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Studies Uncover the Hard-Hitting Consequences of Sports-Related Head Injuries

Findings highlight need for stricter regulations of equipment, better education

WASHINGTON, DC — Playing contact sports can injure the brain even if head impacts don't result in concussions, according to new research presented today at Neuroscience 2017, the annual meeting of the Society for Neuroscience and the world's largest source of emerging news about brain science and health. The studies also suggest that relatively simple changes in equipment and athlete education could improve safety.

The risks of head injuries in sports have gained widespread attention in recent years, as studies of National Football League (NFL) players reveal the high prevalence of a neurodegenerative disease that impairs memory and changes personality. Although the focus has been on concussion, evidence indicates that less severe hits to the brain can also cause lasting damage.

Today's new findings show that:

- In soccer, "heading" the ball disrupts brain connections called axons to a larger extent in females than in males, a possible explanation for why women experience longer-lasting symptoms (Todd G. Rubin, abstract 394.08, see attached summary).
- Sustaining a concussion or simply playing one season of a contact sport temporarily decreases performance on a memory test, possibly because head impacts may affect the ability of the hippocampus to make new neurons (Melissa Danielle McCradden, abstract 394.22, see attached summary).
- Many professional football players — and older athletes in particular — disregard safety recommendations when selecting their helmets, a finding that suggests stricter helmet rules are needed to ensure better protection (Raymond J. Collelo, abstract 754.08, see attached summary).
- Cadets at the U.S. Air Force Academy falsely believe they will be penalized for multiple concussions and thus may deny when one occurs, indicating better education on concussion policy is needed (Brian R. Johnson, abstract 028.01, see attached summary).

"Today's findings continue to emphasize the dangers of head injuries in sports, as well as reveal specifics on the way particular brain regions are affected," said Linda Noble, PhD, of the University of Texas at Austin and an expert on brain injuries. "Understanding how athletes think about concussion — when choosing their equipment or reporting injury — can help create better policies that will keep them safer."

This research was supported by national funding agencies such as the National Institutes of Health, as well as other public, private, and philanthropic organizations worldwide. Find out more about concussions on *BrainFacts.org*.

Related Neuroscience 2017 Presentation

Neurodegenerative Disorders and Injury: Experimental Models Versus Reality of Neurological Disease
Wednesday, Nov. 15 8:30–11 a.m., WCC Ballroom A

Abstract 394.08 Summary

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Women Sustain More Neuronal Damage Than Men Do From Soccer Ball Heading

Female soccer players have decreased axonal integrity in more brain regions than male players

Intentionally hitting a soccer ball with the head — a common maneuver called "heading" — may have more adverse consequences on the brains of women than men, according to new research released today at Neuroscience 2017, the annual meeting of the Society for Neuroscience and the world's largest source of emerging news about brain science and health.

Heading doesn't typically result in a concussion, yet there is growing evidence linking the move to central nervous system damage. Previous studies using a brain scanning technique called diffusion tensor imaging (DTI), for example, have revealed that heading damages the integrity of the axons, the long, thin projections that carry electrical signals from neuron to neuron. Women appear to be more vulnerable than men to problems associated with heading, as they report more symptoms that last longer, but the reason for these gender differences remains unknown.

To assess possible gender differences in the effects of heading, researchers used DTI to examine 49 male and 49 female amateur soccer players, paired based on age and frequency of heading. Higher levels of heading were associated with decreased axonal integrity in three brain regions for men and eight brain regions for women. In seven of the areas identified in women, the association between axonal integrity and heading was significantly stronger than it was in men.

"Given similar amounts of exposure to heading, women show a greater volume of abnormality that is significantly different from what is seen in men," said lead author Todd G. Rubin of Albert Einstein College of Medicine. "Identifying and understanding the basis for differences in susceptibility to injury represent key steps in determining better treatments and guidelines for safer play."

Research was supported with funds from the Dana Foundation's David Mahoney Neuroimaging Program and the National Institute of Neurological Disorders and Stroke.

Scientific Presentation: Wednesday, Nov. 13, 1–5 p.m., WCC Halls A–C

Abstract 7868. Sex divergence of white matter microstructural change associated with soccer heading
T. G. RUBIN[1], E. CATENACCIO[2], R. FLEYSHER[1], L. E. HUNTER[1], N. LUBIN[1], M. E. WAGSHUL[1], W. F. STEWART[3], M. KIM[1], R. B. LIPTON[1], M. L. LIPTON[1];
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TECHNICAL ABSTRACT: Head impacts in soccer are common. Although men may be exposed to a greater number and greater force of impacts, women report more symptoms which take longer to resolve. These findings suggest that women may be more vulnerable to the effects of heading than men. In a small sample of men and women we previously showed that heading is associated with damage to white matter tract integrity as assessed by lower fractional anisotropy (FA) on diffusion tensor imaging MRI (DTI). In that study of 37 amateur athletes, biological sex was treated as a nuisance covariate. The present study explicitly characterizes the role of sex in the association of heading with microstructural changes (FA) in a cohort of 49 male and 49 female soccer players matched for age and prior 12-month heading. Subjects underwent 3.0T DTI imaging. FA was analyzed with a voxelwise linear model to assess where the association of heading with FA was significant for men, for women, and for significant differences between men and women. We found 3 regions with negative association of heading with FA for men (i.e. decreased FA with heading), and 8 regions with negative association of heading with FA for women. The volume of each region was summed to find 2,121mm^3 of white matter exhibiting lower FA associated with more heading in women, but only 408mm^3 in men. These findings provide evidence that, at the level of brain tissue microstructure, women are more sensitive to the effects of heading than men, supporting the sex differences in symptom frequency and persistence.

Abstract 394.22 Summary

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Participation in a Contact Sport May Temporarily Impair Memory

Deficit may be due to problems creating new neurons

Sports-related head injuries may prevent the generation of new neurons in a brain region important for memory, according to new research released today at Neuroscience 2017, the annual meeting of the Society for Neuroscience and the world's largest source of emerging news about brain science and health.

Concussion can lead to cognitive impairments, and recent evidence indicates even sub-concussive hits can cause damage. The hippocampus — a brain region involved in memory and mood — is particularly vulnerable. One way to test the effects of head impacts on the hippocampus is a memory assessment called the mnemonic similarity test (MST), which evaluates a person's ability to distinguish between images that are novel, previously presented, or very similar to images previously presented. Accumulating evidence suggests that MST scores are related to the hippocampus's ability to generate new neurons, called neurogenesis.

To investigate changes in memory following sports-related head injuries, researchers assessed different types of athletes in two studies. In the first study, they compared athletes who had suffered a concussion, uninjured athletes who played the same sport, same-sport athletes with musculoskeletal injuries, and healthy controls. Compared to the other three groups, concussed athletes performed worse on the MST when tested two to four weeks after their injury. The scores didn't remain low, however: By the time they were cleared to play, the concussed athletes' scores had improved to normal levels.

In the second study, rugby players were given the MST before the season started, halfway through the season, and one month after their last game. Scores dropped midseason, compared to preseason scores, but recovered by the postseason assessment.

"Using a cognitive test believed to be sensitive to hippocampal neurogenesis, we found that athletes with concussion show impairments that resolve following recovery," said lead author Melissa Danielle McCradden of McMaster University. "These findings represent, to the best of our knowledge, the first reported evidence in humans suggesting a brain change that might explain the cognitive and emotional symptoms associated with mild traumatic brain injury."

Research was supported with funds from the Canadian Institute of Health Research

Scientific Presentation: Wednesday, Nov. 14, 2–3 p.m., WCC Halls A–C

Abstract 9721. Concussion and a single season of contact sport participation affect performance on a test of high memory interference
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1Neurol., 2Psychology Neurosci. and Behaviour, 3Dept Psych & Behav Neuro, McMaster Univ., Hamilton, ON, Canada; 4Dept Med. & Neurosci, McMaster Univ. Med. Ctr., Hamilton, ON, Canada

TECHNICAL ABSTRACT: Introduction – Sport-related concussion is one of the most impactful injuries sustained by youth and varsity athletes. Recent attention has also been paid to the effects of contact sport participation in the absence of concussion, and the potential cognitive effects of repeated 'subconcussive' head injuries. The hippocampus is known to be vulnerable to head injury. A test involving a high memory interference component, known as the mnemonic similarity test (MST), may be able to detect deficits of hippocampal neurogenesis. The goal of this project was to utilize the MST to investigate cognitive changes in: 1) concussed athletes and 2) contact athletes sustaining subconcussive impacts over a single rugby season. Methods – A total of N = 160 McMaster athletes participated between September 2014-January 2016. During the preseason, all individuals completed sport psychology questionnaires and a semi-structured psychiatric interview. We then administered the MST, which tests recognition of images that are new, old, or very similar previously presented images. Two subgroups were studied: 1) Concussion: 11 athletes in the original cohort supplemented by 6 others referred to our neurology clinic were matched using a 1:2 ratio with athlete controls and were tested while symptomatic (~2-4 weeks postinjury) and again upon recovery; 2) Contact athletes: in addition to the preseason assessment, 13 rugby players also completed midseason and postseason testing. Results – 1) In the concussion subgroup, we found impaired identification of similar stimuli during the symptomatic phase, which had significantly improved upon full concussion recovery. The identification of old stimuli was also mildly impaired while symptomatic, and also improved. Using a regression model we found that concussion was significantly predictive of the degree of impairment in the identification of similar stimuli. 2) In the contact athlete subgroup, we found a significant impairment of their ability to identify similar stimuli during the midseason, but in the postseason this resolved and surpassed preseason performance. Significance – This study is the first to utilize the MST in concussion and contact sport samples. We found that the ability to discriminate between highly similar stimuli is impaired following concussion, and with contact sport participation - in both subgroups, test performance improved after a reprieve from sport participation. This study contributes to the growing body of evidence indicating subconcussive head impacts may affect cognition in the absence of an overt concussion. These results may reflect a head- injury-induced impairment of hippocampal neurogenesis.

Abstract 754.08 Summary

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NFL Players Don't Always Prioritize Safety When Choosing Helmets

Helmet selection varied based on player position and age

Some National Football League players don't choose helmets based on their safety, according to new research released today at Neuroscience 2017, the annual meeting of the Society for Neuroscience and the world's largest source of emerging news about brain science and health.

Recent reports of the prevalence of the neurodegenerative disease chronic traumatic encephalopathy (CTE) among former football players have raised awareness about the risks involved with head impacts. In an attempt to encourage better protection, helmets are given safety ratings; five-star helmets are deemed the safest and one-star helmets the least safe. However, the NFL allows players to wear whatever helmets they like, so long as they are professionally designed and "suitably protective."

To determine whether players choose the safest helmets, researchers analyzed the helmets worn by over 1,000 NFL players during one week of the 2015 season and one week of the 2016 season. The majority of players (74 percent) wore five-star rated helmets, but many opted for three-star choices. Two percent of athletes — including Tom Brady and Drew Brees — wore one-star helmets. Quarterbacks and punters had the most variability in the star ratings of their helmets, and younger players opted for the better-rated helmets. Surprisingly, many players suffering a concussion in 2015 did not switch to a helmet with a higher safety rating in 2016. The researchers also analyzed the forces that differently rated helmets produce when they collide. When two five-star helmets smashed together, for example, they produced thirty percent less force than when two one-star helmets collided, and fifteen percent less force than two four-star helmets.

"Collectively, this novel data suggest that many players are not prioritizing their safety when choosing a helmet and that the NFL should change their helmet policy by mandating that players only wear helmets that receive the highest safety rating," said senior author Raymond J. Colello, DPhil, of Virginia Commonwealth University. "This policy change would likely represent the simplest and most straightforward way to reduce brain injury in football."

Research was supported with funds from the Virginia Commonwealth University Research QUEST fund.

Scientific Presentation: Friday, Nov. 15, 4–5 p.m., WCC Halls A–C

Abstract 13500. Making American Football Safer: What factors play a role in the type of helmets worn on the playing field?
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TECHNICAL ABSTRACT: In 2014, player health concerns, liability issues, and an increasingly popular helmet safety rating system, prompted the NFL to end its official helmet partnership with Riddell and permit players the right to choose what helmet to wear during play. This led us to ask: What helmets do NFL players wear and does this helmet policy make the game safer? To address this, we identified the specific helmets worn by NFL players on Week 13 of the 2015 season and Week 1 of the 2016 season using game film footage. Of the 1000 players whose helmet was identified, we found 14 different helmets worn on the field. The most popular helmets worn were the Riddell Speed Revolution (40% of players) and the Schutt Air XP (34% of players). Players also wore the Riddell Speedflex (7%), Riddell Revolution (6%), Rawlings Quantum (5%), Riddell VSR4 (2%), Schutt Air Advantage (2%), Schutt Vengeance (2%). This represents a wide range of helmets with varying safety ratings. To elucidate what factors may drive helmet choice, we next sought to determine the extent to which helmet selection could be correlated with player position or age. An examination of helmets worn by position showed clear differences in choice; Wide Receivers, Corners and Safeties preferred the Schutt Air XP helmet at almost twice the level as all other positions, whereas players on the defensive and offensive lines preferred the Riddell Speed Revolution. Although Quarterbacks and Punters also showed a preference for these two helmets, a wider range of safety-rated helmets were selected in these two groups over any of the other positions examined. We also found a clear correlation between player's age and helmet choice, with older players preferring helmets produced earlier in their career. Specifically, the average age of players wearing the Riddell VSR4 was 33.5 years old, the Schutt Air Advantage was 30.9 years old, and the Riddell Revolution was 28.5 years old, whereas the average of those players wearing the Schutt Vengenace VTD was 27.7 years old, the Riddell Revolution Speed was 25.7, the Riddell Speedflex was 25.5 year old. Interestingly, by examining helmet production date with its safety rating we found helmets with an older production date scored a consistently lower safety rating than newer produced helmets. Specifically, the Riddell VSR4 and Schutt Air Advantage received at .79 and .69 Star value, respectively whereas the Schutt Vengeance, Riddell Revolution Speed and Riddell Speedflex score a .18, .20 and .189, respectively. Collectively, this data suggest that many players are not prioritizing their safety when choosing a helmet and that the NFL should mandate that players only wear helmets that receive the highest safety rating, to make the game safer.

Abstract 028.01 Summary

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Perceived Consequences Prevent Air Force Cadets From Reporting Concussions

Majority mistakenly believe reporting concussions will negatively affect their careers

U.S. Air Force Academy cadets may be unwilling to admit to sustaining a concussion due to an incorrect belief that too many concussions will bar them from becoming pilots, according to new research released today at Neuroscience 2017, the annual meeting of the Society for Neuroscience and the world's largest source of emerging news about brain science and health.

Cadets at the U.S. Air Force Academy are more likely than typical college students to sustain concussions, due to their military training and required participation in sports. Anecdotal evidence suggests cadets believe in a "two concussion rule" that disqualifies them from becoming pilots if they receive multiple concussions. Such a rule does not exist, but the belief that it does may lead to the underreporting of concussions and an unwillingness to seek treatment.

In this study, researchers surveyed more than 2,000 cadets about their knowledge of concussions, the Air Force Academy's policies relating to concussion, and their likelihood to report a concussion. Eighty two percent of cadets believed in the "two concussion rule," and those that did were less likely to admit they had suffered a concussion.

"When we try to achieve better concussion reporting, we need to consider more than just how much athletes know but also their perceived likely outcomes from reporting an injury," said lead author Brian R. Johnson, PhD, of the U.S. Air Force Academy. "Interventions are planned to improve self-report of concussion including a series of videos that address concussion policy misinformation, an educational program lead by Air Force physicians that manage the pilot medical clearance program, and a return-to-learn program to assist cadets with academics post-concussion."

Research was supported with funds from the National Collegiate Athletic Association and the Department of Defense.

Scientific Presentation: Tuesday, Nov. 12, 8–9 a.m., WCC Halls A–C

Abstract 8275. Concussion policy myths and their effect on self-report of concussion
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TECHNICAL ABSTRACT: Introduction – Military service academy students may have a higher risk for concussion than a typical college student due to year-round physical training, military training, and athletics. Despite this risk, students may be less likely to self-report a concussion due to a perceived effect it may have on their post-academy careers. An unclear understanding of medical policies may contribute to this misperception. For example, at the U.S. Air Force Academy (AFA), a recent survey revealed that that cadet attitudes regarding self-report of concussion change over time. As freshmen, cadets have a high intent to self-report a concussion; however as seniors, cadets' willingness to self-report decreases – especially for cadets that want to become pilots. Anecdotal evidence suggested cadets believe that there is a "concussion rule", i.e., a medical policy that removes their medical clearance to become a pilot if they receive too many concussions. To investigate this a second survey was administered to AFA cadets to better understand their beliefs about concussion injury policies as well as general concussion knowledge. Method – Cadets received a voluntary survey that addressed knowledge about concussion policies and concussion knowledge. 2204 cadets responded. Results – 82% of cadets believe in the "concussion rule", i.e., an AFA medical policy that requires the removal of their medical clearance to become a pilot if they receive too many concussions. When asked how many concussions would instigate this policy the mean was 3.76 concussions. In truth, no such policy exists. Belief in this "concussion rule" significantly predicted intent to self-report a concussion ($R2 = .002$, $F(1, 2034) = 3.93$, $p < .05$). Cadets that believed in the "concussion rule" were less likely to report a concussion. General knowledge regarding signs and symptoms of a concussion were less predictive of whether a cadet would self-report a concussion; however, knowledge regarding the health effects of a concussion was predictive. Specifically, intent to self-report a concussion was positively correlated with knowledge regarding, the increased risk to brain health if a second concussion occurs before the first concussion heals ($r = .13$, $p < .001$), symptom duration lasting several weeks ($r = .12$, $p < .001$), and the effect of concussion on long-term health and well-being ($r = .13$, $p < .001$). Future Plan – Interventions are planned to improve self-report of concussion including, a series of videos that address concussion policy misinformation; an educational program lead by AFA physicians that manage the pilot medical clearance program; a return-to-learn program to assist cadets with academics post-concussion.