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On-field signs of concussion predict deficits in cognitive functioning: Loss of consciousness, amnesia, and vacant look

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Abstract

The usefulness of on-field signs in predicting concussion outcome is under debate. We studied the prevalence of these signs and analyzed the predictive value for post-injury cognitive recovery in Finnish elite-level youth ice hockey players. Of the 570 consecutive athletes, 52 were concussed during seasons 2015-2017. After exclusion criterion analysis included 34 hockey players (14-20 years-old). Follow-up assessment was performed seven days post-injury and compared with pre-injury baseline. Cognitive performance was assessed using the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT®) battery. Hierarchical regression analyses were conducted to examine the relationship between on-field signs of concussion and the post-injury change in cognitive performance. The findings indicated that on-field loss of consciousness, amnesia, and vacant look were associated with larger decrements in cognition. Loss of consciousness accounted for 22% of the variance in verbal memory scores; amnesia accounted for 15% of the variance in verbal memory scores, and the presence of vacant look accounted for 9% of the variance in visual memory performance. The presence of loss of consciousness, amnesia, or vacant look is risk factors for longer recovery times and predict the need for extended cognitive follow-up.

KEYWORDS

exercise-induced damage, injury

1 | INTRODUCTION

Concussion is a common injury in high-velocity sports such as ice hockey, rugby, and American football. For adults involved in such sports, it is estimated that 2.5 concussions occur for every 10 000 games or training sessions the athletes participate in.[1] In youth ice hockey, the estimated incidence rate is much higher—6.2 concussions for every 10 000 athletic exposures.[1] These rates likely underestimate the actual prevalence because a substantial proportion of concussions go unrecognized or unreported.[2-4] A high proportion of concussions in ice hockey occur in contact situations between two players. The incidence increases in youth ice hockey when checking becomes permitted in the game.[5,6]

Most sport-related traumatic brain injuries are mild,[3] and symptoms resolve in most athletes within 10 days.[7]

Demographics and variables such as previous concussion history and age are predictive of the magnitude and persistence of post-concussion deficits.[8] Adolescent athletes may demonstrate more severe neuropsychological deficits 1-10 days post-injury than adults.[9]

Loss of consciousness (LOC) and posttraumatic amnesia (PTA) are traditional on-field signs of concussion and essential in assessing the immediate severity of concussion.[10-12] They may also guide clinical decision-making during recovery when other objective methods (eg, neuropsychological assessment) are not available.[9] The Sport Concussion Assessment Tool (SCAT) is commonly used to gather information about acute effects of concussion.[13,14] The tool includes a systematic assessment of on-field signs of concussion such as LOC, PTA, disorientation, postural instability, and vacant look.[10,12,15]

Previous studies of American football, Australian football, rugby, ice hockey, basketball, and soccer have found an incidence of on-field signs of concussion as follows: LOC approximately in 5%-10%,[3,16] amnesia in 15%-25%,[16-18] disorientation in 44%-48%,[18,19] postural instability in 20%-60%,[18,20-22] and vacant look in 75% of acute cases.[21] Studies thus far have not explored on-field signs in adolescent ice hockey in Northern Europe.

On-field signs and symptoms have been studied as potential predictors of slow recovery[11,23-25] because such prognostic information is pivotal for decisions regarding return to play or return to classroom or work. In an earlier meta-analysis, LOC and amnesia were associated with the severity of neuropsychological deficits within ten days of concussion.[26] A more recent systematic review however indicated that this association is unclear[11] and the importance of LOC and amnesia has been questioned.[10,27] Timing of post-injury assessment affects the observed effect. Usually, large effects are found within 24 hours of injury and they reduce to moderate to small within days to weeks.[26] LOC is also associated with prolonged symptom recovery.[28,29] However, LOC has been suggested to be a relatively weak predictor of outcome compared with duration of PTA.[10]

The immediately visible signs of concussion, such as LOC, vacant look, and postural instability have been found to be sensitive in the detection of concussion in the studies that used video analysis for verification.[15,30,31] While vacant look is considered a particularly common clinical feature of concussion,[12,21] its diagnostic value has been questioned due to its high specificity but low sensitivity in the diagnosis of concussion.[30,32]

Because of the variability in the premorbid cognitive functioning of individual athletes, many organizations have adopted a pre-season baseline cognitive testing protocol for their athletes. Pre-season results can be used as an accurate estimate of the athlete's pre-injury cognitive functioning making the interpretation of post-injury scores more reliable than relying on normative data.[33] There are differences in neuropsychological functioning based on athlete's culture and language of origin.[34] Even though training effects involved in repeated testing have some impact on the test results, repeated cognitive assessment has become one of the primary objective tools for clinical decision-making in sport-related concussion management.[12,35]

Although there are many studies examining on-field signs of concussion and their association with outcome,[10,11,22,26] few of these studies have focused on the association between on-field signs and concussion, and the capacity of each sign individually to predict cognitive performance. The present Northern European study of a consecutive sample of Finnish elite youth ice hockey players adds to the research in this area taking into account cultural and linguistic influence on neurocognitive performance. We analyzed the prevalence of on-field signs of concussion and the impact of these signs on cognitive recovery at seven days post-injury. Our aim was to study the usefulness on-field signs of concussion (ie, LOC, amnesia, disorientation, postural instability, and vacant look), for predicting worse-than-baseline neurocognitive performance during the acute post-injury period. We hypothesized that on-field amnesia would predict deficits in neurocognitive performance at seven days post-injury.

2 | MATERIALS AND METHODS

2.1 | Subjects

The data were collected as part of the "Heads in the Game" project at the University of Helsinki. In Finland, there are multiple levels of youth ice hockey. The subjects were recruited from players in an elite-level junior-divisions. There are seventeen ice hockey clubs with elite-level teams in Finland which all participated in the "Heads in the Game" research project during seasons 2015-2017. The project included baseline assessments of 1823 athletes and a structured program to identify concussion and monitor recovery during the season. Pre-season cognitive functioning, balance, and self-reported symptoms were assessed in all participants.

Players from four ice hockey clubs in Southern Finland were selected for a more intensive follow-up of adolescent and young adult players (12-21 years of age). The clubs were selected based on close proximity to the University of Helsinki where the post-concussion follow-up assessments took place. These clubs included a total of 570 athletes. The medical personnel of the clubs was instructed to contact the project team in case of a suspected concussion.

A total of 55 concussions in 52 athletes were reported during the seasons 2015-2017. If an athlete had another concussion during the same playing season, the second concussion and subsequent evaluations were not included to the analysis (n = 3). Eight athletes were excluded from the study because of pre-existing learning disabilities, attention deficit disorder, migraine, or missing pre-injury data. None of the athletes reported a history of epilepsy, meningitis, prior brain surgery, or psychiatric disease. Incomplete information regarding on-field signs or pre- or post-injury cognitive assessment resulted in a further 10 participants being excluded. Data from the remaining 34 subjects were included in the present study. The athletes were 14-20 years of age (M = 16.91, SD = 1.75), and they had 0-4 previous concussions (Mdn = 0).

2.2 | Identification of concussion and the on-field signs

The teams' medical personnel (eg, physician, physiotherapist, or first-aid personnel) were trained in using the Sport Concussion Assessment Tool, 3rd Edition (SCAT3)[13] to evaluate all suspected concussions acutely at sideline. A concussion was suspected if the player (a) had received a direct blow to the head, face, neck or elsewhere on the body and (b) showed symptoms (somatic-, cognitive- and/or emotional), physical signs (eg, LOC or amnesia) or behavioral change (eg, irritability).[12] The SCAT3 was also used for recording the signs of concussion: LOC, amnesia, disorientation, postural instability, and vacant look. Each of these signs was assessed and recorded independently.

2.3 | Cognitive assessment

Concussed athletes were invited to participate in post-injury follow-up at 7 days post-injury, and they were followed until asymptomatic. Since post-injury neuropsychological deficits usually resolve within seven to 10 days,[16,26] the seven days post-injury assessment point was selected to track the neurocognitive recovery. In the follow-up, the measures used in the baseline assessment were re-administered by either a psychologist or a physiotherapist trained in using the assessment methods. They also interviewed the athlete for the presence of symptoms.

Cognitive functioning was assessed with the ImPACT® computerized neurocognitive test battery (Online version; ImPACT Applications Inc). The battery consists of six individual test modules measuring attention, memory, reaction time, processing speed, learning, and executive functioning. ImPACT® provides composite scores for verbal and visual memory, visual motor speed, reaction time, and impulse control and also includes a Total Symptoms Score describing the severity of subjective symptoms. There are studies supporting the reliability and validity of ImPACT.[36-39] Similar to other computerized tests, also less-than desirable reliability estimates have been reported for ImPACT.[40] The athlete's age, number of previous concussions, medications, and medical history were collected as the background information.

Baseline assessments were carried out the summer preceding the playing season at the local ice hockey practicing venue. Athletes completed ImPACT® in their native language and used headphones to avoid distraction. At the baseline, athletes also completed the SCAT3 sideline screening test[13] and the King-Devick test.[41] The baseline assessment took approximately 1 hours 15 minutes to complete.

2.4 | Statistical analysis

All analyses were performed using the IBM SPSS Statistics software version 25.0 (IBM Corp., Armonk, NY, USA). Outliers or extreme values were scanned but not found. Missing baseline values for three athletes were imputed by average of the group values. Initial analyses using Kolmogorov-Smirnov and Levene's test were performed to confirm that the assumptions underlying the parametric statistical procedures were met. For comparing the baseline and post-injury scores, the follow-up ImPACT® test results were subtracted from the baseline results. This change score was analyzed using a series of independent samples t-tests to test whether the change in cognitive performance differed between the group with and without a specific on-field sign of concussion. Athletes were divided into groups based on whether each on-field sign of concussion existed or not, forming dichotomous independent variables. Based on t-test results, hierarchical linear regression analyses were conducted to test the relationships between on-field signs of concussion (independent variables) and neurocognitive deficits (dependent variable) at seven days post-injury. An a priori power analysis was adopted using G*Power3[42] with a medium effect size ($f^2 = 0.15$) and significance level of 0.05 to estimate the appropriate sample size for hierarchical regression analyses. Results showed that a total sample size of 55 participants was required to achieve a power of 0.80. Each hierarchical linear regression analysis was done in two stages. In the first stage, the analysis produced the null model with no independent variables and only the control variables of age and number of previous concussions. In the second stage, the on-field sign of concussion was added to the null model, to determine whether it had a significant effect on cognitive performance over and above the impact of age and previous number of concussions.

3 | RESULTS

The most common on-field signs of concussion were disorientation (67.6%, n = 23) and postural instability (44.1%,

TABLE 1 Comparisons of change in ImPACT® test results from the baseline to post-injury performance in the group without sign of concussion (no) and the group with on-field sign of concussion (yes). The on-field signs were loss of consciousness, amnesia, disorientation, postural instability, and vacant look

Signs of concussion and change in cognitive performance				
	Loss of consciousness			
	No (n = 26)	Yes (n = 8)		
Change in	M (SD)	M (SD)	*t* (*df* = 32)	*P*
Verbal memory	5.84 (7.15)	−4.47 (9.66)	3.28	<.01**
Visual memory	−1.15 (12.52)	1.26 (13.70)	−0.47	.64
Visuomotor speed	2.01 (5.37)	2.55 (6.96)	−0.23	.83
Reaction time	0.00 (0.06)	−0.03 (0.14)	0.75	.46
	Amnesia			
	No (n = 25)	Yes (n = 9)		
Change in	M (SD)	M (SD)	*t* (*df* = 32)	*P*
Verbal memory	5.55 (7.58)	−2.53 (9.81)	2.54	.02*
Visual memory	−1.88 (11.93)	3.01 (14.55)	−1.00	.33
Visuomotor speed	1.77 (4.96)	3.17 (7.58)	−0.63	.53
Reaction time	−0.01 (0.07)	−0.01 (0.12)	0.14	.89
	Disorientation			
	No (n = 11)	Yes (n = 23)		
Change in	M (SD)	M (SD)	*t* (*df* = 32)	*P*
Verbal memory	5.26 (6.57)	2.53 (9.76)	0.84	.41
Visual memory	0.92 (12.34)	−1.31 (12.99)	0.48	.64
Visuomotor speed	3.07 (3.31)	1.69 (6.53)	0.66	.52
Reaction time	−0.02 (0.05)	0.00 (0.10)	0.81	.38
	Postural instability			
	No (n = 19)	Yes (n = 15)		
Change in	M (SD)	M (SD)	*t* (*df* = 32)	*P*
Verbal memory	5.62 (7.87)	0.62 (9.48)	1.68	.10
Visual memory	0.95 (13.00)	−2.53 (12.32)	0.79	.44
Visuomotor speed	2.34 (6.09)	1.89 (5.30)	0.23	.82
Reaction time	0.00 (0.07)	−0.01 (0.10)	0.50	.62
	Vacant look			
	No (n = 20)	Yes (n = 14)		
Change in	M (SD)	M (SD)	*t* (*df* = 32)	*P*
Verbal memory	4.40 (8.15)	2.00 (9.89)	0.77	.45
Visual memory	3.31 (13.56)	−6.14 (8.94)	2.28	.03*
Visuomotor speed	2.15 (6.01)	2.12 (5.37)	0.02	.99
Reaction time	−0.01 (0.07)	0.00 (0.10)	−0.40	.69

Abbreviations: M, mean; SD, standard deviation.

*$P \leq .05$

**$P < .01$.

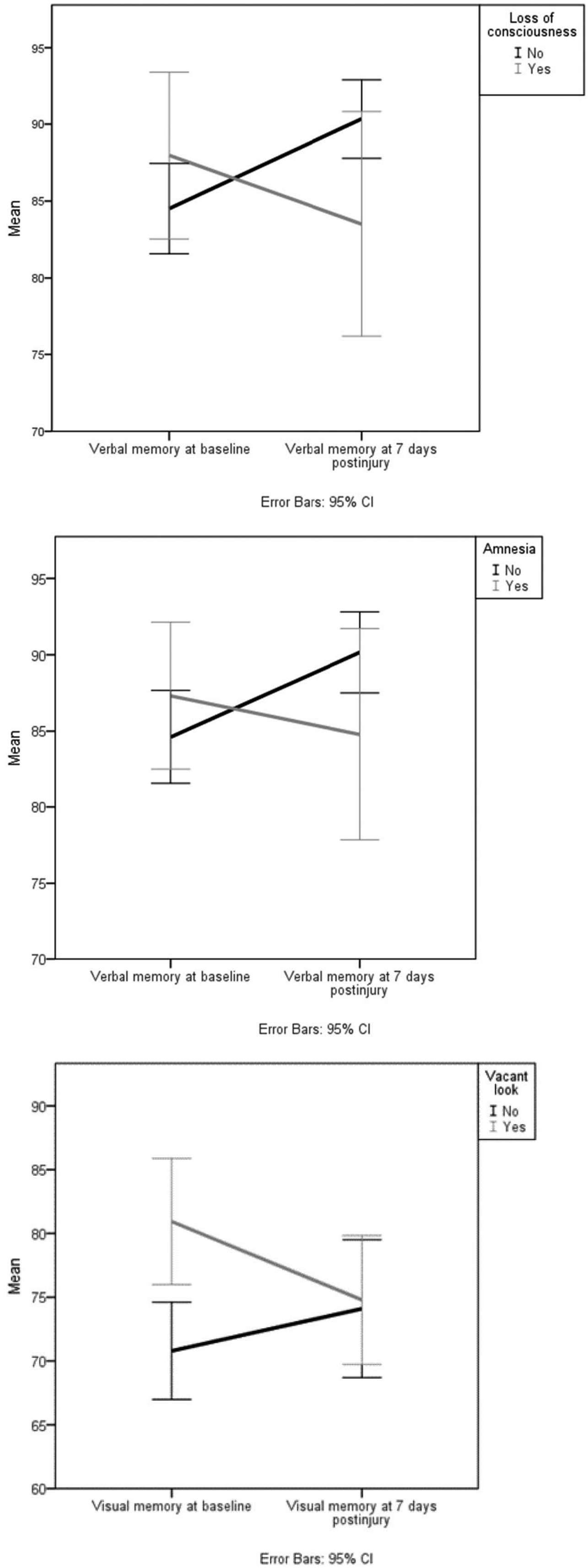

FIGURE 1 Comparison of verbal and visual memory performance at baseline and at 7 days post-injury in the group without sign of concussion (no) and in the group with on-field sign of concussion (yes) and standard error of measurements with 95% confidence interval (CI). The on-field signs were loss of consciousness, amnesia, and vacant look

n = 15). Vacant look was present in 41.2 percent of the cases (n = 14), amnesia in 26.5 percent (n = 9), and LOC in 23.5 percent (n = 8) of cases. In 22 cases (64.7%), more than one sign was reported. LOC or amnesia was present in 11 cases of which 6 cases experienced both (54.5%). Total symptoms score revealed that 41.2 percent (n = 14) of cases were asymptomatic and 58.8 percent (n = 20) of cases experienced some subjective symptoms (M = 3.21, SD = 3.75) at seven days post-injury.

There was a statistically significant group difference in verbal memory performance, between the groups with or without the LOC ($P < .01$) and between the groups with or without the amnesia ($P = .02$) (Table 1.). There was also a significant difference in visual memory in the groups with or without the vacant look ($P = .03$) (Table 1.). Subjects with LOC, amnesia or the vacant look sign performed worse in cognitive tests at follow-up, than at baseline (Figure 1.). Subjects without any of the signs performed better in cognitive test at follow-up than at baseline. Based on t-test results, three further analyses were conducted to clarify the impact of LOC, amnesia, and vacant look on verbal and visual memory functioning.

3.1 | Loss of consciousness

A hierarchical regression analysis was performed to evaluate whether LOC was a significant independent predictor of change in verbal memory performance (Table 2). The first step which included the control variables only was not significant, $F(2, 31) = 0.59$, $P = .56$. In the second step, LOC was entered, and it accounted for an additional 22% of the variance in verbal memory performance, $F(1, 30) = 8.96$, $P = .005$. In total, the three predictors accounted for 26% of the variance of the change in verbal memory performance, $F(3, 30) = 3.48$, $P = .03$. As shown in Table 2, only LOC accounted for a significant proportion of unique criterion variance in the final regression model.

3.2 | Amnesia

The second hierarchical regression analysis evaluated whether amnesia was a significant independent predictor of change in verbal memory performance in follow-up study when age and concussion history were controlled. For step one, results were not significant (Table 2.). In the second step, amnesia accounted for an additional 15% of the variance in verbal memory performance, $F(1, 30) = 5.61$,

TABLE 2 Summary of hierarchical regression analysis predicting change in neurocognitive performance from on-field signs of concussion at follow-up. Age and concussion history are controlled in these models

Variable	B[a,*]	SE B[a,*]	B[b,**]	R^2	R^2 change
Change in verbal memory performance					
Step 1					
Age	0.83	0.89	0.16	0.04	
Concussion history	0.79	1.40	0.10		
Step 2					
Age	0.40	0.81	0.08	0.26[a,*]	
Concussion history	−0.10	1.28	−0.01		
Loss of consciousness	−10.10[b,**]	3.37[b,**]	−0.49[b,**]		0.22[b,**]
Step 1					
Age	0.83	0.89	0.16	0.04	
Concussion history	0.79	1.40	0.10		
Step 2					
Age	0.66	0.84	0.13	0.19	
Concussion history	0.52	1.31	0.07		
Amnesia	−7.75[a,*]	3.27[a,*]	−0.39[a,*]		0.15[a,*]
Change in visual memory performance					
Step 1					
Age	−2.20	1.12	−0.30	0.26[b,**]	
Concussion history	−4.71[b,**]	1.75[b,**]	−0.42[b,**]		
Step 2					
Age	−1.64	1.10	−0.23	0.35[b,**]	
Concussion history	−4.61[b,**]	1.67[b,**]	−0.41[b,**]		
Vacant look	−7.74[a,*]	3.85[a,*]	−0.31[a,*]		0.09[a,*]

[a]Unstandardized Beta coefficient.

[b]Standardized Beta coefficient.

*$P < .05$.

**$P \leq .01$.

$P = .03$. In total, the three predictors accounted for 19% of the variance in change in verbal memory performance, $F(3, 30) = 2.32$, $P = .10$, but the model was not significant. As shown in Table 2, only amnesia accounted for a significant proportion of unique criterion variance in the final regression model.

3.3 | Vacant look

The third hierarchical regression analysis evaluated whether vacant look was a significant independent predictor of change in visual memory performance in follow-up when age and concussion history were controlled. The first step that included the control variables was significant, $F(2, 31) = 5.52$, $P = .01$. In the second step, vacant look accounted for an additional 9% of the variance in visual memory performance, $F(1, 30) = 4.05$, $P = .05$. In total, the three predictors accounted for a significant 35% of the variance in change in verbal memory performance, $R^2 = 0.35$, $F(3, 30) = 5.39$, $P < .01$. As shown in Table 2, vacant look and concussion history accounted for a significant proportion of unique criterion variance in the final regression model.

4 | DISCUSSION

We assessed on-field signs as predictors for change in neurocognitive performance in concussed athletes at seven days post-injury. Athletes with LOC and amnesia had larger decrements in verbal memory performance when compared to athletes without these signs. Additionally, on-field vacant look was associated with more pronounced visual memory deficits. The remaining on-field signs detected by the SCAT3 (disorientation and postural instability) were not significant independent predictors of change in neurocognitive performance when age and previous concussion history were taken into account.

The on-field signs of concussion included in our study were disorientation (present in 68%), postural instability (44%), vacant look (41%), amnesia (27%), and LOC (24%). Almost two thirds of the subjects had more than one on-field sign. The most common on-field sign, disorientation, was not associated with cognitive deficits, which is in contrast to a previous study in which disorientation lasting more than five minutes was associated with memory deficits at seven days post-injury.[19] Especially the prevalence of LOC was higher in current study compared with earlier studies[3,16] indicting that injuries with LOC might have been more easily recognized and reported by the teams' medical personnel.

LOC and amnesia were associated with deficits in neurocognitive functioning which is consistent with prior research. LOC and amnesia immediately after the injury indicate a risk of poor outcome in all head injuries, and the combination of initial LOC and prolonged amnesia diagnosed using a traditional neuropsychological test battery[29] may indicate a severe concussive injury in athletes. A recent systematic review pointed out that while some studies have found an association between LOC or PTA and worse clinical outcome, two thirds of studies looking at this relationship have not found an association.[11] In the studies in which the association was found, the on-field signs of concussion (LOC, PTA, or disorientation) had lasted longer than five minutes.[19] The memory scores of ImPACT have been shown to be sensitive to the effects of sport-related concussion[19] especially in injuries with on-field amnesia.[10] The presence of amnesia is linked to representation of metabolic or other dysfunction in the hippocampal and temporal cortical areas[10] which might explain observed memory deficits also in the current study. The methods used for cognitive assessment and the timing of the post-injury assessment also affect how sensitively predictors of observed clinical outcome are recognized, for example, neuropsychological deficits usually resolve within seven to 10 days.[26] We might have detected a larger effect, if an earlier post-injury assessment had been available, which must be taken into consideration in interpreting the results of our study, which focused on the effects at day seven post-injury. As LOC and amnesia quite often coincide (in 55% of cases in current study), we decided not to fit them in to the same model. Using this approach, both LOC and amnesia predicted worse memory functioning at seven days post-injury. The finding highlights the importance of assessing memory and the importance of these two signs in clinical decision-making.

On-field vacant look was associated with deficits in visual memory. Vacant look has been found to be a very subjective sign, because the assessment heavily depends on the rater's view and is therefore difficult to reliably assess. However, correctly assessed, this clinical sign has high specificity for a diagnosis of concussion. Trained medical personnel should have better accuracy recognizing the vacant look sign than lay observers.[32] In the current study, that teams' medical personnel (eg, physician, physiotherapist, or first-aid personnel) knew the athlete, and his normal appearance well. We think that this provided an advantage in correctly detecting the vacant look sign.

History of prior concussions and age were used as control variables in our analyses in an attempt to statistically isolate the predictive effect of LOC, PTA, or vacant look on cognitive functioning. In the model where vacant look predicted deficits in visual memory, the history of prior concussions was a statistically significant covariate. A recent systematic review[11] explored factors that might influence recovery from concussion. Only a minority of the studies discovered an association between the number of prior concussions and the clinical outcome defined by neuropsychological functioning, symptom reports, or postural stability.[11] Still, the history of repeated concussions is a risk for new concussions and a history of prior concussions is associated with greater self-reported pre-injury symptoms.[11] However, multiple concussions do appear to be a risk factor for long-term cognitive impairment in all individuals.[43] Young age has also been regarded a risk for worse outcome post-injury, but this has been found only in a minority of studies that have looked at this relationship.[11] In our subjects, aged 14 to 20 years, we found no such association.

There are advantages and restrictions in our study to be pointed out. We used pre-defined criteria for the suspicion of a concussion, and a clearly defined concussion management protocol. We used validated assessment methods in a prospective study setting, and special effort was made to train the teams' medical staff and other team personnel in the use sideline assessment methods. Comprehensive data about athletes' medical and concussion history were also gathered. All subjects within our sample underwent pre-injury neurocognitive baseline assessment that permitted direct comparison of pre- and post-injury status. Comparison to the subject's baseline detects cognitive deficits more sensitively than comparison to normative data. In the present study, subgroup differences were evident in visual memory where athletes with vacant look initially performed better than average, based on previously calculated reference values.[44] If comparison had been made between normative data and post-injury performance, this difference would have gone unnoticed.

Our sample size is notably small which limits the strength and generalizability of the findings of this preliminary study. The calculated sample size of 55 was diminished by the selected exclusion criteria. The sample also comprised only male ice hockey players; thus, these results should be generalized to females with caution. Unfortunately, the duration of LOC or amnesia was not known and this is something to consider in future studies.

We used only one assessment tool (ImPACT®) to detect cognitive deficits, which likely decreased sensitivity. However, this tool is specifically designed for sports and is widely used in research, which is beneficial in contrasting our findings to other studies. In current study, we used regression -based methods focusing on cognitive change at group level. However, in future studies, focusing on the change at individual level using reliable change methodology[45,46] is warranted.

5 | PERSPECTIVE

Adolescent athletes presenting with on-field LOC, amnesia, or vacant look after an impact on the head are at risk for having cognitive deficits and should undergo comprehensive and individualized assessment prior to returning to sport activity. Memory functions are more sensitive than other areas and should be carefully evaluated if post-impact amnesia or vacant look were present, or on-field LOC occurred.

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CONFLICT OF INTEREST

None.

ETHICAL APPROVAL

The study was approved by the Ethical Committee of the Helsinki Uusimaa Hospital District. Each participant or, if the athlete was younger than 16 years of age, a parent/guardian has signed an informed consent. The study was conducted according to the Declaration of Helsinki.

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