time of injury and presence of headache, whether at the time of injury or presentation to physical therapy, are noteworthy for the examining clinician and must be managed accordingly.

The current study was only able to comment for those variables of interest at the time of physical therapy evaluation at our facility and could possibly serve as exclusionary criteria for future studies to control for outside factors such as additional treatments. For cervical ROM values, all values except cervical flexion, were significantly different between mechanism of injury, SRC and nSRC, and some ROM values were able to be predicted based on mechanism of injury. With mean differences being small between nSRC and SRC, clinicians should approach their examination of the cervical spine with the thoroughness described by the Cervical Clinical Practice Guideline and other sources as part of a comprehensive examination. The overall values of cervical ROM differences, however, may not be clinically meaningful with this population.

Additional future studies should examine the effect of all initial presentation variables from this study and their relationship to patient's 30 day and discharge presentation during an episode of management in the healthcare system.

Conclusion

This study contributes to the body of evidence that mechanism of injury influences the initial presentation to physical therapy of youth after a concussive injury. While the exact process by which mechanism of injury (SRC or nSRC) contributes to a patient's presentation remains unknown, there appears to be some difference between these groups for cervical values and patient-reported outcome scores. This study would suggest that cervical examination measures and patient-reported outcome measures like the PCSI and PedsQL™ are important to capture at the time of physical therapy evaluation and that differences may exist in these variables between patents who have suffered a SRC vs nSRC.

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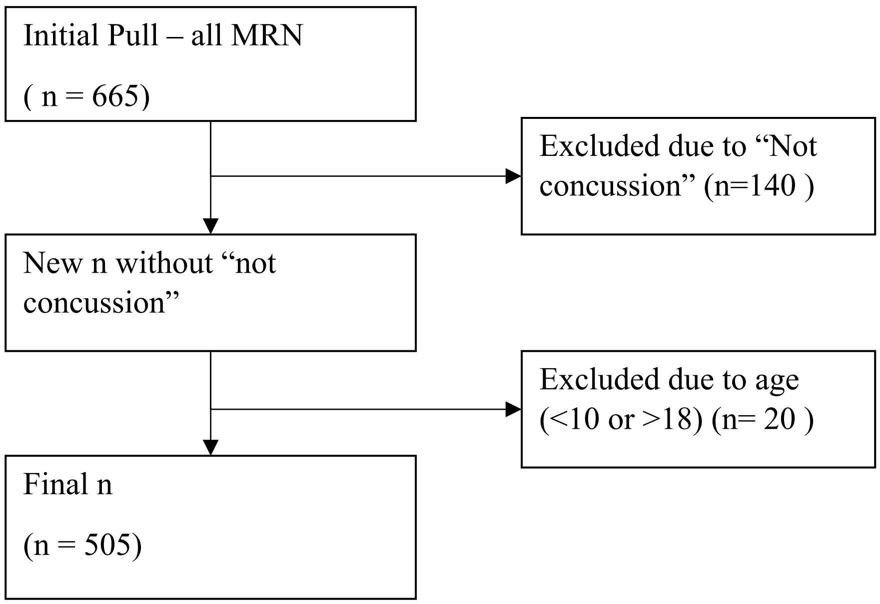
Figure 1

Patient Flowchart for Exclusion



Note. MRN = Medical Record Number

Table 1: Demographic Characteristics of Patients in SRC and nSRC

	SRC N = 257	nSRC N = 248	
	N (%)	N (%)	Total
Age (years)	14.75 (2.07)	15.07 (2.18)	
Sex			
Male	107 (42%)	80 (32%)	187
Female	150 (58%)	168 (68%)	318
Total	257	248	505
Time to PT (days)	42.73 (47.15)	45.69 (61.38)	

Note. SRC = Sport-Related Concussion, nSRC = not Sport-Related Concussion

Table 2

Cervical Range of Motion Differences based on Mechanism of Injury

	SRC		nSRC				
	M	SD	M	SD	T (df)	*p*	Cohen's *d*
Cervical Flexion	59.57	14.844	59.28	14.934	(398) .195	.846	.019
Cervical Extension	63.49	15.756	59.20	17.235	(399) 2.603	.010*	.260
Cervical LF Left	45.15	12.086	42.84	11.055	(410) 2.030	.043*	.200
Cervical LF Right	45.75	11.298	42.89	10.628	(410) 2.643	.009*	.260
Cervical Rotation Left[a]	67.16	12.523	64.15	15.000	(348.874) 2.069	.039*	.218
Cervical Rotation Right	67.32	13.023	64.53	14.317	(360) 1.940	.053	.204

Note. MOI = Mechanism of Injury (Sport-Related Concussion = 1, not Sport-Related Concussion = 2), df = degrees of freedom, LF = Lateral Flexion

a Equal variances not assumed ($p < .05$)

*$p < .05$.

Table 3

Limited vs WFL Cervical Range of Motion Differences based on Mechanism of Injury

	Mechanism of Injury	Limited	WFL	*p*
		N (%)	N (%)	
Cervical Flexion (x≥60°)	nSRC	82 (41%)	118 (59%)	.839
	SRC	84 (42%)	116 (58%)	
Cervical Extension (x≥71°)	nSRC	157 (78.5%)	43 (21.5%)	.033
	SRC	139 (69.2%)	62 (30.8%)	
Cervical Lateral Flexion Left (x≥46°)	nSRC	129 (61.7%)	80 (38.3%)	.064
	SRC	107 (52.7%)	96 (47.3%)	
Cervical Lateral Flexion Right (x≥46°)	nSRC	126 (60.6%)	82 (39.4%)	.096
	SRC	107 (52.5%)	97 (47.5%)	
Cervical Rotation Left (x≥69°)	nSRC	102 (44.5%)	127 (55.5%)	.045
	SRC	81 (35.4%)	148 (64.6%)	
Cervical Rotation Right (x≥68°)	nSRC	97 (42.4%)	132 (57.6%)	.068
	SRC	78 (34.1%)	151 (65.9%)	
Neck Pain Time of Injury	nSRC	140 (57.1%)	105 (42.9%)	.024
	SRC	119 (47%)	134 (53%)	
Headache with Palpation	nSRC	63 (40.4%)	93 (59.6%)	.236
	SRC	82 (46.9%)	93 (53.1%)	

Note. WFL = Within Functional Limits; nSRC = not Sports-Related Concussion; SRC = Sports-Related Concussion

Table 4

Patient Reported Outcome Differences based on Mechanism of Injury

	SRC		**nSRC**				
	M	SD	M	SD	t(327.553)	*p*	Cohen's *d*
PCSI	28.75	23.62	43.02	29.67	-5.075	<.001	-.536
	M	SD	M	SD	t(452)	*p*	Cohen's *d*
PedsQL	64.90	22.08	56.16	21.96	4.228	<.001	.397

Note. MOI = Mechanism of Injury (Sport-Related Concussion = 1, not Sport-Related Concussion = 2), PedsQL = Pediatric Quality of Life Physical Health Functioning

Table 5

Proportion Differences for Presence of Headache or Dizziness based on Mechanism of Injury

	Mechanism of Injury	**Symptom Present**	**Not Present**	***p***
		N (%)	N (%)	
Headache	nSRC	156 (90.2%)	17 (9.8%)	.002
	SRC	156 (78.4%)	43 (21.6%)	
Dizziness	nSRC	112 (64.7%)	61 (35.3%)	.240
	SRC	117 (58.8%)	82 (41.2%)	

Note. nSRC = not Sports-Related Concussion; SRC = Sports-Related Concussion

Table 6

Linear Regression Predicting Cervical Range of Motion based Independently on Mechanism of Injury

	R^2		**Beta**	**SE**	**95% CI**		**β**	***p***
					LL	**UL**		
Cervical Extension	.017	Constant	67.780	2.605	62.658	72.902		<.001
		MOI	-4.293	1.649	-7.534	-1.051	-.129	.010
Cervical Lateral Flexion Left	.010	Constant	47.468	1.811	43.907	51.029		<.001
		MOI	-2.315	1.141	-4.558	-.073	-.100	.043
Cervical Lateral Flexion Right	.017	Constant	48.601	1.713	45.233	51.969		<.001
		MOI	-2.856	1.080	-4.980	-.732	-.129	.009
Cervical Rotation Left	.012	Constant	70.166	2.296	65.650	74.682		<.001
		MOI	-3.006	1.452	-5.862	-.149	-.108	.039
Cervical Rotation Right	.010	Constant	70.110	2.275	65.637	74.584		<.001
		MOI	-2.790	1.439	-5.619	.039	-.102	.053

Note. MOI = Mechanism of Injury (Sport-Related Concussion = 1, not Sport-Related Concussion = 2), CI = Confidence Interval, SE = Standard Error, LL = Lower Limits, UL = Upper Limits, β = Beta Coefficient, R^2 = R Square

Table 7

Linear Regression Predicting Post-Concussion Symptom Inventory and Pediatric Quality of Life based Independently on Mechanism of Injury

	R²		**Beta**	**SE**	95% CI		**β**	***p***
					LL	**UL**		
PCSI	.067	Constant	67.780	2.605	62.658	72.902		<.001
		MOI	-4.293	1.649	-7.534	-1.051	-.129	.010
PedsQL	.038	Constant	47.468	1.811	43.907	51.029		<.001
		MOI	-2.315	1.141	-4.558	-.073	-.100	.043

Note. MOI = Mechanism of Injury (Sport-Related Concussion = 1, not Sport-Related Concussion = 2), PCSI = Post-Concussion Symptom Inventory, PedsQL = Pediatric Quality of Life Physical Health Functioning, CI = Confidence Interval, SE = Standard Error, LL = Lower Limits, UL = Upper Limits, β = Beta Coefficient, R^2 = R Square

Table 8

Linear Regression Examining the Interaction Between Sex, Age, and Time to PT on Mechanism of Injury Predicting Cervical Range of Motion

					95% CI			
	Adj. R^2		**Beta**	**SE**	**LL**	**UL**	**β**	***p***
Cervical Extension	.036	Constant	82.864	6.389	70.304	95.424		<.001
		Sex	-3.019	1.726	-6.413	.375	-.088	.081
		Age (years)	-.800	.384	-1.555	-.044	-.103	.038
		Time to PT (days)	.028	.014	.000	.056	.098	.048
		MOI	-3.929	1.640	-7.154	-.705	-.118	.017
Cervical Lateral Flexion Left	.004	Constant	50.676	4.487	41.854	59.497		<.001
		Sex	-.577	1.211	-2.958	1.803	-.024	.634
		Age (years)	-.185	.269	-.713	.343	-.034	.491
		Time to PT (days)	.009	.010	-.011	.029	.045	.362
		MOI	-2.252	1.148	-4.509	.004	-.097	.050
Cervical Lateral Flexion Right	.015	Constant	52.469	4.241	44.133	60.806		<.001
		Sex	-1.235	1.145	-3.486	1.016	-.054	.281
		Age (years)	-.171	.254	-.670	.328	-.033	.501
		Time to PT (days)	.012	.009	-.007	.031	.062	.205
		MOI	-2.744	1.086	-4.878	-.610	-.124	.012
Cervical Rotation Left	.005	Constant	76.123	5.767	64.781	87.466		<.001
		Sex	.171	1.528	-2.834	3.176	.006	.911
		Age (years)	-.416	.345	-1.095	.263	-.064	.229
		Time to PT (days)	-.003	.013	-.028	.022	-.013	.804
		MOI	-2.920	1.462	-5.794	-.046	-.105	.046

Note. Sex = Male = 1, Female = 2, Age MOI = Mechanism of Injury (Sport-Related Concussion = 1, not Sport-Related Concussion = 2), CI = Confidence Interval, SE = Standard Error, LL = Lower Limits, UL = Upper Limits, β = Beta Coefficient, Adj. R^2 = Adjusted R Square for model

Table 9

Linear Regression Examining the Interaction Between Sex, Age, and Time to PT on Mechanism of Injury Predicting Post Concussion Symptom Inventory and Pediatric Quality of Life Scores

	Adj. R^2				95% CI			
			Beta	**SE**	**LL**	**UL**	**β**	***p***
PCSI	.098	Constant	-23.786	11.064	-45.542	-2.029		.032
		Sex	7.369	2.860	1.745	12.993	.128	.010
		Age	1.888	.656	.598	3.177	.143	.004
		Time to PT	-.021	.025	-.070	.027	-.043	.385
		MOI	13.426	2.730	8.058	18.794	.244	<.001
PedsQL	.039	Constant	73.747	7.994	58.037	89.456		<.001
		Sex	-3.621	2.168	-7.881	.639	-.079	.096
		Age	.285	.490	-.678	1.248	.027	.562
		Time to PT	.026	.019	-.010	.063	.066	.156
		MOI	-8.521	2.084	-12.616	-4.425	-.190	<.001

Note. Sex = Male = 1, Female = 2, Age MOI = Mechanism of Injury (Sport-Related Concussion = 1, not Sport-Related Concussion = 2), PCSI = Post-Concussion Symptom Inventory, PedsQL = Pediatric Quality of Life, CI = Confidence Interval, SE = Standard Error, LL = Lower Limits, UL = Upper Limits, β = Beta Coefficient, Adj. R^2 = Adjusted R Square for model, MOI = Mechanism of Injury (Sport-Related Concussion = 1, not Sport-Related Concussion = 2),

Table 10

Logistic Regression Predicting Likelihood of Presence of Cervical Spine Impairments based on Mechanism of Injury

		Beta	SE	Wald	*df*	*p*	Odds Ratio	95% CI for Odds Ratio	
								Lower	Upper
Cervical Extension	MOI	.488	.230	4.492	1	.034	1.629	1.037	2.557
	Constant	.807	.153	27.946	1	<.001	2.242		
Cervical Rotation Left	MOI	.384	.192	4.000	1	.046	1.467	1.008	2.137
	Constant	-.603	.138	19.020	1	<.001	.547		
Neck Pain TOI	MOI	.406	.180	5.077	1	.024	1.501	1.054	2.138
	Constant	-.119	.126	.888	1	.346	.888		

Note. MOI = Mechanism of Injury (Sport-Related Concussion = 1, not Sport-Related Concussion = 2), TOI = Time of Injury, SE = Standard Error, df = degrees of freedom, CI = Confidence Interval

Table 11

Logistic Regression for Mechanism of Injury Predicting Likelihood of Presence of Concussion Symptoms Headache or Dizziness

Note. MOI = Mechanism of Injury (Sport-Related Concussion, not Sport-Related Concussion),

		B	**SE**	**Wald**	***df***	***p***	**Odds Ratio**	**95% CI for Odds Ratio**	
								Lower	**Upper**
Headache	MOI	.928	.308	9.074	1	.003	2.529	1.383	4.626
	Constant	1.289	.172	55.978	1	<.001	3.628		
Dizziness	MOI	.252	.215	1.380	1	.240	1.287	.845	1.960
	Constant	.355	.144	6.091	1	.014	1.427		

SE = Standard Error, df = degrees of freedom, CI = Confidence Interval