Title: Sport- and Gender-specific Trends in the Epidemiology of Concussions Suffered by High School Athletes

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Introduction: Approximately 300,000 adolescents suffer concussions annually while participating in organized athletics. This mild form of traumatic brain injury (TBI) in this population is a serious public health concern, because developmentally younger brains may have less cognitive reserve and be at risk for protracted recovery. Since 2009, all 50 states and the District of Columbia have passed legislation targeted at reducing the number of concussions in youth athletics. The purpose of this study was to 1) delineate sex- and sport-specific differences among high school sports-related concussion incidences, and 2) evaluate the association between the occurrence of concussions among high school athletes and the enactment of laws targeted at reducing TBI in this population.

Methods: Injury data was collected from High School Reporting Information Online (RIO), which captures data from athletic trainers at participating U.S. high schools. Injuries were reported between 2005-15 for high school boys and girls at 100 representative U.S. high schools in 9 sports: boys football, boys and girls soccer, girls volleyball, boys and girls basketball, boys wrestling, boys baseball, and girls softball. Injury proportion ratio (IPR) was defined as the ratio of total estimated concussions to total estimated injuries. Concussion rate was defined as the number of concussions per 10,000 athlete-exposures (one athlete participating in one practice or competition). Information on TBI laws was obtained from LawAtlas. “Pre-enactment era” was defined as school years up through 2009-10, as it has been reported that widespread awareness of concussion in schools did not occur until 2010.

Results: Approximately 2,190,598 total concussions occurred nationally among high school athletes between 2005-15 in the 9 sports considered (219,060±79,163 concussions annually). The overall proportion of concussions increased significantly post-TBI law enactment (2010-11 school year and later) (IPR=2.146, 95% CI [2.140-2.151]; $p<0.0001$) (Figure 1), as did the overall rate (RR=2.003, 95% CI [1.903-2.108]; $p<0.0001$). A significantly higher proportion of concussions was seen for girls vs. boys (IPR=1.087, 95% CI [1.084-1.091]; $p<0.0001$), and girls soccer vs. boys football (IPR=1.130, 95% CI [1.126-1.134]; $p<0.0001$) after TBI law enactment.

Conclusion: A higher incidence of concussions occurred post-TBI law enactment, even after controlling for athlete-exposures, likely due to health care practitioners, coaches, athletes, and parents becoming more aware of and looking for concussions. These findings suggest an association between the passage of state TBI laws and concussion incidence. To our knowledge, this is the first study to report that concussions now account for a higher proportion of injuries in girls soccer than boys football. The

concussion rate for girls soccer is also increasing rapidly, and is now nearly tied with boys football and 3-fold higher than boys soccer. Currently, no TBI laws address sport- or sex-specific differences in concussion occurrence. By identifying differences in the proportion and rate of concussions in high school sports, this study may help to inform future work aimed at examining specific risk factors and developing targeted measures to reduce concussion incidences.

Summary: The incidence of concussions has increased significantly since the enactment of traumatic brain injury laws, and concussion is now more common in girls soccer than boys football.

Figures:

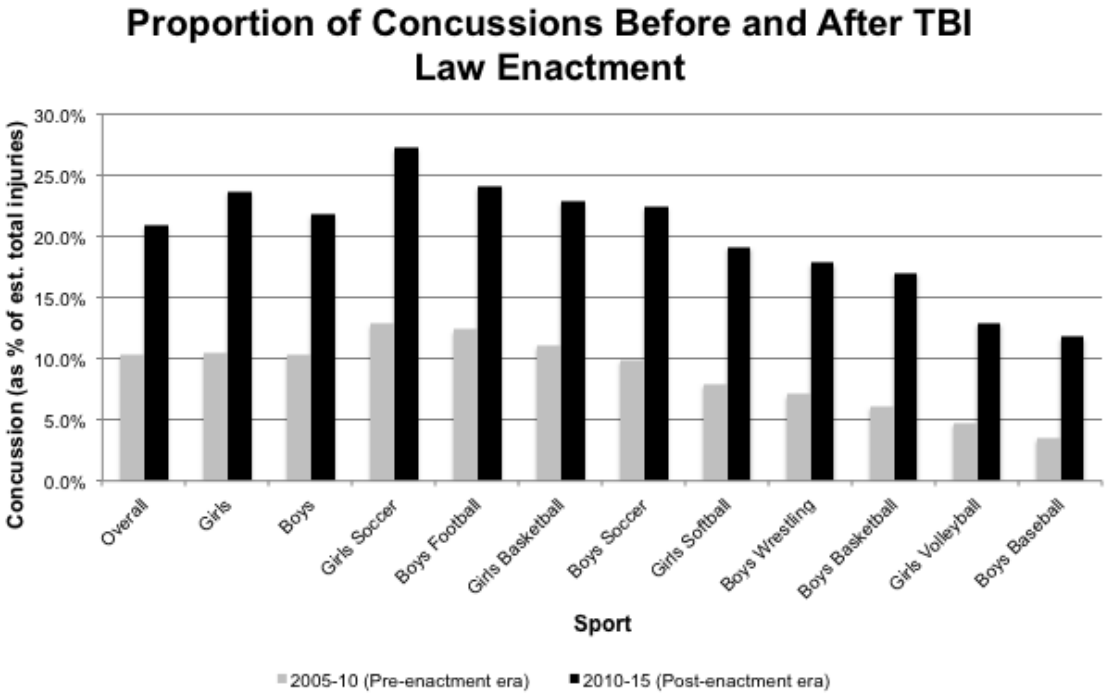

Figure 1: Concussion as a proportion of total injuries among high school athletes before and after implementation of concussion legislation, organized by gender and sport.