The Effects of Concussion and the Risk for Subsequent Musculoskeletal Injuries

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ABSTRACT

Background and Purpose: The purpose of this review was to assess the effects of concussion on the risk for subsequent lower extremity musculoskeletal injuries in athletes. **Methods:** PubMed Central, CINAHL, and Google Scholar with the key words concussion, motor control, musculoskeletal injuries and sports were used for the literature review. Articles' methodological rigor was evaluated using the STROBE guidelines. **Findings:** Twelve articles met the inclusion criteria and assessed athletes in a variety of sports. The overall compliance with reporting between articles was 66% and 23 items (68%) yielded >75% agreement. **Clinical Relevance:** Athletes were twice as likely to sustain a musculoskeletal injury one-year post-concussion compared to matched controls. Athletic movements such as quickly changing directions were affected substantially longer and remained impaired after neurological function had returned to baseline. **Conclusion:** Athletes are more likely to be at risk for injury after concussion. This elevated injury risk should be considered when making return to play and rehabilitation decisions.

Key Words: motor deficits, athletes, lower extremity, injury risk

INTRODUCTION

A concussion is a "complex pathological process induced by traumatic forces secondary to direct or indirect forces to the head that disrupts the function of the brain."[1] It is classified as a mild traumatic brain injury where linear and rotational acceleration of the brain occurs relative to the skull, producing shear forces that result in axonal stretching and disruption of cortical and subcortical pathways.[2] Symptoms include altered mental status, headaches, nausea, vomiting, dizziness, diminished balance, fatigue, difficulty sleeping, drowsiness, sensitivity to light or noise, blurred vision, memory deficits, and difficulty concentrating.[3]

An estimated 1.6 to 3.8 million sports-related concussions occur each year, resulting in approximately 250,000 emergency room visits.[4,5] Twenty to 30% of high school football players will sustain at least one concussion;[6] however, this number represents diagnosed concussions, not including the ones unreported due to difficulty recognizing the signs and symptoms.[7]

Short-term complications include second impact syndrome, as an athlete is 3 to 4 times more likely to sustain another concussion within 7 to 10 days. Long-term complications potentially include chronic traumatic encephalopathy and Alzheimer's disease.[8-12]

While there is variability in the recovery statistics, 80% of individuals demonstrate a significant reduction in neurological symptoms within 3 weeks, although children and adolescents may take longer to recover.[6] The average length to return to sport ranges from 9 to 18 days.[13]

In addition to neurological changes, significant motor changes occur post-concussion with gait,[2,4,14-20] balance,[4,18,21-24] and dynamic stability.[18,21-27] These motor changes may increase risk for musculoskeletal injuries if the athlete is not screened properly, rehabilitated sufficiently, or prematurely returns to competition. Therefore, the purpose of this review was to assess the effects of concussion and the risk for subsequent musculoskeletal injuries in athletes.

METHODS

Literature Search Strategy

A literature review was conducted through December 2019 using PubMed Central, CINAHL and Google Scholar. Key words included concussion, motor control, musculoskeletal injuries and sports.

Selection Criteria

The intent of the chosen inclusion criteria was to capture the most articles possible for analysis of methodology and consistency. Inclusion criteria included articles from peer-reviewed, English language journals; retrospective or prospective cohort, case-control or cross-sectional designs with sufficient data to assess the methodology; athletes competing at any level; use of matched controls or a reference injury that tracked the time taken to return to sport; and an assessment of the occurrence of musculoskeletal injuries post-concussion.

The titles and abstracts of all initial hits from the database searches were screened by 1 of the 5 authors and then every potential full text article was reviewed according to the aforementioned criteria. The search generated a total of 12 articles for the final review. Figure 1 depicts the search strategy.

Quality of Reporting

The quality of reporting for each article was evaluated using the STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) guidelines. The evaluation was performed to identify common characteristics and offer a qualitative depiction. The STROBE guidelines provide guidance on how to improve reporting of observational studies, especially cohort, case-control, and cross-sectional studies.[28,29]

Each item on the STROBE checklist is classified as "yes" (met the criteria), "no" (did not meet the criteria), or "not applicable." Articles were reviewed by 1 of the 5 authors and discrepancies were resolved by the senior author.

An electronic database tabulated the reviewer datasets and the compliance rate for every article as well as the overall compliance rate was calculated by dividing the number of "yes" responses by the sum of the "yes" and "no" responses. If an item was not applicable to the checklist, it did not influence the compliance rate.

RESULTS

Observation studies are useful at identifying best clinical practices and can provide the opportunity to establish high external validity in randomized controlled trials, which can be challenging to accomplish. Accounting for risk of bias, confounding, cause and chance improves the reporting of observational studies, thereby improving their usefulness.[30]

The overall compliance with reporting using the STROBE guidelines was approximately 66% (range 0-100%) and 23 items (68%) yielded >75% agreement. Examples

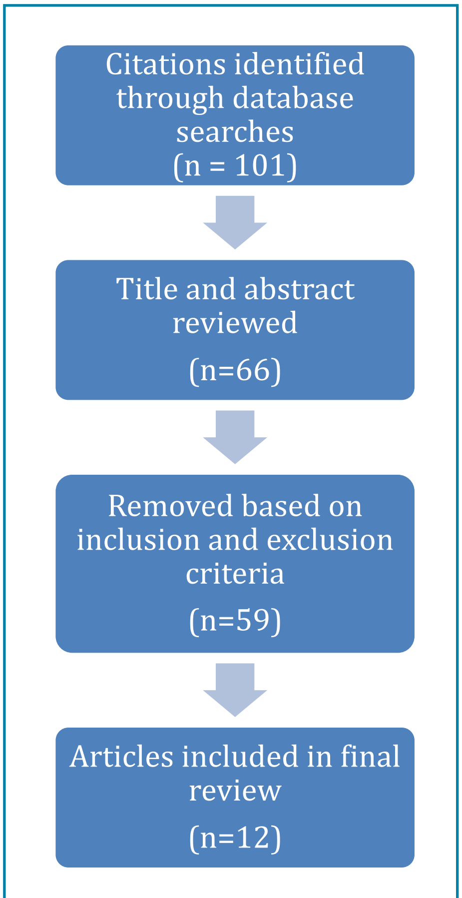

Figure 1. Search strategy results.

Table 1. STROBE Results of Articles included in the Review

Section	Item	Section Score	Percentage
Title and Abstract	1A: Title and abstract	12/12	100.00%
	1B: Balanced summary	12/12	100.00%
Introduction	2: Background/Rationale	12/12	100.00%
	3: Objectives	12/12	100.00%
Methods	4: Study Design	10/12	83.33%
	5:Setting	9/12	75.00%
	6A: Participants: Eligibility Criteria	12/12	100.00%
	6B: Participants: Match Criteria	12/12	100.00%
	7: Variables	12/12	100.00%
	8: Data Sources/Measurement	11/12	91.67%
	9: Bias	1/12	8.33%
	10: Study Size	10/12	83.33%
	11: Quantitative Variables	12/12	100.00%
	12A: Statistical Methods: Overall Description	11/12	91.67%
	12B: Statistical Methods: Subgroups	10/12	83.33%
	12C: Statistical Methods: Missing Data	0/12	0.00%
	12D: Statistical Methods: Loss to follow-up	0/12	0.00%
	12E: Statistical Methods: Sensitivity Analyses	1/12	8.33%
Results	13A: Participants: Numbers	10/12	83.33%
	13B: Participants: Reasons for Non-Participation	6/12	50.00%
	13C: Participants: Flow Diagram	5/12	41.67%
	14A: Descriptive Data: Characteristics	11/12	91.67%
	14B: Descriptive Data: Missing Data	0/12	0.00%
	14C: Descriptive Data: Follow- up	11/12	91.67%
	15: Outcome Data	12/12	100.00%
	16A: Main Results: Unadjusted Estimates	9/12	75.00%
	16B: Main Results: Category Boundaries	0/12	0.00%
	16C: Main Results: Risks	0/12	0.00%
	17: Other Analyses	2/12	16.67%
Discussion	18: Key Results	12/12	100.00%
	19: Limitations	10/12	83.33%
	20: Interpretation	11/12	91.67%
	21: Generalizability	11/12	91.67%
Other Information	22: Funding	7/12	58.33%
	Compliance	8.117647059	67.65%

included study design (100%), eligibility criteria for participants (100%), controls matched to participants (100%), study size (83%), overall description of statistical methods (92%), interpretation of findings (92%), and study limitations (83%).

Three items (9%) had intermediate compliance between 26% and 74%, including reasons for non-participation (50%), diagraming the flow of participation (42%), and source of funding (58%). Seven items (20%) had compliance <25%, including insufficient information regarding risk of bias (8%), the handling of missing data (0%), and an analysis of sensitivity (8%). The percentage of articles addressing STROBE items are provided in Table 1.

Twelve articles met the inclusion criteria and assessed high school, collegiate and professional athletes in a variety of sports including football, soccer, ice hockey, and lacrosse. The overall consensus was athletes who suffered a concussion were up to twice as likely to sustain a subsequent musculoskeletal injury, usually in the lower extremity, up to one-year post-concussion compared to matched controls. Two studies did not use matched controls but instead used a reference injury, such as an ankle sprain, while following the time needed to return to sport.[31,32] Both of these studies found a positive correlation between history of concussion and subsequent lower extremity injuries. Table 2 provides a breakdown of the findings in each study.

DISCUSSION

Several characteristics of motor control are potentially altered due to compromised neural function after a concussion and these can decrease responsiveness of the neurological system well after physical impairments have waned.[15] Examples include joint kine-

Table 2. Summary of Article Results

Author	Design	Population	Matched Controls or Reference Injury Included	Results
Makdissi[33] 2009	Prospective observational cohort	158 professional Australian rules football players	Yes	Injury rate following a concussion was 7.25 per 100 games compared to 3.25 in matched controls
Nordstrom[31] 2014	Prospective observational cohort	46 professional male soccer players	Yes	The concussion group had an increased risk of subsequent injury in the first year after returning from concussion
Lynall[34] 2015	Prospective observational cohort	44 collegiate athletes in various sports	Yes	The concussion group was twice as likely to sustain a lower extremity injury at 180 days and 1 year
Nyberg[35] 2015	Prospective observational cohort	Professional ice hockey players followed over 28 seasons	Yes	Concussed players had significantly more serious subsequent injuries
Burman[36] 2016	Retrospective cohort	281 athletes from various sports	Yes	Concussed athletes were more injury prone compared to the control group
Brooks[37] 2016	Retrospective cohort	75 collegiate athletes in various sports	Yes	Concussed athletes had a 2.48 greater risk of sustaining an acute LE injury at 90 days post-concussion
Gilbert[38] 2016	Cross-sectional design	335 athletes across 13 sports completed an injury questionnaire regarding concussion history and LE injuries	Yes	The risk for LE injuries was 1.6-2.9 times higher for concussed athletes
Cross[39] 2016	Prospective observational cohort	810 concussed and non-concussed athletes in various sports	Yes	Returning during the same season post-concussion had a 60% higher risk of injury. The time between subsequent injuries was significantly shorter following concussion
Fino[15] 2016	Retrospective cohort	The incidence of LE injuries for 1 year before and after a concussion in 110 athletes	Yes	History of concussion had a significantly increased risk of LE injury when adjusting for injury history
Herman[40] 2017	Retrospective cohort	Injury data for 73 collegiate athletes in various sports were followed 90 days after return to play	Yes	Concussed athletes were 3.39 times more likely to suffer an injury
Lynall[41] 2017	Observational cohort	Data from the National Athletic Treatment, Injury and Outcomes Network was assessed for 18,000 athletes across 27 sports	Yes	The odds for sustaining a LE injury significant enough to result in time lost from competition after a concussion increased 34%
Kardouni[42] 2018	Retrospective cohort	Active duty soldiers (11522 concussed and 11522 non-concussed) were compared for incidence of injury	Yes	The risk for of LE injury was >38% after 2 years while the risk at 15 months was >45%

Abbreviation: LE, lower extremity

matics, balance and dynamic stability, gait deviations, navigating obstacles, and dual task performance.

Kinematics

Changes in lower extremity stiffness during a single leg jump or single limb stance activity were noted post-concussion. Dubose used a force plate and 3D motion capture to analyze hip, knee, and ankle kinematics during a single leg jump from a 25 cm step.[30] Concussed athletes had decreased overall leg stiffness and delayed quadriceps activation that potentially suggest an increased risk for knee and ankle ligamentous sprains or meniscal tears due to altered landing mechanics.

Balance and Dynamic Stability

Impaired balance, dizziness, and postural instability are all acute symptoms following a concussion due to somatosensory, visual, and vestibular impairments.[4,16,18,21-24,26] Intracortical inhibition of the motor cortex has been documented one-year post concussion even after resolution of physical symptoms.[34] Diminished joint proprioception has also been reported and could contribute to changes in balance and stability.[35]

Gait Deviations and Navigating Obstacles

The most common gait deficits were decreased speed followed by increased sway, which were correlated with more time in double leg stance.[4,14-20] During obstacle walking, concussed athletes demonstrated a more conservative control of center of mass 14 and 28 days postinjury, possibly due to increased contraction of the spinal stabilizers as a compensatory measure.[14] Since 80% to 90% of athletes typically return to play after 7 to 10 days post-concussion, these findings suggest the ability to navigate obstacles may still be impaired, leading to an increased risk for another injury.[24] Additionally, cortical resources, or the brain's ability to react quickly, are affected post-concussion. Examples include difficulty with visual field processing, reduction in visual field, and difficulty reacting to changes in the external environment.[36] Swanik determined individuals who suffered noncontact ACL injuries had significantly slower processing speeds and reaction times compared to those uninjured.[37]

Dual-Task Activities

Dual-task performance is often measured by introducing auditory interferences, question and answer tasks, cognitive and obstacle tasks, and changing directions.[15,16,18,38] Noticeable changes during dual-task gait included increased sway, decreased gait speed, and decreased dynamic balance.[17,22,23] Deficits during sports-related activities (ie, cutting, jumping, running, etc) lasted up to one year post-concussion, even after single task gait was normal and the athlete was cleared to play.[14,15,25] Athletes need a high processing rate to meet the demands of sports, but a concussion decreases the ability to perform complex dual-task movements, thereby increasing risk for injury.[37,39]

Research Limitations

This review had limitations that should be considered when interpreting the results. The inclusion of English only studies could have excluded potential articles. Although the majority of the studies were prospective, retrospective data was included in the review.[34,37] Additionally, information on the type of musculoskeletal injury and mechanism of injury was usually not included, making it difficult to investigate correlations. Other limitations included unequal exposure of risk to lower extremity injury, a small sampling of concussed athletes, absence of balance or neurocognitive testing, inconsistent follow-up with subjects, and lack of generalizability.[31,34,36,37]

CONCLUSION

Motor control changes post-concussion can potentially increase the risk of lower extremity injuries. This is relevant considering athletes demonstrate motor control deficits even after being asymptomatic and cleared for return to competition. This underscores the need for evidence-based guidelines and protocols when returning athletes back to sport. Cognitive and neuromuscular testing should be performed as a baseline for comparison, with the selection of assessment tools matched to individual symptoms. This could help with prognosis and return to competition considerations.[42]

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