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Does Implementing Neck Strengthening Exercises Reduce the Risk of Concussion?

Brandon M. Desrosiers
Bethel University

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BRANDON DESROSIERS

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BRANDON DESROSIERS

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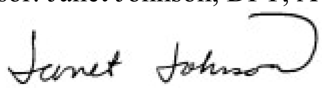
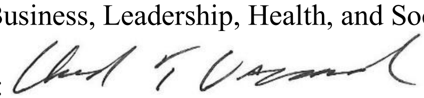
APPROVALS:
Project Advisor: Janet Johnson, DPT, ATC

Signature: 

Dean of Business, Leadership, Health, and Social Sciences: Chad Osgood, Ed.D., LAT, ATC

Signature: 

Program Director: Neal Dutton, MS, LAT, ATC

Abstract

Background: There is currently no standard process or preventative method to reduce the risk of concussions. Researchers have claimed that new helmet technology, q-collar necklace, and mouthguards can reduce concussions, but the evidence is lacking. Neck strength is emerging as a possible preventative method to help athletes decrease the likelihood of sustaining a concussion. The theory suggests that individuals with stronger neck muscles will engage their cervical muscles during a collision, reducing the deceleration of the head.

Purpose: The purpose of this paper is to answer the clinical question, does implementing neck strengthening exercises into an athlete's workout program reduce the risk of concussions in contact sports compared to athletes that do not implement neck strengthening exercises?

Results: Seventeen scholarly articles were analyzed using a matrix format and were evaluated with the PEDro Scale. 6 out of the 17 studies recommended neck strengthening exercises to reduce the risk of concussions; 7 suggested there was no benefit, and four articles were inconclusive.

Conclusion: The findings of this Critical Review show inconclusive evidence suggesting that there is not enough evidence to support implementing a neck strengthening program to reduce concussions. The five articles that supported the use of cervical neck strength programs to reduce the risk presented strong evidence, but seven articles did not support the research.

Implications for Research and Practice: Research has improved the ability to diagnose and treat concussions, but the current protocols established to help reduce the risk of head injuries are lacking. Athletic Trainers are encouraged to remain current with evidence-based practices and help advance future research. Further research is needed to obtain more *excellent* quality articles with a larger number of participants and acquire more data to determine the ability to improve neck-strength to reduce the risk of concussions.

Keywords: concussion, neck-strength, cervical-strength, exercises, prevention

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Chapter I: Introduction

A concussion is defined as a complex pathophysiological injury affecting the brain caused by traumatic biomechanical forces resulting in an impairment of neurological function, which can be caused by direct or indirect forces (Harpham et al., 2014 as cited in Honda et al., 2018). The Center for Disease Control (CDC) estimates approximately 1.6 to 3.8 million sports-related concussions (SRC), both treated and untreated, occur every year in the U.S. (Daneshvar et al., 2011). The importance of research on sports-related head injuries has increased due to the roughly 50,000 individuals who die each year from concussions or other traumatic brain injuries (Fazel et al., 2014). A recent study determined that of 111 NFL brains investigated, 110 of them had Chronic Traumatic Encephalopathy (CTE) (Pascual-Leone and Zafonte, 2019). CTE is a degenerative brain disease caused by repeated trauma to the brain. There is conflicting evidence suggesting that throughout a professional contact sport athlete's career, the repetitive blows to the head may cause the athlete to develop CTE (Concannon et al, 2014). The psychological effects of CTE can cause difficulty for individuals to function normally with their activities of daily living, often causing depression, which can lead to an increase in suicides (Daneshvar et al., 2011).

Although professional leagues are taking steps to prevent an athlete from returning to play after a concussion, there are still issues enforcing the rules. Every five out of ten concussions go undiagnosed or undetected and may become life-threatening if an athlete received a second hit to the head (Meehan et al., 2014). Many athletes tend not to report their symptoms after having a concussion because they fear missing time from their sport and the possibility of letting their teammates and coaches down (Weber-Rawlings et al., 2020). To increase athlete safety, better protocols such as a mandatory presence of an Athletic Trainer (AT) at a sports event should be implemented. There is no gold standard for diagnosing a concussion, leading to inconsistencies when diagnosing the injury. An AT may use various tools to assist in the diagnosis and treatment of concussions; however, due to the complex nature of the injury and subjective patient reports, these tasks remain difficult.

Presently, there is no standard process or preventative method to reduce an athlete's risk of sustaining a concussion (Graham et al., 2014). Researchers have claimed that new helmet technology, q-collar necklace, and mouthguards can reduce concussions, but the evidence is lacking (Graham et al., 2014). Neck strengthening exercises have emerged as a possible preventative method, which can help athletes decrease the likelihood of sustaining a mild traumatic brain injury (Toninato et al., 2018). The theory suggests that an individual with more robust neck musculature will engage their cervical muscles during a collision, which may help reduce the deceleration of the head. In other words, having stronger neck muscles will allow the head to experience less whiplash, and the brain will not move as violently within the skull. The ability to determine the effectiveness of a preventative method for concussions is significant for athletes' overall health.

Statement of Purpose

The purpose of this paper is to answer the clinical question, does implementing neck strengthening exercises into an athlete's workout program reduce the risk of concussions in contact sports compared to athletes that do not implement neck strengthening exercises? The effectiveness of neck-strengthening exercises in relation to concussion prevention will be determined by examining studies conducted on athletes who participated in a strict regimen of neck strengthening exercises compared to athletes who did not implement the exercises during their season. There has been limited research conducted on neck-strengthening exercises, which means that because of limited data, not all strength and conditioning coaches are implementing the exercises in workout programs.

Need for a Clinical Review

Research is continually progressing in the field of concussions, but there is still quite a bit to learn. As research continues to develop, the need to increase preventative methods to minimize traumatic brain injuries becomes more apparent. Many professional athletes have begun to publicly discuss the difficulties battling mental and physical damages that have been caused throughout their athletic careers due to head injuries (Sahler and Greenwood, 2014). In hockey alone, the world saw eight professional hockey players lose the battle caused by depression from concussions, which tragically ended with self-harm (Todd et al., 2018). Although depression does not occur for every individual, there is significant evidence suggesting the importance of focusing research on ways to prevent head injuries (Fann et al., 2009).

The media has also educated many individuals on the importance of understanding a concussion because of its effects on an individual's brain (Sahler and Greenwood, 2014). Many sports have seen decreased participation in younger populations because parents fear for their child's development and health (Merkel, 2013). For example, boxing is a sport that has experienced a decline in popularity over the past 20 years, which some suggest can be attributed to the long-term effects of repetitive collisions to the head (Bernick, & Banks, 2013). Concussion research could reignite high-collision sports popularity because it may help parents trust that their child will be safer.

Researchers have suggested that the type of headgear or mouthguard has little to no effect on the amount of diagnosed concussions (Graham et al., 2014). Previous research has focused on concussion-related side effects to determine methods to diagnose concussions and how to properly rehabilitate head injuries (Graham et al., 2014). To improve concussion management strategies, research has shifted its focus to exploring preventive methods to reduce the number of concussive impacts an athlete is exposed to (Register-Mikhalik et al, 2017). Concussions remain a hot topic in the field of sports medicine due to the risk of both short- and long-term effects. Research on the strength of an individual's cervical muscles has recently emerged as a method to prevent concussions (Honda et al., 2018). Research aimed at exploring preventative methods, such as neck strengthening exercises, is needed as it may be a strategy for reducing the annual number of concussion-related injuries.

Significance for Athletic Training

An AT is a highly qualified, multi-skilled health care professional who renders service or treatment under the direction of or in collaboration with a physician, in accordance with their education, training, and the state's statutes, rules, and relegations (NATA, n.d.). Services that an AT provides include primary care, injury and illness prevention, wellness promotion and education, emergent care, examination, and clinical diagnosis, therapeutic intervention, and rehabilitation of injuries and medical conditions (Kerr et al., 2015). An AT will typically be the first responder to an injured athlete during play and will most often be the individual in charge of determining whether the athlete sustained a concussion (Broglio et al., 2014). The AT is well-versed and has undergone the required education to diagnose the athlete with a concussion (Broglio et al., 2014). However, there is no gold standard for diagnosing a concussion, and there are many different tests that can be used to diagnose the athlete, which can lead to inconsistencies.

Research is significantly lacking within the field of concussions, and although it has had major developments, there is still much to learn. As concussion research continues, protocols and diagnostic tools will continuously need to be updated; this will cause diversity among what the AT believes to be the best possible way to diagnose or prevent concussions. Evidence-based practice must continue to be developed to establish consistency when diagnosing, preventing, and rehabilitating concussions. An AT can play a pivotal role in preventing athletic injuries, which can help keep athletes to stay healthy during a season.

Chapter II: Methods

This chapter will describe the search methods used to examine the research available on neck strengthening exercises as a preventative measure for concussions. The search strategies, criteria for inclusion or exclusion, summary of articles, and the criteria used to evaluate the articles will be discussed below.

Search Strategy

The main search engine used to find articles for this Critical Review of the Literature came from using Bethel's Athletic Training Resource Guide, which is provided to all Athletic Training students at Bethel University. The search engines included in this guide were PubMed, CINAHL, ERIC, Scopus, Cochrane Database of Systematic Reviews, Academic Search Premier, and Google Scholar. Several of the articles were found using the references of high-quality articles such as systemic reviews. Many of these references used high-quality articles in their reference list, which aided in the search process. The keywords used for the search engine included "concussion", "preventative", "neck strength", "cervical strength", "athlete", "youth", "sport", "hockey", "football", and "head injury". The initial results generated between 410 to 445 articles, with the most coming from PubMed and the least from CINAHL. The words that were then disregarded were hockey, football, and youth to broaden the search due to the lack of research articles available. With the inclusion of the word "sport", the results were narrowed down from articles less relevant to 151 on PubMed. The search term AND "athlete" narrowed the search results to 40, which is where the process of analyzing the articles began. In the advanced search section, the option to include only peer-reviewed articles was selected to help narrow the strength of the articles found from the larger range. Another modification made to the search engine was expanding the year of article publication to include one high-quality randomized controlled study (RCT) from 2005.

Inclusion and Exclusion

The inclusion and exclusion criteria were established to only use recent and relative articles for this literature review. For an article to be investigated for use in this literature review, the keywords of concussion, preventative, athlete, and neck or cervical strengthening were researched. All the athletic populations were surveyed, including youth, professional, and collegial athletes. There were no restrictions on the type of article type or design, although efforts were made to try to limit the use of other literature reviews.

The exclusion criteria eliminated the use of articles to remove the research that was not relevant to the critical review of the literature. Articles that focused more on cervical neck injuries or were subject to purchase were excluded from the literature review. The articles were all published between 2011 and 2019, with the exception of the RCT from 2005. Articles that were conducted in languages other than English and any study that was not peer-reviewed were also excluded.

Number and Types of Articles

There were 17 articles selected based on the inclusion criteria. The articles were then evaluated with the use of the John-Hopkins Evidence-Based Appraisal tool (JHEB). All of the articles were assessed as either excellent, good, fair, or poor.

The JHEB tool was the only appraisal tool used in the critical review of the literature in order to maintain consistency. JHEB categorizes the different types of studies into quantitative, qualitative, and mixed methods. After determining the type of category, the researcher must answer the evaluation questions with either “yes”, “no”, or “n/a”. After the category questions have been answered, the articles are then ranked as high quality, good quality, or low quality. The criteria for recommending the level of quality are stated but are determined with the researcher’s discretion. The level of evidence was determined using the “Hierarchy of Evidence for Intervention Studies” chart. Each article was placed in one of the four levels, which represents different article types. Level I represent systematic reviews; level II represents randomized control trials; level III represents controlled trials without randomization, and level IV represents case-control and cohort studies. There were six level I, three level II, two level III, and three level IV (Table 1). The selected articles included 5 systematic reviews, 5 randomized control studies, 2 literature reviews, 2 cohort studies, 2 case-control studies, and 1 clinical trial.

Table 1 provides a representation of the level of quality and evidence included in the literature review.

Table 1: Level of Evidence and Quality of Included Articles

Level of Evidence	Excellent Quality	Good Quality	Fair Quality	Poor Quality	Total Number of Articles
I	1	2	0	3	6
II	1	0	2	2	5
III	0	2	0	0	2
IV	1	1	2	0	4
Total	3	5	4	5	17

Criteria for Evaluating the Studies

Each of the articles used in this critical review for the literature was placed into a matrix developed by the Bethel University Graduate Nursing Program. For each study, the information placed into the matrix included the first author, year, journal, design/method, sample/setting, major variables, measurement, data analysis, findings, and level of evidence. Articles are listed in order of their level of evidence. The level of evidence is based upon the evaluation from the JHEB. A higher-scoring article was defined as being consistent and having generalizable results, a sufficient sample size, adequate controls, and consistent recommendations based on a comprehensive literature review, which included references to scientific evidence (Fineout-Overholt et al. 2010). A good-quality score should be reasonably consistent and have a sufficient sample size, some control, and reasonably consistent recommendations. A low-quality score had little evidence with inconsistent results and insufficient sample size; no conclusions can be drawn from the study (Fineout-Overholt et al. 2010).

Summary

The articles on research containing neck strengthening exercises for concussion preventative methods were identified using various search engines. The process of eliminating or utilizing articles was based on certain inclusion and exclusion criteria. The level of evidence for each of the 17 articles used was then appraised and placed in the Bethel University Graduate Nursing Program.

Chapter III: Literature Review and Analysis

Synthesis of Matrix

The objective of the third chapter is to review and analyze the literature from the 17 scholarly articles based on how well they answer the PICO question from the first chapter. To accomplish this goal, the matrix developed by the Bethel University Nursing Program will be used. The matrix helps organize the key information in a visually appealing manner, which also allows the reader to easily see summary of the articles that were analyzed. The information included in the matrix is source, design, purpose, sample/setting, level of evidence, design instrument, results, quality, and recommendation. The articles used were categorized by their level of evidence, which is determined by the Hierarchy of Evidence for Intervention Studies" chart (Fineout-Overholt et al., 2010). There are seven different evidence levels but only levels one through four are represented and follow a sequential order based on the highest strength. The four levels of evidence include systematic reviews, randomized control trials, controlled trials without randomization, case-control or cohort studies, and case reports. The articles are organized within the matrix and summary alphabetically according to the author's last name. The filled-out matrix by Bethel University's Nursing Program can be found in the Appendix.

Synthesis of Major Findings

Level 1 Evidence: The type of articles that compose the first level of evidence include meta-analysis and systematic review. Six articles fit into this category and are summarized below.

Benson et al. *(2013)* conducted a systematic review to critically review the evidence to determine the efficacy and effectiveness of protective equipment, rule changes, neck strength, and legislation in reducing sport concussion risk. The study performed a search of electronic databases, grey literature, and bibliographies, which were used to search the evidence using Medical Subject Headings and text words. Inclusion and exclusion criteria were used to select articles for the clinical equipment studies, which included original human research data, investigated an outcome of concussion or head impact, evaluated a concussion prevention intervention, included sport participants, was an analytical study design, and peer-reviewed. The following were the exclusion criteria: review articles, case series, or case studies and not in English. The quality of evidence was assessed using epidemiological criteria regarding internal and external validity (e.g., strength of design, sample size/power, bias, and confounding).

The results of the systematic review concluded that there was no evidence provided to suggest an association between neck strength increases and concussion risk reduction. The systematic review found there were mixed results, which were lacking due to insufficient evidence. The review also suggests that there needs to be a multifactorial approach to prevent concussion, which means that equipment, rules, or education can work together to reduce concussion risk. The study's overall results state that further research is needed to be conducted but the available evidence is leaning towards there is no significance with neck strengthening exercises.

Daly et al. (2021) conducted a systematic review to evaluate the evidence regarding the development of neck strength in reducing concussion and cervical spine injuries in adult amateur and professional sport populations. To determine the literature that is available regarding neck strengthening programs, a search was performed in PubMed, CINAHL, Science Direct, and Web of Science databases, which were searched systematically. The criteria for inclusion in the review were as follows: (1) a human adult (≥18 or above); (2) involved in amateur, semi-professional, or professional sports; (3) sports included involved collisions with other humans, apparatus or the environment; (4) interventions included pre- and post-neck muscle strength measures or neck stability measures; (5) outcomes included effects on increasing neck strength in participants and/or injury incidence.

The results of the systematic review identified 2462 articles, but the following title, abstract, and full paper screening, only three papers were eligible for inclusion. All of the papers reported information from male participants; two were focused on rugby union, and one on American football. Two of the included studies found a significant improvement in isometric neck strength following the intervention. None of the studies reported any impact of neck strengthening exercises on cervical spine injuries. The systematic review demonstrated that after a neck strength intervention there was no significant difference ($p = 0.18$) evident between playing seasons for the number of injuries occurring in training, or no significant difference ($p = 0.20$) in the days lost from training for this cohort of professional players. These findings indicate that the introduction and implementation of neck strength development techniques across adult playing populations found no differences in concussion prevention methods and actual concussions.

Enniss et al. (2018) conducted a systematic review to conduct a prospectively registered systematic review of the scientific evidence regarding interventions to prevent contact SRC. The databases that were used included a query of MEDLINE, PubMed, Scopus, Cumulative Index of Nursing and Allied Health Literature, and Embase was performed. Letters to the editor, case reports, book chapters, and review articles were excluded, and all articles reviewed were written in English. The inclusion criteria for this systematic review consisted of reporting original data, published in English and the evaluation of designated intervention and contact-sports-related concussion. The initial search returned 1053 references, but only 31 articles were relevant to the PICO question. Three were Randomized Controlled Studies and the remaining 28 were uncontrolled prospective cohort or observational studies.

The results suggested that there is conditional evidence supporting the PICO question, in which neck strengthening exercises in adult athletes may reduce the risk of concussions. The strongest recommendation found was changing the rules of contact and educating the athletes. Even with emerging concussion research, there is still a lack of research with primary prevention methods. Overall, the study suggests that there is slight evidence indicating that neck strengthening exercises may reduce the risk of concussion, but concussion education and rule changes may be more beneficial.

Honda et al. (2018) conducted a systematic review to determine the effects of vision training, neck musculature strength, the individual's reaction time can prevent concussions. The databases were searched to explore the preventative interventions and tools used in research to prevent concussions from occurring. Over the past decade, researchers considered vision training, neck musculature strength, and reaction time training as interventions to prevent concussions in athletic populations. The participants that were eligible for inclusion in this review included all ages and levels of sports. The purpose of this study was to answer the hypothesis that neck musculature strength is thought to prevent concussions since athletes with weaker necks are more likely to experience greater head impacts. In comparison, athletes with stronger necks can withstand the velocity of a head impact, diffusing the hit through the muscles, reducing head displacement.

The results of the review concluded that neck strength has inconclusive results throughout the literature. The results were mixed, and some findings indicate every one pound increase in neck strength leads to a five percent decrease in the chance of sustaining a concussion. On the other hand, research suggests that increased static cervical neck strength in isolation was not enough to reduce the severity of head impacts sustained by youth hockey players. There are also inconclusive results for neck strength preventing concussions. In basketball, lacrosse, rugby, and soccer, increased neck strength seems to lead to fewer concussions, but in hockey and football, neck strength does not seem to affect concussions.

Instead, research suggests that cervical neck strength may only have an effect when the athlete braces for contact. The overall results of the study indicate that the evidence is inconclusive, and further research needs to be conducted to determine if cervical neck strength reduces the risk of concussion.

Iverson, et al. (2017) conducted a systematic review of factors that might be associated with, or influence, clinical recovery from sport-related concussion. The databases used in this systematic review include PubMed, PsycINFO, MEDLINE, CINAHL, Cochrane Library, EMBASE, SPORTDiscus, Scopus, and Web of Science. The articles excluded from the study included publications after June of 2016, articles that addressed acute outcomes in the initial days following the concussion, and if the clinical recovery time of persistent symptoms was not included. The articles eligible for inclusion had to examine factors associated with concussions and be conducted on human subjects. The initial search found 7,617 articles, but only 101 were eligible for the systematic review.

The results suggest a relationship between gender differences and an increase in concussions for females compared to men. The difference may be accounted for by the differences in cervical neck strength, but the evidence is not strong enough to make solid claims. The differences may be due to differences in size, neck strength, type of sport played, or the fact that women are more likely to report concussions. The recommendations for implementing cervical neck strengthening exercises cannot be made with the lack of evidence present. This systematic review indicates that research lacks the support of evidence for neck strengthening as a preventative measure.

Wood et al. (2019) conducted a study to examine the sports medicine literature surrounding the implication of neck strength and muscle activation in SRC, discuss age-related changes to neck strength and muscle activation, and highlight the potential impact on fall related TBIs in older adults. To determine the literature that is available regarding neck strengthening programs a search was performed in PubMed, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Web of Science, and Ovid-Medline. The search keywords that were used included “concussion,” “traumatic brain injury,” “head injury,” “neck” “cervical;” “muscle strength,” “muscle activation,” and “impact velocity.”

The search results provided a total of 160 unduplicated articles that were identified through the keyword and reference search, by which 134 articles were excluded by title and abstract screening. Twenty-six articles were assessed in full texts, in which 18 articles were identified and included in the review. Six studies were excluded because they did not examine neck strength or activation with head movement. One study was excluded because it was a review, and another was excluded because it was a dissertation. The remaining 18 articles that were reviewed concluded that there were mixed results. Neck strength is a significant predictor of concussions in high school athletes, but Mansell et al. (2018) found that it was not neck strength, but neck stiffness that contributed to decreased injury risk. Additionally, it is important to note that resistance training in college-aged athletes did not alter EMG activity or head kinematics during impact, which could imply that there would not be a decrease in the risk of concussion.

Level 2 Evidence: The type of articles that compose the second level of evidence include randomized control studies. There are five articles analyzed that fit into this category, and they are summarized below.

Bauer et al. (2001) conducted a RCT to determine the impact forces and neck activity in heading by collegiate female soccer players. The study recorded three soccer header types (shooting, clearing, and passing) and two heading approaches (standing and jumping), which were manipulated to quantify impact forces and neck muscle activity in Division I female soccer players. The 15 participants were separated into two different groups, which included the neck strength exercise program (intervention group) and the others received no exercise program (control group). To determine the athlete's neck strength, the left and right sternocleidomastoid (SMD) and trapezius muscles were measured with the use of an electromyography (EMG).

The results indicated no differences between the control group and the intervention group. The impact forces and impulses did not differ among the header types or approaches. Higher values were found for jumping versus standing headers in the mean normalized EMG for the right sternocleidomastoid. In addition, the integrated EMG was greater for the right sternocleidomastoid and right and left trapezius ($P < 0.05$). The sternocleidomastoid demonstrated earlier activation times than the trapezius and showed greater activity before ball contact. The research suggests that there is no evidence that the neck strengthening program resulted in lower impact forces or impulses.

Becker et al. (2019) conducted a RCT to analyze the influence of a 6-week strength training program (neck flexors, neck extensors) on the acceleration of the head during standing, jumping, and running headers and after the fatigue of the trunk muscles on a pendulum header. The participants included 33 active male soccer players that were divided into an intervention group that received the 6-week strength training program and the control group that received no training program. The pre-test consisted of three different heading scenarios (standing, jumping, running), whereas the post-test asks for two heading scenarios (post-jumping, post-running). The difference between the pre-test and post-test is the fatigue treatment, which was achieved by performing the Bourban test. The Bourban test is an economic alternative to measure trunk strength endurance. To analyze the effectiveness of the 6-week strength training, the two pre-tests (standing jumping and running header) and the two post-tests (post-jumping, post-running) were compared. The tools used to determine the quantitative data were the isometric maximum voluntary contraction (IMVC) measured by a telemetric Noraxon DTS force sensor. The head acceleration during ball contact was determined using a telemetric Noraxon DTS 3D accelerometer.

The results indicated no significant change of the IMVC over time between the groups ($F=2.265$, $p=.121$). Head acceleration was not reduced significantly for standing headers. The research found that the predicted preventive benefit of a 6-week strength training program of neck flexors and neck extensors could not be confirmed statistically. The effects of a neck strengthening for the acceleration of the head while heading seems to be more complex than previously assumed and presumably only come into effect in the case of strong impacts. The only individuals that benefited from the immediate impact of neck strengthening exercises were individuals that had fundamentally weaker necks from pretesting. The overall evidence did not suggest that neck strengthening exercises can reduce head acceleration, which would decrease the risk of concussion.

Eckner et al. (2018) conducted a randomized controlled study to assess the feasibility and effect of targeted neck strengthening exercises in youth athletes. The study consisted of seventeen participants that were allocated to perform 8-week manual resistance-based neck strengthening (n=13) or control resistance exercise (n=4) programs. The tools used to determine cervical neck strength during each laboratory session included overall neck girth, the sonographic cross-sectional area (CSA) of the sternocleidomastoid (SCM) muscle, the peak moment generated by the neck during maximum voluntary isometric contraction (MVIC) in each plane of motion, and the head's linear and angular accelerations in response to the application of standardized test loads in each plane of motion were measured. Surface electromyography (sEMG) of four key cervical muscles was also recorded during MVIC testing and voluntary cervical muscle co-contraction.

The research results concluded that the neck strength and girth increased in both with 1.6 times greater increases in the neck strengthening group. The girth increase was suspected to be due to hypertrophy of the cervical neck muscles. The research concluded a decrease in neck velocity, which may be associated with a decrease of risk with concussions. There was a significant increase of 2.6 times more neck strength throughout all planes of motions than the individuals in the control group. The observed increases in neck girth and strength are associated with decreases in velocity change, which is suspected to reduce the risk of a concussion. The data collected from this RCT indicates the potential decrease of SRC can be attributed to implementing cervical neck strengthening programs. The potential benefits of neck strengthening exercises to reduce the risk of concussions may allow for reducing the risk of concussions in athletes.

Gutierrez et al. (2014) conducted a randomized control study to investigate the relationship between neck strength, impact of headers, and neurocognitive function in an acute bout of soccer heading in a sample of female high school varsity soccer players. The sample size in this study consisted of 17 high school female soccer players. Each participant was outfitted with custom headgear with timing switches and a three-dimensional accelerometer affixed to the back of the head, which allowed for measurement of impact during heading. Participants performed a series of 15 directional headers, including five forward, five left, and five right headers in a random order, then completed the ImPACT test again. The ImPACT test is a standardized test used to measure neurocognitive function and it is used to determine whether an individual has suffered a concussion or return-to-play decisions.

The results indicate that there is no significant difference between the pre- and post-neurocognitive testing. There were both moderate correlations and significant statistical results ($r = –0.500:–0.757$; $p < .05$) found for correlations between the neck strength and head acceleration. The overall suggestion made by this RCT is that there is a direct correlation between strengthening the athlete’s neck and decreasing the magnitude of impact that was caused by heading the ball in all directions. Athletes with a weaker neck cannot mitigate the forces that are caused by heading as well as another that has stronger cervical muscles. The RCT makes a strong recommendation that further testing needs to be conducted but they found strong evidence that would suggest the importance of strengthening an athlete’s neck muscles.

Mansell et al. (2018) conducted a randomized control study to determine the effect of an 8-week resistance-training program on head-neck segment dynamic stabilization in male and female collegiate soccer players. Thirty-six national collegiate Division I athletes participated in this research study. The participants were randomized into a control group that received no cervical neck strengthening exercises and the intervention group performed an 8-week resistive neck strengthening exercise program. The resistance training group underwent an 8-week cervical resistance training program that consisted of three sets of ten repetitions of neck flexion and extension at 55% to 70% of their 10-repetition maximum two times a week. Participants in the control group performed no cervical resistance exercises. The tools used to measure cervical strength were dead-neck segment kinematics and stiffness, EMG activity of the upper trapezius (UT) and SCM muscles during force application to the head, and neck flexor and extensor isometric strength with an external force applicator. The study also used a PEAK Motus Motion Analysis System to determine the peak head-neck angular acceleration and displacement values.

The results of the study indicated that no kinematic, EMG, or stiffness training effects were observed. The posttest resistance training group's isometric neck flexor strength was 15% greater than the pretest measurement. Isometric neck extensor strength in the female resistance training group was 22.5% greater at the posttest than at the pretest. Women's neck girth increased 3.4% over time regardless of training group level. Women exhibited 7% less head-neck segment length and 26% less head-neck segment mass than men. The result of the study reported that the 8-week cervical neck strength training did not enhance the head-neck segment dynamic restraint during the application of force, which means that SRC may not be reduced with neck strengthening exercises.

Level 3 Evidence: The type of articles that compose the third level of evidence include control studies with no randomization. There are two articles analyzed that fit into this category, and they are summarized below.

Collins et al. (2014) conducted a control study to develop and validate a cost-effective tool to measure neck strength in a high school setting. The goal was to conduct a feasibility study to determine if the developed tool could be reliably applied by certified athletic trainers (ATs). The study sought to determine whether implementing a cost-effective tool to measure neck strength could be a possible predictor of whether the individual was more susceptible to concussions. The objective was also to determine if a less cost-effective method of determining neck strength can be as reliable as the handheld dynamometer. The study consisted of 16 adults and ATs from 51 high schools in 25 states, which captured pre-season anthropometric measurements for 6,704 high school athletes in boy’s and girls’ soccer, basketball, and lacrosse, as well as reported concussion incidence and athletic exposure data. In the first phase of the study, 16 adult athletes completed neck strength testing, which was conducted with a hand-held scale by 5 ATs to determine reliability and validity. The athletes were separated into two different groups that were based contact sports and non-contact sports. The second phase was conducted by collecting data from preseason measurements of anthropometric and base strength scores in order to compare the first phase results to a larger sample size.

The results indicated high correlations between neck strength measurements taken with the developed tool and a hand-held dynamometer measurement taken by five ATs. Smaller mean neck circumference (p = 0.001), smaller mean neck to head circumference ratio (p = 0.001), and weaker mean overall neck strength (p = 0.001) were significantly associated with concussion. Overall neck strength ($p < 0.001$), gender ($p < 0.001$), and sport ($p = 0.007$) were significant predictors of concussions in unadjusted models. After adjusting for gender and sport, overall neck strength remained a significant predictor of concussion ($p = 0.004$). For every one-pound increase in neck strength, odds of concussion decreased by 5 % (*OR* = 0.95, 95 % CI 0.92–0.98). The overall results suggest that the developed method of measuring neck strength may be cost-effective, and that neck strength is a predictor of concussion risk.

Toninato, et al. (2018) conducted a control study to determine the relationship between neck strength and risk of SRC in student-athletes. The participants consisted of student-athletes from the age of 12 - 23, which were from local middle schools, high schools, and colleges. The individuals were instructed on a manual-resistance-based neck strengthening exercise program to be performed twice a week on non-consecutive days compared to no neck strengthening exercises. To measure the athlete's neck strength, a handheld dynamometer was used. During the course of the season, concussion diagnosis and severity will be evaluated using the SCAT5. The study also performed eye tracking data to determine the severity of the concussion. The tool used to determine eye-tracking data was the SR Research Eyelink 1000, which consists of a screen, an infrared eye-tracker, and a mount to stabilize the subject's head. Once the subject is seated comfortably and properly with their head in the mount, a 220-s video will play on the screen.

This video only takes up a fraction of the screen and moves around its square perimeter. The infrared camera will track the movement of the subject's eyes independently.

The results of the study suggest that every 1-pound increase in neck strength contributed a 5% decrease in odds for a concussion event occurring. The data was analyzed to compare neck strength between concussed and non-concussed subjects within various subpopulations defined by age, sex, sports, etc., in order to analyze the hypothesis. The overall results of the study indicate that there are strong recommendations for supporting neck strengthening exercises to reduce the risk of TBI.

Level 4 Evidence: The type of articles that compose the fourth level of evidence include cohort studies. There are four articles analyzed that fit into this category and they are summarized below.

Dezman et al. (2013) conducted a case-control study to determine whether neck strength imbalance correlates to increasing head acceleration during impact while heading a soccer ball. The study was conducted on sixteen Division I and II collegiate soccer players who were asked to head a ball in a controlled indoor laboratory setting while player motions were recorded by a 14-camera Vicon MX motion capture system. Neck flexor and extensor strength of each player were measured using a spring-type clinical dynamometer. The data was analyzed using independent samples *t*-tests, which were used to compare differences in mean neck flexion strength, mean neck extension strength, and mean strength imbalance between sexes.

The results of this study indicated that there were no significant differences between sexes in mean neck flexion ($P = 0.201$), extension strength ($P = 0.130$), or mean imbalance ($P =$

0.631). The ball was pitched to subjects at a mean 4.29 m/s (±0.74 m/s) and subjects returned them at a mean velocity of 5.48 m/s (±1.18 m/s). The data illustrated the mean neck strength difference was positively correlated with angular head acceleration (rho = 0.497; *P* = 0.05), with a trend toward significance for linear head acceleration (rho = 0.485; *P* = 0.057). The study suggests a correlation between neck strength imbalance and angular head acceleration during heading. The exact mechanism underlying this correlation is not clear. Still a balance of neck flexor/extensor strength may reduce head acceleration by increasing the relative mass of the head and neck and damping the flexion/extension oscillations that the head experiences during and after the act of heading.

Lisman et al. (2011) performed a case-control study to examine the effects of an eight-week isoinertial cervical resistance training program on the EMG activity of the sternocleidomastoid (SCM) and UT as well as the kinematics of the head and neck in response to a football tackle. The study used sixteen college-aged males (21.6 ± 2.8 yrs) with previous high school football playing experience and completed an eight-week isoinertial cervical resistance-training program consisting of three sets of 10 repetitions of neck extension, flexion, and right and left lateral flexion at 60-80% of 10 repetition maximum (RM), two to three times per week. The data was recorded with the use of an EMG and kinematic head responses were recorded with a ViconNexus 3D motion capturing system.

The results of the case control study found that despite modest training-induced improvements in isometric cervical strength, the eight-week isometrical cervical resistance training program failed to augment dynamic stabilization of the head and neck during a football tackle. After implementing a neck-strengthening program, the data indicated that all cervical isometric strength measurements tended to increase with training. Still only the 7 and 10% of strength increases in extension and left lateral flexion were found to be statistically significant. Although the slow isometrtical training program was sufficient to result in modest improvements in isometric cervical extension and left lateral flexion strength, the lack of emphasis on hypertrophy, contractile velocity, or co-contraction of the SCM and UT may have prevented it from improving head and neck stabilization during the football tackle.

Mihalik, et al. (2011) performed a cohort study to evaluate the effect of cervical muscle strength on head impact biomechanics. Thirty-seven ice hockey players participated in this study. The athletes were equipped with accelerometer-instrumented helmets to collect head impact biomechanics (linear and rotational acceleration) throughout an entire playing season. Before the season, isometric cervical muscle strength was measured for the anterior neck flexors, anterolateral neck flexors, cervical rotators, posterolateral neck extensors, and UT. Data were analyzed using random intercept general mixed linear models, with each player as a repeating factor/cluster. The dependent variables included linear and rotational head accelerations. Cervical strength data were categorized into tertiles, creating groups with high, moderate, and low strength. Strength measures were averaged and normalized to the body mass of the hockey player.

The results of the cohort study indicated that there were no significant differences in cervical muscle strength across our strength groups ($P < 0.05$). No differences were observed in linear or rotational acceleration across strength groups for the anterior neck flexors (P_{Lin} =

0.399; PRot = 0.060), anterolateral neck flexors (PLin = 0.987; PRot = 0.579), cervical rotators (PLin = 0.136; PRot = 0.238), posterolateral neck extensors (PLin = 0.883; PRot = 0.101), or UT (PLin = 0.892; PRot = 0.689). The results of the research study indicated that although an individual may have stronger cervical neck muscles, there were no differences in deceleration of head impacts during the course of the season. The overall findings are not consistently supportive of the hypothesis of the cohort study, which means that cervical neck strengthening does not reduce the risk of SRC.

Schmidt et al. (2014) conducted a cohort study to compare the odds of sustaining higher magnitude in-season head impacts between athletes with higher and lower preseason performance on cervical muscle characteristics. Forty-nine high school and collegiate American football players completed a preseason cervical testing protocol, which included measures of cervical isometric strength, muscle size, and response to cervical perturbation. Cervical perturbation indicates the stiffness, angular displacement, and muscle onset latency of the neck. The researchers then calculated the odds of sustaining moderate and severe head impacts and then computed the data against the odds of sustaining mild head impacts with different cervical motions such as flexion, extension, etc. The odds determined by calculating the numerical force a lineman receives on average during a football game with the use of head acceleration sensors.

The results that were concluded by the cohort study suggested that linemen with stronger lateral flexors and composite cervical strength had about 1.75 times increased odds of sustaining moderate linear head impacts rather than mild impacts compared with weaker linemen. Players who developed extensor torque more quickly had two times an increase in the odds of sustaining severe linear head impacts (odds ratio [OR], 2.10; 95% CI, 1.08-4.05) rather than mild head impacts. However, players with greater cervical stiffness had reduced odds of sustaining both moderate (OR, 0.77; 95% CI, 0.61-0.96) and severe (OR, 0.64; 95% CI, 0.46-0.89) head impacts compared with players with less cervical stiffness. The study showed that greater cervical stiffness and less angular displacement after perturbation reduced the odds of sustaining higher magnitude head impacts, which would reduce the risk of SRC.

Critique of Strengths and Weaknesses

The appraisal of the articles provided strengths with the quantity of systematic reviews, which allowed for a wide variety of articles to be evaluated and be relevant to the PICO question. Another strength would be the number of articles that were considered to be of excellent or good quality, which was eight. In this literature review, an aspect that was not required but worked out well was the consistency of studies that used the similar tools such as a dynamometer, helmet sensors, and EMG used to measure neck strength, muscular activity, and head accelerations. The frequent use of the same tools allowed for reliability and validity when appraising the articles. Of the seventeen articles used for this critical review, eleven out of the seventeen were from within the last six years, which provides more up-to-date information and is another strength.

The weaknesses of the studies available were, unfortunately, vast. There was a lack of available research, and most research articles made recommendations that further research was needed to be conducted to answer the PICO question. The majority of studies that were included had very small sample sizes, and several did not use impact helmet sensors for contact sports and/or follow the athletes through the course of a season. There were conflicting results, making it harder for the clinician to choose whether neck strengthening may reduce SRC. The majority of the studies contradicted each other and found some significance but not in the aspects of neck strengthening and reduction of head velocity. For example, Honda et al. (2018) found that the results were inconclusive but suggest that cervical neck strength may only have an effect when the athlete braces for contact. Eckner et al. (2018) found that for every one-pound increase in neck strength leads to a decrease in five percent chance of sustaining a concussion, and also found that increased static cervical neck strength in isolation was not enough to reduce the severity of head impacts sustained by youth hockey players. The last weakness was the amount of articles that were rated as fair or poor, which consisted of five.

Summary

Seventeen articles were critically reviewed to determine whether implementing neck strengthening exercises into an athlete's workout program would reduce the risk of concussions in contact sports compared to athletes that do not implement neck strengthening exercises. All of the articles were categorized into levels 1 to 4, according to the "Hierarchy of Evidence for Intervention Studies" chart (Fineout-Overholt et al., 2010), and were organized alphabetically. The articles were assessed for quality and categorized into either excellent (3), good (5), fair (4), or poor (5) according to the JHEB scale. The reviewed research studies' results were mixed when answering the question of the effectiveness of the use of neck strengthening exercises to reduce concussions.

Chapter IV: Discussion, Implications, and Conclusions

The purpose of this review is to determine whether implementing neck strengthening exercises into an athlete's workout program would reduce the risk of concussions in contact sports compared to athletes that do not implement neck strengthening exercises. After critically analyzing 17 articles, this chapter will discuss the synthesis of the literature, current trends and gap in the literature, implications for athletic training, recommendations for future research, and the conclusion.

Literature Synthesis

The goal of the Critical Review of the Literature is to answer the clinical question, "Does implementing neck strengthening exercises into an athlete's workout program reduce the risk of concussions in contact sports compared to athletes that do not implement neck strengthening exercises?" A total of 17 articles, which were reviewed and appraised because of their relevance to answering the clinical question. The articles were categorized into the three following categories: neck strengthening does prevent concussions, neck strengthening does not prevent concussions, and neck strengthening has inconclusive evidence with preventing concussions.

Of the 17 articles that were appraised, only five supported the clinical question of implementing neck-strengthening exercises to reduce the risk of concussion. The three out of the five that were appraised to be *good* quality articles included Ennis et al. (2018) and Tonninto et al. (2018), Colins et al. (2014). The first study by Ennis et al. (2018) found that increasing neck strength as an intervention for the primary prevention of concussion, many adult amateur athletes would consider it an acceptable and recommended implementing cervical exercise to reduce the risk of concussion. The second study found a statistically significant correlation between weaker neck strength and increased susceptibility to concussion in high school contact sports. It was determined that every one-pound increase in neck strength contributed to a 5% decrease in odds for a concussion event occurring. The third study, by Colins et al. (2014) found that having a smaller mean neck circumference, smaller mean neck to head circumference ratio, and weaker mean overall neck strength were all significantly associated with risks of concussion. The fourth study by Gutierrez et al. (2017) was of *fair* quality and found that greater cervical stiffness and less angular displacement after perturbation reduced the odds of sustaining higher magnitude head impacts. Gutierrez (2017) found that there were statistically significant, moderate, negative correlations between neck strength and resultant header acceleration. This suggests that there is a moderate association between the two variables. The last article, Eckner et al. (2018) was of *poor* quality, concluded there were observed increases in neck girth and strength and the associated decreases in ΔV and Δω are encouraging with respect to the potential for resistance training exercises to reduce youth athletes' risk for SRC

Of the 17 articles that were appraised, there were eight that did not support the clinical question of implementing neck-strengthening exercises to reduce the risk of concussion. There were three studies that were of *excellent* quality: Mihalik et al. (2011), Becker et al. (2019) and Iverson et al. (2017). The first study by Mihalik et al. (2011) found that players with greater static neck strength did not experience lower resultant head accelerations, which contradicts the notion that cervical muscle strength mitigates head impact acceleration. The last two studies by Becker et al. (2019) and Iverson et al. (2017) found that a 6-week strength training of the neck flexors and neck extensors did not show the presumed preventive benefit. Both the effects of a training intervention and the consequences of an effective intervention for the acceleration of the head while heading seems to be more complex than previously assumed and presumably only come into effect in case of strong impacts. Two studies were of *good* quality, which included Daly et al. (2021) and Lisman et al. (2011). The first study by Daly et al. (2021) was a systematic review, which found that none of the studies reported any impact of neck strengthening exercises on cervical spine injuries. The next study by Lisman et al. (2011) was a case-control study that found that no improvements in the dynamic stabilization of the head and neck during a football tackle after undergoing isometric cervical resistance training. There were two studies of *fair quality was* conducted by Mansell et al. (2005), which found that even with cervical resistance training increasing neck girth (women only) and isometric strength (male neck flexors only and female neck flexors and extensors), no training effect was noted for the kinematic, EMG, or stiffness values on force application. The next study by Schmidt et al. (2014) found that the football lineman with stronger and larger neck muscles did not mitigate head impact severity. The last study by Bauer et al (2001) was of *poor* quality and did not find any statistically significant evidence suggesting that neck-strength had any positive effect on being a preventative for concussions.

Of the 17 articles, there were four articles with inconclusive results on the effects of cervical neck strength on reducing the risk of concussions. There were two articles, which were of *poor* quality, and included Benson et al. (2018) and Wood et al (2019). There was only one study of *fair* quality, which was conducted by Dezman et al. (2013). The first study conducted by Benson et al. (2018) suggested that there was an insufficient amount of evidence to support an association between neck strength and reduced risk of concussions. The authors did not assess whether there was an association between differences in neck strength and/or head accelerations and a reduction in concussion incidence on the playing field. The last study by Dezman et al. (2013) found evidence that cervical neck strength may play a role but noted that neck strength alone may not fully characterize the neuromuscular control of the head necessary to mitigate head impact during a collision. The last study by Honda et al. (2018) was of *poor quality* found that the results were inconclusive but suggest that cervical neck strength may only have an effect when the athlete braces for contact.

Current Trends and Gaps in Literature

Throughout this critical review of the literature some gaps and trends were identified. The most prevalent trend throughout this review was the focus on neck strength to prevent concussions, which was apparent as ten out of the 17 articles were from 2018 to more recent. Another trend was the use of a dynamometer to determine neck strength and similar use of SCAT5 or ImPACT to evaluate concussions. Dezman et al. (2013) used a spring-type clinical dynamometer to maintain consistency when evaluating the participants neck-strength across all planes of motion. Although a few other studies such as Eckner et al. (2018) used an surface EMG of four key cervical muscles with maximum voluntary muscle isometric contractions to load the muscles in each plane of motion, the trend was still maintained because of having the similar goal of obtaining accurate data. Another noticeable trend was the type of sports targeted for this type of research, which mainly focused on soccer, hockey, and football. Of the 17 articles, seven focused on soccer players performing a series of different headers, such as in Gutierrez et al. (2014) which had participants performing 15 directional headers, including five forward, five left and five right headers in a randomized order.

The Critical Review of the Literature also found different gaps that were present. The most common gap was the large variations in sample sizes. Of the 17 studies included, it was rare to find a sufficient sample size, which may make it more difficult for the nature of having an injured population. The largest sample size found was a study conducted by Jeffries et al. (2020), which consisted of 223 Division I and II soccer players. The average study size was under 18, with the majority of studies only having about 15 participants. Smaller sample sizes with lack of RCT are an issue because the statistical analysis is more underpowered making it difficult to generalize to athletic populations. Future work should explore these methods with a larger sample size. A major gap in the literature was the inconsistency of methods used, which may correlate to variances in the results. There was a major variation of different tools and tests that were performed to determine whether neck strengthening exercises reduced the risk of concussions, which could have potentially led to inconsistent results. Another major gap in the literature was the lack of *good* quality studies. Of the 17 studies included, there were five *poor* and three *fair,* which can hinder the significance of the results found.

Implications for Athletic Training

A major role of an AT is to provide evidence-based care for their athletes. As an AT, preventative care is provided to mitigate some of the chances of sustaining an injury, but we cannot prevent this 100% of the time. Research has improved the ability to diagnose and treat for concussions, but there is no current protocol established to help reduce the risk of head injuries. Jeffries et al. (2020) suggested that (69.86%) ATs believed that cervical strengthening would aid in concussion prevention, and only 17% currently used such programs. This is significant because as research continues to grow, AT must continue to use the best evidence-based practices to provide the most efficient care. With research continually developing and our understanding of the importance of reducing head injuries, it is important that AT's stay up-to-date on current research to apply effective and efficient care for our athletes' well-being.

The use of implementing a neck strengthening program is safe, has minimal risk, and is cost-effective (Collins et al. 2014). Jeffries et al. (2020) suggested that a program as short as eight weeks can increase cervical strength and reduce the velocity of head impacts. With a lack of research and the evidence suggesting that concussions will not be reduced, at this time there is no indication that neck strengthening exercises should be implemented (Collins et al. 2014). The evidence may not be conclusive, but some studies, such as Ennis et al. (2018), Tonninto et al. (2018), and Collins et al. (2014) found that there was a statistical association between weaker neck strength and increasing susceptibility to concussion in high school contact sports. Although there is limited evidence-based research, research is ongoing, but there is inconclusive evidence suggesting the benefits of reducing head velocity (Mihalik et al. 2011).

Recommendations for Future Research

After reviewing and analyzing the 17 research articles, there were many gaps and inconsistencies in the articles, leaving opportunities for future research recommendations. The area with the largest room for improvement is having consistency of testing methods. As mentioned earlier, there were various different tools, methods, and cervical neck strengthening programs used, which makes the evidence more scattered and harder to compare. Conducting more research to include different ages, levels, genders, and sports will allow research to be more conducive to all athletes and solidify the strength of the data.

Another key aspect of this Critical Review of the Literature was the quality of the research articles. Of the 17 studies included, three were of *excellent* quality, five were of *good* quality, four of *fair* quality, and five were *poor* quality. There were only five articles that were systematic reviews and five that were RCT, which are in the top two tiers of the "Hierarchy of

Evidence for Intervention Studies" chart (Fineout-Overholt et al., 2010). Although, this shows that there was high quality evidence available there was inconsistent data which leaves room for more RCT of *good* quality to support or disprove this clinical question. The last major aspect that can be improved upon is the years of the research present. Although, there were many new emerging studies that were recently conducted, there was still a lack of studies that directly answered the clinical question, with four articles being included that were completed prior to 2015.

Conclusion

The findings of this Critical Review of the Literature indicate inconclusive results that implementing a neck strengthening program can reduce the risk of concussions. Of the five articles that supported the use of cervical neck strength programs to reduce the risk, they presented moderate evidence. The evidence was inconsistent, but there seems to be an association between neck strengthening and reducing the velocity of head impacts. This conclusion was made by analyzing 17 scholarly articles using the Bethel University Graduate Nursing Program matrix format and using the PEDro Scale. There were eight articles that did not support whether neck strength had any effect on the reduction of head velocity and reducing the risk of concussion. The last four articles found slight evidence but were unable to determine the reduced risk of concussions when implementing neck strengthening exercises. Overall, research is continually growing, and more information is emerging on methods to reduce concussions. With more research being directed to neck strengthening, there may be more evidence in the future, but currently the results are inconclusive to support the reduced risk of concussion.

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Appendix A: Literature Review Matrix

<table>
<tr><td colspan="4">Source Bauer, J. A., Thomas, T. S., Cauraugh, J. H., Kaminski, T. W., & Hass, C. J. (2001). Impact forces and neck muscle activity in heading by collegiate female soccer players. Journal of sports sciences, 19(3), 171–179. https://doi.org/10.1080/026404101750095312</td></tr>
<tr>
<td>Design Methodology/ Purpose
Randomized Control Study
Purpose:
Our objective is to conduct a randomized control study to determine the impact forces and neck activity in heading by collegiate female soccer players.

Method:
Three soccer header types (shooting, clearing and passing) and two heading approaches (standing and jumping) were manipulated to quantify impact forces and neck muscle activity in elite female soccer players</td>
<td>Sample/ Setting
The 15 participants were Division I intercollegiate soccer players. Impact forces were measured by a 15-sensor pressure array secured on the forehead

Level: IV

Quality: Poor</td>
<td>Design Instruments
The electromyographic (EMG) activity of the left and right sternocleidomastoid and trapezius muscles was recorded using surface electrodes. Maximum impact forces and impulses as well as the EMG data were analysed with separate repeated-measures analyses of variance</td>
<td>Results
Impact forces and impulses did not differ among the header types or approaches. Higher values were found for jumping versus standing headers in the mean normalized EMG for the right sternocleidomastoid. In addition, the integrated EMG was greater for the right sternocleidomastoid and right and left trapezius ($P < 0.05$). The sternocleidomastoid became active earlier than the trapezius and showed greater activity before ball contact. The trapezius became active just before ball contact and showed greater activity after ball contact</td>
</tr>
<tr><td colspan="4">Recommendation: The increased muscle activity observed in the neck during the jumping approach appears to stabilize the connection between the head and body, thereby increasing the stability of the head-neck complex</td></tr>
</table>

Source Becker, S., Berger, J., Backfisch, M., Ludwig, O., Kelm, J., & Fröhlich, M. (2019). Effects of a 6-Week Strength Training of the Neck Flexors and Extensors on the Head Acceleration during Headers in Soccer. *Journal of sports science & medicine*, *18*(4), 729–737.

Design Methodology/ Purpose	**Sample/ Setting**	**Design Instruments**	**Results**
Randomized Control Study **Purpose:** The aim of the study was to analyze the influence of a 6-week strength training program (neck flexors, neck extensors) on the acceleration of the head during standing, jumping and running headers as well as after fatigue of the trunk muscles on a pendulum header . **Method:** The pre-test always consists of three different heading scenarios (standing, jumping, running), whereas the post-test asks for two heading scenarios (post-jumping, post-running) (see *header*). The difference between the pre-test und post-test is the fatigue treatment (see t*reatment*) in between. To analyze the effectiveness of the 6-week strength training the two pre-tests (standing jumping and running header) and the two post-tests (post-jumping, post-running) are compared	A total of 33 active male soccer players (20.3 ± 3.6 years, 1.81 ± 0.07 m, 75.5 ± 8.3 kg) participated and formed two training intervention groups (IG1: independent adult team, IG2: independent youth team) and one control group (CG: players from different teams) **Level**: II **Quality:** Excellent	isometric maximum voluntary contraction (IMVC) measured by a telemetric Noraxon DTS force sensor. The head acceleration during ball contact was determined using a telemetric Noraxon DTS 3D accelerometer	There was no significant change of the IMVC over time between the groups (F=2.265, p=.121). Head acceleration was not reduced significantly for standing (IG1 0.4 ± 2.0, IG2 0.1 ± 1.4, CG -0.4 ± 1.2; F = 0.796, p = 0.460), jumping (IG1-0.7 ± 1.4, IG2-0.2 ± 0.9, CG 0.1 ± 1.2; F = 1.272, p = 0.295) and running (IG1-1.0 ± 1.9, IG2-0.2 ± 1.4, CG -0.1 ± 1.6; F = 1.050, p = 0.362) headers as well as after fatigue of the trunk musculature for post-jumping (IG1-0.2 ± 2.1, IG2-0.6 ± 1.4; CG -0.6 ± 1.3; F = 0.184, p = 0.833) and post-running (IG1-0.3 ± 1.6, IG2-0.7 ± 1.2, CG 0.0 ± 1.4; F = 0.695, p = 0.507) headers over time between IG1, IG2 and CG

Recommendation: A 6-week strength training of the neck flexors and neck extensors could not show the presumed preventive benefit

Source Benson BW, McIntosh AS, Maddocks D*, et al* What are the most effective risk-reduction strategies in sport concussion? *British Journal of Sports Medicine* (2013);**47:**321-326.			
Design Methodology/ Purpose Literature review **Purpose:** To critically review the evidence to determine the efficacy and effectiveness of protective equipment, rule changes, neck strength and legislation in reducing sport concussion risk . **Method:** Electronic databases, grey literature and bibliographies were used to search the evidence using Medical Subject Headings and text words. Inclusion/exclusion criteria were used to select articles for the clinical equipment studies. The quality of evidence was assessed using epidemiological criteria regarding internal/external validity (eg, strength of design, sample size/power, bias and confounding)	**Sample/ Setting** The search consisted of the entire athletic population . **Level**: IV **Quality:** Poor	**Design Instruments** Electronic databases, grey literature and bibliographies	**Results** No new valid, conclusive evidence was provided to suggest the use of headgear in rugby, or mouth guards in American football, significantly reduced players' risk of concussion. No evidence was provided to suggest an association between neck strength increases and concussion risk reduction. There was evidence in ice hockey to suggest fair-play rules and eliminating body checking among 11-years-olds to 12-years-olds were effective injury prevention strategies. Evidence is lacking on the effects of legislation on concussion prevention. Equipment self-selection bias was a common limitation, as was the lack of measurement and control for potential confounding variables. Lastly, helmets need to be able to protect from impacts resulting in a head change in velocities of up to 10 and 7 m/s in professional American and Australian football, respectively, as well as reduce head resultant linear and angular acceleration to below 50 g and 1500 rad/s^2, respectively, to optimise their effectiveness.
Recommendation: A multifactorial approach is needed for concussion prevention			

Source Collins, C.L., Fletcher, E.N., Fields, S.K. *et al.* Neck Strength: A Protective Factor Reducing Risk for Concussion in High School Sports. *J Primary Prevent* **35,** 309–319 (2014). https://doi.org/10.1007/s10935-014-0355-2			
Design Methodology/ Purpose Control Study **Purpose:** We sought to develop and validate a cost-effective tool to measure neck strength in a high school setting, conduct a feasibility study to determine if the developed tool could be reliably applied by certified athletic trainers (ATs) in a high school setting, and conduct a pilot study to determine if anthropometric measurements captured by ATs can predict concussion risk . **Method:** In the study's first phase, 16 adult subjects underwent repeated neck strength testing by a group of five ATs to validate the developed hand-held tension scale, a cost effective alternative to a hand-held dynamometer. In the second phase, during the 2010 and 2011 academic years, ATs from 51 high schools in 25 states captured pre-season anthropometric measurements for 6,704 high school athletes	**Sample/ Setting** 16 adults and ATs from 51 high schools in 25 states captured pre-season anthropometric measurements for 6,704 high school athletes in boys' and girls' soccer, basketball, and lacrosse, as well as reported concussion incidence and athletic exposure data **Level**: III **Quality:** Good	**Design Instruments** measurements taken with the developed tool and a hand-held dynamometer and the measurements taken by five ATs	**Results** We found high correlations between neck strength measurements taken with the developed tool and a hand-held dynamometer and the measurements taken by five ATs. Smaller mean neck circumference, smaller mean neck to head circumference ratio, and weaker mean overall neck strength were significantly associated with concussion. Overall neck strength ($p < 0.001$), gender ($p < 0.001$), and sport ($p = 0.007$) were significant predictors of concussions in unadjusted models. After adjusting for gender and sport, overall neck strength remained a significant predictor of concussion ($p = 0.004$). For every one pound increase in neck strength, odds of concussion decreased by 5 % (*OR* = 0.95, 95 % CI 0.92–0.98)
Recommendation: We conclude that identifying differences in overall neck strength may be useful in developing a screening tool to determine which high school athletes are at higher risk of concussion			

Source Daly, E., Pearce, A. J., & Ryan, L. (2021). A Systematic Review of Strength and Conditioning Protocols for Improving Neck Strength and Reducing Concussion Incidence and Impact Injury Risk in Collision Sports; Is There Evidence?. *Journal of functional morphology and kinesiology*, *6*(1), E8. https://doi.org/10.3390/jfmk6010008			
Design Methodology/ Purpose Systematic review **Purpose:** The objective of this systematic literature review was to evaluate the evidence regarding the development of neck strength in reducing concussion and cervical spine injuries in adult amateur and professional sport populations . **Method:** Electronic databases, grey literature and bibliographies were used to search the evidence using Medical Subject Headings and text words. Inclusion/exclusion criteria were used to select articles for the clinical equipment studies. The quality of evidence was assessed using epidemiological criteria regarding internal/external validity (eg, strength of design, sample size/power, bias and confounding)	**Sample/ Setting** The search consisted of athletes involved in amateur, semi-professional, or professional sports. **Level**: I **Quality:** Good	**Design Instruments** Electronic databases, grey literature and bibliographies. Database searches identified 2462 articles. Following title, abstract, and full paper screening, three papers were eligible for inclusion. All of the papers reported information from male participants, two were focused on rugby union, and one on American football	**Results** Two of the included studies found a significant improvement in isometric neck strength following intervention. None of the studies reported any impact of neck strengthening exercises on cervical spine injuries. This study examined, sagittal plane and frontal plane isometric neck strength alone, it is acknowledged that these two planes of motion are not the only contributing factors contributing to overall neck stability. In conjunction with this, the study did not evaluate how the strength program affects proprioception or motor control in the segmental cervical spine. This study did demonstrate that there can be improvements in neck strength over a relatively short period of time. However, it did not demonstrate that the improvements in neck strength would have an effect on reducing cervical neck injury.
Recommendation: This review has shown that there is currently a lack of evidence to support the use of neck strengthening interventions in reducing impact injury risk in adult populations who participate in sport			

Source Dezman, Z. D., Ledet, E. H., & Kerr, H. A. (2013). Neck strength imbalance correlates with increased head acceleration in soccer heading. *Sports health*, *5*(4), 320–326. https://doi.org/10.1177/1941738113480935			
Design Methodology/ Purpose Case-control study **Purpose:** Neck strength imbalance correlates to increasing head acceleration during impact while heading a soccer ball . **Method:** Sixteen Division I and II collegiate soccer players headed a ball in a controlled indoor laboratory setting while player motions were recorded by a 14-camera Vicon MX motion capture system. Neck flexor and extensor strength of each player was measured using a spring-type clinical dynamometer	**Sample/ Setting** Sixteen Division I and II collegiate soccer players **Level**: IV **Quality:** Fair	**Design Instruments** The acceleration of the subject's head during heading was measured using a 14-camera Vicon MX3 Motion Capture System. To record motion, 11 retro-reflective markers were attached to anatomic landmarks: the suprasternal notch (Clav) and the xyphoid (Strn), as well as the seventh cervical (C7) and tenth thoracic (T10) vertebrae.	**Results** Players were served soccer balls by hand at a mean velocity of 4.29 m/s (±0.74 m/s). Players returned the ball to the server using a heading maneuver at a mean velocity of 5.48 m/s (±1.18 m/s). Mean neck strength difference was positively correlated with angular head acceleration (rho = 0.497; P = 0.05), with a trend toward significance for linear head acceleration (rho = 0.485; P = 0.057).
Recommendation: Balanced neck strength may reduce head acceleration cumulative subclinical injury. Since neck strength is a measurable and amenable strength training intervention, this may represent a modifiable intrinsic risk factor for injury.			

Source Eckner, J. T., Goshtasbi, A., Curtis, K., Kapshai, A., Myyra, E., Franco, L. M., Favre, M., Jacobson, J. A., & Ashton-Miller, J. A. (2018). Feasibility and Effect of Cervical Resistance Training on Head Kinematics in Youth Athletes: A Pilot Study. *American journal of physical medicine & rehabilitation*, *97*(4), 292–297. https://doi.org/10.1097/PHM.0000000000000843			
Design Methodology/ Purpose Randomized Control Study **Purpose:** Our objective is to assess the feasibility and effect of targeted neck strengthening exercises in youth athletes **Method:** Before and after the intervention, participants completed laboratory-based assessments of neck size, strength, and head kinematics during standardized test loading in each plane of motion. Descriptive statistics were calculated to compare pre/-post changes between the two groups	**Sample/ Setting** Seventeen participants were allocated to perform 8-week manual resistance-based neck strengthening (n=13) or control resistance exercise (n=4) programs **Level**: II **Quality:** Poor	**Design Instruments** During each laboratory session, overall neck girth, the sonographic cross sectional area (CSA) of the sternocleidomastoid (SCM) muscle, the peak moment generated by the neck during maximum voluntary isometric contraction (MVIC) in each plane of motion, and the head's linear and angular accelerations in response to application of standardized test loads in each plane of motion were measured. Surface electromyography (sEMG) of four key cervical muscles was also recorded during MVIC testing and voluntary cervical muscle co-contraction	**Results** Neck girth and strength increased in both groups, with greater increases in the neck strengthening group. Across all planes of motion, overall changes in head linear and angular velocity (ΔV and $\Delta \omega$) decreased in both groups, with greater decreases in $\Delta \omega$ in the neck strengthening group and greater decreases in ΔV in controls. These results suggest the potential for resistance exercise training to reduce youth athletes' risk for SRC by increasing neck girth and strength
Recommendation: Additional research is needed to determine optimal neck strengthening programs			

Source: Enniss, T. M., Basiouny, K., Brewer, B., Bugaev, N., Cheng, J., Danner, O. K., Duncan, T., Foster, S., Hawryluk, G., Jung, H. S., Lui, F., Rattan, R., Violano, P., & Crandall, M. (2018). Primary prevention of contact sports-related concussions in amateur athletes: a systematic review from the Eastern Association for the Surgery of Trauma. Trauma surgery & acute care open, 3(1), e000153. https://doi.org/10.1136/tsaco-2017-000153

Design Methodology/ Purpose	Sample/ Setting	Design Instruments	Results
Systematic review **Purpose:** Our objective is to conduct a prospectively registered systematic review of the scientific evidence regarding interventions to prevent contact sports-related concussions. . **Method:** Using the Grading of Recommendations Assessment, Development, and Evaluation methodology, we performed a systematic review of the literature to answer seven population, intervention, comparator, and outcomes (PICO) questions regarding concussion education, head protective equipment, rules prohibiting high-risk activity, and neck strengthening exercise for prevention of contact sports-related concussion in pediatric and adult amateur athletes	A query of MEDLINE, PubMed, Scopus, Cumulative Index of Nursing and Allied Health Literature, and Embase was performed. Letters to the editor, case reports, book chapters, and review articles were excluded, and all articles reviewed were written in English. **Level**: I **Quality:** Good	Thirty-one studies met the inclusion criteria and were applicable to our PICO questions. Conditional recommendations are made supporting preventive interventions concussion education and rules prohibiting high-risk activity for both pediatric and adult amateur athletes and neck strengthening exercise in adult amateur athletes	The search returned 1053 references. Titles were screened for relevance, identifying 37 potentially pertinent articles. The references of these articles were reviewed, identifying 106 additional potentially pertinent articles. Abstracts for these 143 articles were reviewed by the working group, narrowing articles for full-text review to 54. Subgroups then undertook a detailed review of all articles relevant to individual PICO questions, identifying 31 articles for inclusion. These include three randomized control trials, all of which contain significant methodological flaws. The remaining 28 studies were uncontrolled retrospective cohort or prospective observational studies. The number of pertinent studies per PICO question ranged from 1 study evaluating concussion education in adult amateur athletes to 14 studies evaluating various aspects of head protective equipment in adult amateur athletes

Recommendation: Strong recommendations are supported for head protective equipment in both pediatric and adult amateur athletes

Source Gutierrez, G. M., Conte, C., & Lightbourne, K. (2014). The relationship between impact force, neck strength, and neurocognitive performance in soccer heading in adolescent females. *Pediatric exercise science*, *26*(1), 33–40. https://doi.org/10.1123/pes.2013-0102			
Design Methodology/ Purpose Randomized Control Study **Purpose:** this study investigated the relationship between neck strength, impact, and neurocognitive function in an acute bout of soccer heading in a sample of female high school varsity soccer players **Method:** Each participant was outfitted with custom headgear with timing switches and a three-dimensional accelerometer affixed to the back of the head, which allowed for measurement of impact during heading. Participants performed a series of 15 directional headers, including 5 forward, 5 left and 5 right headers in a random order, then completed the ImPACT test again	**Sample/ Setting** Seventeen female soccer players **Level**: II **Quality:** Fair	**Design Instruments** custom headgear with timing switches and a three-dimensional accelerometer affixed to the back of the head. Impact test.	**Results** Neurocognitive tests revealed no significant changes following heading. However, there were statistically significant, moderate, negative correlations (r = -0.500:-0.757, p < .05) between neck strength and resultant header acceleration, indicating that those with weaker necks sustained greater impacts
Recommendation: This suggests neck strengthening may be an important component of any head injury prevention/reduction program			

Source Honda, J., Chang, S. H., & Kim, K. (2018). The effects of vision training, neck musculature strength, and reaction time on concussions in an athletic population. *Journal of exercise rehabilitation*, *14*(5), 706–712. https://doi.org/10.12965/jer.1836416.208			
Design Methodology/ Purpose Literature review **Purpose:** The purpose of this study is to review the literature on vision training, neck musculature, and reaction time, and how these interventions can prevent concussions. **Method:** explore the preventative interventions and tools used in research to prevent concussions from occurring. Over the past decade, researchers considered vision training, neck musculature strength, and reaction time training as interventions to prevent concussions in athletic populations	**Sample/ Setting** all ages and levels of every sport Athletic setting **Level**: I **Quality:** Poor	**Design Instruments** N/A	**Results** Neck strength has inconclusive results throughout the literature Vision training, neck musculature strength, and reaction time may all have an impact in preventing concussions in sport
Recommendation: There are substantial results concluding reaction time does prevent concussions by allowing the athlete to protect and anticipate head impact lessening the severity of the blow to the head			

Source Iverson, G. L., Gardner, A. J., Terry, D. P., Ponsford, J. L., Sills, A. K., Broshek, D. K., & Solomon, G. S. (2017). Predictors of clinical recovery from concussion: a systematic review. *British journal of sports medicine*, *51*(12), 941–948. https://doi.org/10.1136/bjsports-2017-097729			
Design Methodology/ Purpose Systematic review **Purpose:** A systematic review of factors that might be associated with, or influence, clinical recovery from sport-related concussion. Clinical recovery was defined functionally as a return to normal activities, including school and sports, following injury . **Method:** PubMed, PsycINFO, MEDLINE, CINAHL, Cochrane Library, EMBASE, SPORTDiscus, Scopus and Web of Science Studies published by June of 2016 that addressed clinical recovery from concussion.	**Sample/ Setting** Athletic population of any ages were included **Level**: I **Quality:** Excellent	**Design Instruments** We searched PubMed, PsycINFO, MEDLINE, CINAHL, Cochrane Library, EMBASE, SPORTDiscus, Scopus and Web of Science for articles published in English, from database inception to June 2016. Two general categories relating to (1) sport and athlete-related terms and (2) brain concussion-related terms were used as key search terms	**Results** Most children, adolescents and young adults who experience a sport-related concussion will recover, from a clinical perspective, within 1 month. However, it is important to appreciate that the subgroup of children and adolescents who are taken to the emergency department following a sport-related concussion is at much greater risk for symptoms lasting beyond a month. In a multisite Canadian study, 30% of these children and adolescents reported persistent symptoms after 4 weeks
Recommendation: At present, it is reasonable to conclude that the large majority of injured athletes recover, *from a clinical perspective*, within the first month following injury			

Source Lisman, P. J., Signorile, J. F., Del Rossi, G., Asfour, S., Abdelrahman, K. Z., Eltoukhy, M., . . . Jacobs, K. A. (2010). Cervical strength training does not enhance dynamic stabilization of head and neck during football tackling. *Medicine & Science in Sports & Exercise, 42*, 679. doi:10.1249/01.mss.0000385895.27611.c8			
Design Methodology/ Purpose Case Control Study **Purpose:** The purpose of this study was to examine the effects of an eight-week isoinertial cervical resistance training program on the electromyographic (EMG) activity of the sternocleidomastoid (SCM) and upper trapezius (UT) as well as the kinematics of the head and neck in response to a football tackle. **Method:** Sixteen college-aged males (21.6 ± 2.8 yrs) with previous high school football playing experience completed an eight-week isoinertial cervical resistance-training program consisting of three sets of 10 repetitions of neck extension, flexion, and right and left lateral flexion at 60-80% of 10 repetition maximum (RM), two to three times per week. Isometric cervical strength, neck girth, and both the EMG and kinematic responses of the head and neck during tackling were measured before and after training	**Sample/ Setting** Sixteen college-aged male football players **Level**: IV **Quality:** Poor	**Design Instruments** All kinematic data were gathered using a ViconNexus 3D motion capturing system. Statistical analyses of EMG and kinematic data were performed by utilizing an ANCOVA with repeated measures (level of significance was set at $p < 0.05$)	**Results** Training resulted in 7 and 10% increases ($p < 0.05$) in isometric cervical extension and left lateral flexion strength, respectively, but had no influence on the EMG responses of the SCM or UT, peak linear or angular head accelerations during tackling. The UT demonstrated approximately 40% higher absolute EMG activity than the SCM during tackling both before and after training.
Recommendation: This study showed that despite modest training-induced improvements in isometric cervical strength, the eight-week isoinertial cervical resistance training program failed to augment dynamic stabilization of the head and neck during a football tackle.			

Source Mansell, J., Tierney, R. T., Sitler, M. R., Swanik, K. A., & Stearne, D. (2005). Resistance training and head-neck segment dynamic stabilization in male and female collegiate soccer players. *Journal of athletic training*, *40*(4), 310–319.			
Design Methodology/ Purpose Randomized Control Study **Purpose:** To determine the effect of an 8-week resistance-training program on head-neck segment dynamic stabilization in male and female collegiate soccer players. **Method:** The resistance training group underwent an 8-week cervical resistance training program that consisted of 3 sets of 10 repetitions of neck flexion and extension at 55% to 70% of their 10-repetition maximum 2 times a week. Participants in the control group performed no cervical resistance exercises	**Sample/ Setting** Thirty-six National Collegiate Athletic Association Division I collegiate soccer players (17 men, 19 women) University research laboratory and fitness center **Level**: II **Quality:** Fair	**Design Instruments** Head-neck segment kinematics and stiffness, electromyographic activity of the upper trapezius and sternocleidomastoid muscles during force application to the head, and neck flexor and extensor isometric strength	**Results** No kinematic, electromyographic, or stiffness training effects were seen. The posttest resistance training group isometric neck flexor strength was 15% greater than the pretest measurement. Isometric neck extensor strength in the female resistance training group was 22.5% greater at the posttest than at the pretest. Women's neck girth increased 3.4% over time regardless of training group level. Women exhibited 7% less head-neck segment length and 26% less head-neck segment mass than men
Recommendation: Future researchers should examine the effect of head-neck segment training protocols that include traditional and neuromuscular activities (eg, plyometrics) with the focus of reducing head acceleration on force application			

<table>
<tr><td colspan="4">Source Mihalik, J. P., Guskiewicz, K. M., Marshall, S. W., Greenwald, R. M., Blackburn, J. T., & Cantu, R. C. (2011). Does cervical muscle strength in youth ice hockey players affect head impact biomechanics?. Clinical journal of sport medicine : official journal of the Canadian Academy of Sport Medicine, 21(5), 416–421. https://doi.org/10.1097/JSM.0B013E31822C8A5C</td></tr>
<tr>
<td>Design Methodology/ Purpose
Prospective Cohort
Purpose:
To evaluate the effect of cervical muscle strength on head impact biomechanics
Method:
Participants were equipped with accelerometer-instrumented helmets to collect head impact biomechanics (linear and rotational acceleration) throughout an entire playing season. Before the season, isometric cervical muscle strength was measured for the anterior neck flexors, anterolateral neck flexors, cervical rotators, posterolateral neck extensors, and upper trapezius. Data were analyzed using random intercept general mixed linear models, with each individual player as a repeating factor/cluster</td>
<td>Sample/ Setting
Thirty-seven volunteer ice hockey players (age = 15.0 ± 1.0 years, height = 173.5 ± 6.2 cm, mass = 66.6 ± 9.0 kg, playing experience = 2.9 ± 3.7 years)

Level: IV

Quality:
Excellent</td>
<td>Design Instruments
Dependent variables included linear and rotational head accelerations. Cervical strength data were categorized into tertiles, creating groups with high, moderate, and low strength. Strength measures were averaged and normalized to body mass</td>
<td>Results
Significant differences in cervical muscle strength existed across our strength groups ($P < 0.05$). No differences were observed in linear or rotational acceleration across strength groups for the anterior neck flexors (PLin = 0.399; PRot = 0.060), anterolateral neck flexors (PLin = 0.987; PRot = 0.579), cervical rotators (PLin = 0.136; PRot = 0.238), posterolateral neck extensors (PLin = 0.883; PRot = 0.101), or upper trapezius (PLin = 0.892; PRot = 0.689)</td>
</tr>
<tr><td colspan="4">Recommendation: cervical strength isometrically, future studies should consider dynamic (ie, isokinetic) methods in the context of head impact biomechanics.</td></tr>
</table>

Source Schmidt, J. D., Guskiewicz, K. M., Blackburn, J. T., Mihalik, J. P., Siegmund, G. P., & Marshall, S. W. (2014). The influence of cervical muscle characteristics on head impact biomechanics in football. *The American journal of sports medicine*, *42*(9), 2056–2066. https://doi.org/10.1177/0363546514536685			
Design Methodology/ Purpose Cohort study **Purpose:** To compare the odds of sustaining higher magnitude in-season head impacts between athletes with higher and lower preseason performance on cervical muscle characteristics. **Method:** The odds of sustaining moderate and severe head impacts were computed against the reference odds of sustaining mild head impacts across cervical characteristic categorizations	**Sample/ Setting** Forty-nine high school and collegiate American football players completed a preseason cervical testing protocol that included measures of cervical isometric strength, muscle size, and response to cervical perturbation **Level:** IV **Quality:** fair	**Design Instruments** Head impact biomechanics were captured for each player using the Head Impact Telemetry System. A median split was used to categorize players as either high or low performers for each of the following outcome measures: isometric strength (peak torque, rate of torque development), muscle size (cross-sectional area), and response to cervical perturbation (stiffness, angular displacement, muscle onset latency)	**Results** Linemen with stronger lateral flexors and composite cervical strength had about 1.75 times' increased odds of sustaining moderate linear head impacts rather than mild impacts compared with weaker linemen. Players who developed extensor torque more quickly had 2 times the increased odds of sustaining severe linear head impacts (odds ratio [OR], 2.10; 95% CI, 1.08-4.05) rather than mild head impacts. However, players with greater cervical stiffness had reduced odds of sustaining both moderate (OR, 0.77; 95% CI, 0.61-0.96) and severe (OR, 0.64; 95% CI, 0.46-0.89) head impacts compared with players with less cervical stiffness
Recommendation: The study findings showed that greater cervical stiffness and less angular displacement after perturbation reduced the odds of sustaining higher magnitude head impacts			

Source Toninato, J., Casey, H., Uppal, M., Abdallah, T., Bergman, T., Eckner, J., & Samadani, U. (2018). Traumatic brain injury reduction in athletes by neck strengthening (TRAIN). *Contemporary clinical trials communications*, *11*, 102–106. https://doi.org/10.1016/j.conctc.2018.06.007

Design Methodology/ Purpose	**Sample/ Setting**	**Design Instruments**	**Results**
Clinical Trial **Purpose:** Understand the relationship between neck strength and risk of SRC in student-athletes . **Method:** instructed on a manual-resistance-based neck strengthening exercise program, to be performed twice a week on non-consecutive days compared to no neck strengthening exercises	student-athletes, ages 12–23, from local high schools and colleges. These athletes are involved in a range of both contact and non-contact sports **Level**: III **Quality:** Good	MicroFet2 handheld dynamometer to determine the peak force in pounds of a subject's neck muscles in each of the stated directions	every 1-pound increase in neck strength contributed to a 5% decrease in odds for a concussion event occurring

Recommendation: Strong recommendations are supported for neck strengthening exercises to reduce the risk of TBI.

Source Wood, T. A., Morrison, S., & Sosnoff, J. J. (2019). The Role of Neck Musculature in Traumatic Brain Injuries in Older Adults: Implications From Sports Medicine. *Frontiers in medicine*, *6*, 53. https://doi.org/10.3389/fmed.2019.00053			
Design Methodology/ Purpose Literature review **Purpose:** the purpose of this perspective article is to examine the sports medicine literature surrounding the implication of neck strength and muscle activation in sports-related concussion, discuss age-related changes to neck strength and muscle activation, and highlight the potential impact on fall-related TBIs in older adults **Method:** A keyword search was performed in PubMed, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Web of Science, and Ovid-Medline. The search algorithm included all possible combinations of the keywords from the following three groups: (1) “concussion,” “traumatic brain injury,” and “head injury;” (2) “neck” and “cervical;” and (3) “muscle strength,” “muscle activation,” and “impact velocity.” A reference list search (i.e., backward reference search) and cited reference search (i.e., forward reference search) were also conducted based on the full-text articles that met the study selection criteria that were identified from the keyword search	**Sample/ Setting** Older adults. **Level**: I **Quality:** Poor	**Design Instruments** T. Wood conducted the literature search. Figure 1 displays the study selection flowchart. A total of 160 unduplicated articles were identified through the keyword and reference search, by which 134 articles were excluded by title and abstract screening. Twenty-six articles were assessed in full texts, in which 18 articles were identified and included in the review. Eight articles were excluded after full text review. Six studies were excluded because they did not examine neck strength or activation with head movement. One study was excluded because it was a review, and another was excluded because it was a dissertation. The basic characteristics of each of the included studies	**Results** Given the link between neck strength and head motion, several studies have examined the effectiveness of exercise programs targeting the muscles around the neck/head complex for improving overall head control. These previous investigations found mixed results. It was found that resistance training in college aged athletes did not alter EMG activity or head kinematics during impact
Recommendation: In addition to resistance training, it has also been suggested that neuromuscular training designed to enhance the neck muscles' dynamic responses to perturbation may be more beneficial than resistance training alone			

Appendix B: Quality Assessments and Level of Evidence Chart

PEDro scale

1.	eligibility criteria were specified	no ❑ yes ❑ where:
2.	subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received)	no ❑ yes ❑ where:
3.	allocation was concealed	no ❑ yes ❑ where:
4.	the groups were similar at baseline regarding the most important prognostic indicators	no ❑ yes ❑ where:
5.	there was blinding of all subjects	no ❑ yes ❑ where:
6.	there was blinding of all therapists who administered the therapy	no ❑ yes ❑ where:
7.	there was blinding of all assessors who measured at least one key outcome	no ❑ yes ❑ where:
8.	measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups	no ❑ yes ❑ where:
9.	all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat"	no ❑ yes ❑ where:
10.	the results of between-group statistical comparisons are reported for at least one key outcome	no ❑ yes ❑ where:
11.	the study provides both point measures and measures of variability for at least one key outcome	no ❑ yes ❑ where:

Hierarchy of Evidence for Intervention Studies

Type of evidence	Level of evidence	Description
Systematic review or meta-analysis	I	A synthesis of evidence from all relevant randomized controlled trials.
Randomized controlled trial	II	An experiment in which subjects are randomized to a treatment group or control group.
Controlled trial without randomization	III	An experiment in which subjects are nonrandomly assigned to a treatment group or control group.
Case-control or cohort study	IV	Case-control study: a comparison of subjects with a condition (case) with those who don't have the condition (control) to determine characteristics that might predict the condition. Cohort study: an observation of a group(s) (cohort[s]) to determine the development of an outcome(s) such as a disease.
Systematic review of qualitative or descriptive studies	V	A synthesis of evidence from qualitative or descriptive studies to answer a clinical question.
Qualitative or descriptive study	VI	Qualitative study: gathers data on human behavior to understand *why* and *how* decisions are made. Descriptive study: provides background information on the *what*, *where*, and *when* of a topic of interest.
Expert opinion or consensus	VII	Authoritative opinion of expert committee.

Adapted with permission from Melnyk BM, Fineout-Overholt E, editors. Evidence-based practice in nursing and healthcare: a guide to best practice [forthcoming]. 2nd ed. Philadelphia: Wolters Kluwer Health/Lippincott Williams and Wilkins.