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original research

Safe-Play Knowledge, Aggression, and Head-Impact Biomechanics in Adolescent Ice Hockey Players

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Context: Addressing safe-play knowledge and player aggression could potentially improve ice hockey sport safety.

Objectives: To compare (1) safe-play knowledge and aggression between male and female adolescent ice hockey players and (2) head-impact frequency and severity between players with high and low levels of safe-play knowledge and aggression during practices and games.

Design: Cohort study.

Setting: On field.

Patients or Other Participants: Forty-one male (n = 29) and female (n = 12) adolescent ice hockey players.

Intervention(s): Players completed the Safe Play Questionnaire (0 = *less knowledge*, 7 = *most knowledge*) and Competitive Aggressiveness and Anger Scale (12 = *less aggressive*, 60 = *most aggressive*) at midseason. Aggressive penalty minutes were recorded throughout the season. The Head Impact Telemetry System was used to capture head-impact frequency and severity (linear acceleration [*g*], rotational acceleration [rad/s^2], Head Impact Technology severity profile) at practices and games.

Main Outcome Measure(s): One-way analyses of variance were used to compare safe play knowledge and aggression between sexes. Players were categorized as having high or low safe-play knowledge and aggression using a median split. A 2 × 2 mixed-model analysis of variance was used to compare head-impact frequency, and random-intercept general linear models were used to compare head-impact severity between groups (high, low) and event types (practice, game).

Results: Boys (5.8 of 7 total; 95% confidence interval [CI] = 5.3, 6.3) had a trend toward better safe-play knowledge compared with girls (4.9 of 7 total; 95% CI = 3.9, 5.9; $F_{1,36}$ = 3.40, P = .073). Less aggressive male players sustained significantly lower head rotational accelerations during practices (1512.8 rad/s^2, 95% CI = 1397.3, 1637.6 rad/s^2) versus games (1754.8 rad/s^2, 95% CI = 1623.9, 1896.2 rad/s^2) and versus high-aggression players during practices (1773.5 rad/s^2, 95% CI = 1607.9, 1956.3 rad/s^2; $F_{1,26}$ = 6.04, P = .021).

Conclusions: Coaches and sports medicine professionals should ensure that athletes of all levels, ages, and sexes have full knowledge of safe play and should consider aggression interventions for reducing head-impact severity among aggressive players during practice.

Key Words: concussions, mild traumatic brain injuries, head trauma, adolescent sports

Key Points

- Adolescent boys had slightly better knowledge of safe play than adolescent girls. More resources should be allocated to ensure that athletes across both sexes and all levels of play understand the safe-play principles of ice hockey.
- Less aggressive players sustained less severe head impacts during practices compared with games. During games, adolescent boys sustained head impacts of similar severities, regardless of their level of aggression.
- Aggression interventions should be further investigated as a means to reduce head-impact severity.

Sport-related concussion remains one of the most elusive injuries that sports medicine professionals face.[1] With growing concern over the potential long-term consequences of concussion, contact sports such as ice hockey have come under great scrutiny, and efforts are needed to improve safety.[1] Although important, most efforts to enhance education in hockey are aimed at improving concussion recognition and reporting[2]; little emphasis has been placed on concussion prevention.[1] Sport safety could potentially be improved by addressing safe-play knowledge and player aggression in ice hockey players; however, little research to date is available supporting these efforts.[3]

Second to high school football players, high school ice hockey athletes have the highest rate of concussions.[4] The aggressive and physical nature of legal body checking increases the incidence of head and neck injury,[5] which has promoted considerable scrutiny of the role of body

Table 1. Adolescents' Demographic and Descriptive Results for Safe Play Questionnaire Score, Competitive Aggressiveness and Anger Scale Score, and Aggressive Penalty Minutes

Characteristic	Boys (n = 29)	Girls (n = 12)	*F* Value	*P* Value
Demographic information (mean ± SD)				
Age, y	15.5 ± 1.0	14.2 ± 1.4		
Height, cm	171.1 ± 6.3	161.6 ± 5.2		
Mass, kg	66.1 ± 8.5	57.3 ± 6.8		
Position group, No. of players				
Offense	17	7		
Defense	12	5		
Outcome measures (mean ± SD)				
Safe Play Questionnaire	6.7 ± 1.6	5.5 ± 1.9	3.40 (df = 1,36)	.073
Competitive Aggressiveness and Anger Scale	29.3 ± 8.2	28.3 ± 13.4	0.09 (df = 1,38)	.766
Aggressive penalty min/100 shifts	5.0 ± 11.7	2.4 ± 1.8	0.59 (df = 1,40)	.449

checking in adolescent hockey.[3] Checking in ice hockey accounts for 86% of all injuries and is associated with an increased concussion risk.[6,7] Specifically, checking from behind poses a threat of cervical spine injury, as an unsuspecting player's spine may be in a vulnerable neck-flexed position when looking down at the puck.[8] Alarmingly, 26% of adolescent ice hockey players who knew that checking from behind could result in serious injury or death said they would continue to do so if they were angry or wanted "to get even,"[6] and checking from behind remains a common occurrence in ice hockey.[5] Ice hockey players with poorer understanding of safe and proper body-checking technique may be at increased risk of head injuries, such as concussions. Athletes who are more knowledgeable about safe playing techniques in ice hockey may refrain from illegal checking and unnecessary head contact and may also be better prepared for player-to-player contact.[9,10] If so, more efforts should be directed toward ensuring that ice hockey players have a sound understanding of safe play through behavior modification.[11]

Legal body checking, which is allowed as early as age 12, is an innate component of boy's and men's ice hockey.[12,13] Even though checking is prohibited in girl's ice hockey, girls had approximately the same prevalence of concussion relative to all other injury types as boys (girls, 28.6%; boys, 24.6%)[14] and sustained head impacts from contact with other players at the same rates as male hockey players.[15] Some players possess a more aggressive nature,[16] which may make them more likely to engage in physical and potentially illegal on-ice behaviors. Ice hockey collisions resulting in aggression penalties, such as elbowing, head contact, and high sticking, resulted in higher measures of head-impact severity compared with legal collisions.[9] Players who exhibit aggressive behavior may express these tendencies differently during games and practices, but no previous authors have assessed the interaction between event type and aggression.

If safe-play knowledge and aggression play roles in mediating the frequency or severity of head impacts, efforts should focus on improving safe-play knowledge and reducing aggressive behaviors. The purpose of this study was multifaceted. First, we aimed to compare safe-play knowledge and aggression between male and female adolescent ice hockey players. Second, we aimed to compare head-impact frequency and severity between ice hockey players with high or low levels of safe-play knowledge and aggression during practices and games. We hypothesized that female ice hockey players would be less knowledgeable about safe play and less aggressive compared with male ice hockey players. We also hypothesized that ice hockey players with less safe-play knowledge and higher aggression levels would sustain head impacts at a higher frequency and with greater severity during both practices and games.

METHODS

Forty-one male (n = 29; 14 aged 15–18 years at the under [U] 18 AAA level and 15 aged 13–14 years at the U14 AAA level) and female (n = 12; all ≤16 years old and at the U16 level competing against all-female teams) adolescent ice hockey players participated in this study. All participants in this study played for a single USA Hockey travel-based association. Demographic information is presented in Table 1. Because of attrition due to injury and departures from the team midseason (n = 4), certain analyses were based on fewer athletes than others. All athletes and at least 1 parent or legal custodian per participant read and signed institutional review board–approved informed assent and consent forms, respectively. Inclusion criteria were being a rostered member of one of the teams. Goalies were excluded from this study because instrumented goalie helmets are not available.

We developed and used the Safe Play Questionnaire (SPQ; Table 2) to measure each player's knowledge of safe playing techniques specific to ice hockey, as a hockey-specific questionnaire to gauge the athlete's knowledge of safe playing techniques was not available. The SPQ is a 7-item multiple-choice questionnaire based on USA Hockey rules, regulations, and guidelines for skating and body checking.[17] The SPQ was developed and reviewed for content validity by the authors, all of whom have expertise in safe play in ice hockey.

The Competitive Aggressiveness and Anger Scale (CAAS) assesses 12 items of athlete self-reported trait aggression and anger and was used to measure aggression.[18] Each item is measured by asking the athlete how the statement relates to him or her using a 5-point Likert scale ranging from 1 (*almost never*) to 5 (*almost always*). The CAAS was previously validated among collegiate competitive athletes of both sexes in a variety of sports.[18]

Paper versions of the SPQ and CAAS were administered before practice on 2 occasions, approximately 1 week apart, during the midpoint of the season after a bye week, so as to eliminate game bias. The second administration was used to

Table 2. Safe Play Questionnaire Questions, Possible Responses, and Reliability Results

Question and Response Options	Response Agreement, %	κ Value
1. A player can help protect himself/herself in hockey by __.	71.8	0.48
a. being the best skater he/she can be		
b. staying alert at all times		
c. not watching the puck when he/she skates		
d. all of the above		
e. I don't know		
2. The "danger zone" for injuries in hockey is __.	92.3	0.24
a. in front of the net		
b. 3–4 feet from the boards		
c. beside the player who has the puck		
d. I don't know		
3. To help keep himself/herself safe, a player should approach the boards __.	94.9	0.48
a. at an angle		
b. straight on		
c. quickly		
d. I don't know		
4. All of the following are examples of unsafe play, EXCEPT __.	69.2	0.41
a. hitting an opponent from behind		
b. criticizing the game official		
c. purposefully clearing the puck into the opposing team's bench		
d. slashing		
e. I don't know		
5. The purpose of body checking is to separate the puck carrier from the puck.	100	1.00
a. true		
b. false		
c. I don't know		
6. To deliver a check, it will be most effective and safest for you to do all of the following EXCEPT __.	69.2	0.38
a. keep your feet parallel to the boards		
b. lead with your head		
c. have your knees bent and back straight		
d. keep a low center of gravity		
e. go into the hit at an angle		
f. I don't know		
7. You can be better prepared to take a hit by doing all of the following EXCEPT __.	69.2	0.43
a. keeping your hands on your stick		
b. keeping your knees straight		
c. knowing where your opponents are		
d. keeping your head away		
e. I don't know		
Total Safe Play Questionnaire score, sum of correct responses	NA	Intraclass correlation coefficient [2,1] = 0.68

Abbreviation: NA, not applicable.

determine SPQ and CAAS reliability only. Athletes were instructed to put forth their best effort and answer each question to the best of their ability, without help from teammates. Each athlete was given as much time as needed to complete the questionnaire individually in the locker room and had access to the researcher to ask questions if needed. Values for the SPQ and CAAS were summed. The SPQ total scores can range from 0 to 7; higher scores indicate better safe-play knowledge. The CAAS total scores range from 12 (*low aggression*) to 60 (*very high aggression*).

Construct validity of both the SPQ and the CAAS was established to determine the survey instrument's characteristics by performing principal-component analyses to understand which items grouped around certain concepts. The factor analysis for the SPQ revealed 3 loadings ranging from 0.897 to 0.410 with a cutoff value of 0.400. After reviewing the items, we operationally defined the following 3 constructs (Table 2): safe play (questions 1, 2, and 4), body checking (questions 5, 6, and 7), and approaching boards (question 3). The factor analysis for the CAAS revealed 2 loadings ranging from 0.910 to 0.483 with a cutoff value of 0.400. After reviewing the items, we operationally defined the following 2 constructs (Table 2): anger (questions 1–5) and aggression (questions 6–12) similar to previous researchers who have evaluated CAAS constructs.[18] All loadings were included as part of the respective total scores.

Cohen κ values were calculated to measure the agreement between the first and second administrations of the SPQ. The κ values ranged from 0.235 to 1.00 (Table 2). One-way repeated-measures analyses of variance and intraclass correlation coefficients were used to determine the reliability of the SPQ and CAAS total scores. The SPQ total scores ($F_{1,37} = 1.09$, $P = .303$) and CAAS total scores ($F_{1,37} = 39.00$, $P = .800$) did not differ between administrations. We observed moderate reliability (intraclass correlation coefficient [2,1] = 0.68, SEM = 0.81) of the SPQ total score and very good reliability (intraclass correlation coefficient [2,1] = 0.93, SEM = 2.68) of the CAAS total score between administrations. We split players into groups of high and low safe-play knowledge and into groups of high and low aggression as measured by the CAAS using a median split. We chose to use a median split because no previously published cutoffs exist for the SPQ or CAAS.

During each game, participants' aggressive penalty minutes for the season were tallied by the official scorekeeper, and a copy of the official score sheet was collected after each game.[19] Aggressive penalties consisted of fighting, spearing, butt ending, high sticking, slashing, cross-checking, instigating, roughing, boarding, charging, kneeing, elbowing, checking from behind, head butting, attempting to injure, and unsportsmanlike conduct, as well as head contact, and body checking for girls only.[19] A research assistant tallied the number of shifts completed by each player during all games. We summed each player's aggressive penalty minutes and shifts across the season and then divided the total aggressive penalty minutes by the total number of shifts to account for penalty minutes per 100 shifts. We controlled for exposure to account for differences in game time as some games differed in duration based on age, sex, and event type (eg, exhibition, regular season, tournament). We divided players into groups of high and low aggression as measured by aggressive penalty minutes using a median split.

Head-impact biomechanical measures were captured using the Head Impact Telemetry (HIT) System (Simbex, Lebanon, NH). The HIT System consists of the following components: an encoder unit located in the helmet, an antenna, and a laptop computer. The encoder consists of 6 single-axis accelerometers, a telemetry unit, a data-storage device, and an onboard battery pack. Data collection occurs over 40 milliseconds at 1000 Hz.[20–22] The impact data recorded by the HIT System were time stamped, encoded, stored locally, and then transmitted in real time to a sideline controller via an antenna incorporated within the Sideline Response System (Riddell Corp, Elyria, OH). The telemetry system reported linear acceleration, rotational acceleration, and HIT severity profile (HITsp; calculated as a weighted composite score encompassing linear and rotational accelerations, Gadd Severity Index, Head Injury Criterion, and impact location). Participants' helmets were fitted before the season and checked monthly by the research team (A.F.P., J.P.M.).[22] Previous authors[23] have reported that acceleration values captured by the ice hockey HIT system are correlated with gold standard Hybrid III head models but are not equivalent.

Data were analyzed using SAS 9.3 (SAS Institute, Cary, NC) with an a priori α level of .05. We used 3 separate 1-way analyses of variance to compare SPQ total score, CAAS total score, and aggressive penalty minutes between the boys and girls. We compared head-impact frequency between levels of safe-play knowledge and aggression (high, low) across event types (practices, games) using 3 separate 2 (high group, low group for the SPQ, the CAAS, and aggressive penalty minutes) $\times$ 2 (practice, game) mixed-model repeated-measures analyses of variance. We excluded girls from analyses involving head-impact biomechanics because our research team did not consistently capture practice data using the HIT System. We used separate random-intercept general linear models to compare linear acceleration, rotational acceleration, and HITsp between levels of safe-play knowledge and aggression (high, low) across event types (practices, games).

RESULTS

Adolescent boys (5.8 of 7 total; 95% confidence interval [CI] = 5.3, 6.3) demonstrated a trend toward better safe-play knowledge compared with adolescent girls (4.9 of 7 total; 95% CI = 3.9, 5.9, $F_{1,36} = 3.40$, $P = .073$; Table 1). Further analysis across teams revealed that U18 boys (6.4 of 7 total; 95% CI = 5.9, 6.8) demonstrated better safe-play knowledge compared with U16 girls (4.9 of 7 total; 95% CI = 3.9, 5.9) but not U14 boys (5.4 of 7 total; 95% CI = 4.6, 6.2; omnibus $F_{2,35} = 3.44$, $P = .043$). To conduct subanalyses, we evaluated total scores by the questions pertaining to safe-play constructs (questions 1, 2, and 4) and the questions pertaining to body-checking constructs (questions 5, 6, and 7) and found that adolescent boys (2.4 of 3 total; 95% CI = 2.1, 2.7) had better knowledge regarding safe play than adolescent girls (1.8 of 3 total; 95% CI = 1.1, 2.4; $F_{1,36} = 5.93$, $P = .020$) but had similar knowledge regarding body checking ($F_{1,36} = 0.91$, $P = .346$).

We did not observe a significant interaction effect between SPQ group and event type or main effect for SPQ group for head-impact frequency ($F_{1,24} = 0.56$, $P = .460$), linear acceleration ($F_{1,24} = 1.39$, $P = .249$), rotational acceleration ($F_{1,24} = 1.17$, $P = .289$), or HITsp ($F_{1,24} = 1.64$, $P = .213$; these analyses included only adolescent boys). However, a significant main effect was present for event type ($F_{1,24} = 44.70$, $P < .001$), such that players sustained approximately 7 times more head impacts during games (146.9 $\pm$ 100.1) compared with practices (21.9 $\pm$ 15.8). Similarly, we observed a main effect for event type, such that games resulted in greater head linear acceleration ($F_{1,24} = 10.63$, $P = .003$), rotational acceleration ($F_{1,24} = 10.93$, $P = .003$), and HITsp ($F_{1,24} = 13.60$, $P = .001$) than practices. Main effect results for head-impact frequency and severity differences between practices and games were similar throughout all analyses.

Adolescent boys and adolescent girls did not differ in aggression as measured by the CAAS ($F_{1,38} = 0.09$, $P = .766$) or aggressive penalty minutes ($F_{1,40} = 0.59$, $P = .449$; Table 1). We did not observe a significant interaction between aggression group (CAAS and aggressive penalty minutes) and event type or main effect for aggression group for head-impact frequency. No interaction effect occurred between event type and level of aggression for linear acceleration and HITsp (these analyses included only adolescent boys). We observed a significant interaction for rotational acceleration between event types and CAAS groups ($F_{1,26} = 6.04$, $P = .021$). Players categorized as low aggression, as measured by the CAAS, sustained head impacts of less rotational acceleration during practices compared with games ($t_{26} = -4.55$, $P < .001$; Table 3). During practices, players categorized as low aggression

Table 3. Head-Impact Severity Descriptive and Statistical Results for Competitive Aggressiveness and Anger Scale Aggression Groups and Event Type Interaction and Main Effects

Variable	Competitive Aggressiveness and Anger Scale Score (n = 14/group)	Sessions, Mean (95% Confidence Interval)		Interaction Effect Between Group and Event Type		Main Effect			
						Group		Event Type	
		Practices	Games	*F* Value	*P* Value	*F* Value	*P* Value	*F* Value	*P* Value
Linear acceleration, *g*	High	19.2 (17.4, 21.3)	20.0 (19.0, 21.0)	2.61	.118	0.23	.632	13.28	.001[b]
	Low	19.1 (17.6, 20.7)	21.1 (19.8, 22.5)						
Rotational acceleration, rad/s^2	High	1773.5 (1607.9, 1956.3)	1834.3 (1688.5, 1992.8)	6.04	.021[a]	3.62	.068	15.22	<.001[b]
	Low	1512.8 (1397.3, 1637.6)	1754.8 (1623.9, 1896.2)						
Head Impact Technology severity profile	High	13.4 (12.5, 14.3)	14.1 (13.5, 14.6)	0.84	.368	0.00	.995	12.80	.001[b]
	Low	13.1 (12.6, 13.7)	14.3 (13.7, 15.0)						

[a] Significant group-by-event type interaction effect.
[b] Significant main effect for event type.

sustained head impacts of less rotational acceleration than players with high aggression ($t_{26} = -2.59$, $P = .016$). Players with low aggression sustained less severe head rotational acceleration during practices compared with players with high aggression during games ($t_{26} = -3.45$, $P = .002$). During games, head rotational acceleration did not differ between the high- and low-aggression groups ($t_{26} = -0.80$, $P = .429$). We did not observe a significant main effect for group.

No significant interaction effects existed between event type and levels of aggression as measured by aggressive penalty minutes. There was no main effect for aggression group. Descriptive and statistical results are shown in Table 3.

DISCUSSION

Less aggressive players sustained less severe head impacts during practices compared with games and compared with more aggressive players. Our results suggest that a player's level of aggression may influence the severity but not the frequency of head impacts sustained during practices. However, during games, male players sustained head impacts of similar severities regardless of their level of aggression. Consistent with other investigators,[20,22] we found that practices resulted in fewer and less severe head impacts than games.

In our sample, adolescent boys had slightly better safe-play knowledge than adolescent girls, and U18 boys were more knowledgeable than U14 boys. We hypothesized that female players may be more exposed to safe-play education efforts because previous research[24] suggested that female coaches and coaches of female athletes are not as accepting of the glorification of risk taking, pain, and injury in sport. However, it seems that coaches, regardless of their sex or the sex of their athletes, are ambivalent regarding sport injury as they believe athletes should push their physical limits but do not want athletes to take excessive risks with their bodies.[24] Previous hockey experience may also play a role in safe-play knowledge, as the U18 boys' team had an average of 2 additional years of experience compared with the U16 girls' team and U14 boys' team. Players with more sport experience likely have had more exposure to a variety of coaching staffs, coaching methods, and safe-play teaching techniques. Many of the questions in the SPQ encompassed hitting and checking rules and techniques. Interestingly, the differences in overall safe-play knowledge in this study stemmed from girls missing more questions on safe-play constructs but not on body checking. Although body checking is not permitted in female ice hockey, girls in this study possessed similar knowledge regarding safe body-checking techniques but lacked knowledge of general safe play. Girls should be aware of how to play as safely and effectively as possible. Coaches and sports medicine professionals should ensure that ice hockey players of all levels, ages, and sexes have full knowledge of safe play.

Adolescent boys and girls did not differ in aggression as measured by the CAAS or aggressive penalty minutes, which contradicts previous research[18] that suggested male players were more aggressive than female players. Although we did not observe statistically significant differences in aggression between adolescent boys and girls, analysis of the descriptive statistics revealed that on average boys had twice as many aggressive penalty minutes per 100 shifts but greater overall variability (Cohen d = 0.31; Table 1). This level of variability among the male group was because some of the U18 boys accumulated high numbers of penalty minutes per shift (8.3 aggressive penalty minutes per 100 shifts on average for the U18 boys' team). The penalty-minute variability within the U18 boys' team could have been caused by some players being deemed *enforcers*, that is, players who respond to violent play by fighting or checking the offender.[25] Adolescent male ice hockey players who participate in checking leagues do not present with greater aggression than those in nonchecking leagues, but trends of increasing aggression with age may be attributed to increased exposure to body checking.[26] The U18 boys' team was more experienced and typically played 4 or 5 games per weekend compared with the 3 games played by the U14 boys' and U16 girls' teams. It seems possible that U18 boys may incur more aggressive penalty minutes because they have more exposure to body checking. We controlled for exposure to account for differences in shifts on ice, but participating in more shifts could have caused U18 boys to fatigue and try to take the easy way out by drawing a penalty rather than executing a play.

We found that less aggressive adolescent boys sustained less severe rotational head impacts during practices compared with games. Furthermore, less aggressive adolescent boys sustained less severe head impacts during practices compared with more aggressive adolescent boys. However, during games, adolescent boys sustained head impacts of similar severities regardless of their level of aggression. Adolescent boys with higher aggression levels may act aggressively at all times, regardless of whether they are matched against a teammate or opponent, whereas the low-aggression group may better control their aggression when matched against teammates during practice. This suggests that players with less aggression may increase their intensity of play in a way that increases the severity of head impacts sustained during games, whereas players with more aggression may take on the "practice-how-you-play" mentality. Previous researchers[16] have shown that aggression interventions in minor hockey leagues result in a decrease in injuries. Aggression interventions may be successful in lowering the severity of head impacts sustained by more aggressive players during practice. In addition to aggression interventions, efforts should focus on rewarding safe play and penalizing aggressive play. Use of fair-play leagues, where teams receive season points for playing without excessive penalties, has been shown to reduce the frequency and severity of injuries sustained while playing hockey.[27] The influence of aggression on head-impact biomechanics and concussion risk should be studied further in other sports, such as football and lacrosse. Aggression interventions, combined with efforts to reduce head-impact exposure during practice, may be an effective means to reduce head-impact frequency and severity.[28] Coaches and sports medicine professionals should consider how the level of aggression may influence efforts to reduce head-impact frequency and severity during practices. Because we did not measure levels of aggression separately during practices and games, it is also possible that more aggressive players sustain more severe head impacts during practices because they increase their level of aggression when playing against less aggressive teammates. Adolescent girls were not included in analyses of head-impact biomechanics, so these results may not apply to adolescent girl ice hockey players.

Head-impact severity was not influenced by aggression as represented by penalty minutes. Previous investigators[29] suggested that penalty minutes were not associated with injury or concussion risk. More research is needed to determine whether aggression interventions can reduce the risk of injury while maintaining or improving sport performance, as aggression is often seen as a positive sport attribute. Future authors should examine the influence of aggression on concussion risk. Although concussion incidence was not an outcome measure in this study, the U18 boys' team sustained the most concussions among the 3 teams for the season, but it is not known if their greater mean CAAS total score and aggressive penalty minutes increased their risk of concussion.

Consistent with previous findings,[20,22,28,30] adolescent ice hockey players sustained higher head-impact frequency and severity during games compared with practices, regardless of the level of aggression. During practice, play continually stops and starts for the coach to give instruction, whereas during games, play moves quickly and is only stopped when needed.[17] Mihalik et al found that collisions that occur on the open ice[10] and collisions that involve infractions[9] result in greater head-impact severity. It seems possible that head-impact frequency and severity may be lower in practices compared with games because most practices do not involve the types of collisions that occur on the open ice or result in infractions. In previous investigations[20–22] of high school and collegiate football, head-impact frequency was higher during games compared with practices. Athletes likely increase their physicality against opponents compared with teammates, which is evidenced by the higher rate of injuries during ice hockey games compared with practices.[16]

We observed moderate reliability of the SPQ total score and low to perfect reliability for individual questions (κ = 0.24–1.00). Although the moderate reliability level was lower than desirable for this tool, we found the SPQ to be satisfactory because the standard error of the measure indicated only a 1-point deviation in total scores and the first and second administrations did not differ. However, further research is needed to improve the SPQ's reliability and determine its validity. This study had a small sample size and focused on adolescent ice hockey players. Therefore, the results may not apply to ice hockey players of other ages or skill levels. In addition, even though the HIT System has been used previously and remains the only commercially available tool to capture head-impact biomechanical data, the instrument is limited in capturing rotational acceleration.[23] The main interaction of this study was observed with rotational acceleration, so these results should be interpreted with caution. We captured head-impact magnitudes across groups and event types, and it is generally accepted that players who sustain high-magnitude impacts are at an increased risk of sustaining concussive injuries, but future researchers should assess the influence of safe play and aggression on concussion.[31]

CONCLUSIONS

Efforts should focus on increasing knowledge regarding safe play in ice hockey players of all levels, ages, and sexes. More resources should be allocated to ensuring that athletes across both sexes and all levels of play understand the safe-play principles of ice hockey. The level of aggression may influence the head-impact severity sustained by ice hockey players during practices. We recommend that aggression interventions be considered as a means of addressing aggressive behavior in hockey. Further study is needed to determine whether safe-play knowledge and aggression influence concussion risk.

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