Evidence Summary: Ice Hockey

Paul Eliason, MSc, PhD (C)

Version 1
February 2018

The British Columbia Injury Research and Prevention Unit (BCIRPU) was established by the Ministry of Health and the Minister's Injury Prevention Advisory Committee in August 1997. BCIRPU is housed within the Evidence to Innovation research theme at BC Children's Hospital (BCCH) and supported by the Provincial Health Services Authority (PHSA) and the University of British Columbia (UBC). BCIRPU's vision is *to be a leader in the production and transfer of injury prevention knowledge and the integration of evidence-based injury prevention practices into the daily lives of those at risk, those who care for them, and those with a mandate for public health and safety in British Columbia.*

Author: Paul Elaison

Editors: Sarah A Richmond, Amanda Black

For any questions regarding this report, contact:

BC Injury Research and Prevention Unit
F508 – 4480 Oak Street
Vancouver, BC V6H 3V4
Email: bcinjury1@cw.bc.ca
Phone: (604) 875-3776
Fax: (604) 875-3569
Website: www.injuryresearch.bc.ca

Suggested Citation:

Elaison P, Black A, Richmond SA, Babul S, Pike I. *Evidence Summary: Ice Hockey.* Active & Safe Central. BC Injury Research and Prevention Unit: Vancouver, BC; 2018. Available at http://activesafe.ca/.

Evidence synthesis tool

SPORT:	Ice Hockey	**Target Group:**	Youth, Junior and Professional Level	
Injury Mechanisms:	Common Injuries in hockey include strains/sprains, contusions and concussions. Body checking, stick contact, and puck contact are the primary mechanisms of injury.			
Incidence/Prevalence	**Risk/Protective Factors**	**Interventions**	**Implementation/Evaluation**	**Resources**
Youth Hockey Common injuries that occur in youth ice hockey are sprains/strains and contusions (Benson & Meeuwisse, 2005); however, concussions have been estimated to represent 18-66% of all youth injuries that result in time loss from activity or medical attention (Black, Hagel, Palacios-Derflingher, Schneider, & Emery, 2017). The incidence of concussion in youth ice hockey is 1.20/1000 athletic exposures (AEs) (95% CI 1.00-1.31) (Pfister, Pfister, Hagel, Ghali, & Ronksley, 2016). Minor players are most likely to be injured to the upper extremities (23-55%), followed by the spine/trunk (13-32.8), head (7-30%), and lower extremity (21-27%) (Benson & Meeuwisse, 2005).	**Youth Hockey Players** **Playing Environment (Games vs. Practices, Body Checking League)** Participation in games versus practices was associated with an increased risk of injury. Playing in a body checking league was also associated with 2.5-3-fold increased risk of all game-related injury and concussion (Benson & Meeuwisse, 2005; Emery, Hagel, Decloe, & Carly, 2010; C. Emery & Meeuwisse, 2006; Kerr et al., 2015; McKay et al., 2014; Black et al., 2016; Black et al., 2017). **Injury History** Players with a history of injury are at an increased risk for future injury (Emery, Hagel, et al., 2010; Emery, Kang, et al., 2010; Emery & Meeuwisse, 2006). **Pre-season symptom reports** Preseason report of neck pain and headache on the Sport Concussion Assessment Tool (SCAT) has been reported as a risk factor for concussion (Schneider, Meeuwisse, Kang, Schneider, &	**Youth Rule Change Mandating Full facial Equipment** Mandating full facial protection in youth hockey has been shown to decrease the incidence of head and facial injuries (Black, Eliason, Patton, & Emery, 2017). Full facial protection is more effective than half-shield visors in preventing facial injuries (RR=2.31; 95% CI 1.53-3.48) (Asplund, Bettcher, & Borchers, 2009; Black, Patton, Eliason, & Emery, 2017; Meeuwisse, 2002), and may also reduce concussion severity (Benson, Hamilton, Meeuwisse, McCrory, & Dvorak, 2009). **Youth Body Checking Policy Changes** Removal of body checking has been associated with a reduction in the number of injuries including concussions (Benson et al., 2013; Black et al., 2017; Black et al., 2016; Cusimano, Nastis, & Zuccaro, 2013), and an evaluation of Hockey Canada's national body checking policy change resulted in a 50% reduction in the injury rate and 64% reduction in the	There were no studies found that examined the implementation or evaluation of hockey interventions.	**Hockey Canada Concussion Awareness App:** https://www.hockeycanada.ca/en-ca/mobile-apps **Hockey Canada Concussion Awareness:** https://www.hockeycanada.ca/en-ca/hockey-programs/safety/concussions **Hockey Canada Concussion Card:** http://cdn.agilitycms.com/hockey-canada/Hockey-Programs/Safety/Concussion/Downloads/concussion_card_e.pdf **Hockey Canada Checking Skills:** https://www.hockeycanada.ca/en-ca/hockey-programs/coaching/checking **Parachute Canada's ThinkFirst Smart Hockey:** http://www.parachutecanada.org/programs/topic/C66 **Concussion Awareness Training Tool:** http://www.cattonline.com/ **USA Hockey Heads Up, Don't**

Junior/Collegiate Level Hockey At the junior level, the lower extremity was most likely to be injured (24.9-33.7%), followed by the upper extremity (9.6-35.4%), the head (14.4-28%), and the spine/trunk (6-14.9%) (Benson & Meeuwisse, 2005). The game-related injury rate at the collegiate level was estimated between 9.19-18.69/1000 AEs in males and 6.1-12.1 in females (Agel & Harvey, 2010; Flik, Lyman, & Marx, 2005; Kerr et al., 2015; Schick & Meeuwisse, 2003). Junior players competing in men's world ice hockey championships have an injury rate of 11.0/1000 AEs in games (39.8/1000 player-game hours) (Tuominen, Stuart, Aubry, Kannus, & Parkkari, 2017). **Professional Level** At the professional male level, the head was the most commonly injured specific body region (16.8%), although when grouped together, the thigh (14.0%)	Emery, 2013). **Athletic Identity** Elite Bantam and Midget players (AAA, AA, A) who score below the 25th percentile in athletic identity were at an increased risk of first injury (IRR: 1.53; 95%CI 1.05-2.22), but scoring above the 25th percentile was associated with increased risk of subsequent injury (IRR: 2.28; 95%CI 1.01-6.04) (McKay, Campbell, Meeuwisse, & Emery, 2013). **Mouth Guard Use** The use of mouth guards has been shown to prevent dental injuries and possibly allow for faster return to play following concussion (Black, Patton, et al., 2017). **Professional Hockey players** **Post-concussion Symptoms** After diagnosis of concussion, reporting of post-concussion headache, low energy or fatigue, amnesia, and abnormal neurological examination were significant predictors of time loss from sport (Benson et al., 2011). **Position** Defenceman are more likely to report a game-related time-loss injury compared to forwards, but	concussion rate in 11-12 year olds (Black et al., 2017). In an evaluation of the cost-effectiveness of removing body checking from youth ice hockey, healthcare costs where policy allowed body checking was over 2.5 times higher compared to areas where there is no body checking (Lacny et al., 2014). The removal of body checking has been estimated to save $200,000 CAD in healthcare costs per season in Alberta Pee Wee players (Lacny et al., 2014). **Fair Play Programs** Programs designed to decrease violence in youth ice hockey and promote fair play and development lead to a reduction in hits to the head and from behind (Benson et al., 2013; Smith et al., 2016). Comparing regular rules to a program that promoted fair play rules was associated with a reduced number of time-loss injuries, including concussions (Benson et al., 2013; Cusimano et al., 2013).		**Duck:** http://www.usahockey.com/page/show/1011484-heads-up-hockey

and knee (13.0%) accounted for a greater percentage when considered as the lower extremity (McKay, Tufts, Shaffer, & Meeuwisse, 2014). The overall regular season incidence density was 15.6/1000 AE. The incidence of concussion in the National Hockey League was 1.8/1000 player-hours (Benson, Meeuwisse, Rizos, Kang, & Burke, 2011), and 1.4/1000 player-games in men's world championship play (1.9/1000 player-games in A-pool play only) (Tuominen, Stuart, Aubry, Kannus, & Parkkari, 2015). Female players competing in world championships and the Olympic Games have an injury rate of 6.4/1000 player-games (22.0/1000 player-game hours) (Tuominen et al., 2016).	forwards, specifically, centreman, are more likely to suffer a concussion compared to other positions (Hutchison, Comper, Meeuwisse, & Echemendia, 2015; Tuominen et al., 2015). Being a goaltender, injured on the road, and mechanism of injury being a body check are all predictors of an injury leading to time loss greater than five games (McKay et al., 2014). **Off-season Training** Low levels of off-season sport-specific training and previous injury have been identified as risk factors for groin injury (Emery & Meeuwisse, 2001).			
Works Cited: Agel, J., & Harvey, E. J. (2010). A 7-year review of men's and women's ice hockey injuries in the NCAA. *Canadian Journal of Surgery*, 53(5), 319-323. Benson, B., & Meeuwisse, W. (2005). Ice hockey injuries	**Works Cited:** Benson, B., & Meeuwisse, W. (2005). Ice hockey injuries: Epidemiology of Pediatric Sports Injuries (Vol. 49, pp. 86-119): Karger Publishers. Benson, B. W., Meeuwisse, W. H., Rizos, J., Kang, J., & Burke, C. J. (2011). A prospective study of	**Works Cited:** Asplund, C., Bettcher, S., & Borchers, J. (2009). Facial protection and head injuries in ice hockey: a systematic review. *British Journal of Sports Medicine*, 43(13), 993-999. Benson, B., Hamilton, G. M., Meeuwisse, W. H., McCrory, P., &		

Epidemiology of Pediatric Sports Injuries (Vol. 49, pp. 86-119): Karger Publishers. Benson, B. W., Meeuwisse, W. H., Rizos, J., Kang, J., & Burke, C. J. (2011). A prospective study of concussions among National Hockey League players during regular season games: the NHL-NHLPA Concussion Program. *Canadian Medical Association Journal*, 183(8), 905-911. Black, A. M., Hagel, B. E., Palacios-Derflingher, L., Schneider, K. J., & Emery, C. A. (2017). The risk of injury associated with body checking among Pee Wee ice hockey players: an evaluation of Hockey Canada's national body checking policy change. *British Journal of Sports Medicine*, 51(24), 1767-1772. Flik, K., Lyman, S., & Marx, R. G. (2005). American collegiate men's ice hockey: an analysis of injuries. *American Journal of Sports Medicine*, 33(2), 183-187. Kerr, Z. Y., Marshall, S. W., Dompier, T. P., Corlette, J., Klossner, D. A., & Gilchrist, J.	concussions among National Hockey League players during regular season games: the NHL-NHLPA Concussion Program. *Canadian Medical Association Journal*, 183(8), 905-911 Emery, C., & Meeuwisse, W. (2001). Risk factors for groin injuries in hockey. *Medicine & Science in Sports & Exercise*, 33(9), 1423-1433. Emery, C., & Meeuwisse, W. (2006). Injury rates, risk factors, and mechanisms of injury in minor hockey. *American Journal of Sports Medicine*, 34(12), 1960-1969. Emery, C. A., Meeuwisse, W. H., & McAllister, J. R. (2006). Survey of sport participation and sport injury in Calgary and area high schools. *Clinical Journal of Sport Medicine*, 16(1), 20-26. Emery, C., Hagel, B., Decloe, M., & Carly, M. (2010). Risk factors for injury and severe injury in youth ice hockey: a systematic review of the literature. *Injury Prevention*, 16(2), 113-118. Emery, C., Kang, J., Shrier, I., Goulet, C., Hagel, B., Benson, B., Meeuwisse, W. (2010). Risk of injury associated with body	Dvorak, J. (2009). Is protective equipment useful in preventing concussion? A systematic review of the literature. *British Journal of Sports Medicine*, 43 Suppl 1, i56-67. Black, A. M., Eliason, P. H., Patton, D. A., & Emery, C. A. (2017). Epidemiology of facial injuries in sport. *Clinics in Sports Medicine*, 36(2), 237-255. Cusimano, M. D., Nastis, S., & Zuccaro, L. (2013). Effectiveness of interventions to reduce aggression and injuries among ice hockey players: a systematic review. *Canadian Medical Assocaiton Journal*, 185(1), E57-69. Lacny, S., Marshall, D. A., Currie, G., Kulin, N. A., Meeuwisse, W. H., Kang, J., & Emery, C. A. (2014). Reality check: the cost-effectiveness of removing body checking from youth ice hockey. *British Journal of Sports Med*icine, 48(17), 1299-1305. Meeuwisse, W. H. (2002). Full facial protection reduces injuries in elite young hockey players. *Clinical Journal of Sport Medicine*, 12(6), 406. Smith, A. M., Gaz, D. V., Larson,		

(2015). College sports-related injuries - United States, 2009-10 through 2013-14 academic years. *Morbidity & Mortality Weekly Report*, 64(48), 1330-1336. McKay, C. D., Tufts, R. J., Shaffer, B., & Meeuwisse, W. H. (2014). The epidemiology of professional ice hockey injuries: a prospective report of six NHL seasons. *British Journal of Sports Medicine*, 48(1), 57-62. Pfister, T., Pfister, K., Hagel, B., Ghali, W. A., & Ronksley, P. E. (2016). The incidence of concussion in youth sports: a systematic review and meta-analysis. *British Journal of Sports Medicine*, 50(5), 292-297. Schick, D. M., & Meeuwisse, W. H. (2003). Injury rates and profiles in female ice hockey players. *American Journal of Sports Medicine*, 31(1), 47-52. Tuominen, M., Stuart, M. J., Aubry, M., Kannus, P., & Parkkari, J. (2015). Injuries in men's international ice hockey: a 7-year study of the International Ice Hockey	checking among youth ice hockey players. *Journal of the American Medical Association*, 303(22), 2265-2272. Hutchison, M. G., Comper, P., Meeuwisse, W. H., & Echemendia, R. J. (2015). A systematic video analysis of National Hockey League (NHL) concussions, part I: who, when, where and what? *British Journal of Sports Medicine*, 49(8), 547-551. Kerr, Z. Y., Marshall, S. W., Dompier, T. P., Corlette, J., Klossner, D. A., & Gilchrist, J. (2015). College sports-related injuries - United States, 2009-10 through 2013-14 academic years. *Morbidity & Mortality Weekly Report*, 64(48), 1330-1336. McKay, C. D., Tufts, R. J., Shaffer, B., & Meeuwisse, W. H. (2014). The epidemiology of professional ice hockey injuries: a prospective report of six NHL seasons. *British Journal of Sports Medicine*, 48(1), 57-62. Schneider, K. J., Meeuwisse, W. H., Kang, J., Schneider, G. M., & Emery, C. A. (2013). Preseason reports of neck pain, dizziness, and headache as risk factors for concussion in male youth ice hockey players. *Clinical Journal of*	D., Jorgensen, J. K., Eickhoff, C., Krause, D. A., . Stuart, M. J. (2016). Does fair play reduce concussions? A prospective, comparative analysis of competitive youth hockey tournaments. *BMJ Open Sport & Exercise Medicine*, 2(1), e000074.		

Federation Adult World Championship Tournaments and Olympic Winter Games. *British Journal of Sports Medicine*, 49(1), 30-36. Tuominen, M., Stuart, M. J., Aubry, M., Kannus, P., Tokola, K., & Parkkari, J. (2016). Injuries in women's international ice hockey: an 8-year study of the World Championship tournaments and Olympic Winter Games. *British Journal of Sports Medicine*, 50(22), 1406-1412.	*Sport Medicine*, 23(4), 267-272 Tuominen, M., Stuart, M. J., Aubry, M., Kannus, P., Tokola, K., & Parkkari, J. (2016). Injuries in women's international ice hockey: an 8-year study of the World Championship tournaments and Olympic Winter Games. *British Journal of Sports Medicine*, 50(22), 1406-1412.			

Review of Sport Injury Burden, Risk Factors and Prevention

Ice Hockey

Incidence and Prevalence

It has been noted the injury rates in ice hockey are difficult to summarize in either a single approximation or as a range due differences in study design, sample populations at risk of injury (e.g., associations, leagues, age groups, equipment rules, officiating rules), sources of injury collection (players, therapists, team designates, physicians, emergency departments), methods of measuring exposure (estimation vs. direct observation; player hours, athlete exposures), and methods of calculating injury rates (injuries per 1,000 athletic exposures - AEs, per 1000 player-hours, prevalence per 100 players) (Benson & Meeuwisse, 2005). Ice hockey accounts for approximately 10% of all youth sport-related injuries in Canada (Emery & Tyreman, 2009; Emery, Meeuwisse, & McAllister, 2006), and is reported as the second leading cause of injury reported to Canadian emergency departments among 13 sports reviewed (Fridman, Fraser-Thomas, McFaull, & Macpherson, 2013). Ice hockey injuries account for more injuries than lacrosse or field hockey in the United States (Yard & Comstock, 2006), and the number of injuries presenting to US emergency departments from ice hockey, increased from 1990-2006, likely due to an increase in popularity over this time frame (Deits, Yard, Collins, Fields, & Comstock, 2010).

Common injuries that occur in youth ice hockey are sprains/strains and contusions (Benson & Meeuwisse, 2005); however, concussions have been estimated to represent 18-66% of all youth injuries (Black, Hagel, Palacios-Derflingher, Schneider, & Emery, 2017). A systematic review estimated the incidence of concussion in youth ice hockey to be 1.20 injuries per 1000 AEs (95% CI 1.00-1.31) (Pfister, Pfister, Hagel, Ghali, & Ronksley, 2016). Minor players are more likely to be injured to the upper extremities (23-55%), followed by the spine/trunk (13-32.8%), head (7-30%), and lower extremity (21-27%). The primary reported mechanisms for injury in ice hockey are body checking, stick contact, and puck contact (Benson & Meeuwisse, 2005). The overall injury rate among 9-17 year olds is 30 injuries per 100 players per season (95% CI 27.2-33), or 4.1 injuries per 1000 player-hours (95% CI 3.7-4.6) (Emery & Meeuwisse, 2006). The risk of injury increases with age group, with Midget players (15-17 years old) having the highest risk of injury (6.07/1000 player-hours), followed by Bantam (ages 13-14; 4.16/1000 player-hours), Pee Wee (ages 11-12; 3.32/1000 player-hours), and Atom (ages 9-10; 1.12/1000 player-hours). Higher divisions of play also tend to have higher injury rates compared to lower divisions of play (Emery & Meeuwisse, 2006).

In female only leagues, the overall injury rate per 1000 player-hours by age group is: 1.9 (95% CI 1.4-2.7) in Midget, 1.0 in Bantam (95% CI 0.5-1.8), 1.5 in Pee Wee (95% CI 0.4-5.0), and 1.0 in Atom (95% CI 0.3-3.0) (Decloe, Meeuwisse, Hagel, & Emery, 2014). Comparing the types of injuries between males and females, it was noted that female players sustain more soft tissue injuries [Female (F):39.8% vs. Male (M):32.6%] and sprains/strains (F:21.1% vs. M:17.6%) than males, and males experienced more fractures (M:27.1% vs. F:18.2%), shoulder injuries (M:45.2% vs. 39.2%), and injuries due to body checking (M:42.8% vs. F:25.7%) (female-only leagues do not allow body checking) (Forward et al., 2014). Across both sexes within Canada, the overall injury rate was approximately 40 injuries per 100 participants per year among surveyed junior high students (ages 12-15 years) (Emery & Tyreman, 2009), and 36 injuries per 100 participants per year among surveyed Canadian high school students (ages 14-19 years) (Emery et al., 2006). Another study estimated the overall injury rate in high school players to be 2.32 injuries per 1000 AEs, with the rate of injury higher among games (5.63/1000 AEs) than practices (0.72/1000 AEs) (Matic et al., 2015). High school players were most commonly injured to the head (14.8-31%), followed by the lower extremity (20.6-37%), upper extremity (3.4-29%), and spine/trunk (7.4-17.2%) (Benson & Meeuwisse, 2005).

At the junior level, the lower extremity is the area most likely to be injured (24.9-33.7%), followed by the upper extremity (9.6-35.4%), the head (14.4-28%), and the spine/trunk (6-14.9%) (Benson & Meeuwisse, 2005). The game-related injury rate at the collegiate level is estimated between 9.19-18.69 injuries per 1000 AE in males and 6.1-12.1 in females (Agel & Harvey, 2010; Flik, Lyman, & Marx, 2005; Kerr et al., 2015; Schick & Meeuwisse, 2003). The injury rate in practice is much lower than the game-related rate for both men (1.96-2.23/1000 AE) and women (2.90/1000 AE) (Agel, Dompier, Dick, & Marshall, 2007; Agel & Harvey, 2010; Flik et al., 2005). It is noted that the annual game-injury rate increased in American men's collegiate hockey from 1988-2004, yet the practice rate remained constant (Agel et al., 2007). The rate of concussion is estimated at 0.72 injuries per 1000 AE in men and 0.82 injuries per 1000 AE in women (Agel & Harvey, 2010). Junior players competing in men's world ice hockey championships have an injury rate of 11.0 injuries per 1000 AE in games (39.8/1000 player-game hours), with specific injury rates of 4.3 injuries per 1000 player-games to the head/face, 3.2 injuries per 1000 player-games for the upper body, 2.6 injuries per 1000 player-games for the lower body, and 1.0 injury per 1000 player-games for the spine and trunk (Tuominen, Stuart, Aubry, Kannus, & Parkkari, 2017).

At the professional level in men, the head was the most commonly injured body region (16.8%); although, when grouped together, the thigh (14.0%) and knee (13.0%) account for a greater proportion of all injuries (McKay, Tufts, Shaffer, & Meeuwisse, 2014). The overall regular season incidence density is reported as 15.6 injuries per 1000 AEs (McKay et al., 2014). The incidence of concussion in the National Hockey League is reported as 1.8 concussions per 1000 player-hours (Benson, Meeuwisse, Rizos, Kang, & Burke, 2011), and 1.4 concussions per 1000 player-games in men's world championship play (1.9/1000 player-games in A-pool play only) (Tuominen, Stuart, Aubry, Kannus, & Parkkari, 2015). Female players competing in world championships and the Olympic Games have an injury rate of 6.4 injuries per 1000 player-games (22.0/1000 player-game hours) (Tuominen et al., 2016). Specifically, the rates of injury per 1000 player-games are: 2.7 for the lower body, 1.4 for the upper body, 1.3 for the head and face (concussion was the most common head injury and accounted for 1.0 injury per 1000 player-games), and 0.9 for the spine and trunk.

Risk and Protective Factors

Participation in games versus practices is associated with an increased risk of injury (RR range: 2.45-6.32) (Benson & Meeuwisse, 2005; Emery, Hagel, Decloe, & Carly, 2010; Emery & Meeuwisse, 2006; Kerr et al., 2015; McKay et al., 2014). Playing in a body checking league is also associated with an increased risk of all game-related injury (summary rate ratio: 2.45; 95% CI 1.7-3.6) and concussion (summary odds ratio: 1.71; 95% CI 1.2-2.44) (Emery, Hagel, et al., 2010). Specific to the Pee Wee level (ages 11-12), playing in a league that allows body checking has a 3.3-fold (95% CI 2.3-4.6) greater risk of injury and 3.9-fold (95% CI 1.9-7.9) greater risk of concussion, compared to leagues without body checking (Emery, Kang, et al., 2010). The relative risk of injury associated with body checking in youth ice hockey ranged from 0.6 to 39.8, and was the reported mechanism of injury for 2.9-91% of all injuries (Warsh, Constantin, Howard, & Macpherson, 2009).

Players with a history of injury are at an increased risk for future injury (Emery, Hagel, et al., 2010; Emery, Kang, et al., 2010; Emery & Meeuwisse, 2006), while players lighter in body weight categories may also be greater risk (Brust, Leonard, Pheley, & Roberts, 1992; Emery, Kang, et al., 2010). Preseason reporting of neck pain and headaches on the Sport Concussion Assessment Tool (SCAT) is reported as a risk factor for concussion (IRR 1.67; 95% 1.15-2.41 and IRR: 1.47; 95% CI 1.01-2.13), and a combination of any 2 symptoms on the SCAT is a risk factor for Pee Wee non-body contact and Bantam levels (IRR: 3.65; 95% 1.20-11.05 and IRR: 2.40; 95% CI 1.15-4.97, respectively) (Schneider, Meeuwisse, Kang, Schneider, & Emery, 2013). In professional players diagnosed with concussion, post-concussion headache, low energy or fatigue, amnesia, and abnormal neurological examination are reported as significant predictors of time loss (Benson et al., 2011). Athletic identity, defined as the degree to which an individual identifies with the athlete role, (McKay, Campbell, Meeuwisse, & Emery, 2013) has also been examined as a risk factor for injury. Elite Bantam and Midget players (AAA, AA, A) who score below the 25^{th} percentile in athletic identity were at an increased risk of first injury (IRR: 1.53; 95%CI 1.05-2.22), but scoring above the 25^{th} percentile was associated with subsequent injury (IRR: 2.28; 95%CI 1.01-6.04) (McKay, Campbell, Meeuwisse, & Emery, 2013). At the youth level, age, level of play, and player position may be potential risk factors, but the research remains inconclusive (Emery, Hagel, et al., 2010). At the professional level, defenceman are more likely to report a game-related time-loss injury compared to forwards (incidence density ratio: 1.2; 95% CI 1.1-1.3) (McKay et al., 2014), but forwards, specifically, centreman, are more likely to suffer a concussion compared to other positions (Hutchison, Comper, Meeuwisse, & Echemendia, 2015; Tuominen et al., 2015). Further, being a goaltender (OR: 1.68; 95% CI 1.18-2.38), being injured on the road (OR: 1.43; 95% CI 1.25-1.63), and mechanism of injury being a body check (OR: 2.21; 95% CI 1.86-2.62) were all predictors of an injury leading to time loss greater than five man games (McKay et al., 2014). Interestingly, injuries including concussions were more likely to occur in the first period of play in professional players (Hutchison et al., 2015; McKay et al., 2014; Tuominen et al., 2015). Professional goaltenders were not at a higher risk of intra-articular hip injuries when measuring injuries per hours played, but were at an increased risk than other positions when measured per game-played (goaltenders: 1.84/1000 vs. other positions 0.40/1000; RR: 4.7) (Epstein, McHugh, Yorio, & Neri, 2013).

Though ice hockey players have a high incidence of groin injuries relative to other sports, the differences were not significantly between collegiate men and women (Orchard, 2015). Low levels of off-season sport-specific training and previous injury have been identified as risk factors for groin injury in professional ice hockey players (Emery & Meeuwisse, 2001), and higher levels of play, and reduced hip abductor and adductor strength have been identified as risk factors for groin injury for all sports (Whittaker, Small, Maffey, & Emery, 2015). Compared to traditional board/glass systems, flexible board/glass had a 29% lower risk of injury (IRR: 0.71; 95% CI 0.56-0.91), including lower rates of shoulder injuries (IRR: 0.36; 95% CI 0.15-0.90) and concussions (OR: 0.43; 95% CI 0.18-1.01) (Tuominen et al., 2015). Single-frame dasher boards with light and flexible protective shielding material that do not include shielding support posts has been recommended as a safe dasher board design (Poutiainen, Peltonen, Isolehto, & Avela, 2014).

Mandating full facial protection in youth hockey has decreased the incidence of head and facial injuries (Black, Eliason, Patton, & Emery, 2017). Full facial protection is more effective than half-shield visors in preventing facial injuries and lacerations (RR: 2.31; 95% CI 1.53-3.48) (Asplund, Bettcher, & Borchers, 2009; Black, Patton, Eliason, & Emery, 2017; Meeuwisse, 2002), and may also reduce concussion severity (Benson, Hamilton, Meeuwisse, McCrory, & Dvorak, 2009). The use of mouth guards have been shown to prevent dental injuries and possibly allow for faster return to play following concussion (Black, Patton, et al., 2017). Though there is limited evidence regarding the protective effect of mouth guards in reducing the risk of concussion (Benson et al., 2009), some recent and emerging research has supported this (Chisholm et al., 2017). However, despite the several protective benefits of mouth guards, many athletes are not wearing them regularly during game play (Black, Patton, et al., 2017). Helmets have been recommended to be properly fitted in order to prevent focal injury (Smith et al., 2011), though one study found the majority of youth players were not wearing their helmet in a manner that meets all helmet fit criteria (Patton, Blackmore, Hagel, & Emery, 2017). Based on biomechanical data, changing the design of the shoulder pads or adding a layer of foam padding to the plastic caps can reduce the impact force from body checking (Richards et al., 2016; Virani et al., 2016), which may help reduce injuries from checking.

Opportunities for Prevention: Effective Interventions, Cost-Effectiveness, Implementation and Evaluation

The removal of body checking is associated with a reduction in the number of injuries including concussions (Benson et al., 2013; A. M. Black et al., 2017; Black et al., 2016; Cusimano, Nastis, & Zuccaro, 2013), and an evaluation of Hockey Canada's national body checking policy change [which changed the introduction of body checking from Pee Wee (ages 11-12) to Bantam (12-13)] resulted in a 50% reduction in the injury rate and 64% reduction in the concussion rate in 11-12 year olds (Black et al., 2017). In an evaluation of the cost-effectiveness of removing body checking from youth ice hockey, healthcare costs were over 2.5 times higher where policy allowed body checking compared to areas where policy did not allow body checking (Lacny et al., 2014). The removal of body checking is estimated to save $200,000 CAD in healthcare costs per season in Alberta Pee Wee players (Lacny et al., 2014).

Programs designed to decrease violence in youth ice hockey and promote fair play and development lead to a reduction in hits to the head and from behind (Benson et al., 2013; Smith et al., 2016). Comparing regular rules to a program that promoted fair play rules (i.e., gaining extra points for staying below a certain number of penalties), was associated with a reduced number of time-loss injuries, including concussions (Benson et al., 2013; Cusimano et al., 2013). Aggressive behaviour such as seeking revenge for an injured teammate has been shown to be reinforced by a player's social environment and justified by players in competitive body checking leagues, but not in non-body checking leagues (Cusimano et al., 2016). Knowledge and education about injuries has been evaluated in various ice hockey stakeholders including players and coaches. Youth players have demonstrated gaps in their knowledge of concussion, and younger players were more likely to ignore current recommended guidelines for concussions (Mrazik, Perra, Brooks, & Naidu, 2015).

In an evaluation of having minor players and coaches watch the ThinkFirst Canada, Smart Hockey, brain and spinal cord injury prevention video, an educational injury prevention video that teaches the mechanisms, consequences, and prevention of brain and spinal cord injury in ice hockey, found that knowledge and behaviours can improve after viewing the video (Cook, Cusimano, Tator, & Chipman, 2003). It should be noted that initiatives aimed at reducing the number of injuries may lead to unintended consequences. For instance, in 2011 Hockey Canada introduced the "zero tolerance for head contact", a rule which penalizes all intentional and unintentional head contact to an opponent at all levels of play, and found after the policy change there was an increased risk of game-related concussions in Pee Wee (IRR: 1.85; 95% CI 1.20-2.86) and Bantam players (IRR: 2.48; 95% CI 1.17-5.24) (Krolikowski et al., 2016). The authors suggest that the increased risk may be due to increased concussion awareness and education after the policy change (Krolikowski et al., 2016). Additionally, it has been suggested that the inclusion of a 40'' (1m) wide orange "Look Up Line" (LUL) painted on the ice around the perimeter of the boards would help reduce the number of head and spinal injuries near the boards by acting as a visual cue for players to remember to look up and adjust their head and body position prior to being checked (The Thomas E. Smith Foundation, 2014). However, while the LUL has been shown to increase the eye fixation and traction compared to a control setting in elite offensive and defensive players, it also caused players to look down more often when being checked (Vickers et al., 2017). These results fail to support two main contentions of the LUL originators- that the line will "warn players to keep their head up when approaching the boards" and "give players an opportunity to make proper bodily adjustments before hitting the boards" (The Thomas E. Smith Foundation, 2014; Vickers et al., 2017). Further research is needed into the association between the LUL and risk of injury before its recommendation.

References

Agel, J., Dompier, T. P., Dick, R., & Marshall, S. W. (2007). Descriptive epidemiology of collegiate men's ice hockey injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2003-2004. *Journal of Athletic Training*, 42(2), 241-248.

Agel, J., & Harvey, E. J. (2010). A 7-year review of men's and women's ice hockey injuries in the NCAA. *Canadian Journal of Surgery*, 53(5), 319-323.

Asplund, C., Bettcher, S., & Borchers, J. (2009). Facial protection and head injuries in ice hockey: a systematic review. *British Journal of Sports Medicine*, 43(13), 993-999. doi:10.1136/bjsm.2009.060152.

Benson, B., Hamilton, G. M., Meeuwisse, W. H., McCrory, P., & Dvorak, J. (2009). Is protective equipment useful in preventing concussion? A systematic review of the literature. *British Journal of Sports Medicine*, 43 Suppl 1, i56-67. doi:10.1136/bjsm.2009.058271.

Benson, B., McIntosh, A., Maddocks, D., Herring, S., Raftery, M., & Dvorak, J. (2013). What are the most effective risk-reduction strategies in sport concussion? *British Journal of Sports Medicine*, 47(5), 321-326. doi:10.1136/bjsports-2013-092216.

Benson, B., & Meeuwisse, W. (2005). Ice hockey injuries: Epidemiology of Pediatric Sports Injuries (Vol. 49, pp. 86-119): Karger Publishers.

Benson, B. W., Meeuwisse, W. H., Rizos, J., Kang, J., & Burke, C. J. (2011). A prospective study of concussions among National Hockey League players during regular season games: the NHL-NHLPA Concussion Program. *Canadian Medical Association Journal*, 183(8), 905-911. doi:http://dx.doi.org/10.1503/cmaj.092190.

Black, A. M., Eliason, P. H., Patton, D. A., & Emery, C. A. (2017). Epidemiology of facial injuries in Sport. *Clinics in Sports Medicine*. 36(2), 237-255.

Black, A. M., Hagel, B. E., Palacios-Derflingher, L., Schneider, K. J., & Emery, C. A. (2017). The risk of injury associated with body checking among Pee Wee ice hockey players: an evaluation of Hockey Canada's national body checking policy change. *British Journal of Sports Medicine,* 51(24), 1767-1772. doi:10.1136/bjsports-2016-097392.

Black, A. M., Macpherson, A. K., Hagel, B. E., Romiti, M. A., Palacios-Derflingher, L., Kang, J., . . . Emery, C. A. (2016). Policy change eliminating body checking in non-elite ice hockey leads to a threefold reduction in injury and concussion risk in 11- and 12-year-old players. *British Journal of Sports Medicine*, 50(1), 55-61. doi:http://dx.doi.org/10.1136/bjsports-2015-095103.

Brust, J. D., Leonard, B. J., Pheley, A., & Roberts, W. O. (1992). Children's ice hockey injuries. *American Journal of Diseases of Children*, 146(6), 741-747.

Chisholm, D., Atkins, C., Palacios-Derflingher, L., Schneider, K., Emery, C., & Hagel, B. (2017). Mouthguard use in youth ice hockey and the risk of concussion and dental Iinjuries. *British Journal of Sports Medicine*, 51(4), 306-306.

Cook, D. J., Cusimano, M. D., Tator, C. H., & Chipman, M. L. (2003). Evaluation of the ThinkFirst Canada, Smart Hockey, brain and spinal cord injury prevention video. Injury Prevention, 9(4), 361-366.

Cusimano, M. D., Ilie, G., Mullen, S. J., Pauley, C. R., Stulberg, J. R., Topolovec-Vranic, J., & Zhang, S. (2016). Aggression, Violence and Injury in Minor League Ice Hockey: Avenues for Prevention of Injury. *PLoS ONE*, 11(6), e0156683. doi:http://dx.doi.org/10.1371/journal.pone.0156683

Cusimano, M. D., Nastis, S., & Zuccaro, L. (2013). Effectiveness of interventions to reduce aggression and injuries among ice hockey players: a systematic review. *Canadian Medical Association Journal*, 185(1), E57-69. doi:10.1503/cmaj.112017.

Decloe, M. D., Meeuwisse, W. H., Hagel, B. E., & Emery, C. A. (2014). Injury rates, types, mechanisms and risk factors in female youth ice hockey. *British Journal of Sports Medicine*, 48(1), 51-56. doi:http://dx.doi.org/10.1136/bjsports-2012-091653.

Deits, J., Yard, E. E., Collins, C. L., Fields, S. K., & Comstock, R. D. (2010). Patients with ice hockey injuries presenting to US emergency departments, 1990-2006. *Journal of Athletic Training*, 45(5), 467-474. doi:http://dx.doi.org/10.4085/1062-6050-45.5.467.

Emery, C., Hagel, B., Decloe, M., & Carly, M. (2010). Risk factors for injury and severe injury in youth ice hockey: a systematic review of the literature. *Injury Prevention*, 16(2), 113-118. doi:10.1136/ip.2009.022764.

Emery, C., Kang, J., Shrier, I., Goulet, C., Hagel, B., Benson, B., . . . Meeuwisse, W. (2010). Risk of injury associated with body checking among youth ice hockey players. *Journal of the American Medical Association*, 303(22), 2265-2272. doi:10.1001/jama.2010.755.

Emery, C., & Meeuwisse, W. (2001). Risk factors for groin injuries in hockey. *Medicine & Science in Sports & Exercise*, 33(9), 1423-1433.

Emery, C., & Meeuwisse, W. (2006). Injury rates, risk factors, and mechanisms of injury in minor hockey. *American Journal of Sports Medicine*, 34(12), 1960-1969.

Emery, C., & Tyreman, H. (2009). Sport participation, sport injury, risk factors and sport safety practices in Calgary and area junior high schools. *Paediatrics & Child Health*, 14(7), 439-444.

Emery, C. A., Meeuwisse, W. H., & McAllister, J. R. (2006). Survey of sport participation and sport injury in Calgary and area high schools. *Clinical Journal of Sport Medicine*, 16(1), 20-26.

Epstein, D. M., McHugh, M., Yorio, M., & Neri, B. (2013). Intra-articular hip injuries in national hockey league players: a descriptive epidemiological study. *American Journal of Sports Medicine*, 41(2), 343-348. doi:http://dx.doi.org/10.1177/0363546512467612

Flik, K., Lyman, S., & Marx, R. G. (2005). American collegiate men's ice hockey: an analysis of injuries. *American Journal of Sports Medicine*, 33(2), 183-187. doi:10.1177/0363546504267349.

Forward, K. E., Seabrook, J. A., Lynch, T., Lim, R., Poonai, N., & Sangha, G. S. (2014). A comparison of the epidemiology of ice hockey injuries between male and female youth in Canada. *Paediatrics & Child Health*, 19(8), 418-422.

Fridman, L., Fraser-Thomas, J. L., McFaull, S. R., & Macpherson, A. K. (2013). Epidemiology of sports-related injuries in children and youth presenting to Canadian emergency departments from 2007-2010. *BMC Sports Science, Medicine and Rehabilitation*, 5(1), 30. doi:http://dx.doi.org/10.1186/2052-1847-5-30.

Hutchison, M. G., Comper, P., Meeuwisse, W. H., & Echemendia, R. J. (2015). A systematic video analysis of National Hockey League (NHL) concussions, part I: who, when, where and what? *British Journal of Sports Medicine*, 49(8), 547-551.

Kerr, Z. Y., Marshall, S. W., Dompier, T. P., Corlette, J., Klossner, D. A., & Gilchrist, J. (2015). College sports-related injuries - United States, 2009-10 through 2013-14 academic years. *Morbidity & Mortality Weekly Report*, 64(48), 1330-1336. doi:http://dx.doi.org/10.15585/mmwr.mm6448a2.

Krolikowski, M. P., Black, A. M., Palacios-Derflingher, L., Blake, T. A., Schneider, K. J., & Emery, C. A. (2016). The effect of the "Zero Tolerance for Head Contact" rule change on the risk of concussions in youth ice hockey players. *American Journal of Sports Medicine*, 27. doi:http://dx.doi.org/10.1177/0363546516669701.

Lacny, S., Marshall, D. A., Currie, G., Kulin, N. A., Meeuwisse, W. H., Kang, J., & Emery, C. A. (2014). Reality check: the cost-effectiveness of removing body checking from youth ice hockey. *British Journal of Sports Medicine*, 48(17), 1299-1305. doi:http://dx.doi.org/10.1136/bjsports-2014-093493.

Matic, G. T., Sommerfeldt, M. F., Best, T. M., Collins, C. L., Comstock, R. D., & Flanigan, D. C. (2015). Ice hockey injuries among United States high school athletes from 2008/2009-2012/2013. *Physician & Sportsmedicine*, 43(2), 119-125. doi:http://dx.doi.org/10.1080/00913847.2015.1035210.

McKay, C., Campbell, T., Meeuwisse, W., & Emery, C. (2013). The role of psychosocial risk factors for injury in elite youth ice hockey. *Clinical Journal of Sport Medicine*, 23(3), 216-221. doi:10.1097/JSM.0b013e31826a86c9.

McKay, C. D., Tufts, R. J., Shaffer, B., & Meeuwisse, W. H. (2014). The epidemiology of professional ice hockey injuries: a prospective report of six NHL seasons. *British Journal of Sports Medicine*, 48(1), 57-62. doi:http://dx.doi.org/10.1136/bjsports-2013-092860.

Meeuwisse, W. H. (2002). Full facial protection reduces injuries in elite young hockey players. *Clinical Journal of Sport Medicine*, 12(6), 406.

Mrazik, M., Perra, A., Brooks, B. L., & Naidu, D. (2015). Exploring minor hockey players' knowledge and attitudes toward concussion: implications for prevention. *Journal of Head Trauma Rehabilitation*, 30(3), 219-227. doi:http://dx.doi.org/10.1097/HTR.0000000000000018.

Orchard, J. W. (2015). Men at higher risk of groin injuries in elite team sports: a systematic review. *British Journal of Sports Medicine*, 49(12), 798-802. doi:http://dx.doi.org/10.1136/bjsports-2014-094272.

Patton, D., Blackmore, S., Hagel, B., & Emery, C. (2017). Helmet fit in youth ice hockey. *British Journal of Sports Medicine*, 51(4), 372-372. doi:10.1136/bjsports-2016-097372.224.

Pfister, T., Pfister, K., Hagel, B., Ghali, W. A., & Ronksley, P. E. (2016). The incidence of concussion in youth sports: a systematic review and meta-analysis. *British Journal of Sports Medicine*, 50(5), 292-297. doi:http://dx.doi.org/10.1136/bjsports-2015-094978.

Poutiainen, P., Peltonen, J., Isolehto, J., & Avela, J. (2014). Comparison of impact characteristics of four different ice hockey arena dasher boards. *European Journal of Sport Science*, 14(1), 11-18. doi:http://dx.doi.org/10.1080/17461391.2012.725106.

Richards, D., Ivarsson, B. J., Scher, I., Hoover, R., Rodowicz, K., & Cripton, P. (2016). Ice hockey shoulder pad design and the effect on head response during shoulder-to-head impacts. *Sports Biomechanics*, 15(4), 385-396. doi:http://dx.doi.org/10.1080/14763141.2016.1163414.

Schick, D. M., & Meeuwisse, W. H. (2003). Injury rates and profiles in female ice hockey players. *American Journal of Sports Medicine*, 31(1), 47-52.

Schneider, K. J., Meeuwisse, W. H., Kang, J., Schneider, G. M., & Emery, C. A. (2013). Preseason reports of neck pain, dizziness, and headache as risk factors for concussion in male youth ice hockey players. *Clinical Journal of Sport Medicine*, 23(4), 267-272. doi:10.1097/JSM.0b013e318281f09f.

Smith, A. M., Gaz, D. V., Larson, D., Jorgensen, J. K., Eickhoff, C., Krause, D. A., . . . Stuart, M. J. (2016). Does fair play reduce concussions? A prospective, comparative analysis of competitive youth hockey tournaments. *BMJ Open Sport & Exercise Medicine*, 2(1), e000074.

Smith, A. M., Stuart, M. J., Greenwald, R. M., Benson, B. W., Dodick, D. W., Emery, C., . . . Meeuwisse, W. H. (2011). Proceedings from the Ice Hockey Summit on Concussion: a call to action. *American Journal of Physical Medicine & Rehabilitation*, 90(8), 694-703. doi:10.1097/PHM.0b013e318224736b.

The Thomas E. Smith Foundation. (2014). Look-Up-Line. Retrieved from http://justcureparalysis.org/look-up-line/

Tuominen, M., Stuart, M. J., Aubry, M., Kannus, P., & Parkkari, J. (2015). Injuries in men's international ice hockey: a 7-year study of the International Ice Hockey Federation Adult World Championship Tournaments and Olympic Winter Games. *British Journal of Sports Medicine*, 49(1), 30-36. doi:10.1136/bjsports-2014-093688.

Tuominen, M., Stuart, M. J., Aubry, M., Kannus, P., & Parkkari, J. (2017). Injuries in world junior ice hockey championships between 2006 and 2015. *British Journal of Sports Medicine*, 51(1), 36-43. doi:http://dx.doi.org/10.1136/bjsports-2016-095992.

Tuominen, M., Stuart, M. J., Aubry, M., Kannus, P., Tokola, K., & Parkkari, J. (2016). Injuries in women's international ice hockey: an 8-year study of the World Championship tournaments and Olympic Winter Games. *British Journal of Sports Medicine*, 50(22), 1406-1412. doi:http://dx.doi.org/10.1136/bjsports-2015-094647.

Vickers, J. N., Causer, J., Stuart, M., Little, E., Dukelow, S., Lavangie, M., . . . Scott, M. (2017). Effect of the look-up line on the gaze and head orientation of elite ice hockey players. *European Journal of Sport Science*, 17(1), 109-117.

Virani, S., Russell, C., Bruschetta, M. L., Hua, K. N., Potvin, B. M., Cox, D., & Robinovitch, S. N. (2016). The effect of shoulder pad design on head impact severity during checking. *Medicine & Science in Sports & Exercise*, 21. doi:10.1249/MSS.0000000000001136.

Warsh, J. M., Constantin, S. A., Howard, A., & Macpherson, A. (2009). A systematic review of the association between body checking and injury in youth ice hockey. *Clinical Journal of Sport Medicine*, 19(2), 134-144. doi:10.1097/JSM.0b013e3181987783.

Whittaker, J. L., Small, C., Maffey, L., & Emery, C. A. (2015). Risk factors for groin injury in sport: an updated systematic review. *British Journal of Sports Medicine*, 49(12), 803-809. doi:10.1136/bjsports-2014-094287.

Yard, E. E., & Comstock, R. D. (2006). Injuries sustained by pediatric ice hockey, lacrosse, and field hockey athletes presenting to United States emergency departments, 1990-2003. *Journal of Athletic Training*, 41(4), 441.