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Subconcussive Head Blows in American Football: An underestimated Risk?

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Abstract

Objective: Concussions and subconcussive head blows (SHB) appear to affect cerebral health in American football athletes. However, it is still unclear whether SHBs affect cognitive and neuropsychiatric outcomes during the course of a single season.

Method: In a longitudinal pilot study, we examined 32 male German amateur American football athletes (M = 23.97 +/- 2.95). Effects of concussion history and playing position on differences between pre- and postseason cognitive and neuropsychiatric composite scores were analyzed by repeated measures ANOVAs. The relationships between the numbers of seasons played in the career and cognitive/neuropsychiatric composite scores were analyzed using partial correlations.

Results: Results did not reveal cognitive or neuropsychiatric longitudinal changes over the course of one season. However, athletes with a concussion in the past showed higher pre- and postseason neuropsychiatric composite scores compared to athletes without concussion in the past. Moreover, the number of seasons inversely correlated with the cognitive composite score (controlled for documented concussions in the past).

Conclusion: One American football season might be too short to detect SHB-related cognitive or neuropsychiatric changes manifesting over multiple years. However, concussion history appears to be related to neuropsychiatric burden, whereas the length of the career may be associated with attentional dysfunctions.

Keywords: Traumatic Brain Injury; Concussion; Cognition; Symptom Severity; Playing Position; Season

Introduction

Extensive research in the last decade has revealed that repeated concussions can have a negative impact on cerebral health in American football players. In a number of studies, repeated concussions were linked to cognitive deficits, reduced brain activation, cortical thinning, enlarged ventricles, axonal damage, glial activation, increased tau protein concentrations in the cerebrospinal fluid, affective symptoms or even suicidal tendencies [1]. Whereas the negative consequences of repeated concussions in American football are well studied, however, it is unclear whether playing American football may involve cerebral health risks beyond a history of repeated concussions. American football players incur hundreds of subconcussive head blows (SHBs) each season. SHBs are defined as multiple repetitive impacts to the head (e.g. at the line of scrimmage) that do not meet the diagnostic criteria for concussion or mild traumatic brain injury [2]. Initially, SHBs do not lead to acute symptoms normally associated with a concussion, but may rather pose a cumulative harm for the cerebral health of the athletes [3].

Moreover, there is some evidence that athletes with high-impact playing positions such as defensive or offensive linemen are particularly exposed because they suffer more frequent and severe hits compared to athletes with lower-impact (e.g. receiver) playing positions [4-6]. Moreover, athletes with high-impact playing positions were reported to exhibit poorer cognitive performances and higher neuropsychiatric symptom severity compared to their teammates with low-contact positions [7]. Most studies examined the cumulative effects of SHBs after several seasons. However, SHBs may affect cognition even during a single season. Mc Allister and colleagues (2012) [8], for example, reported that a higher percentage of football and ice hockey players showed poorer performances than predicted post-season in comparison to noncontact athletes. Bazarian and colleagues (2012) [9] showed that the number of self-reported SHBs correlated with changes in white matter integrity over the course of one football or ice hockey season, but without affecting cognition or neuropsychiatric burden. Other studies did not find any SHB-related changes [10]. Taken together, data on the effects of SHBs is sparse and inconsistent due to inconsistent methodology and operationalization across studies [11]. In particular, this applies to possible effects of past concussions and different playing positions on the impact of SHBs on cognitive and neuropsychiatric health.

Methods

Participants

In a longitudinal pilot study, we therefore examined 32 male German amateur American football players between 19 and 31 years of age (M = 23.97, SD = 2.95) over the course of one season (Table 1). Athletes were recruited in a local 3rd league American football club in Germany. All participants provided informed written consent. The study protocol was in accordance with the Declaration of Helsinki and approved by the institutional review board of Bielefeld University.

Measures

Beside the collection of demographic and football-related data, the study protocol included neuropsychological and neuropsychiatric assessments. Neuropsychological examination involved the Test of Attentional Performance (TAP), an established and well-validated computerized neuropsychological test battery assessing different attentional sub functions such as tonic and phasic alertness, working memory, flexibility, divided attention, focused attention, and visual scanning [12]. For each these sub tests, reaction time medians and age-standardized T-scores of these medians were collected. Moreover, we computed a cognitive composite score by the summation of age-standardized T-scores divided by the number of sub tests. Neuropsychiatric symptom severity was assessed with the symptom checklist as implemented in the SCAT-5 [13]. For each of the 22 symptoms, severity was rated on a 7-point-Likert scale (0 – 6). Moreover, we defined a neuropsychiatric composite score by the summation of severity scores with a possible range between 0 and 132.

N	32
Age in years (M/SD/range)	24.0/2.9/19-31
Education in years (M/SD/range)	11.6/1.5/10-13
Height in cm (M/SD/range)	185.1/7.3/169-198
Weight in kg (M/SD/range)	100.3/19.9/76-158
Number of games in the current season (M/SD/range)	7.1/4.7/0-12
Number of seasons in the career (M/SD/range)	4.2/4.0/0-13
Number of concussions in the current season	0
Concussions in the past (%)	34.5
Cognitive composite score (pre-season), T-value	49.7/4.6/39-60
Neuropsychiatric composite score (pre-season)	8.5/13.2/0-69
Regular medication (%)	3.1
Head injury in the past (%)	36.7
Headaches in the past (%)	33.3
Migraine (%)	13.3
Psychiatric/psychological history (%)	3.3
Sleeping problems (%)	34.4

N = number of participants; M = mean value; SD = standard deviation; cm = centimeters; kg = kilogram

Table 1: Sample characteristics

TAP performance and neuropsychiatric symptom severity were assessed pre- and post-season. Total duration of each assessment was 45 – 60 minutes. Mean time interval between both assessments was 32.3 weeks with a range between 30.4 and 34.6 weeks.

Statistics

Data analyses included descriptive statistics of the total sample, repeated measures analyses of variance (ANOVAs) and correlation analyses. To examine the impact of a past concussion and the playing position on cognitive performance and neuropsychiatric symptom severity over the course of one season, we conducted 2 (Group: documented concussion in the past versus no documented concussion in the past) x 2 (Position: high- versus low-contact) x 2 (Time: pre-season versus post-season) repeated measures ANOVAs for cognitive and neuropsychiatric composite scores. Post-hoc comparisons were utilized to specify significant main and interaction effects (t-tests). The group of athletes with high-impact playing positions included 6 offensive linemen, 4 defensive linemen, 4 linebackers and 7 running backs. The low-contact group involved 5 defensive backs, 4 receivers, 1 kicker/punter and 1 quarterback.

To examine whether playing football may involve long-term health risks beyond one season and beyond the impact of a past concussion, pre-season cognitive and neuropsychiatric composite scores were correlated with the number of seasons played in the career, controlled for documented concussions in the past (partial correlations). Exploratory, the same analyses were run for attentional sub scores and single neuropsychiatric symptoms. Finally, a Chi^2 test was conducted to compare athletes with high- and low-impact playing positions regarding the occurrence of documented concussions in the past. Data were analyzed with IBM SPSS Statistics 20.0 (SPSS Inc.). All levels of significance were $\alpha \leq 0.05$ and tests were two-tailed.

Results

Participants showed a mean cognitive composite score of T = 49.7 (SD = 4.6) before the season and of 50.9 (SD = 3.7) after the season indicating an average level of cognition in the current sample (compared to the general population). Neuropsychiatric composite scores were 8.5 (SD = 13.2) pre-season and 8.2 (SD = 8.7) post-season indicating a low average symptom severity in the current sample of athletes.

The 2 (Group) x 2 (Position) x 2 (Time) repeated measures ANOVA for the cognitive composite score did not result in significant main or interaction effects. The 2 (Group) x 2 (Position) x 2 (Time) repeated measures ANOVA for the neuropsychiatric composite score revealed a significant main effect of group ($F = 4.35$, $p = 0.50$). Post-hoc t-tests confirmed higher neuropsychiatric composite scores in athletes with documented concussion in the past than in athletes without documented concussion in the past. This group difference was evident pre-season ($t = 2.47$, $p = 0.04$) and, at a lower statistical threshold, post-season as well ($t = 2.1$, $p = 0.06$). Apart from this main effect of group, no other main or interaction effects were found (Figure 1).

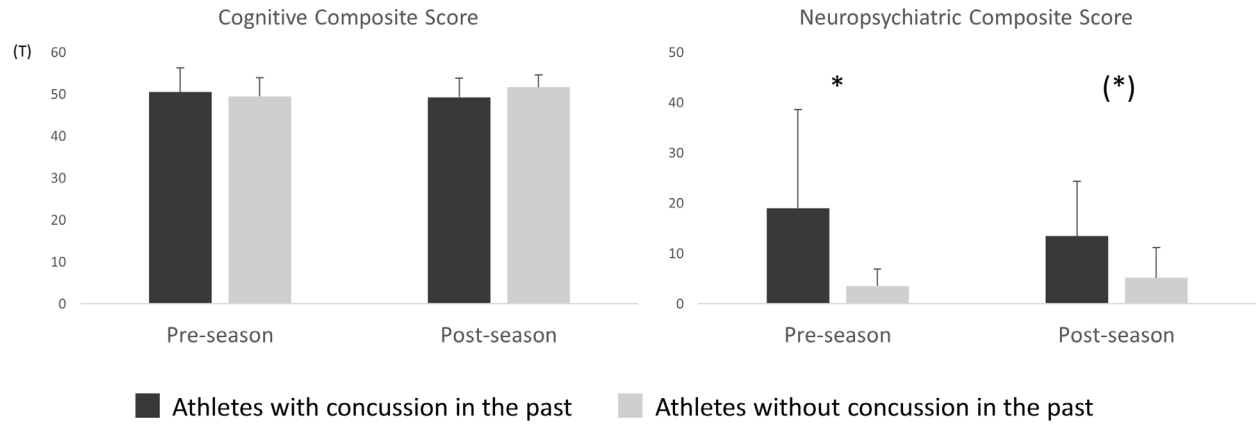

Figure 1: Pre-season and post-season cognitive and neuropsychiatric composite scores in athletes with and without documented concussion in the past. * $p < 0.05$, (*) $p < 0.10$

Partial correlation analyses revealed that the number of seasons played in the career was moderately correlated with a decreased pre-season cognitive composite score ($r = -0.49$, $p = 0.12$), after being controlled for documented concussions in the past. Explorative analyses additionally showed that specifically reaction times during visual scanning ($r = 0.39$, $p = 0.04$) and divided attention ($r = 0.43$, $p = 0.02$) were correlated with the number of seasons (Figures 2A and B). Age did neither correlate with the number of played seasons, nor with visual scanning or divided attention. The number of seasons played in the career did not correlate with pre- or post-season neuropsychiatric composite scores or with single neuropsychiatric symptoms (after being controlled for documented concussions in the past).

Finally, results revealed that about 33 % of athletes with high- and low-impact playing positions had a documented concussion in the past, but without differences between the groups ($Chi^2 = 0.01$, $p = 0.93$).

Discussion

In sum, our findings did not reveal longitudinal changes over the course of one American football season, neither for cognitive performance nor for neuropsychiatric symptom severity. However, results showed that athletes who suffered a concussion in the past exhibit increased neuropsychiatric symptom severity compared to athletes without concussion in the past. Moreover, the number of season played in the career was associated with poorer attentional performance.

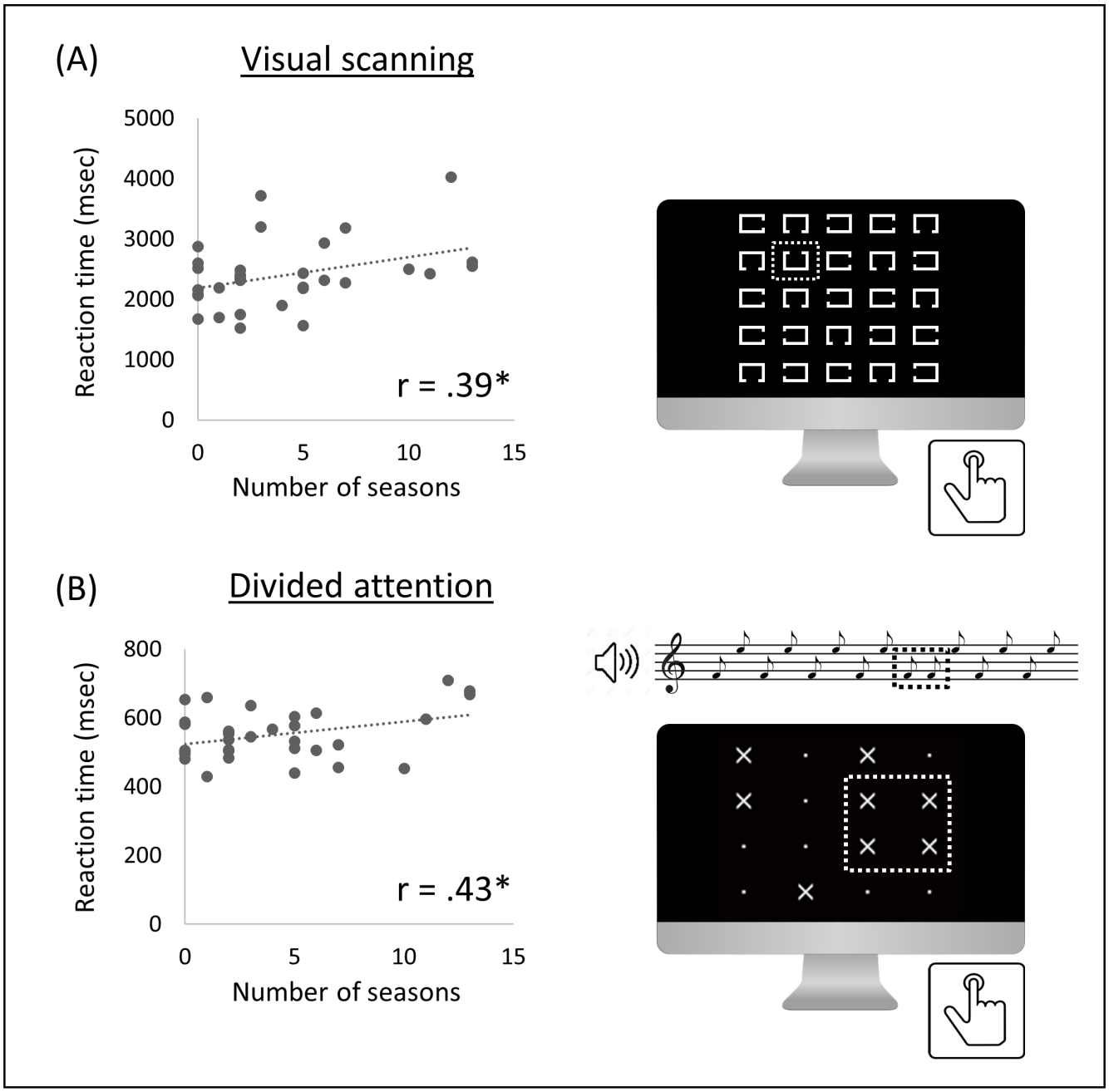

Figure 2: (A) Correlation between number of seasons in the career and reaction time in the subtest "Visual Scanning" of the Test of Attentional Performance TAP [12] controlled for documented concussions in the past. In this subtest, participants have to react as fast as possible by button press, if a pattern of 25 rectangles includes a rectangle open at the top (highlighted in the figure by the dashed line). Please note that some of the athletes played their first regular football season; **(B)** Correlation between number of seasons in the career and reaction time in the subtest "Divided Attention" of the TAP, controlled for documented concussions in the past. In this subtest, a visual and an auditory task must be processed in parallel. In the visual task, participants have to react as fast as possible by button press, if four letters X form a square on the screen (highlighted in the figure by the dashed line). In the auditory task, participants have to react as fast as possible by button press, if two tones of the same height are presented one after the other within a tone sequence of high and low tones. Please note that some of the athletes played their first regular football season. * $p < 0.05$

Subconcussive head blows

The results of the current pilot study indicated an average level of cognition and a rather low level of neuropsychiatric burden in the sample of athletes. In the context of similar cognitive and neuropsychiatric outcomes before and after the season, our findings suggest that SHBs do not pose a high risk for the cerebral health of the athletes. Noteworthy, recent studies suggest that imaging and biomarkers may be more sensitive to SHB-related changes than cognitive measures [11]. In fact, there is evidence for changes in cerebral activation, functional connectivity [14], white matter integrity [15,16] and cerebrovascular function [17] across a single season. By contrast, one season might be too short to detect SHB-related changes of cognitive or neuropsychiatric symptom severity manifesting over multiple years. In line with this assumption, our data revealed a relationship between the numbers of seasons played in the career and reduced pre-season attentional performance. Reduced attentional performance particularly involved slower reaction times during visual scanning and divided attention. The relationships were independent from age and concussion history indicating that greater exposure to SHBs may have led to these cognitive dysfunctions. Matching results were reported by Stamm and colleagues who found associations between lower age at first exposure to SHBs and reduced cognitive performance as well as white matter integrity in later life [18,19]. Other than expected, the playing position did not have an impact on cognitive performance and neuropsychiatric burden in our study, although athletes with high-impact playing positions (e.g. defensive or offensive line) have been reported [6] to show poorer cognition and increased neuropsychiatric symptom severity than athletes with low-impact playing positions (e.g. receiver).

Taken together, evidence on possible long-term consequences of cumulative SHBs during the football career is very sparse, so that more studies including larger samples are urgently needed to be able to draw valid conclusions. Thereby, methodological challenges particularly involve longitudinal designs over a longer period of time, a more precise definition and quantification of SHBs as well as the definition of biomechanical thresholds [1].

Concussions

Next to above conclusions about possible long-term consequences of SHBs on cognitive health in American football players, our results indicate that concussions in the past are associated with increased neuropsychiatric symptom severity years later. This finding confirms a large body of previous evidence on the possible long-term consequences of repeated concussions [1,20]. To lower the risk for long-term health disturbances, there are several options particularly involving an early detection and optimal treatment of concussions. As recommended by the 2017 Concussion in Sport Group [21], an efficient concussion management should involve a rapid multidimensional sideline screening including cognitive and neuropsychiatric symptom evaluation and a comparison with baseline performance. Currently, The SCAT-5 [13] represents the most common screening tool for sideline diagnostics. Concussion rehabilitation represents a multimodal and multidisciplinary challenge with close neuropsychological and neuropsychiatric monitoring during the recovery process that should follow a graduated stepwise rehabilitation strategy of at least 7 days [21]. Interventions may combine cognitive, psychological, cervical and vestibular rehabilitation, while risk factors for slower recovery (e.g. initial symptoms, migraine, depression) and possible preventive strategies should be taken into account.

Practical implications

All of these diagnostic and therapeutic options may be useful components for the management of both concussive and subconcussive head blows. SHBs, however, are often overlooked or ignored, because possible negative consequences do not stand out initially, but usually manifest over years or even decades. Hence, athletes are usually not removed from the field nor examined directly after the game [3]. In fact, American football is unavoidably associated with SHBs that cannot be prevented without turning football into a different sport. If negative long-term effects of SHBs on physical, mental or cognitive health should be confirmed by future research, however, it must be discussed how the number and biomechanical impact of SHBs can be reduced or attenuated. This would particularly apply to youth football, when players are in critical neurodevelopmental life periods in order to lower the risk for future health disturbances [18,22].

The few diagnostic options for subconcussion management involve the examination of visual-vestibular balance [23], the use of sensors to measure impact kinematics [23], acute changes in serum S100B levels [24] or sideline screenings to detect immediate but temporary cognitive dysfunctions [25]. Therapeutic options are usually restricted to preventive approaches such as nutritional supplementation [26,27] or jugular vein compression collars [28] that may reduce the negative effects of SHBs and protect attention functions.

Importantly, the impact of concussive and subconcussive head blows may particularly concern professional sports since speed and forces are more intense than at Amateur level. On the other hand, professional players appear to be more resistant and have a far better access to professional neuropsychological and medical treatment. Hence, it appears to be of particular relevance that the guidelines for concussion management find their way into mass sports as well.

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