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## **A comparative analysis of Hungarian football, handball and ice hockey game officials' concussion recognition ability**

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### **Abstract**

*The objective of the present study was to assess and compare Hungarian football, handball and ice hockey game officials' concussion recognition ability. A total of 133 game officials were evaluated using the Concussion Recognition Questionnaire. At the time of the assessment, all participants were working in the highest-level Hungarian league of their respective sports. The findings showed that ice hockey game officials recognized more true symptoms and signs of concussion compared to handball game officials, while no significant difference was found in recognizing false symptoms. Importantly, game officials' previous personal experience of concussion did not influence their ability to recognize concussion symptoms. These findings have crucial practical implications, since they highlight the importance of improving game officials' knowledge of concussion and their ability to recognize related symptoms in order to prevent negative physical health outcomes and to create a safe playing environment.*

**Keywords:** *football, handball, ice hockey, concussion, symptoms, recognition, game officials*

In previous studies we assessed the concussion recognition ability of ice hockey participants such as players, coaches and players' parents (Nagy, Kiss, Géczi, & Soós, 2018). The aim of the present study was to continue this series of investigations, this time including game officials. Game officials are considered as the third team at sporting events, who are responsible for enforcing the rules of the game. Nowadays, their job is more than blowing a whistle –they are required to ensure a safe environment for athletes to show their skills. Consequently, the flow of accurate information between game officials, coaches, players and parents should facilitate early recognition of concussions and prevention of negative consequences.

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Since physical contact between players is allowed in ice hockey, we picked to compare the two most popular team sports in Hungary, that is, football and handball.

Players are generally exposed to a higher risk of concussion in sports where physical contact is allowed (Clay, Glover, & Lowe, 2013). Athletes cannot prepare or train their brain for traumatic brain injury. Current sports literature focuses on sport concussion history emphasizing the practical relevance of this topic (Nagy & Géczi, 2014). Concussion is a specific type of injury – and game officials have the right to impose greater penalties or ask special medical treatment in case of injuries. Most signs and symptoms of a concussion are different and less visible than those of other types of injuries (e.g., a broken hand or a bleeding lip). Game officials have a crucial role in recognizing early signs of concussions, since this ability is required for imposing adequate penalties and avoiding some of the negative consequences of concussions for the injured players' health.

Concussion is defined as a brain injury and as a complex pathophysiological process affecting the brain, induced by biomechanical forces (McCrory, Meeuwisse, Dvorák, Aubry, & Bailes, 2017). Researchers in the field have adopted the term “sport-related concussion” (SRC), which is based on expert consensus and not on clinical practice guidelines, the latter used by health care professionals in cases of non-professional sport participants. According to McCrory and colleagues (2017), cases of SRC have several common features which may be used in clinical practice for defining the nature of a concussive head injury, and these include the following: (1) it may be caused either by a direct blow to the head, face, neck or indirectly by an “impulsive” force transmitted by the body to the head; (2) it typically results in the rapid onset of short-lived impairment of neural functions that resolves spontaneously, but there are cases in which symptoms and signs evolve over a period of minutes to hours; (3) it may be followed by neuropathological changes, yet the acute symptoms largely reflect a functional disturbance rather than a structural injury and, as such, no abnormality is revealed by standard structural neuroimaging investigations; and (4) SRC results in a graded set of clinical symptoms that may or may not involve loss of consciousness (McCrory et al., 2017).

Unfortunately, while this medical definition may be adequate for the qualified medical personnel, it may be too complicated for sport participants, as it does not help them understand what and why actually happens to the brain during or as a consequence of an SRC (Caron, Bloom, Johnston, & Sabiston, 2013). Additionally, although the concept is well defined and described in clinical settings, people may hold some misconceptions. For example, many people think that concussion necessarily involves loss of consciousness or amnesia. However, loss of consciousness or amnesia are seen in relatively few cases of concussion and it is important to underline that loss of consciousness and amnesia are only some of the possible symptoms among many others (Meier et al., 2015). There may be an immediate loss of consciousness, in which case the injured person usually does not

remember pre- and post-accidental events (McRea et al., 2002; Notebaert & Guskiewicz, 2005). It is another common belief that only a blow to the head may cause concussion, whereas, as earlier mentioned, any part of the body can cause shock if the impulsive force is transmitted to the head (McCrorry et al., 2005). According to Coghlin, Myles, and Howitt (2009), there are four types of symptoms and signs of concussion: physical symptoms, cognitive symptoms, emotional symptoms, and physical signs, which are presented in Table 1.

Table 1.  
*Signs and symptoms of concussion*

<b>Physical symptoms</b>	<b>Cognitive symptoms</b>	<b>Emotional symptoms</b>	<b>Physical signs</b>
Headache	Confusion	Depression	Loss of consciousness
Dizziness	Amnesia	Irritability	Poor coordination
Nausea	Disorientation	Moodiness	Easily distracted
Feeling “unsteady”	Poor concentration		Poor concentration
Feeling “dinged”, “stunned”, “dazed”	Memory disturbance		Slow responses
Describing bell ringing			Vomiting
“Seeing stars”, visual disturbance			“Glassy eyed”
Tinnitus			Photophobia
Diplopia			Aphasia
			Personality change
			Inappropriate behavior
			Decreased physical ability

According to the literature, it is of great significance to recognize even the mildest concussion, since the likelihood of negative consequences of a recent concussion increases over time if early detection is failed (Slobounov, 2008). The symptoms and consequences of a second concussion may be more acute than those of the first one, and therefore recovery time may be significantly increased (Guskiewicz, McCrea, & Marshall, 2003). According to some researchers, special attention should be paid to young athletes’ concussions, since their brain is still developing, and hence injuries at this age may have serious consequences (e.g., headache), cognitive impairments (e.g., memory and executive function disturbances), visual problems, motor and sensory changes, and seizures (Annegers, Hauser, Coan, & Rocca, 1998; Marchie & Cusimano, 2003). The seriousness of concussions has recently attracted a lot of media attention due to tragic events in many major sport leagues such as the National Football League (NFL) or the National Hockey League (NHL; Armour, 2017; Associated Press, 2013, 2014; Boylen, 2017; Campbell, 2017; Cantu, 2007). As recognition is a key element of the treatment – all three sports use the SCAT5 card at the international level, which was developed in several different congresses on sport concussions (McCrorry, Meeuwisse, Aubry, Cantu, & Dvorák, 2013; McCrorry et al., 2017). The development of the SCAT5 card was based on preexisting concussion assessment tools employed in different sports, including the Management of Concussion Sports

Palm Card developed by the American Academy of Neurology and Brain Injury Association (Kelly et al., 1991), the Standardized Assessment of Concussion (McCrea, Randolph, & Kelly, 2000), the Sideline Concussion Check of the UPMC/Thinksafe/Sports Medicine New Zealand Inc. and Brain Injury Association (Khrapko, McLelland, Russell, & Henry, 2017), the McGill Abbreviated Concussion Evaluation (unpublished), the National Hockey League Physician Evaluation Form (unpublished), the United Kingdom Jockey Club Assessment of Concussion (Turner, 1998), and the Maddocks Questions Test for Concussion (Maddocks, Dicker, & Saling, 1995).

Early management of concussion symptoms and making an adequate decision on concussed athletes' return to play, essentially requires early detection and proper documentation. Game officials have the right to prevent a player from continuing playing. Relevant regulations in football, handball and ice hockey are designed so that injured players do not return to play too early.

In football, the rules of the game provide that the referee must stop the game immediately in case of a head injury. In accordance with the concussion protocol of the Fédération Internationale de Football Association (FIFA), only the medical team has the right to diagnose a concussion. This protocol is based on relevant regulations of the FIFPro (professional football players' international association). According to Boden, Kirkendall, and Garrett (1998), 0.96 concussion accidents were diagnosed per year, per team in the Elite College Soccer League. Of these cases, 69% occurred in games, but not as a direct result of heading the ball. The average number of headers in a football match is 4.1 per player, which suggests that the associated risk of a resulting concussion is very low (Stephenes et al., 2010). In the Canadian university leagues, 62.7% of football players noticed symptoms of a concussion, and the symptoms persisted for a day or longer in 18.8% of the cases (Delaney, Lacroix, Leclerc, Johnston, & Karen, 2002). Another study found that (American) football players received more extensive concussion education than soccer players (Chrisman, Schiff, Chung, Herring, & Rivara, 2014). According to a study on associates (parents, coaches, referees, club officers), 96% of them knew that concussion was a type of traumatic brain injury, and 90% believed that the return of the concussed players to the game should be delayed (Shenouda, Hendrickson, Davenport, Barber, & Bell, 2012). During the Football World Cup Final (2014), a German player suffered a head injury from an opponent's shoulder. After 14 minutes of playing, he asked the referee, "is this the final?" (Wendt & Miller, 2015). At that time, the Laws of the game did not allow referees to prevent players from continuing playing. After the incident, however, the Laws were changed and now only the medical staff has the right to let the player back to the game in case of a head injury.

In handball, the frequency of head injuries is 23% (Langevoort, Myklebust, Dvorak, & Junge, 2007). Injury occurrence was estimated to 2.5 injuries per 1000 player hours, with a significantly higher incidence of game injuries (14.3 injuries per 1000 game hours) compared to practice injuries (0.6 injuries per 1000 practice

hours; Seil, Rupp, Tempelhof, & Kohn, 1998). In this sport, the goal keeper is exposed to the highest risk of concussion, since the ball can reach a speed over 100 km/h (Bayios & Boudolos, 1998), and a size 3 ball can reach a force of 969 N (Bergquist et al., 2018).

In ice hockey, the average concussion rate was 1.1 per 1000 ice hockey player games for all IIHF World Championship tournaments. In cases when a concussion resulted from contact with a flexible board, the injury rate was 0.2 per 1000 player games. By contrast, the injury rate was 1.1 in cases when the board and glass were traditional. Concussion rate in men's tournaments has been lower than that in the World Junior tournaments since 2012. (Tuominen et al., 2017)

The Hungarian Ice Hockey Federation (HIHF) follows the directives provided by the International Ice Hockey Federation (IIHF). The IIHF has its own medical regulations, which include a concussion protocol, but the HIHF has still not adopted these regulations. The IIHF concussion protocol has been updated using data and research from recent symposia to ensure the safety and health of players competing in the IIHF Championship Program, the IIHF Club Competitions and the Olympic Winter Games. The concussion protocol strictly determines what the medical staff has to do. Game officials and referee supervisors have the right to report to the medical supervisor. The medical staff makes the final decision on whether or not to let an injured player continue the game, on which it may consult the medical supervisor. In case of disagreement between the medical staff and the medical supervisor, the latter consults the chairman. In case a concussion is reported, the player may not continue the tournament. In North America, most of the pro and university leagues use the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT Test Battery; Schatz, Pardini, Lovell, Collins, & Podell, 2006), since these tests provide more information about the condition of the injured player. This test battery is the most widely used scientifically proven computer-based assessment method for concussion management. Each player is first assessed in an asymptomatic state, to which each further assessment conducted in case of a possible concussion is compared. Differences between the two assessments provide information about the severity of the injury. Only those players are allowed to play in the mentioned leagues who pass the test. It is game officials' duty to check whether players are eligible to play.

Concussed players are generally unable to detect the symptoms of the injury, and they may choose not to consider their condition as a serious problem or not to report it to the medical staff, since they want to continue playing (Osborne, 2001). Although it is generally true that athletes' awareness and knowledge of concussions should be improved, many symptoms such as glassy eyes, a dazed look, irritability or balance problems are more easily detected by game officials. Even if an athlete is trying to conceal their symptoms after suffering a concussion, game officials may request a medical evaluation and may prevent the injured athlete from playing or at least consult the athlete's medical staff.

Diagnosis of a concussion and assessment of its severity requires complex neuropsychological tests. However, there are simpler concussion tests that can be performed by non-qualified people and only require a smartphone or paper and pencil (McCrea, 2001). Research on the most effective methods of concussion recognition is in progress. In sports, game officials have an extremely important role in concussion management, since they are responsible for ensuring a safe environment for players, and they have a better chance to recognize a concussion so that concussed players receive adequate medical care.

In football, handball and ice hockey, different terms are used for game officials. Referee and assistant are used in football, referee in handball, and referee and linesman in ice hockey. For the sake of clarity, we use the term game official in this article, which equally includes the terms referee, assistant and linesman.

**Current study.** The present study aims to conduct a comparative analysis of game officials' concussion recognition ability in three different sports. Hungarian football, handball and ice hockey game officials were compared for their knowledge of the signs and symptoms of concussions as measured with the Concussion Recognition Questionnaire (CRQ; Coghlin et al., 2009). The study fulfilled two specific aims: (1) an assessment of game officials' ability to recognize both true and false concussion symptoms; and (2) an analysis of the effects of game officials' sport (football vs. handball vs. ice hockey) and their previous personal experience of a concussion (concussed vs. non-concussed) on the number of correctly recognized concussion symptoms.

## METHOD

### Participants

A total of 142 questionnaires were filled out by game officials, 39 coming from football, 66 from handball and 37 from ice hockey. The total number of correctly filled out questionnaires were 39 from football, 63 from handball and 31 from ice hockey because only the fully completed questionnaires were analyzed, therefore, the study sample ( $N = 133$ ). All game officials were licensed to officiate in the highest-level league of their respective sport at the time of the assessment. The participants were divided into 3 different age groups (between 18-30 with 46 game officials (35%), between 30-40 with 46 game officials (35%) and over 40 were 41 game officials (30%)).

### Measures

Participants' ability to recognize concussion signs and symptoms was assessed with the Concussion Recognition Questionnaire (CRQ; Coghlin et al., 2009). The CRQ was originally developed for collecting information from parents of 13 to 14-year-

old athletes participating in hockey tournaments. These athletes were chosen because they had been in a body contact age group for at least two seasons, and thus they had been exposed to an increased risk of having sustained a concussion compared to younger players (Willer, Kroetsch, Darling, Hutson, & Leddy, 2005). The authors of the CRQ gave permission to use the questionnaire for the purposes of the present study. Adaptation of the original questionnaire was conducted in accordance with the procedure proposed by Geisinger (1994). The validity of the Hungarian translation was verified by means of the back-translation procedure in collaboration with the authors of the CRQ (Nagy, Kiss, Sós, & Gécz, 2016.). Minor modifications to the Hungarian wording were performed. The survey was distributed to participants via e-mail during the spring of 2018.

The demographic questions were designed to indicate the license level and the age group of the game officials. The next 6 questions are based on guideline information currently used to determine whether a player has suffered a concussion. All questions except Question 5 are presented in a non-parametric format (yes-no). Question 5 lists a total of 25 signs and symptoms, which respondents have to judge according to whether or not each is a symptom of a concussion. Of the 25 items, 17 describe true symptoms (actually indicating a concussion), and 8 describe false symptoms (including inability to swallow, difficulty with urination, difficulty with defecation, lowered pulse rate, sinus congestion, chest pain, hearing voices, and feelings of euphoria). False symptoms have been included in the list in order to minimize the effect of random guessing on the validity of the results and to establish the extent to which respondents are able to discriminate between true and false symptoms. Recognition rate of true symptoms and that of false symptoms are scored separately according to the number of correctly recognized symptoms

**Procedure.** All participants individually completed the CRQ scale. Consequently, we calculated a score for the number of correctly indicated symptoms, as well as for the correctly recognized fake symptoms.

## RESULTS

The data presented in Table 2 show that game officials in all three sports gave a high percentage of correct responses to the first four questions although handball game officials' responses to Question 3 showed somewhat lower accuracy. Question 5 required game officials to mark the true concussion symptoms among the 25 listed items. In the first step of the analysis, we compared the average of the correct answers. ANOVA was performed to reveal possible differences between football, handball and ice hockey game officials in the mean frequency of correct answers among the responses to the 25 items. The results showed that ice hockey game officials made significantly more correct judgments ( $M = 17.94$ ,  $SD = 2.90$ ) than handball game officials ( $M = 15.92$ ,  $SD = 2.87$ ;  $F(2,133) = 6.105$ ,  $p = .003$ ).

No significant difference was found either between ice hockey and football game officials ( $M = 17.20$ ,  $SD = 2.56$ ) or between handball and football game officials.

Table 2.

*Percentage of correct answers regarding concussion symptoms by football, handball and ice hockey game officials*

Questions	Football	Handball	Ice Hockey
	$N = 39$	$N = 63$	$N = 31$
1. Does a loss of consciousness determine whether a concussion has occurred?	94.9%	98.4%	96.8%
2. Can a player who has suffered a concussion return to play in the same day?	97.4%	93.7%	93.5%
3. A concussion may be caused by a blow to the neck, jaw, or elsewhere in the body?	97.4%	90.5%	100%
4. Is it necessary for a player to be medically evaluated after having heard bell ringing?	97.4%	96.8%	96.8%

Table 3 includes percentages corresponding to the number of times real symptoms were incorrectly identified by the game officials when completing the questionnaire. The results suggest that the real symptoms were incorrectly identified by a large portion of the Football, Handball and Ice Hockey game officials. Several real symptoms were however more difficult to recognize. The increased emotion/irritability was marked as not real symptom by 92% of the football and handball game officials, and 68% of the ice hockey game officials. Increased sleeping was not considered a real symptom by 79% of the football and 86% of the handball and 58% of the ice hockey game officials. The third problematic symptom was seizures, as 90% of the Football, 89% of the Handball and 76% of the Ice Hockey game officials believed that it is not a real symptom of concussion. Difficulty falling asleep was interesting, as only a minority (39%) of ice hockey game officials marked it as fake symptom, but the majority (74% and 81%) of the Football and Handball game officials thought it was not a real symptom.

Table 3.

*Percentage of game officials who incorrectly indentified each real symptom of concussion*

	Game officials			Rank of symptoms		
	Football	Handball	Ice Hockey	Football	Handball	Ice Hockey
Dizziness	2.56%	0.00%	2.63%	17	17	16
Neck pain	43.59%	68.25%	50.00%	7	6	4
Difficulty concentrating	30.77%	42.86%	23.68%	9	11	9
Difficulty with memory	17.95%	36.51%	13.16%	14	12	13
Problems with vision	23.08%	22.22%	10.53%	12	15	15
Inability to describe time and place	25.64%	47.62%	18.42%	11	10	11



	Game officials			Rank of symptoms		
	Football	Handball	Ice Hockey	Football	Handball	Ice Hockey
Feeling dazed or in a "fog"	28.21%	26.98%	10.53%	10	14	14
Seizures	89.74%	88.89%	76.32%	2	2	1
Ringing the ears	10.26%	49.21%	13.16%	15	9	12
Increased emotion/irritability	92.31%	92.06%	68.42%	1	1	2
Increased sleeping	79.49%	85.71%	57.89%	3	3	3
Headache	2.56%	4.76%	0.00%	16	16	17
Feeling nauseous	43.59%	52.38%	28.95%	8	8	8
Difficulty falling asleep	74.36%	80.95%	39.47%	4	4	6
Slurred speech	51.28%	74.60%	34.21%	6	5	7
Drowsiness / fatigue	61.54%	60.32%	44.74%	5	7	5
Feeling of "pressure" in the head	17.95%	34.92%	23.68%	13	13	10

Each real symptom of a concussion which was not identified as a true symptom was assigned a rank, meaning that a real symptom which was most often not identified as a true symptom received the highest rank and the other answers were assigned a rank in descending order considering the frequency of them being misidentified. This is an indirect measure of the respondents' ability to associate knowledge about a symptom with the notion of concussion. The results showed that regarding the incorrectly recognized real symptoms, the rank correlations of answers provided by football, handball and ice hockey game officials were high (Spearman rank correlation football – ice hockey  $\rho = 0.92$ , football – handball  $\rho = 0.91$  and handball – ice hockey  $\rho = 0.95$ ). This result suggested that game officials from all the three sports encountered difficulties in correctly recognizing the similar symptoms.

MANOVA was conducted to test the effect of game officials' sport on the number of correctly recognized true and false symptoms, these latter entered as two dependent variables. The results revealed that sport had a significant effect on the number of correctly recognized true symptoms ( $F(2,133) = 7.042$ ,  $p = .001$ ), while it had no effect on correctly recognized false symptoms ( $F(2,133) = 2.237$ ,  $p = .111$ ). Post-hoc Scheffé's tests indicated that handball game officials recognized significantly fewer true symptoms ( $M = 8.32$ ,  $SD = 3.28$ ) than either football game officials ( $M = 10.05$ ,  $SD = 3.03$ ) or ice hockey game officials ( $M = 10.68$ ,  $SD = 3.09$ ;  $t(133) = 3.38$ ,  $p = .001$ ).

In response to Question 6 of the CRQ, 94 game officials (football: 30 (32%), handball: 47(50%), ice hockey: 17 (18%)) reported that they had never had a concussion, while 39 reported to have had a concussion before (football: 9 (23%), handball: 16 (41%), ice hockey: 14 (36%)). Independent samples *t*-tests were conducted to compare previously concussed and non-concussed game officials in

the overall sample and in each subsample for the mean number of correctly recognized concussion symptoms. Means and standard deviations for each group are reported in Table 4. The results indicated that previous exposure to concussion had no effect on concussion recognition either in the overall sample ( $t(131) = -.585$ ,  $p = .56$ ) or in any of the subsamples (handball  $t(61) = 1.821$ ,  $p = .07$ ; ice hockey  $t(29) = 0.012$   $p = .99$ ; football  $t(37) = -0.316$ ,  $p = .75$ ).

Table 4.

*The average of number of correct answers among concussed/not concussed and football, handball and ice hockey game officials.*

	Mean	N	SD
No concussion / Handball	16.29	47	2.99
No concussion / Ice Hockey	17.94	17	2.98
No concussion / Football	17.13	30	2.30
Concussion / Handball	14.81	16	2.16
Concussion / Ice Hockey	17.92	14	2.89
Concussion / Football	17.44	9	3.43

## DISCUSSIONS

The first objective of this study was to assess Hungarian football, handball and ice hockey game officials' concussion recognition ability. The first four questions of the CRQ concerning concussion symptoms (see Table 2) were answered correctly by the vast majority of game officials, while the overall recognition rate of symptoms was approximately 70%. Consequently, it can be concluded that concussion history does not seem to influence the game officials' ability to correctly recognize symptoms. The results of the statistical analysis revealed a significant difference between ice hockey and handball game officials: the former proved better informed on the symptomatology of concussion, since they recognized more true and false symptoms and signs of concussion. One possible interpretation of this finding is that ice hockey involves more body contact, and body check is allowed. Concussion rate in ice hockey was 1.4/1000 player games (Tuominen, Stuart, Aubry, Kannus, & Parkkari, 2015), while the incidence of concussion was 1.5/1000 player games in handball (Langevoort, et al., 2007). These results suggest that the difference in game officials' knowledge about concussion cannot be attributed to the difference frequency of concussion in ice hockey and handball. Probably media awareness and coverage of concussion cases are superior in ice hockey compared to similar situations in handball. The most widely known case in ice hockey occurred when Sidney Crosby had to miss nearly 11 months from the National Hockey League after suffering a concussion during a game (Boylan, 2017). This case attracted a great deal of media attention, which may explain the significant difference between ice hockey and handball game officials' concussion recognition ability.

Interestingly, a separate analysis of responses to false symptoms revealed no difference between the three subgroups. The most frequently discarded real symptoms and signs were the same in the football, handball and ice hockey subgroups. A comparison of these results with our previous findings on Hungarian ice hockey coaches and players' parents (Nagy et al., 2016) and on Hungarian and Canadian ice hockey players (Nagy, Kiss, Sós, & Géczi, 2017) reveals that three out of the four most frequently discarded real symptoms were the same in all three studies. These findings suggest that although game officials have a good general knowledge of the most common symptoms and signs, they need further education on concussion recognition criteria similarly to other sport participants (players, coaches, parents). The most frequently discarded true symptoms (e.g., seizures, excessive sleepiness, increased irritability) deserve special attention in the education of game officials. The high rank correlations of the symptoms between the three subsamples suggest that better awareness of concussion symptoms is not closely related to the ice hockey culture, which underlines the importance of general education on the subject (at school, in the media etc.).

Additionally, contrary to our expectations, no significant difference was found between game officials with versus without previous experience of a concussion in the recognition of true signs and symptoms. That is, exposure to a mild traumatic brain injury in itself does not increase awareness of concussion, which also highlights the importance of educating sport participants on concussion symptoms.

The above discussed findings have important practical implications, since increasing awareness of concussion symptoms has an impact on players' immediate and long-term health status. Athletes' health should be the highest priority at all levels of sport, since professional athlete's career spans only a few years, therefore it is vital for them to have knowledge that may prevent injury-related negative health outcomes. Game officials are primarily responsible for ensuring a safe environment for athletes, and we consider it important that game officials in all sports be well informed in the future about concussion in order to protect athletes' health. Continuous education of game officials enables them to create a better environment for athletes, to correctly identify the symptoms of concussion, and to understand why they have to stand up for concussed players' interests rather than letting them continue playing.

### **Limitations and future research directions**

The validity of the above discussed findings has certain limitations. First, only Hungarian and top-level officials were included in the sample, while no Hungarian statistics on the incidence of sport concussion is available to our knowledge. As game officials gain more experience over time, their knowledge of various injuries possibly increases, while older game officials are less likely to work at a high level, therefore future studies on game officials' concussion recognition ability should

involve a more diverse sample encompassing a wider range of sports and age groups. Second, research should be extended to lower-level game officials, since while game officials at the top level are supported by professional medical staff, no such professional support is available at lower levels, so game officials and coaches have more responsibility for detecting concussions. Third, there are factors that were not taken into consideration in the present study, while they might have an effect on the obtained results such as, for example, previous education on concussion recognition. Future studies should examine the possible effects of such variables on concussion recognition ability. Fourth and finally, further research based on a similar methodology should focus on handball and football players, coaches and players' parents. Future research might reveal whether better knowledge of mild traumatic brain injuries enables sport participants either to prevent concussions during ice hockey, handball and football matches or to quickly intervene under circumstances when concussions occur by recommending a medical check for the injured player.

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