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Not just contact sports: significant numbers of sports-related concussions in cycling

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ABSTRACT

BACKGROUND: Although sports-related concussions (SRCs) / mild traumatic brain injuries (mTBIs) in contact sports have recently received much attention, investigation of SRCs in cycling - a sport yielding some of the highest percentages of SRC - remains strikingly limited. In particular, rates of incidence, cycling-specific causes, and potential long-term effects of SRC have not been examined in this sport. Here, a retrospective online survey was used to investigate the incidence and potential long-term effects of SRCs among cyclists. METHODS: A cycling-specific questionnaire was developed and administered to 2792 cyclists via an online survey. First, participants were asked about their acute symptomatology, and secondly, cycling-specific items and concussion history were addressed. RESULTS: Of the 999 cyclists whom completed the questionnaire, 23.8% had experienced a concussion. Incidence of concussion was significantly higher in cyclists who were club members, who cycled more than 200 kilometers per week, and who wore a helmet. Cyclists with a history of concussion complained significantly more often about headaches, pressure in the head, sensitivity to light, confusion, and irritability. CONCLUSIONS: Concussions in cycling are a serious injury with a high incidence relative to other sports. Although wearing a helmet reduces the risk of severe brain injury, interesting, the present results show a relation between helmet use, participation in cycling clubs, and increased concussion incidence. These data are in line with the growing number of findings showing that athletes with a history of concussion report more symptoms.

Key words: mild Traumatic Brain Injury (mTBI), cycling, post-concussive symptoms, sports-related concussion

Introduction

Between 2001 and 2009, sports-related TBI visits to the emergency department (ED) among children and teenagers increased an estimated 62 percent.[1] Strikingly, bicycle riding was the most common reason for sports-related emergency department visits, above American football, soccer, and basketball [2]. In 2013, cycling accounted for 383,790 ED visits and 26,530 hospital stays [2]. Findings from neurosurgical intervention found that 83 of 86 bicycle accident victims suffered from skull fractures and 73% suffered from cerebral contusions [3]. 21% of polytraumatized patients in the intensive care unit were cyclists, of whom 94% had suffered from a head injury [4]. Kloss et al. (2006) found concussion to be the most common medical diagnosis following a bicycle accident [5].

Burt & Overpeck (2001) reported that cycling had the highest number of injuries of any individual sport in Canada, accounting for 16.1% of all sports-related injuries [6]. The brain was the second most frequently lesioned body region behind the lower extremities. Fridman, Fraser-Thomas, McFaull, & Macpherson (2013) reported that concussions accounted for 4% of all injuries in cycling [13]. Data from emergency medical services calls during a 1-day recreational cycling tour revealed that concussions, defined as “head injury with a loss of consciousness”, accounted for 5% of reported injuries [8].

Concussion diagnoses can be difficult because of a lack of objective clinical and radiographic findings [9]. In cycling, sport-specific problems, the definition of a concussion and potentially unreported incidents might negatively affect a reliable estimate of concussions [6,10–13]. Whereas classification of head injuries in emergency departments was pursued according to the ICD-9-CM [6,10], classification outside the emergency department, i.e., during cycling competitions, is a particular problem because of the absence of sidelines, timeouts, or substitutions [11]. Greve and Modabber (2012) reported that medical personnel are required to make decisions within 1 or 2 minutes, thus, “the general practice is a brief assessment of the rider and, as long as the athletes are able and willing to get on their bike, to allow them to do so” [11]. The medical staff would “often accompany the rider, keeping him under close observation”; however, a detailed examination would be performed once the rider reaches the finish

[11]. Such procedures are problematic and allow potentially brain-injured athletes to get back on their bikes. Although far from the gold standard of the evaluation of sports-related concussion [12], two symptoms of brain injury - loss of consciousness and amnesia - have been argued to be critical for the removal of a cyclist from competition [11]. This procedure contrasts the most recent definition of a concussion, which states that a concussion results in a graded set of clinical symptoms that may or may not involve loss of consciousness [12]. Because of these problems and the fact that athletes often neglect to report their concussions to medical personnel [13], the occurrence of concussions in cycling are likely underestimated.

Surprisingly, while two studies evidence a high frequency of head injuries in cycling [6,10], there are only scarce data (available) on concussive incidents in cycling. The neuropsychological consequences of concussions in cycling have not been addressed yet, likely because conducting assessments during cycling competitions would take too much time and thus negatively affect competitions [11]. We therefore conducted a retrospective online survey [14]. Because a history of a concussion showed to be associated with long-term deficits in the domains of executive functioning and increased self-reported symptoms [15], we hypothesized that cyclists with a history of a concussion report more post-concussion symptoms than cyclists without the history of a concussion. Secondly, we hypothesized that cyclists with a history of concussion account for more than 13% within a group of cyclists when concussions are defined according to recent statements that do not presuppose a *loss of consciousness* or *amnesia*.

Materials and methods

Participants

1019 participants completed a cycling-specific questionnaire (2792 distributed; 36% response rate). As the reliable maximum number of cycled kilometers [km] per athlete per year has previously been recorded at 40.000 km per athlete (i.e., 800 km per month) [16], we excluded 20 participants who reported riding in excess of 800 km per week. Thus, 999 participants (301 female, 698 male) were included in the statistical analyses (mean [M] age = 36.5 years (Standard deviation [SD] = 12.3, Minimum [Min] = 14, Maximum [Max] = 72; average weekly distance travelled on a bike = 113,2 km (SD = 94.2, Min = 1, Max = 800; 253 club members, 746 non-members of clubs; 246 cycle 1-

2 days a week, 409 cycle 3-5 days per week, 272 cycle daily, 72 do not cycle regularly; 54.6% ride a speed bike, 49.3% ride a mountain bike [MTB], 0.5% ride a Bicycle Motocross [bmx], 2.8% play cycle ball, 0.9% perform artistic cycling, 36.1% ride the bike in their leisure time).

The local Ethics Committee of the German Sports University Cologne approved the study. Storing and analysis of data was conducted according to the APA ethical principles and code of conduct [17].

Study design

A two-part cycling-specific questionnaire was conducted using the online survey tool "Unipark" (QuestBack GmbH). In the first part, the questionnaire examined post-concussive symptoms using the PCS [18] on the day of the administration of the questionnaire (Likert scale from 0 = no symptoms to 6 = severe symptoms). Special care was taken to ensure that the PCS-related questions were presented prior to addressing a subject's history of concussions. Concussion history and cycling-specific questions were asked in the second part of the questionnaire. This order of the questions ensured that participants were not biased in their answers by their attention on experienced concussions. SRC was defined according to Gänsslen & Schmehl (2015), which provides a German version of the recent definition of a concussion according to the Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012 [20]. Cyclists were recruited via the internet using email lists and social network groups (e.g., Facebook); the questionnaire was posted to each group.

Data analysis

Data analysis was performed using Microsoft Excel 2011 and SPSS 23 for Macintosh. Statistical analyses were performed using Chi-Square test [χ^2], Mann-Whitney-U test [U], and binary logistic regressions of individuals with and without a history of sports-related concussion and concerning sport-specific items such as bike sport, gender, how the concussion happened, symptom scores, etc.. Significant results are reported with p-values smaller than 0.05. Multiple testings (particularly for the symptom scores) were Bonferroni corrected; for Chi-Square tests, Bonferroni corrections were performed according to Beasley & Schumacker, (1995) [21].

Results

Number of concussions

Overall, 23.8% of the 999 participants experienced a concussion during cycling (N=238, 68 female; average time since concussion=5.5±6.95 years, 0.17 - 38.22 years). 29.8% of the individuals who reported experiencing a concussion lost consciousness at the time of the concussion. With regards to activity engagement during incidence of concussion, 30.7% occurred during cycling training, 10.1% during a competition, and 59.2% during leisure time.

Characteristics of concussion incidence

The distribution of concussions between cyclists whether they are members of a cycle club or not revealed a significant deviation from the expected distribution ($\chi^2(1)=37.225$, $p<0.001$). Cyclists with a club membership experienced significantly more concussions than expected (40.3% within concussed participants, adjusted z-score [ad-z]=6.1, $p<0.001$; Figure 1).

<**Figure 1.** place here.>

The distribution of concussions regarding how many kilometers cyclists achieve per week (5 categories: 1-10km; 11-50km; 51-100km; 101-200km; 201-800km) revealed a significant deviation from the expected distribution ($\chi^2(4)=21.466$, $p<0.001$; Figure 2). Cyclists that travelled more than 200km per week experienced significantly more concussions than expected (4.8% of all participants, ad-z=4.2, $p<0.01$).

<**Figure 2.** place here.>

The distribution of wearing (/or not wearing) a helmet and the occurrence of concussions revealed a significant deviation from the expected distribution ($\chi^2(1)=10.412$, $p<0.01$; Figure 3). Post-hoc analyses showed that cyclists wearing a helmet answer significantly more often that they experienced a concussion (91.2%, ad-z=3.2, $p<0.01$).

<**Figure 3.** place here.>

Because club members achieve significantly more km per week than cyclists who are not members of an organized club (U=72229, z=-5.597, p<0.001; mean km per week$_{club\ members}$=142.9±107.4, mean km per week$_{non\text{-}club\ members}$=103.1±87) and cyclists wearing a helmet achieve significantly more km per week than cyclists who are not wearing a helmet (U=38337, z=-8.137, p<0.001; mean km per week$_{wearing_helmet}$=120.92±94.6, mean km per week$_{not_wearing_helmet}$=70.5±79.2), we additionally calculated a binary logistic regression to gain insights about which independent variable (club membership, km cycled per week, wearing a helmet) most likely influences concussion incidence. The analysis revealed a significant influence of all variables (χ^2(3)=54.255, p<0.001, R^2=0.079), i.e., club membership (b coefficient [b coef]=-0.853, p<0.001, Wald statistic (W)=26.129, odds ratio=0.433), km cycled per week (b coef=-0.003, p<0.01, W=10.291, odds ratio=0.997), and wearing a helmet (b coef=-0.582, p<0.05, W=5.262, odds ratio=0.559) influence the probability to experience a concussion during cycling.

The distribution of disciplines (i.e., speed bike, MTB, track cycling, bmx, cycle ball, artistic cycling, and leisure) and incidence of concussion revealed a significant deviation from the expected distribution (χ^2(7)=55.989, p<0.001). Cyclists who used their bike only during their leisure time experienced concussions significantly less often (3.9%, ad-z=-4.68, p<0.01). The majority of concussions reported occurred when using speed bikes (9.97%, ad-z=1.18) and MTBs (9.56%, ad-z=2.11). Interestingly, out of the 5 participating bmx cyclists, 4 reported that they experienced a concussion (0.27%, ad-z=2.84). However, more data is needed as post-hoc tests did not reveal significance.

Symptomatology

Summed PCS scores between the two groups with and without a history of a concussion revealed a significant difference (U=80229.5, z=-2.66, p<0.01). The mean summed symptom scores of the concussed group reached 13.45±14.27, versus 10.56±11.55 for the non-concussed group.

When comparing the single symptoms of the PCS between groups, headache (U=80160.5, z=-3.755, p<0.001, mean score concussed=0.6±1.16, mean score non-concussed=0.36±0.9), pressure in the head (U=80805.5, z=-3.648, p<0.001, mean score concussed=0.57±1.17, mean non-concussed=0.29±0.76), sensitivity to light (U=81716.5, z=-3.371, p<0.001, mean score concussed=0.48±1.00, mean non-concussed=0.28±0.75), confusion (U=84546, z=-3.289, p<0.001, mean score concussed=0.23±0.7, mean non-concussed=0.11±0.49), and irritability (U=79921.5, z=-3.102, $p<0.01$, mean score concussed=0.97±1.3, mean non-concussed=0.7±0.1.13) revealed significant differences between groups. To control for potentially influencing factors such as age, we additionally calculated a binary logistic regression with the dependent variable of the presence/absence of the (significant) symptoms and the independent variables concussion history and age. The analysis revealed a significant positive influence of concussion history onto the symptoms headache ($\chi^2(2)=32.478$, $p<0.001$, $R^2=0.05$; b coef=0.619, $p<0.001$, W=12.980, odds ratio=1.856), pressure in the head ($\chi^2(2)=25.018$, $p<0.001$, $R^2=0.04$; b coef=0.572, $p<0.01$, W=10.486, odds ratio=1.772), sensitivity to light ($\chi^2(2)=14.909$, $p<0.001$, $R^2=0.024$; b coef=0.179, $p<0.001$, W=10.139, odds ratio=1.767), confusion ($\chi^2(2)=11.469$, $p<0.01$, $R^2=0.027$; b coef=0.766, $p<0.001$, W=9.927, odds ratio=2.151), and irritability ($\chi^2(2)=9.175$, $p<0.001$, $R^2=0.012$; b coef=0.418, $p<0.001$, W=7.782, odds ratio=1.519). Age showed to (significantly) negatively influence headaches (b coef=-0.029, $p<0.001$, W=18.079, odds ratio=0.972), pressure in the head (b coef=-0.025, $p<0.001$, W=13.554, odds ratio=0.975), and sensitivity to light (b coef=-0.015, $p<0.001$, W=4.605, odds ratio=0.985). Thus, concussion history but not age would explain increased symptoms in the present cohort.

Discussion

Overall, 23.8% of the cyclists reported that they had experienced a concussion during cycling. Males and females were equally often affected. Cyclists, who were club members, who travelled more than 200 kilometers per week, or who were wearing a helmet experienced significantly more concussions than expected. Most concussions occurred with speed bikes and mountain bikes. Cyclists who used their bike only during their leisure time experienced significantly less often a concussion. Concerning the symptomatology, participants with a history of a concussion reported more often symptoms than non-concussed participants, particularly headaches, pressure in the head, sensitivity to light, confusion, and irritability.

Occurrence and course of events

23.8% of the study participants experienced a concussion during cycling. These percentages are high as compared to previous studies, which reported percentages between 4 and 16.1% [6–8,10]. There are several possible explanations for the high incidence rate in the present survey. First, we used an up-to-date definition of concussion [20], i.e., concussions "result in a graded set of clinical symptoms that may or may not involve loss of consciousness" whereas previous studies either used emergency visits or a *loss of consciousness* as criteria, or did not differentiate between head injuries in general and concussions [6,10–13]. Athletes often neglect to report their concussions to medical personnel [13] , thus, many concussions might not be represented in ED reports. In addition, because bicycling is far more common in European countries than in the United States, and Canada [23], the high rates of the present study might also differ from the previous studies that took place in the USA or Canada [6–8,10]. Another explanation might be that we asked in our questionnaire participants if they experienced at least one concussion during their lifetime. Previous studies investigated head injuries during a 1-year period reporting to the emergency department [6,10] or during a 1-day recreational cycling tour in New York [8]. Thus, 23.8% of reported concussions seem to reflect that there exists a high number of sports-related concussions in cycling, however, it points out that further research is needed that concerns concussive incidents in cycling during single events, seasons, etc..

The data further shows that cyclists who were club members, or who travelled more than 200 km per week experienced significantly more concussions. Bikers who used their bike during their leisure time experienced significantly less often a concussion than expected. In contrast, amateurs in soccer or handball experience more concussions than professional players [24] suggesting that individuals who are less skilled and less trained underlie a higher risk of concussive incidents in those sports. The present study demonstrates that for cyclists the opposite applies, i.e., cyclists who are performing in a more professional way in a club and/or who ride less than 200km per week also experience more concussions.

The study further revealed that cyclists with a helmet experience more concussions. Previous data showed that contemporary bicycle helmets are highly effective at reducing head injury metrics and the risk for severe brain injury in bicycle crashes [25,26]. However, the present data indicates that wearing a helmet is associated with a higher risk of concussions during cycling. A study on the protective performance of bicyclists helmets found that predominant form of head injury recorded when wearing a helmet was low severity concussion [27]. Wearing a helmet reduced the risk of head injury by 63% and of loss of consciousness by 86% [28]. However, the latter authors did not differentiate between head injuries and concussions by including injuries to the skull, forehead, and scalp or loss of consciousness into one variable. Thus, the present results indicate that helmets protect against severe TBI, however, the incidence of mild TBI might increase with wearing a helmet.

Further analyses revealed that the factors club membership and wearing a helmet impact concussion history the most. Someone might speculate that cyclists who achieve more km per week would be exposed to a higher risk, and, in fact, club members presented more km per week than non-members, however, in the regression analysis the km per week did not show high impacts on concussion history in comparison to the other variables. Thus, cyclists organized in clubs and wearing helmets are of increased risk to concussions.

Symptomatology

In line with previous findings [15], we also found that athletes with a history of concussion report more symptoms than individuals without a history of concussion. Main differences between individuals with and without a history of concussion were observed for the symptoms *headache*, *pressure in the head*, *sensitivity to light*, *confusion*, and *irritability*. *Headaches* have been reported as the most apparent symptom in previous studies as well [18]. Thus, to protect athletes from more severe injuries, cyclists should be examined in more detail after an incident including questions concerning headaches, pressure in the head, sensitivity to light, confusion, and irritability.

Conclusions

The present study demonstrates that concussions are common in cycling and increase with factors such as club membership and achieved km per week. While wearing a helmet reduces the risk of severe brain injuries, it increases the risk of experiencing a concussion. The fact that affected individuals report more symptoms than individuals without a history of concussion indicates that concussions in cycling leave individuals with potentially persistent health problems. Because *headaches* were reported as the most frequent symptom, key diagnostic criterions in cycling should use an up-to-date definition of sports-related concussions.

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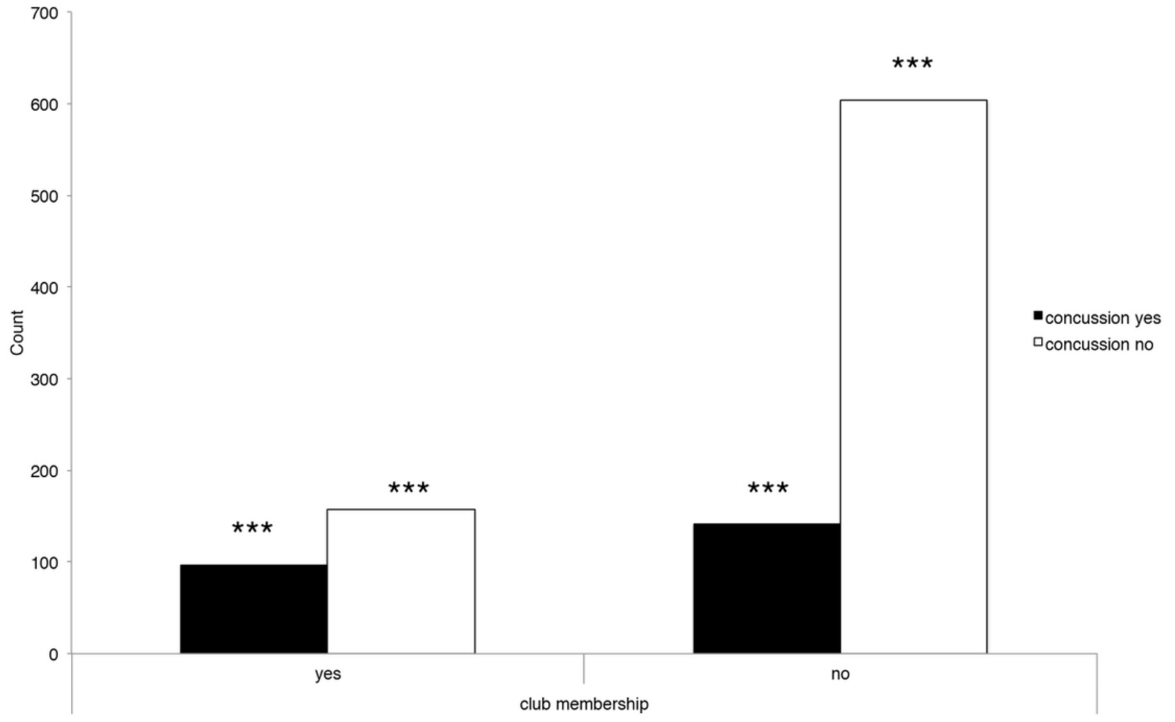
Authors' contributions. Daniel von Götz[1], Carina Emsermann[1], Fu Xuanjin[1], Anne Griese[1], Ilka Lauterbach[1] collected the data and helped writing the manuscript. Hedda Lausberg helped writing the manuscript. Author Disclosure Statement. No competing financial interests exist.

TITLES OF FIGURES

Figure 1. Club membership and the occurrence of concussions.

Figure 2. The occurrence of concussions with regard to distance travelled per week.

Figure 3. The (unequally) distributed occurrence of wearing a helmet in cyclists with and without a history of a concussion.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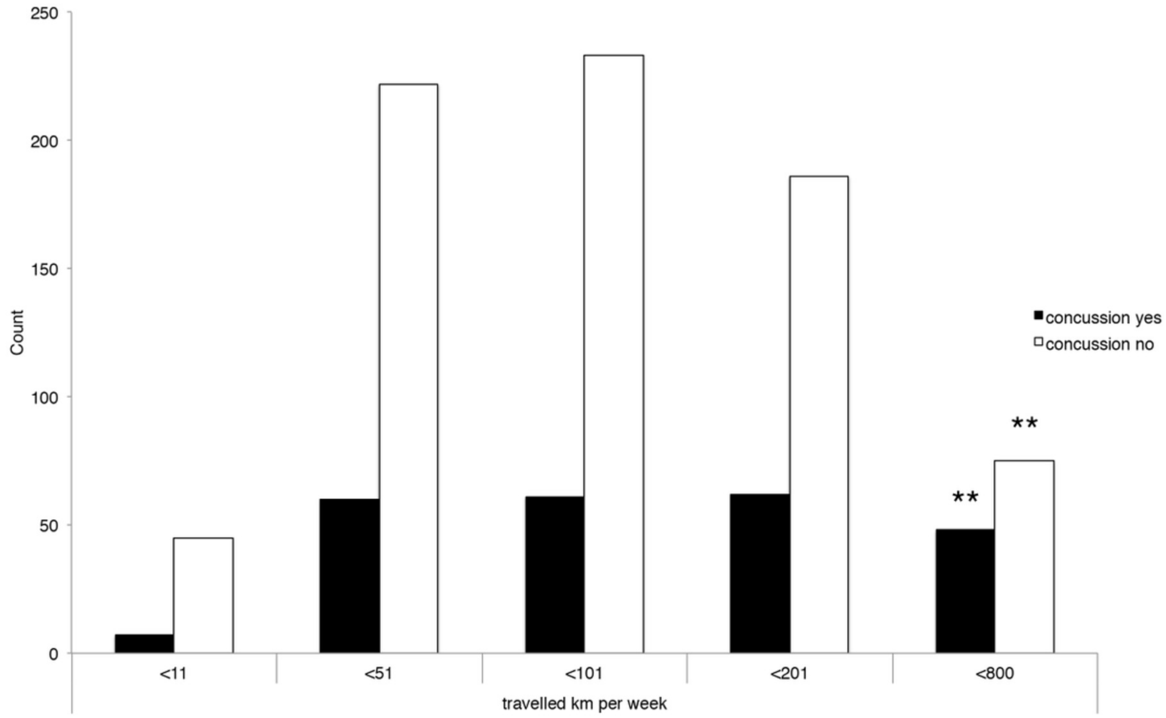
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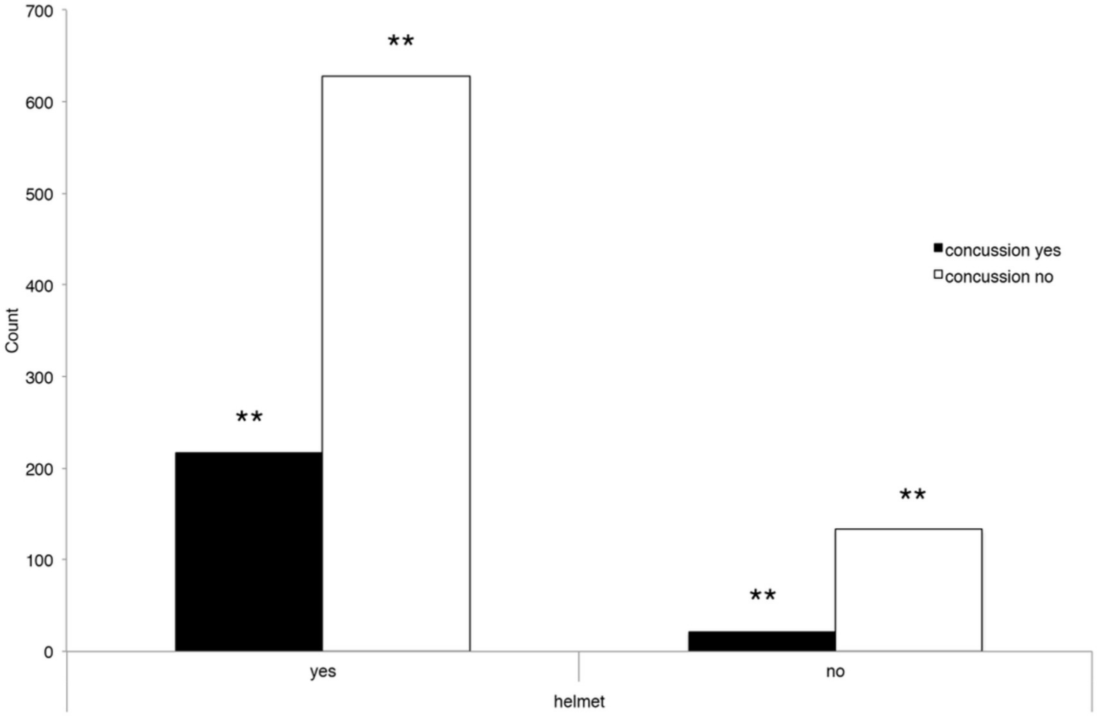
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