Helmet Fit Assessment and Concussion Risk in Youth Ice Hockey Players: A Nested Case-Control Study

Alexander S. D. Gamble, MSc*; Jessica L. Bigg, MSc*; Stacy Sick†; Maciek Krolikowski, MSc†; Declan A. Patton, PhD†; Brent E. Hagel, PhD†; Carolyn A. Emery, PhD†

*Department of Human Health and Nutritional Sciences, University of Guelph, ON, Canada; †Sport Injury Prevention Research Centre, Faculty of Kinesiology, University of Calgary, AB, Canada

Context: Injury surveillance has shown that concussions are the most common injury in youth ice hockey. Research examining the criteria for ensuring the correct fit of protective equipment and its potential relationship with concussion risk is very limited.

Objective: To evaluate the association between helmet fit and the odds of experiencing a concussion among youth ice hockey players.

Design: Nested case-control within a cohort study.

Setting: Calgary, Alberta, Canada.

Patients or Other Participants: Data were collected for 72 concussed, 41 nonconcussion-injured, and 62 uninjured ice hockey players aged 11 to 18 years.

Main Outcome Measure(s): Helmet-fit assessments were conducted across players and encompassed helmet specifications, condition, certification, and criteria measuring helmet fit. Using a validated injury-surveillance system, we identified participants as players with suspected concussions or physician-diagnosed concussions or both. One control group comprised players who sustained nonconcussion injuries, and a second control group comprised uninjured players. Helmet-fit criteria (maximum score = 16) were assessed for the concussed players and compared with each of the 2 control groups. The primary outcome was dichotomous (>1 helmet-fit criteria missing versus 0 or 1 criterion missing). Logistic and conditional logistic regression were used to investigate the effect of helmet fit on the odds of concussion.

Results: The primary analysis (54 pairs matched for age, sex, and level of play) suggested that inadequate helmet fit (>1 criterion missing) resulted in greater odds of sustaining a concussion when comparing concussed and uninjured players (odds ratio [OR] = 2.67 [95% CI = 1.04, 6.81], P = .040). However, a secondary unmatched analysis involving all participants indicated no significant association between helmet fit and the odds of sustaining a concussion when we compared concussed players with nonconcussion-injured players (OR = 0.98 [0.43, 2.24], P = .961) or uninjured players (OR = 1.66 [0.90, 3.05], P = .103).

Conclusions: Inadequate helmet fit may affect the odds of sustaining a concussion in youth ice hockey players. Future investigators should continue to evaluate this relationship in larger samples to inform helmet-fit recommendations.

Key Words: adolescents, head injury, injury prevention, protective equipment

Key Points

- The majority of players reported excellent or good helmet fit even though only about one quarter of helmet-fit assessments resulted in all criteria being met.
- The most common helmet-fit criterion not met was a chin strap that was too loose.
- Our helmet-fit comparison between concussed players and uninjured players suggested a possible association between inadequate helmet fit and the risk of experiencing a concussion.
- Future researchers should assess individual helmet-fit criteria in larger samples while controlling for other possible covariates.

Registration numbers for Hockey Canada and USA Hockey have grown by more than 90,000 participants each in the past decade (Hockey Canada: approximately 644,000 in 2018–2019, USA Hockey: approximately 649,000).1,2 Although ice hockey is a popular sport in North America, the risk of injury has been highlighted by injury surveillance in youth ice hockey, which showed that concussions were the most common injury (64% of all injuries).3–6 Concussion incidence rates during a season were estimated at 1.58 concussions per 1000 athlete-exposures (9.32 concussions per 100 players) in youth ice hockey players in the United States and 1.31 concussions per 1000 player hours (17.60 concussions per 100 players) in elite youth ice hockey in Canada.7,8 Given the high incidence of concussion, it is essential to investigate risk factors related to sport rules, equipment, player behavior, and education to inform preventive strategies.

Regarding the effect of protective equipment in preventing head injuries in sport, most researchers who evaluated helmet fit studied athletes who participated in bicycling,9–12 skiing and snowboarding,13,14 or American football.15–21
Proper helmet fit for athletes has been discussed for years with inconsistent claims about the preventive benefits of comfortable versus tight-fitting helmets and helmets that move naturally on the head to attenuate forces and accelerations. Two groups reported that cyclists who move naturally on the head to attenuate forces and accelerations. and sports, and the lack of satisfied helmet-fit criteria in poorly fitting helmets resulted in greater injury risk in other in this youth ice hockey sample. Therefore, the primary purpose of our investigation was to address the relationship between concussion symptoms when their helmets did not fit properly. However, no validated criteria were used to measure the association between concussion symptoms and helmet fit, limiting any conclusion on this relationship in football players.

Similar to those in many other sports, ice hockey equipment manufacturers encounter limitations when trying to combine comfort, aesthetics, manufacturing cost, customer affordability, and safety. Furthermore, the responsibility of understanding the proper fitting of helmets falls on officials, parents, coaches, and players, which is challenging due to limited manufacturing guidelines and education on the topic. In an investigation of high school American football coaches, 59% of those responsible for fitting player helmets had limited knowledge of correct helmet fit. Only 2 sets of authors have evaluated helmet fit in youth ice hockey players using such criteria as helmet coverage, location, movement, modification, condition, age, and certification. In a preliminary exploration of helmet-fit knowledge and characteristics in youth ice hockey and lacrosse players, more than 70% of players answered helmet-fit knowledge questions correctly, but only 38% of players (30% of hockey players) satisfied all helmet-fit criteria. Most recently, helmet-fit criteria were assessed as a potential tool for youth ice hockey players. More than 87% of these players reported that their helmet fit properly and that the comfort of their helmet was excellent or good. However, examination revealed that only 23% satisfied all helmet-fit criteria.

To our knowledge, no researchers have determined the association between helmet-fit criteria and the risk of concussion in youth ice hockey athletes. Given the high risk of concussion in youth ice hockey, the evidence that poorly fitting helmets resulted in greater injury risk in other sports, and the lack of satisfied helmet-fit criteria in youth ice hockey players, the relationship between helmet fit and the risk of concussion needs to be addressed. Therefore, the primary purpose of our investigation was to determine the association between helmet fit and the odds of sustaining a concussion in youth ice hockey players. A secondary purpose was to describe helmet-fit characteristics in this youth ice hockey sample.

**METHODS**

**Participants**

A total of 190 volunteers, consisting of Pee Wee (age = 11–12 years), Bantam (13–14 years), and Midget (15–17 years) ice hockey players in Calgary, Alberta, who registered as members of Hockey Calgary during the 2017–2018 season, were recruited to participate in this nested case-control substudy from 1 season of a 5-year longitudinal cohort study called Safe2Play (Principal investigator: C. Emery, Sport Injury Prevention Research Centre, University of Calgary). This study was approved by the Conjoint Health Research Ethics Board at the University of Calgary (Ethics ID: REB14-0348). All participants and their parents or guardians were provided with written instruction and details of the study before they signed the consent form.

**Study Design**

Based on a validated method of injury surveillance, concussion cases were players with a suspected (injury report form completed by the team safety designate or athletic therapist) concussion, a physician-diagnosed concussion, or both. The 2 control groups were (1) players who did not sustain a concussion but experienced a musculoskeletal injury during the season and (2) players who remained uninjured (ie, by either concussion or musculoskeletal injury) during the season. When any injury occurred, a team designate contacted a member of the research team to schedule a time for the player to have a helmet-fit assessment. At this time, the research team attempted to recruit a player who had remained uninjured to administer a helmet-fit assessment. When possible, players who sustained a concussion were matched with a non-concussion-injured player, an uninjured player, or both based on age, sex, and level of play. All helmet-fit assessments were conducted within 10 days of injury; players were asked to wear and fasten all parts of their helmet as they normally would before ice time, and all players confirmed that no helmet-fit changes were made in the time between injury and helmet-fit assessment. When a participant had multiple suspected concussions (3 athletes had 2 suspected concussions each during the same season), each occurrence was treated as a new case, and the player was matched with a new control each time due to the opportunity to make helmet-fit changes after the first assessment.

**Measurements**

We adapted the helmet-fit criteria from previous guidelines and literature that measured helmet fit in other settings. The 16 criteria encompassed helmet specifications, age (based on manufacturing date and self-reported length of use by player), condition, certification, and fit characteristics of the helmet for each individual evaluated by the research team (Table 1).

**Statistical Analysis**

All data were entered into the Research Electronic Data Capture platform hosted at the University of Calgary, Alberta, and analyzed using Stata (version 15; StataCorp). Descriptive statistics were presented for participant characteristics, including age, sex, playing age group, helmet specifications, and self-reported items for all players who had their helmet fit assessed. Conditional logistic regression was the primary analysis for assessing the relationship between outcome (the odds of sustaining a concussion) and exposure (≥2 helmet-fit criteria missing) for concussed players matched with both nonconcussion-injured and uninjured players based on age, sex, and level of play. A secondary logistic regression analysis, clustered by team, was used to assess the relationship between the outcome (the odds of sustaining a concussion) and exposure (≥2 helmet-fit criteria missing) for the entire sample while
Table 1. Helmet Fit Assessment Criteria Used by Patton et al (2017)\textsuperscript{a,b}

| Self-Reported Questions | Excellent | Good | Fair | Poor |
|-------------------------|-----------|------|------|------|
| How does the helmet fit? | Yes       | No   | No   | No   |
| Comfortable is the helmet? | Yes       | No   | No   | No   |

| Assessor Observations | Yes | No |
|-----------------------|-----|----|
| 3. Helmet fits snugly on all sides | Yes | No |
| 4. Helmet fits the base of the skull | Yes | No |
| 5. Chin strap fastened | Yes | No |
| 6. Chin strap not loose | Yes | No |
| 7. Crown of helmet is 1–2 fingers above eyebrows | Yes | No |
| 8. Helmet does not impinge neck movement | Yes | No |
| 9. Helmet does not cover eyes when pressing down | Yes | No |
| 10. Facemask does not slip when pulled left or right | Yes | No |
| 11. Facemask does not slip when pulled up or down | Yes | No |
| 12. Helmet cannot be removed without undoing chin strap | Yes | No |
| 13. All snaps and screws in place | Yes | No |
| 14. All padding in place | Yes | No |
| 15. Liner not cut or shaved | Yes | No |
| 16. Liner not worn, broken, or cracked | Yes | No |
| 17. Shell appears in good condition | Yes | No |
| 18. Standard sticker is visible\textsuperscript{b} | Yes | No |
| 19. Helmet does not have “cage hang” (loose facemask straps) | Yes | No |

\textsuperscript{a} Instrument is reproduced in its original format.
\textsuperscript{b} Criterion 18 (standard sticker is visible) was not included in the helmet-fit criteria score to determine exposed and unexposed players.

adjusting for age and body-checking policy as possible modifiers or confounders (or both). We defined unexposed individuals as players with <2 helmet-fit criteria not met and exposed individuals as players with ≥2 criteria not met based on the mean (1.49) and median (1.00) of criteria not met for the entire sample. The results of these analyses were presented as odds ratios (ORs) and 95% CIs at a .05 level of significance.

RESULTS

Participant Characteristics

Helmet-fit assessments were performed on 190 players (165 males and 25 females) from 42 Calgary Minor Hockey Association teams, consisting of 3 Pee Wee teams from playing divisions 4, 5, and 6 (all non–body-checking leagues), 19 Bantam teams representing 9 divisions (5 body-checking leagues), 17 Midget teams representing 9 divisions (6 body-checking leagues), and 3 female hockey teams from the Midget and Bantam levels (all non–body-checking leagues; Table 2). The age of the participants was 14.55 ± 1.47 years. Of the athletes who had their helmet fit assessed during the season, 72 sustained concussions, 41 sustained nonconcussion injuries, and 77 were uninjured. For the primary analysis, 54 concussed players were matched with uninjured players, and 25 concussed players were matched with nonconcussion-injured players based on age, sex, and level of play.

Table 2. Demographic Characteristics of Youth Ice Hockey Players Whose Helmet Fit Was Assessed During the 2018–2019 Hockey Season

| Characteristic | Concussed Players (n = 72) | Nonconcussion-Injured Players (n = 41) | Uninjured Players (n = 77) |
|---------------|---------------------------|--------------------------------------|---------------------------|
| Median age, y (range) | 14 (11–17) | 15 (12–17) | 14 (11–17) |
| Sex, No. (%) | Male 57 (79) | 38 (93) | 70 (91) |
| Female 15 (21) | 3 (7) | 7 (9) |
| Age group, No. (%) | Pee Wee 4 (6) | 0 | 2 (3) |
| Bantam 34 (47) | 18 (44) | 39 (51) |
| Midget 34 (47) | 23 (66) | 36 (46) |

Helmet-Fit Assessment

Entire Sample. After completing helmet-fit assessments, we determined that 177 players (93%) reported their helmet fit as excellent or good, and 182 players (96%) described their helmet comfort as excellent or good (Table 3). The mean of helmet-fit criteria not met (ranging from all criteria met to 6 criteria not met) was 1.49 (95% CI = 1.30, 1.70), and only 27% (32% concussed, 27% nonconcussion-injured, and 22% uninjured) of the athletes wore helmets that met all helmet-fit criteria (Table 3). After comparing the 72 concussed players with the 41 nonconcussion-injured (OR = 0.98 [95% CI = 0.43, 2.24], P = .961) and 72 uninjured (OR = 1.66 [95% CI = 0.90, 3.05], P = .103) players, no significant associations were found between helmet fit and concussion (unexposed players, no significant associations were found between helmet-fit criteria score to determine exposed and unexposed players, no significant associations were found between helmet-fit criteria score to determine exposed and unexposed players). We defined unexposed individuals as players with <2 helmet-fit criteria not met and exposed individuals as players with ≥2 criteria not met based on the mean (1.49) and median (1.00) of criteria not met for the entire sample. The results of these analyses were presented as odds ratios (ORs) and 95% CIs at a .05 level of significance.

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|---------------|---------------------------|--------------------------------------|---------------------------|
| Helmet age, No. (%) | <3 31 (55.36) | 17 (50.00) | 30 (50.85) |
| Reported time worn, No. (%) | >3 25 (44.64) | 17 (50.00) | 29 (49.15) |
| Helmet fit | <3 51 (79.69) | 33 (86.84) | 47 (81.03) |
| >3 13 (21.31) | 5 (13.16) | 11 (19.97) |
| Self-reported questions, No. (%) | Excellent 29 (40) | 21 (51) | 27 (35) |
| Good 39 (54) | 18 (44) | 43 (56) |
| Fair 4 (6) | 2 (5) | 6 (8) |
| Poor 0 | 0 | 1 (1) |
| Helmet comfort | Excellent 44 (61) | 25 (61) | 41 (53) |
| Poor 25 (35) | 15 (37) | 32 (42) |
| Fair 3 (4) | 1 (2) | 4 (5) |
| Poor 0 | 0 | 0 |

\textsuperscript{a} Age was missing for 38 helmets because the manufacturing stickers and expiration dates had worn off before assessment.
DISCUSSION

The purpose of our study was to determine the association between helmet fit and the odds of sustaining a concussion in youth ice hockey players. We demonstrated (1) a significant association between inadequate helmet fit and players who sustained concussions when we compared concussed players with uninjured players using a conditional logistic regression analysis matched for age, sex, and level of play; (2) no association between player helmet fit and the odds of sustaining a concussion when comparing concussed players with nonconcussion-injured or uninjured players using an unmatched logistic regression analysis for the entire sample; and (3) that the most common helmet-fit criterion not met by players involved the chin strap being too loose.

Helmet-Fit Assessment

Most players (93%, 177 of 190) reported that the fit and comfort of their helmet was excellent or good, yet 78 helmets had ≥2 criteria that were not met, and 19 helmets had ≥4 criteria that were not met. This suggests that the players’ perceptions of helmet fit differed from those of the helmet assessors using these helmet-fit criteria.

Given the limited research on helmet fit in ice hockey players, we compared our findings with those in sports such as football and lacrosse. McGuire and Nasi19 reported that 5% of high school football players’ helmets had 1 fitting error and 62% had multiple fitting errors. Similarly, 62% of 67 helmets failed to meet all criteria for youth lacrosse and ice hockey players.22 Although the criteria were obviously different, our results were consistent, with 73% (139 of 190) of the helmets having ≥1 helmet-fit criterion not met. The mean helmet-fit criteria not met were 1.49 (median = 1). Because most helmets did not meet all criteria, players were considered exposed to inadequate helmet fit if ≥2 helmet-fit criteria were not met. Future researchers should strive for a larger sample size to examine different approaches (e.g., different numbers of criteria not met, individual criteria, criteria weighted differently) when assessing the relationship between helmet fit and players who sustained concussions.

Based on interviews with emergency department patients, Romanow et al12 reported that inadequate helmet fit and position could affect the risk of head and facial injuries in cyclists. In American high school football players, McGuire et al20 suggested that incorrect helmet fit could be associated with a risk of concussion, and Greenhill et al21 noted that inadequate helmet fit in football players increased concussion severity based on the number and length of symptoms. However, no investigators have studied youth ice hockey players. We could not address previous concussion and injury severity, among other potentially relevant covariates, but were able to look at age, sex, and level of play in the matched analysis. In this scenario, inadequate helmet fit appeared to be associated with players who sustained concussions when we compared concussed and uninjured players (OR = 2.67). The direction and magnitude of this effect was similar to that in a recent nested case-control study28 of mouthguard use in a youth ice hockey population (OR = 2.78). When considering the entire sample to compare helmet fit in concussed players with helmet fit in nonconcussed-injured and uninjured players, we identified no association. Age and body-

| Table 4. Helmet-Fit Criteria for Exposed and Unexposed Youth Ice Hockey Players Whose Helmet Fit Was Assessed During the 2018–2019 Hockey Season |
|----------------|----------------|----------------|
| Variable       | Concussed Players (n = 72) | Nonconcussion-Injured Players (n = 41) | Uninjured Players (n = 77) |
| No. of criteria not met | 0 | 23 | 11 |
| Criteria score (not met) | 0 | 23 | 11 |
| <2 | 39 | 22 | 51 |
| ≥2 | 33 | 19 | 26 |

4). The most common helmet-fit criterion not met in all 3 groups (43% to 46% of players) was chin strap not loose.

Players Matched on Age, Sex, and Level of Play. When we matched the concussed players with nonconcussion-injured players (n = 25 matched pairs) based on age, sex, and level of play, no significant association was present between players who had ≥2 helmet-fit criteria not met (unexposed = 0 or 1 criteria not met, exposed = ≥2 criteria not met) and the odds of sustaining a concussion (OR = 1.60 [95% CI = 0.52, 4.89], P = .410). However, when concussed players were matched with uninjured players based on age, sex, and level of play, the odds of sustaining a concussion were 2.67 (95% CI = 1.04, 6.81) greater for players who had ≥2 helmet-fit criteria not met (n = 54 matched pairs, P = .040).

Helmet Characteristics. The average age of the players’ helmets was 2.98 years (95% CI = 2.45, 3.50) for concussed players, 2.94 years (95% CI = 2.37, 3.51) for nonconcussion-injured players, and 3.04 years (95% CI = 2.63, 3.46) for uninjured players. The self-reported average numbers of years that the helmets were used were 1.98 (95% CI = 1.63, 2.32) in concussed, 1.58 (95% CI = 1.19, 1.98) in nonconcussion-injured, and 2.12 (95% CI = 1.81, 2.42) in uninjured players (Table 5). Only 8 of 190 helmets (4 concussed, 1 nonconcussion-injured, 3 uninjured players) were determined to be expired; however, 68 helmets were missing the Hockey Equipment Certification Council (HECC) sticker that displays the expiration date. Of these helmets, 54 were unexpired based on the manufacturing sticker date (<6.5 years old), which left 14 helmet expiration dates undetermined.

The most common brands of helmets and helmet masks were Bauer (124 helmets, 117 masks), CCM (41 helmets, 54 masks), and Reebok (16 helmets, 9 masks). In the 190 helmets assessed, 20 materials were used. Although some helmets included more than 1 material, the most common materials found in helmets were Bauer PORON Performance Cushioning XRD Extreme Impact Protection foam (63 helmets), Bauer Suspend-Tech liner (28 helmets), and CCM Impact Pods with a Rotational Energy Dampening System (14 helmets). All players wore a full facemask (187 full cages and 3 full plastic shields).
Checking policy were assessed as possible modifiers and confounders, but the limited and different sample sizes between groups did not allow for the adjustment of other potentially relevant covariates (eg, sex, level of play, previous concussion, injury severity).

**Helmet Characteristics**

The HECC sticker on the helmet specifies when the helmet expires (6.5 years after the manufacturing date). Only 8 of the 190 helmets were expired; however, 14 helmets were missing the manufacturer’s date and the HECC sticker and date, making it impossible to determine the expiration date for those helmets. Of the expired helmets, 4 were worn by concussed players, 1 by a nonconcussion-injured player, and 3 by uninjured players. An investigation of the effect of bicycle helmet age on impact performance showed limited differences in helmets ranging from new to 26 years old. Another group determined that most ice hockey helmet impact-attenuation characteristics were maintained after 10 years in storage, yet no researchers have examined the effect of helmet age or expiration on the risk of injury in ice hockey or other sports.

In contrast to Patton et al., who observed no difference between actual and estimated helmet ages, 69% of our players stated that they had worn their helmets for <3 years, even though the manufacturing stickers indicated that only 51% (78 of 152) of helmets were <3 years old. This suggested 2 possible scenarios: (1) players started using their helmets a considerable length of time after the manufacturing date or (2) players were not aware of the age using their helmets a considerable length of time after the manufacturing date. This suggested 2 possible scenarios: (1) players started using their helmets a considerable length of time after the manufacturing date or (2) players were not aware of the age using their helmets a considerable length of time after the manufacturing date, making it impossible to determine the helmet expires (6.5 years after the manufacturing date).

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**Limitations**

We are among the first to consider the association between helmet fit and players who sustained concussions in youth ice hockey; however, the limitations of our work are worth noting. The different results when analyzing the entire sample compared with only the participants capable of being matched raises concern for selection bias. A larger sample size would help avoid the limitations surrounding the lack of potential covariates that could be considered when we analyzed these relationships (eg, player position, game situation, concussion severity, concussion history). The size of the sample also restricted a wide range of possibilities for examining the most appropriate threshold for categorizing exposed and unexposed individuals. Also, a larger sample size would allow for a sensitivity analysis to investigate this outcome specifically to ensure that the criteria do not overlap too much and that the most accurate threshold is selected for determining exposed individuals. Second, we were able to collect data in a timely manner from all player helmets and all players with an injury who contacted the Sport Injury Prevention Research Centre, but teams that were less responsive restricted some of the data that could be collected. Lastly, considerably fewer players were in the female and Pee Wee groups. Therefore, the generalizability of our results to players in those categories may be limited.

**CONCLUSIONS**

Although more than 93% (177 of 190) of players reported that their helmet fit was excellent or good, only 27% (51 of 190) of players met all helmet-fit criteria. No association was found between helmet fit and players who sustained concussions among the entire sample, but inadequate helmet fit resulted in greater odds of concussion when we compared concussed and uninjured players who were matched on age, sex, and level of play. Despite these different results, inadequate helmet fit may affect the odds of sustaining a concussion in youth ice hockey. A larger sample size is needed in future research to evaluate these helmet-fit criteria with certainty, confirm this relationship, and inform helmet-fit recommendations and potential policy changes in youth ice hockey.
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