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Effectiveness of interventions to reduce aggression and injuries among ice hockey players: a systematic review

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ABSTRACT

Background: The increasing incidence of injuries related to playing ice hockey is an important public health issue. We conducted a systematic review to evaluate the effectiveness of interventions designed to reduce injuries related to aggressive acts in ice hockey.

Methods: We identified relevant articles by searching electronic databases from their inception through July 2012, by using Internet search engines, and by manually searching sports medicine journals, the book series *Safety in Ice Hockey* and reference lists of included articles. We included studies that evaluated interventions to reduce aggression-related injuries and reported ratings of aggressive behaviour or rates of penalties or injuries.

Results: We identified 18 eligible studies. Most involved players in minor hockey leagues. Of 13 studies that evaluated changes in mandatory rules intended to lessen aggression

(most commonly the restriction of body-checking), 11 observed a reduction in penalty or injury rates associated with rule changes, and 9 of these showed a statistically significant decrease. The mean number of penalties decreased by 1.2–5.9 per game, and injury rates decreased 3- to 12-fold. All 3 studies of educational interventions showed a reduction in penalty rates, but they were not powered or designed to show a change in injury rates. In 2 studies of cognitive behavioural interventions, reductions in aggressive behaviours were observed.

Interpretation: Changes to mandatory rules were associated with reductions in penalties for aggressive acts and in injuries related to aggression among ice hockey players. Effects of educational and cognitive behavioural interventions on injury rates are less clear. Well-designed studies of multifaceted strategies that combine such approaches are required.

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Over the last 15 years, the incidence of brain and spinal cord injuries among ice hockey players has increased.¹ A recent study involving players in junior leagues found that, in the 2009/10 hockey season, the incidence of game-related concussions was 7 times higher than the highest rate previously reported in 1998/99.² Brain injuries frequently result from aggressive bodychecking³ and account for 15% of injuries among players 9–16 years of age.^{4,5} In a study of a community-based hockey program involving boys aged 9–15 years, hostile aggressive acts, which have an intention to do harm,⁶ were the primary cause of injury in one-third of games in which an injury resulted.⁷ Among high school students in Minnesota who played varsity ice hockey, those who played to relieve aggression were 4 times more likely than other players to experience a concussion.⁸ These findings highlight the association between aggressive behaviour and injury in ice hockey. However, little is known about what can

be done to reduce this behaviour to create a safer environment for the sport.

Existing reviews about reducing injury in sport have primarily assessed equipment or risk factors associated with injury.^{9–11} Recent systematic reviews highlighted the risks of bodychecking and renewed calls for policies to disallow bodychecking among youth playing ice hockey.^{3,12} We conducted a systematic review to assess the effectiveness of interventions designed to reduce aggressive acts and related injuries among ice hockey players. We were particularly interested in evaluating the effectiveness of rule changes, educational interventions and behavioural modification in reducing aggressive acts and related injuries.

Methods

Data sources

We searched 8 electronic databases for potentially relevant articles published from the time

of the database's inception through July 2012: MEDLINE (using the search engines Ovid [from 1950] and PubMed [from 1948]), Embase (from 1980), CINAHL (from 1981), Journals @ Scholars Portal (from 1960), the Cochrane Library (from 1980), PsycINFO (from 1987) and Web of Science (from 1976). For each search, we used a combination of Medical Subject Headings (MeSH) and key words, including "hockey," "ice hockey," "aggression," "violence," "anger," "injury," "wounds and injuries," "injury prevention," "prevention studies," "intervention," "intervention studies," "prevention," "reducing," "protection" and "education." (Details of the search strategy are provided in Appendix 1, available at www.cmaj.ca/lookup/suppl/doi:10.1503/cmaj.112017/-/DC1). Search terms were modified based on search results to generate increasingly inclusive sets of potentially relevant articles. We did not restrict these searches by language, publication year or publication status.

We also used the Internet search engines Yahoo!, Google, Google Scholar and Dogpile, with the same search terms as those listed above. We manually searched for related articles in 4 sports medicine journals (*American Journal of Sports Medicine*, *British Journal of Sports Medi-*

cine, *Injury Prevention*, and *Sports Medicine*, all of which commonly publish articles related to ice hockey and injury prevention) from 2000 to 2010; all 5 volumes of *Safety in Ice Hockey*;¹³⁻¹⁷ and the bibliographies of all included studies. We reviewed the titles and abstracts of potentially relevant articles to identify studies that met our selection criteria (Figure 1).

Study selection

We included studies of interventions applied directly to the hockey coaches or players that attempted to reduce aggressive behaviours in ice hockey, had a comparison group (cross-sectional, case-control, cohort, before-after, quasi-experimental and randomized controlled trial designs were all considered), and measured injuries, penalties or ratings of aggressive behaviour as outcomes. We excluded studies that applied to other types of hockey, involved only the use of protective equipment or were not conducted in an ice hockey setting.

Data extraction and synthesis

Two of us (S.N. and L.Z.) independently reviewed the articles of the included studies and extracted the data; the third author (M.D.C.) confirmed that the extraction of data was complete. We obtained data on the study design, the study population, the hypothesis or research question, the outcome measures, the study methods, the statistical analyses, the results and the conclusions. We assessed the methodologic quality of each study based on a checklist created by Downs and Black.¹⁸

The individual studies had considerable heterogeneity and varied by interventions, outcome measures and definitions of exposure. This heterogeneity precluded the ability to perform a meta-analysis.

Results

Included studies

Of the 29 full-text manuscripts retrieved for preliminary consideration, 18 were selected for inclusion in our review. We excluded 11 articles because the study did not assess aggression or injury related to players in an actual ice hockey setting ($n = 4$), there was no intervention ($n = 5$), only qualitative feedback from coaches was reported, or the study had no comparison group. (The citations of the excluded studies are provided in Appendix 2, available at www.cmaj.ca/lookup/suppl/doi:10.1503/cmaj.112017/-/DC1).

Of the 18 included studies, 13 assessed the effectiveness of changes in mandatory league rules,¹⁹⁻³¹ 3 assessed the effectiveness of educational interventions,³²⁻³⁴ and 2 assessed the effec-

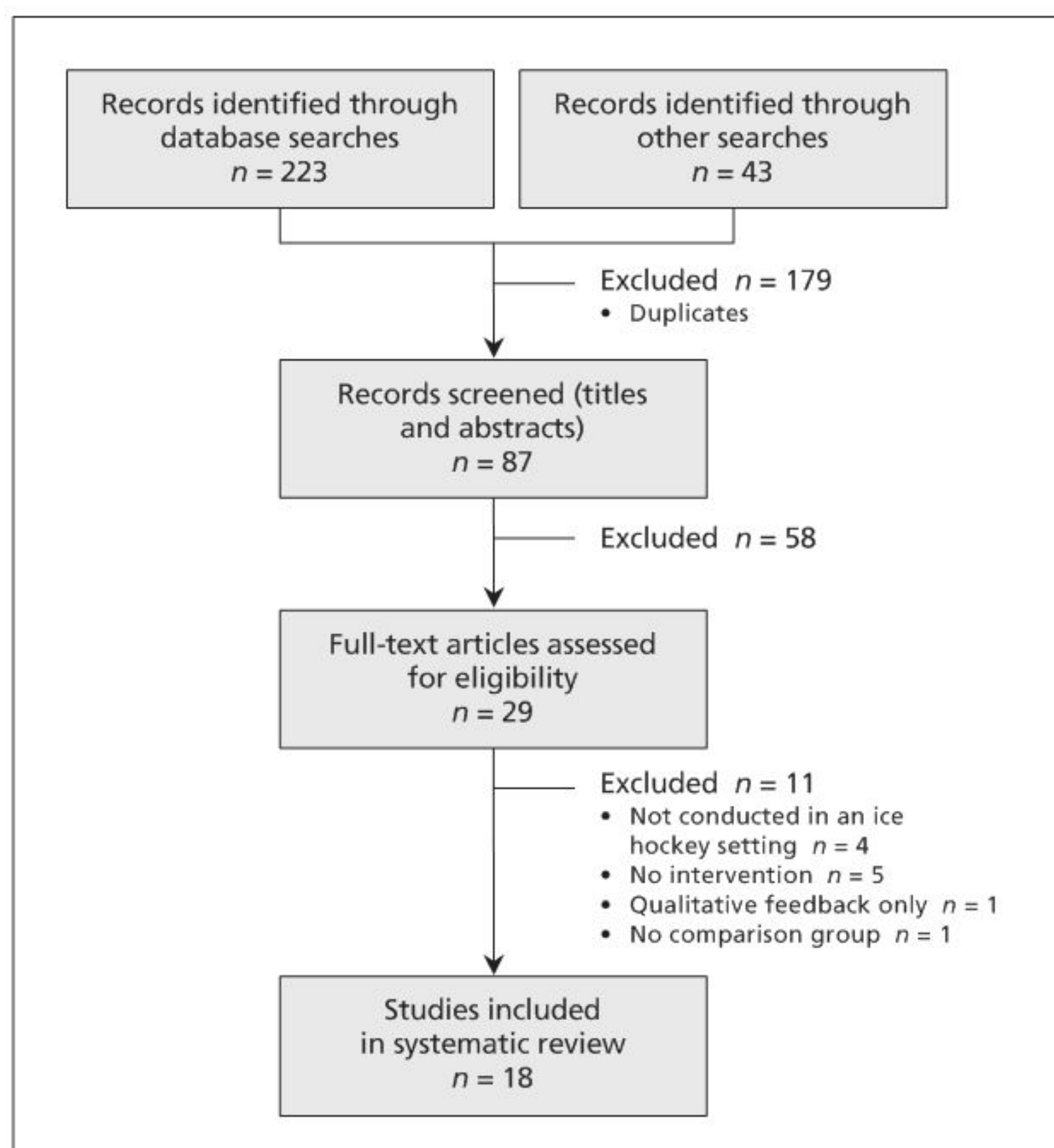


Figure 1: Selection of articles for inclusion in the systematic review.

tiveness of psychosocial interventions.^{35,36} Thirteen of the studies included youth players in minor leagues. One study involved players in Canada and the United States, 13 studies were completed solely in Canada, and 4 were completed in the United States. Characteristics of the included studies are summarized in Table 1.

Quality assessment

Details of our assessment of the methodologic quality of the studies based on the criteria of Downs and Black¹⁸ are provided in Appendix 3 (available at www.cmaj.ca/lookup/suppl/doi:10.1503/cmaj.112017/-/DC1). In brief, several studies^{19–22,24,26,28–31,34} drew on large samples, such as all hospital visits in multiple Canadian provinces. In some studies, confounding variables were difficult to control because of their retrospective or observational nature;^{25,26,30} and only one of the studies was randomized.³³ No studies looked at broader outcomes such as the effects of injury on participation rates in hockey or advancement of players to higher or elite levels of play.

Effect of interventions

The effects of the interventions on aggressive acts and related injuries are summarized in Table 2.

Rule changes

Thirteen studies evaluated changes in mandatory rules intended to curb aggressive behaviour and subsequent injury.^{19–31} Three studies examined the Fair Play Program.^{20,21,23} This program includes sportsmanship as a component of the final standings, adapted from an experimental program created by Edmond Vaz.³⁷ Points are awarded to teams at the end of every season or tournament for staying below a pre-established limit of team penalties per game.²¹ Nine studies investigated bodychecking rules.^{19,22,24,25,27–31} The remaining study examined legal punishment for aggressive illegal acts in professional hockey.²⁶

The 3 studies of the Fair Play Program noted an overall decrease in the number or severity of penalties,^{20,21,23} and one also reported a decrease in injury rates.²¹

Most of the 9 studies evaluating the enforcement of rules prohibiting bodychecking observed reductions in penalties, injuries or both, and in many studies these differences were statistically significant. Seven of the 9 studies showed decreased injury rates.^{19,22,24,25,27,28,30} Typical of this group of studies, Regnier and colleagues¹⁹ noted more penalties in games in which bodychecking was allowed, along with a higher risk of serious injury among Peewee

players (age 11–12 years). Macpherson and colleagues²⁴ found that injury rates in boys' minor hockey in Ontario and Quebec were higher in leagues in which bodychecking was allowed than in leagues in which it was not allowed. The players in leagues that allowed bodychecking were also more likely to experience a concussion or fracture. Among older players (age 14–15 years), all of whom were in leagues that allowed bodychecking, checking-related injuries were more common among those who had previous experience with it (Ontario leagues) than among those introduced to bodychecking for the first time (Quebec leagues); this difference suggests a protective effect of delaying the introduction of bodychecking. On the contrary, Kukaswadia and colleagues' retrospective cohort study noted a beneficial effect of introducing bodychecking at an earlier age, but it excluded a large number of possible cases to control for confounding variables.²⁹

One study examined the impact of legal punishment on the frequency of aggressive behaviour across the National Hockey League (NHL).²⁶ After the Bertuzzi incident (a widely publicized incident of highly aggressive and injurious behaviour for which player Todd Bertuzzi received a high-profile legal charge), there was an insignificant reduction in the overall frequency of aggressive behaviour but a significant decrease in specific acts of aggression (fighting and game misconduct infractions).

Educational interventions

All 3 studies that evaluated the effectiveness of educational interventions showed a reduction in penalties, but they were not powered or designed to show a change in injury rates.^{32–34}

In the only randomized controlled trial included in our review, Cook and colleagues³³ evaluated the effectiveness of ThinkFirst Canada's *Smart Hockey* video, which encourages respectful play to avoid injury and educates players and coaches about the diagnosis and treatment of concussion. This small study showed a decrease in the number of bodychecking-related penalties and the occurrence of aggressive and negligent behaviour, but it did not measure injury rates.

In a before–after study, Trudel and colleagues evaluated an intervention from the 1980s that introduced coaches to methods for properly teaching hockey skills through both video and training sessions.³² The authors reported a significant decrease in the number of penalties per game in only 1 of the 4 leagues that adopted the strategy and showed that the proportion of major injuries related to body-

Table 1 (part 1 of 4): Description of study characteristics

Intervention; study	Study design	Participants	Study groups	Methods	Outcome measures	Downs and Black score (out of 27)*
Rule changes						
Regnier et al., 1989; ¹⁹ Québec City, Canada	Retrospective cohort study	279 Peewee-level amateur hockey players participating in 521 games (for penalty rates) or 82 games (for injury rates); 227 parents and 63 coaches were surveyed by telephone	Intervention group: Players during the 1984/85 season (bodychecking not allowed) Comparison group: Players during the 1985/86 season (bodychecking allowed)	Penalty records were examined and analyzed to determine number and types of penalties; analysis of injuries was based on 82 direct observations and telephone surveys; circumstances leading to the injuries were also identified	Number and types of penalties; player injury rate and types of injuries	15†
Marcotte et al., 1993; ²⁰ Québec City, Canada	Retrospective cohort study	23 Peewee and 24 Bantam amateur teams in third-tier competitive division in Québec	Intervention group: 7 Peewee and 8 Bantam teams using Fair Play rules† Comparison group: 16 Peewee and 16 Bantam teams not using Fair Play rules	Game sheets from 329 regular- season games in the Peewee category and 338 in the Bantam category were used to compile number and types of penalties for a comparative analysis	Number and type of penalties	12†
Roberts et al., 1996; ²¹ Minnesota, United States	Retrospective cohort study	273 male hockey players in high school (age < 20 yr) on the rosters of 16 teams during the 1994 Junior Gold ice hockey tournament	Intervention group: Players in 24 tournament games using Fair Play rules† (n = 882 player-exposures) Comparison group: Players in 7 tournament games using regular rules (n = 217 player-exposures)	Injuries were recorded by an on-site certified athletic trainer, and penalties were tallied from score sheets	Number of injuries and penalties	11†
Watson et al., 1996; ²² Ontario, Canada	Retrospective cohort study	653 injury records and 389 penalty records for 3 Ontario University Athletic Association teams that had complete records for 3 yr before and 3 yr after introduction of a bodychecking rule in 1989	Intervention group: 211 games played by the 3 teams after the rule was introduced (minor 2-minute penalty for bodychecking into the boards or major 5-minute penalty if an injury resulted from that check) Comparison group: 178 games played by the 3 teams before the rule was introduced	Data on injuries and penalties were collected from game reports	Injury and penalty rates	15†
Brunelle et al., 2005; ²³ Québec, Canada	Prospective cohort study	52 elite Bantam teams	Intervention group: 13 games using Fair Play rules† Comparison group: 36 games not using Fair Play rules†	49 games were systematically assessed; data on rule transgressions were obtained using a time- observation system based on the classification of adversary interactions in nonconformity with rules; injury data were collected using a self-administered questionnaire	Observations of rule transgressions (nature, referee's decision and level of transgressions) and hockey-related injuries	14
Macpherson et al., 2006; ²⁴ Ontario and Québec, Canada	Retrospective cohort study	Boys in minor hockey leagues at the Atom (10–11 yr), Peewee (12–13 yr) and Bantam (14–15 yr) levels in Ontario and Québec leagues from September 1995 to August 2002	Intervention group: Players aged 10– 13 yr in leagues that did not allow bodychecking; players aged 14–15 yr (bodychecking allowed) who had no previous experience with bodychecking Comparison group: Players aged 10–13 in leagues that allowed bodychecking; players aged 14–15 yr (bodychecking allowed) who had previous experience (2–4 yr) with bodychecking	CHIRPP data were used to characterize hockey-related injuries experienced by players presenting at emergency departments	Injury rate and types of injuries	17†

Table 1 (part 2 of 4): Description of study characteristics

Intervention; study	Study design	Participants	Study groups	Methods	Outcome measures	Downs and Black score (out of 27)*
Hagel et al., 2006; ²⁵ Edmonton, Canada	Retrospective cohort study	249 hockey players aged 11 yr before and after a policy change in 2002	Intervention group: 98 players not exposed to bodychecking before the policy change (a change in age classification for minor ice hockey, whereby 11-year-old children were moved from the Atom level [no bodychecking] to the Pee wee level [bodychecking allowed]) Comparison group: 151 players exposed to bodychecking after the policy change	ACCS data were used to identify records of children aged 10–12 yr who were injured playing ice hockey during the 2000/01 to 2003/04 seasons	Injury rates	18†
Gee et al., 2007; ²⁶ United States and Canada	Retrospective cohort study	50 National Hockey League (NHL) games played before and after the Todd Bertuzzi incident on Mar. 8, 2004 (a widely publicized incident of highly aggressive and injurious behaviour for which Todd Bertuzzi received a high-profile legal charge)	Intervention group: 50 games after the incident Comparison group: 50 games before the incident	All penalty infractions were coded according to type, score differential, aggressor team's status at the time of the infraction and whether the act occurred before or after the Todd Bertuzzi incident; the frequency of each aggressive infraction was compared before and after the incident	Frequency and type of penalty called	16†
Emery et al., 2009; ²⁷ Calgary, Canada	Prospective cohort study	283 players at the Pee wee (11–12 yr), Bantam (13–14 yr) and Midget (15–16 yr) levels in the Calgary Minor Hockey Association	Intervention group: 138 players on 24 teams in the league that did not allow bodychecking Comparison group: 145 players on 13 teams in the league that allowed bodychecking	A series of self-administered questionnaires were completed by players to assess their bodychecking attitudes, empathy and aggression. Injury report forms were completed by the study coordinator (with consultation of a physiotherapist for accuracy)	Injury rates	18
Emery et al., 2010; ²⁸ Alberta and Quebec, Canada	Prospective cohort study	2154 hockey players at the Pee wee level (11–12 yr) in the top 60% of divisions of play during the 2007/08 season	Intervention group: 1046 players on 76 teams in Quebec (bodychecking not allowed) Comparison group: 1108 players on 74 teams in Alberta (bodychecking allowed)	Injury report forms were completed by trained study personnel	Injury and concussion rate ratios	22
Kukawadla et al., 2010; ²⁹ Kingston, Canada	Retrospective cohort study	Minor hockey players aged 7–14 yr before and after the introduction of a rule change in Ontario minor ice hockey in 2002	Intervention group: Players in games during the 1997/98 to 2001/02 seasons, before the rule change (introduction of bodychecking at the Atom level [9–10 yr] instead of at the Pee wee level [12–13 yr]) Comparison group: Players in games during the 2002/03 to 2006/07 seasons, after the rule change	CHIRPP data were used to identify injuries experienced by players presenting at 2 emergency departments	Injury rates	16†

Table 1 (part 3 of 4): Description of study characteristics

Intervention; study	Study design	Participants	Study groups	Methods	Outcome measures	Downs and Black score (out of 27)*
Cusimano et al., 2011; ³⁰ Canada	Retrospective cohort study	Male hockey league players aged 6–17 yr before and after a rule change in 1998/99	Intervention group: Injuries from bodychecking before the rule change (lowering of the age when bodychecking is allowed from 11 to 9 yr) Comparison group: Injuries from bodychecking after the rule change	CHIRPP data on 8552 hockey-related injuries from September 1994 to May 2004 were collected from 5 hospitals in Ontario; injuries were classified as being related to or not related to bodychecking	Injury rates, and the odds ratio of an emergency department visit because of a bodychecking-related injury	18†
Emery et al., 2011; ³¹ Canada	Prospective cohort study	1971 Bantam hockey players (13–14 yr) in the top 30% of divisions of play during the 2008/09 season	Intervention group: 995 players on 68 teams in Alberta who had 2 years of bodychecking experience Comparison group: 976 players on 62 teams in Quebec who had no bodychecking experience	Baseline questionnaires about attitudes toward bodychecking and injury report forms were used	Incidence of all injuries and concussions	17†
Educational intervention						
Trudel et al., 2000; ³² Ottawa and Québec City, Canada	Before–after study	28 coaches of 42 Bantam (14–15 yr) hockey teams from 5 competitive leagues before and after the 1988/89 season	Intervention group: Games played during the 1988/89 hockey season, when a two-stage self-supervision strategy was in place (stage 1: coaches watched instructional videos on the teaching of proper hockey skills and the concept of self-supervision; stage 2: coaches prepared players for the proper use of bodychecking through the use of videos and training sessions) Comparison group: Games played during the 1987/88 season before the strategy was introduced; 1 of the 5 leagues did not add the educational intervention in the 1988/89 season and was considered the control group	Bodychecking was analyzed by 3 coders using video recordings of the games; penalties were counted and categorized using game reports; injury statistics were gathered during games via data collection	Observation of the frequency of legal bodychecks, the type and frequency of penalties, and the number of injuries during games	12
Cook et al., 2003; ³³ Toronto, Canada	Randomized controlled trial	Male hockey players on 5 competitive-level Atom (11–12 yr) teams and their coaches in the Greater Toronto Hockey League during the 2001/02 season	Intervention group: 45 players on 3 teams who watched ThinkFirst Canada's <i>Smart Hockey</i> video at midseason (a video about the mechanisms, consequences and prevention of brain and spinal cord injury in ice hockey) Comparison group: 30 players on 2 teams who did not watch the video	Players completed a test on their knowledge of concussions at different times throughout the season; the total number of penalties received during the season was collected; coaches were given a qualitative interview by a single blinded observer	Test of concussion knowledge; incidence of aggressive penalties	14†

Table 1 (part 4 of 4): Description of study characteristics

Intervention; study	Study design	Participants	Study groups	Methods	Outcome measures	Downs and Black score (out of 27)*
Smith et al., 2009, ³⁴ Minnesota, United States	Before-after study	55 900 players at Squirt, PeeWee, Bantam and Junior Gold levels, and all girls' hockey groups in the Minnesota Hockey League, as well as coaches and officials registered in the league; 17 678 records of game data were obtained, 4420 (25%) of which were randomly selected for analysis of the Fair Play Program	Intervention group: Games played in 2007/08 season, after introduction of the Hockey Education Program in 2003 (program consists of 3 primary components: skill development, coaching excellence and fair play; an empirically based curriculum was created for hockey coaches to help improve players' development of hockey skills; a Fair Play scoring component was also introduced†) Comparison group: Games played in 2004/05 season, soon after the program's introduction	The program was implemented to all players, coaches, parents and officials. For the analysis of the Fair Play Program, data from 4 seasons were collected from game sheets	Attrition of girls (under 10, 12 and 14 yr) and boys (Squirt, Pee Wee, Bantam and Junior Gold), coaches and officials; Fair Play points; and prevalence and types of penalties collected	16†
Psychosocial interventions						
Mattesi, 2002, ³⁵ West Virginia, United States	Before-after study	Male hockey players in the West Virginia University collegiate club	Intervention group: 3 players who received a 3-week aggression-management training intervention program (3 sessions of psychological skills training that included positive self-talk, deep breathing and coping imagery) Comparison group: The same 3 players before the intervention program	Demographic questionnaire was given to players; the Bredemeier Athletic Aggression Inventory (BAAGI) was used to assess aggression	Number of penalty minutes and BAAGI aggression scores	15
Lauer et al., 2009, ³⁶ United States	Before-after study	3 ice hockey players aged 12–14 yr described as physical, tough players who also received penalties for dirty play	Intervention group: 3 players enrolled in the Playing Clean and Tough Hockey Program (a program designed to teach players how to play the game of hockey "tough" and intensely while playing it "clean" by learning emotional control skills in adverse situations) Comparison group: The same 3 players before the intervention	Players had to commit to 9 sessions and complete all activities, logs and postgame reports. Postgame self-reported emotions and feelings stated in logs, program test results, program evaluations and descriptive statistics were used. Aggressive behaviours were video recorded and visually inspected by 2 independent coders	Frequency of aggressive acts per game	13
<p>Note: ACCS = Ambulatory Care Classification System, CHIRPP = Canadian Hospitals Injury Reporting and Prevention Program.</p> <p>*The score reflects how many of the 27 Downs and Black criteria¹⁸ were clearly met by the study. See Appendix 3 for details about the criteria (available at www.cmaaj.ca/lookup/suppl/doi:10.1503/cmaj.112017/-/DC1).</p> <p>†Includes qualified responses (e.g., "yes, probably" and "yes, likely").</p> <p>#Fair Play rules: each team can earn points for good conduct based on the number of penalty minutes called by referees; the points are added to the general standings after each game.</p>						

Table 2 (part 1 of 3): Description of study outcomes, by type of intervention

Intervention; study	Effect on penalties for aggressive acts	Effect on injury rate
Rule changes		
Regnier et al. ¹⁹	<ul style="list-style-type: none"> Intervention group (bodychecking not allowed): Mean 9.1 penalties per game in the regular season, 6.8 per game during tournaments Comparison group (bodychecking allowed): Mean 12.4 penalties per game in the regular season, 8.2 per game during tournaments Penalties for hostile aggressive behaviour were more frequent in games played with bodychecking than in those played without bodychecking (average increase 2.9 and 1.6 penalties per game for regular season and tournament play, respectively) ($p < 0.05$) 	<ul style="list-style-type: none"> Intervention group: 7 injuries (1 fracture) in 263 games Comparison group: 26 injuries (14 fractures) in 315 games; 1 fracture per 22.5 games; injury rate was 12 times greater than in intervention group (p value not reported) 88% of all fractures were related to bodychecking (p value not reported)
Marcotte et al. ²⁰	<p>Intervention group (Fair Play rules)</p> <ul style="list-style-type: none"> Peewee league: Mean 4.5 penalties per team per game, and 1.2 major penalties per team per season; 1 fewer penalty per game on average than in comparison group (p value not reported) Bantam league: Mean 7.8 penalties per team per game; fewer penalties than in comparison group (p value not reported) Bantam league: 30% fewer major penalties and 25% fewer game suspensions than in comparison group (p value not reported) <p>Comparison group (regular play)</p> <ul style="list-style-type: none"> Peewee league: Mean 5.7 penalties per team per game, and 6.4 major penalties per team per season Bantam league: Mean 8.4 penalties per team per game 	Not reported
Roberts et al. ²¹	<ul style="list-style-type: none"> Intervention group (Fair Play rules): 7.1 penalties per game Comparison group (regular play): 13.0 penalties per game; there were 4 times more penalties related to rough play than in the intervention group (p value not reported) 	<ul style="list-style-type: none"> Intervention group: 5.7 notable injuries (> 1 d of play lost, facial laceration or concussion) per 1000 player-exposures Comparison group: 27.6 notable injuries per 1000 player-exposures Ratio of notable injuries per 1000 player-exposures in regular games to such injuries in games following Fair Play rules was nearly 5:1 (p value not reported)
Watson et al. ²²	<ul style="list-style-type: none"> Intervention group: 669 body-contact penalties per game and 498 stick-related penalties per game after introduction of rule disallowing checking from behind Comparison group: 762 body-contact penalties per game and 695 stick-related penalties per game before introduction of the rule Significantly lower rates for body-contact and stick-related penalties after introduction of the rule ($p < 0.001$) 	<ul style="list-style-type: none"> Intervention group: 16 head/neck injuries per 1000 player-games and 16 back injuries per 1000 player-games Comparison group: 26 head/neck injuries per 1000 player-games and 21 back injuries per 1000 player-games Rates of head/neck and back injuries decreased significantly after introduction of the rule ($p < 0.001$)
Brunelle et al. ²³	<ul style="list-style-type: none"> Intervention group (Fair Play rules): 3195 transgressions recorded Comparison group (regular play): 8076 transgressions recorded Significantly fewer penalties per game in the intervention group ($p < 0.01$) 	Not reported
Macpherson et al. ²⁴	Not reported	<ul style="list-style-type: none"> Intervention group: 1730 (37%) of 4736 hockey-related injuries were in Quebec, where bodychecking was not allowed until Bantam level (14–15 yr) Comparison group: 3006 (63%) of 4736 hockey-related injuries were in Ontario, where bodychecking was introduced at the Peewee level (12–13 yr), and at the Atom level in competitive leagues (10–11 yr) in certain jurisdictions Most of the injuries (3618 [76.4%]) occurred in games where bodychecking was allowed Players aged 10–13 yr in leagues that allowed bodychecking were at increased risk of a bodychecking-related injury (OR 2.65, 95% CI 2.21–3.18); they were also at increased risk of concussion (OR 1.53, 95% CI 0.93–2.52) or possibly a fracture (OR 1.20, 95% CI 1.00–1.47)
Hagel et al. ²⁵	Not reported	<ul style="list-style-type: none"> Intervention group (bodychecking not allowed): 40.6 injuries per 1000 players; 33 (40.2%) of players had severe injuries Comparison group (bodychecking allowed): 85.5 per 1000 players; 77 (51.0%) of players had severe injuries The overall injury rate was significantly greater in the comparison group than in the intervention group (rate ratio 1.9, 95% CI 1.4–2.6); the rate of severe injuries was more than 2 times greater in the comparison group (rate ratio 2.4, 95% CI 1.6–3.6)

Table 2 (part 2 of 3): Description of study outcomes, by type of intervention

Intervention; study	Effect on penalties for aggressive acts	Effect on injury rate
Gee et al. ²⁶	<ul style="list-style-type: none"> Intervention group (after the Bertuzzi incident): Mean 5.2 aggressive infractions per game, 60 fighting infractions and 2 game-misconduct infractions Comparison group (before the incident): Mean 6.5 aggressive infractions per game, 91 fighting infractions, and 22 game-misconduct infractions Slight but nonsignificant reduction in the frequency of aggressive behaviours after the incident ($p = 0.3$) When individual acts of aggression (e.g., slashing, fighting) were examined independently, infractions for fighting and game misconduct significantly decreased after the incident ($p < 0.05$) 	Not reported
Emery et al. ²⁷	Not reported	<ul style="list-style-type: none"> Intervention group (bodychecking not allowed): 1.37 injuries per 100 players per season (95% CI 0.17–4.89); 0.43 injuries per 100 player-hours Comparison group (bodychecking allowed): 24.64 injuries per 100 players per season (95% CI 17.71–32.69); 3.16 injuries per 100 player-hours Relative risk of injury considering exposure-hours was 4.89 (95% CI 1.54–24.9) in the comparison group; however, attitudes toward bodychecking, empathy and aggression did not influence injury rates
Emery et al. ²⁸	Not reported	<ul style="list-style-type: none"> Intervention group (bodychecking not allowed): 91 injuries (23 concussions) reported during 82 099 player exposure-hours Comparison group (bodychecking allowed): 241 injuries (78 concussions) reported during 85 077 player exposure-hours The risk of any game-related injury and of concussion or other severe injury was 3-fold greater (95% CI 2.31–4.60) in the comparison group than in the intervention group
Kukaswadia et al. ²⁹	Not reported	<ul style="list-style-type: none"> Intervention group: Before the rule change (to lower the age when bodychecking is introduced), the overall injury rate was 59.9 injuries per 1000 player-years (95% CI 55.4–64.4) Comparison group: After the rule change, the rate was 49.1 injuries per 1000 player-years (95% CI 44.8–53.3) Contrary to hypothesis, the overall injury rate decreased after the rule change (p value not reported); the overall rate of injury and concomitant neurotraumatic events did not increase (p value not reported)
Cusimano et al. ³⁰	Not reported	<ul style="list-style-type: none"> Intervention group: Before the rule change (to lower the age when bodychecking is introduced from the Pee wee level to the Atom level), there were 1617 injuries overall (158 at the Atom level) Comparison group: After the rule change, there were 2843 injuries overall (243 at the Atom level) The odds of a bodychecking-related injury were significantly increased after the rule change in all divisions (OR 1.26, 95% CI 1.16–1.38) and at the Atom level (OR 2.20, 95% CI 1.70–2.84) Rates of injuries involving the head and neck (OR 1.52, 95% CI 1.26–1.84) and shoulder and arm (OR 1.18, 95% CI 1.04–1.35) increased most substantially
Emery et al. ³¹	Not reported	<ul style="list-style-type: none"> Intervention group: 272 injuries (51 concussions) were reported during 96 907 player-hours among players with previous bodychecking experience Comparison group: 244 injuries (49 concussions) were reported during 85 464 player-hours among players without previous bodychecking experience The adjusted incidence rate ratio for game-related injury and concussion overall between players with previous bodychecking experience and those without it were as follows: injury overall 0.85 (95% CI 0.63–1.16), concussion overall 0.84 (95% CI 0.48–1.48) and injury resulting in more than 7 d of lost play 0.67 (95% CI 0.46–0.99) The rate of injury resulting in loss of on-ice time was reduced by 33% among players who had 2 years of bodychecking experience compared with players who had no previous bodychecking experience

Table 2 (part 3 of 3): Description of study outcomes, by type of intervention

Intervention; study	Effect on penalties for aggressive acts	Effect on injury rate
Educational interventions		
Trudel et al. ³²	<ul style="list-style-type: none"> Intervention group: After use of the self-supervision strategy for coaches, only 1 of the 4 Quebec third-tier leagues showed a significant reduction in the number of penalties per game (mean 9.0 before v. 8.1 after strategy; $p < 0.001$). In terms of minor aggression penalties per game, this Quebec league showed a significant reduction (mean 5.9 before v. 5.4 after strategy; $p = 0.02$); however, the Ottawa top-tier league showed a significant increase (mean 4.7 before v. 5.2 after strategy; $p = 0.02$). The Quebec top-tier and Ottawa third-tier leagues showed no significant difference with the strategy Comparison group: The Franc-Sud third-tier Quebec league showed a significant decrease in the number of penalties per game the next year without using the strategy (mean 8.4 per game in 1987/88 season v. 7.4 per game in 1988/89 season; $p = 0.009$); this team showed no significant change in the no. of minor aggression penalties per game Significant decrease in no. of penalties only in the Quebec third-tier league ($p < 0.001$) Significant decrease in no. of minor aggressive penalties in the Quebec third-tier league ($p < 0.02$), but significant increase in Ottawa top-tier league ($p < 0.02$) 	<ul style="list-style-type: none"> Intervention group: Two leagues using the strategy experienced a mean decrease in the no. of minor injuries per game per team (Ottawa top tier: mean 0.6 before v. 0.5 after strategy; Ottawa third tier: mean 0.8 before v. 0.6 after strategy); the other 2 leagues using the strategy experienced a mean increase in minor injuries per game per team (Quebec top tier: mean 1.0 before v. 1.6 after strategy; Quebec third tier: mean 1.1 before v. 1.7 after strategy) Comparison group: The Franc-Sud third-tier league had a mean of 1.4 minor injuries per game in the 1988/89 season The proportion of major injuries related to bodychecking decreased from 75.0% to 68.7% after the strategy The strategy had no significant effect on the no. of minor injuries in all leagues Bodychecking was the main cause of all minor injuries during both seasons (in 46.2% of injuries in the 1987/88 season and 46.7% in the 1988/89 season)
Cook et al. ³³	<ul style="list-style-type: none"> Intervention group (<i>Smart Hockey</i> video): The total no. of penalties per game did not change significantly among players after they watched the video (p value not reported); however, the mean (\pm SEM) no. of penalties per 1000 player-hours decreased significantly ($p < 0.05$) for cross-checking penalties (from 23.7 ± 1.3 to 13.0 ± 3.4) and for penalties for checking from behind (from 38.4 ± 3.7 to 7.6 ± 0.7) Comparison group (no video): The mean (\pm SEM) no. of penalties per 1000 player-hours significantly ($p < 0.05$) decreased for interference penalties (from 50.0 ± 5.0 to 28.4 ± 5.7) and increased for holding penalties (from 12.5 ± 2.5 to 22.7 ± 0.0) Overall, the total no. of penalties did not change significantly after watching the video (p value not reported) 	Not reported
Smith et al. ³⁴	<ul style="list-style-type: none"> Intervention group: In the 2007/08 season, 4 yr after HEP was implemented, the mean no. of penalties per 100 games was 310 tactical penalties, 205 minor penalties, 15 major penalties and 40 other penalties Comparison group: In the 2004/05 season, the first season after HEP was implemented, the mean no. of penalties per 100 games was 230 tactical penalties, 275 minor penalties, 80 major penalties and 140 other penalties The penalty rate decreased across all 4 seasons in all 4 sectors (tactical, minor, major, other) (p value not reported) The percentage of Fair Play points increased across all 4 seasons (p value not reported) 	Not reported
Psychosocial interventions		
Mattesi ³⁵	<ul style="list-style-type: none"> Intervention group: During the aggression-management training, the no. of penalty minutes per game was 1.67 for player 1, 0.00 for player 2 and 0.286 for player 3; after the intervention, the mean no. per game was 1.32 for player 1, 0.947 for player 2 and 1.0 for player 3 Comparison group: Before the training, the mean no. of penalty minutes per game was 2.00 for player 1, 1.4 for player 2 and 1.18 for player 3 Each player had a reduction in penalty minutes during and after the training; overall, the percentage of penalty minutes decreased after the training (p value not reported) 	Not reported
Lauer et al. ³⁶	<ul style="list-style-type: none"> Intervention group: After the Playing Clean and Tough Hockey Program, the mean no. of aggressive acts per game was 3.92 for player 1, 3.90 for player 2 and 4.90 for player 3; for major aggressive acts, the mean no. per game was 1.00 for player 1, 1.70 for player 2 and 2.70 for player 3 Comparison group: At baseline, the mean no. of aggressive acts per game was 4.00 for player 1, 4.42 for player 2 and 6.75 for player 3; for major aggressive acts, the mean no. per game was 1.25 for player 1, 2.25 for player 2 and 4.58 for player 3 Overall, the ability to manage emotions increased and aggressive-behaviour variables decreased after the program for 2 of the 3 participants (p value not reported) 	Not reported
Note: CI = confidence interval, HEP = Hockey Education Program, OR = odds ratio, SEM = standard error of the mean.		

checking dropped from 75.0% to 68.7% after the intervention.

Smith and colleagues performed a before–after study of the Hockey Education Program — the most multifaceted of the educational interventions designed to ensure youth players develop sportsmanship, skills and a Fair Play approach to the game.³⁴ They found that the mean number of penalties per 100 games decreased in all 4 penalty sectors (tactical, minor, major and other) and that the percentage of Fair Play points increased throughout the 4 seasons studied.³⁴

Psychosocial interventions

Two articles reported the effects of cognitive behavioural strategies used with individual hockey players to prevent their aggressive behaviour, but neither reported on the effects of such interventions on injuries.^{35,36} Mattesi reported an overall decrease in the percentage of penalty minutes after his aggression-management training was implemented among 3 players.³⁵ In the study by Lauer and colleagues,³⁶ the Playing Tough and Clean Hockey Program was found to help 2 of the 3 players enhance their ability to manage their emotions and decrease their aggressive behaviour.

Interpretation

In our review of the literature, we found that interventions based on rule changes showed the greatest likelihood of making ice hockey safer for youth. The introduction of the Fair Play Program in several Canadian and American ice hockey leagues has succeeded in reducing penalties; however, only 1 of the 3 studies of the program that we reviewed evaluated injury rates, and it showed a decline.²¹ Educational and psychosocial approaches were found to reduce aggression-related high-risk behaviours. Although existing studies of these approaches lacked the power to show reductions in injury rates, these interventions show promise.

Rule changes essentially alter the culture of a sport and clearly define acceptable behaviour for all stakeholders (players, coaches, parents and officials) simultaneously. Although educational interventions, such as the *Smart Hockey* video, can do this to a certain extent, their effectiveness depends on the involvement and simultaneous change in attitudes and behaviour of all stakeholders. For this involvement and change to occur, educational interventions need to be implemented consistently, associated with an intrinsic reward for the change and have widespread universal application. Such an effect occurred at the New Zealand Rugby Union: when rule changes were implemented along

with mandatory nationwide educational programs for injury prevention at all levels, the number of neurologic injuries decreased significantly.³⁸ More research is needed regarding mandatory rule changes combined with well-designed educational interventions implemented at a national level.

Introducing the Fair Play Program in conjunction with educational interventions and enforced rules holds promise in reducing injuries related to aggressive behaviour. Critics of the Fair Play Program's practice of having a pre-established limit of team penalties per game argue that it may encourage teams to believe they are entitled to fill their penalty quotas and that it may limit the number of penalties referees call in high-stakes games.⁶ Removing quotas from the Fair Play Program and introducing stricter penalties for high-risk behaviours (e.g., hits to the head and bodychecking from behind), with a loss of points in the overall standings, may also improve the effectiveness of such systems.³⁹ The Fair Play Program is already an accepted part of a minority of hockey organizations, so it could be a means by which to ultimately alter hockey culture.

A change toward different rules and their strict enforcement combined with universal education, structural changes in hockey governance, financial and other incentives for safe play and disincentives for unsafe play holds promise for curbing aggression-related injury.

Limitations

Most of the studies we reviewed were retrospective in nature. Although attempts were made in some studies to control for confounding factors, this is difficult to accomplish without randomization. The cardinal issues associated with selection bias, information bias and confounding with case–control and cohort studies need to be carefully considered. Randomization is a key to addressing these limitations in future studies of the effects of interventions that attempt to reduce aggression-related hockey injuries.

Variability in outcomes was another limitation. Some studies reported on penalty minutes, others measured injury reduction, and some reported on both. None of the studies assessed outcomes such as attrition from the sport or any positive aspects of aggression. The studies of educational and psychosocial interventions generally had smaller samples and were not designed to measure injury reduction.

Feasibility was not specifically addressed in any of the studies. However, studies that evaluated rule changes reported that the implementation of rule changes was achieved across large numbers of

players. Cognitive behavioural approaches are time and resource intensive and likely of limited widespread acceptability. Experience from rugby has shown that educational approaches are in between these extremes but that universal nationwide implementation is possible.³⁸ None of the studies assessed the cost-effectiveness of interventions — a characteristic closely associated with feasibility. Use of computer technology in future interventions, for example through the Web⁴⁰ and smartphone applications, could make widespread implementation more cost-effective and feasible.

We were unable to identify any interventions based on economic incentives or disincentives, such as changes in fines, insurance premiums or salaries. A complete assessment of how to make ice hockey safer should include implementation and evaluation of such interventions.

All of the studies included in our review were from North America. Future research should also come from other countries.

Finally, we did not identify studies of legislative changes. However, research into bicycle safety has shown that such changes have the potential to alter behaviour and reduce injury rates.⁴¹

Conclusion

Several studies included in our review showed that changes to rules to limit the exposure of youth to bodychecking were associated with reduced rates of injury among ice hockey players. Other interventions, including the Fair Play Program, educational interventions and cognitive behavioural modification, had positive effects on reducing aggressive acts; however, more research is needed to determine whether these approaches reduce injury rates on their own. Well-designed multifaceted strategies that combine such approaches hold promise and should be the topic of future research.

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