Concussion in sport: Minimizing the risk to modify the "impact"

Kathryn Schneider PT, DSc, FCAMT, PhD (candidate)

Sport Injury Prevention Research Centre, Faculty of Kinesiology, University of Calgary, 2500 University Drive N.W., Calgary, Alberta, Canada, T2N 1N4

Sport Division Submission to the Inter-Divisional Review, October 15, 2010

Word count: 2235

Individuals of all ages frequently participate in recreational activities and sport. Decreased risk of all cause mortality and chronic diseases such as diabetes, heart disease, obesity and cancer through participation in physical activities has been well established in the literature.(SN Blair, et al., 1995; SM Blair, Kohl, Paffenbarger, Clark, & Gibbons, 1989; Helmrich, Ragland, & Paffenbarger, 1994; Lee & Paffenbarger, 1994) While physical activity has benefits from a disease prevention standpoint, it also carries an increased risk of injury due to the inherent nature of participating in sport. Sport injuries have been reported to be one of the leading causes of injury in youth(King, Pickett, & King, 1998), with sport related concussions being one of the most commonly occurring injuries in sport.(CA Emery & Meeuwisse, 2006)

What is a concussion

Concussion is defined as "A complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces."(P. McCrory, et al., 2009). Sport related concussions typically occur following direct trauma to the head or by force transmission to the head (P. McCrory, et al., 2009). Neuroimaging is typically normal and the majority of findings are believed to be functional rather than structural.(P. McCrory, et al., 2009) Loss of consciousness may occur but is not required for a concussion to have occurred. Typically, transient neurological disturbances are seen followed by rapid spontaneous recovery(P. McCrory, et al., 2009).

A myriad of symptoms may occur following a concussion and tend to resolve spontaneously(P. McCrory, et al., 2009). The most commonly reported initial symptoms following a concussion in National Hockey League players include headache (71%), dizziness (34%), nausea (24%), neck pain (23%) and low energy/fatigue (22%)(Benson, Meeuwisse, Burke, & Rizos, 2009). Similarly, the most common symptoms following concussion in professional football players have been reported to be headache (55%), dizziness (42%) and blurred vision (16%).(Pellman, 2004)

The majority if individuals recover from symptoms of a concussion in a week or ten days, however, some individuals are left with persistent symptoms.(P. McCrory, et al., 2009; Pellman, 2004) Ongoing symptoms have been reported in 13.7% of school-aged children 3 months following a mild traumatic brain injury(Barlow, et al., 2010). Individuals reporting initial symptoms of headache, loss of consciousness and low energy/fatigue have been reported to be more likely to have a greater than 10 day time loss (Benson & Meeuwisse, 2009). Collegiate football players with a history of three or greater concussions were more likely to take greater than one week to become asymptomatic when compared to individuals with only a history of one previous concussion (Kevin M. Guskiewicz, et al., 2003). In addition, both initial and persistent alterations in balance and cognition have been seen following a concussion(Fait, McFadyen, Swaine, & Cantin, 2009; K M Guskiewicz, 2001; Peterson, Ferrara, Mrazik, Piland, & Elliott, 2003; Slobounov, Cao, Sebastianelli, Slobounov, & Newell, 2008). Persistent symptoms may cause significant alterations in both sport and recreation activities, leading to decreased physical fitness and alterations in both

occupational and daily living activities. These persistent symptoms and altered functional capacity may lead to an increased public health burden from this potentially avoidable injury.

One potential long-term sequela of a sport related concussion is chronic traumatic encephalopathy or, as it has previously been referred to, dementia pugilistica. This condition typically occurs in middle life, years after a history of repetitive closed head traumas (Gavett, Stern, Cantu, Nowinski, & McKee, 2010). Common signs and symptoms include irritability, memory loss, general cognitive dysfunction, and Parkinsonian signs, including gait and speech abnormalities (McKaa, et al., 2009). This condition has been seen in a variety of athletes. (McKaa, et al., 2009). Second-impact syndrome is a highly debated and potentially fatal consequence believed to occur following sport related concussions.(P McCrory, 2001; Meehan W.P., 2009) This condition is typically believed to occur following a second concussion when an individual is still symptomatic.(P McCrory, 2001; Meehan W.P., 2009) A rapid decompensation in addition to changes in the autoregulatory control of cerebral blood flow are believed to lead to vascular engorgement and increased intracranial pressure, and ultimately death.(Meehan W.P., 2009) With the large number of individuals participating in sports and recreation and the high risk of a concussive injury and potential for life altering long term sequelae, identification of modifiable risk factors is imperative.

How common are concussions?

Concussions have been reported to account for 5.8% of all college athletic injuries and 8.9% of all high school athletic injuries (Gessel, 2007). However, the rate of concussion was seen to be higher in females for sports that both sexes played and in collegiate athletes (Gessel, 2007). Concussion has been reported to account for the greatest proportion of all injury types in youth ice hockey (CA Emery & Meeuwisse, 2006; CA Emery, et al., 2009; K. D. Kelly, H. L. Lissel, B. H. Rowe, J. A. Vincenten, & D. C. Voaklander, 2001). Younger individuals (under the age of 20 years) tend to be more likely to suffer a sport related head injury (K.D. Kelly, H.L. Lissel, B.H. Rowe, J.A. Vincenten, & D.C. Voaklander, 2001). Males tend to suffer concussions more frequently than females, although this is likely due to an increase participation rate in collision sport by males (K.D. Kelly, et al., 2001). Concussion is a commonly encountered injury in sport and recreation.

Multifactorial Etiology of Injury

Rarely are injuries unifactorial. For an injury to occur at a given moment in time, multiple factors are present and are often termed component causes (Rothman, Greenland, & Lash, 2008). A group of component causes that form conditions that allow a given event to occur (in this case an injury) is termed a sufficient cause (Rothman, et al., 2008). For example, in the case of an ankle sprain, the field may be muddy, the player may be fatigued, he may have suffered a previous ankle sprain, another player may collide with him, his calf may be tight, he may arrive late and have a less than optimal warm up, etc. In many cases, a large number of these factors are modifiable and may alter the risk of the said injury.

When we discuss the prevention of injuries, we must first understand the potential factors that may contribute to the causal mechanism. A multifactorial model of injury was initially proposed by Meeuwisse in 1994 (Meeuwisse, 1994). In this multifactorial model, risk factors are divided into intrinsic and extrinsic risk factors. Intrinsic factors are those internal to the athlete and may include flexibility, previous injury status and age. Extrinsic factors include factors such as field conditions, rules, equipment and the weather (Meeuwisse, 1994). An athlete would be predisposed based on his or her set of risk factors and then may become susceptible if a specific event were to occur, at which time the individuals would become injured by an inciting event (Meeuwisse, 1994). This model was further developed into a recursive model where by the athlete continues to participate in sport and may recover from their injury or adapt from recurrent participation, all the while their given set of risk factors is changing over time (Meeuwisse, Tyreman, Hagel, & Emery, 2007). Thus, an individual will have different sets of causal mechanisms depending on his/her intrinsic and extrinsic risk factors at a given point in time, adaptation from recurrent participation or recovery from injury (Meeuwisse, et al., 2007).

If we take this model and apply it to an injury such as a concussion, one can examine the potential risk factors that are both intrinsic and extrinsic to an athlete. For example, individuals who have suffered a previous concussion have been shown to have a higher risk of concussion than individuals who have not previously suffered a concussion. Guskiewicz et al, 2003 reported a three fold increased risk of incident concussions in collegiate football players who had a history of three or more concussions (Kevin M. Guskiewicz, et al., 2003).

A study of 15,802 high school athletes involved in twelve different sports found that previous history of a concussion increased the rate of incident concussion by 2.28 times (95% CI; 1.24, 4.19) (Schulz, et al., 2004). Previous history of concussion is an example of an intrinsic risk factor that is within a given athlete or participant.

Participating in a league that allows body checking at the Pee Wee (11-12 year old) level has been shown to increase the risk of concussion 3.88 times (95% CI; 1.91, 7.89) times that of individuals participating in a league where body checking is not allowed (C Emery, et al., 2010). This is finding is consistent with a recent systematic review (CA Emery, Hagel, Decloe, & McKay, 2010). Increased rates of concussion have been reported in high school athletes participating in full contact sports, when compared to individuals participating in non-contact sport with a reported adjusted incidence rate ratio of 3.28 (95% CI; 1.26, 8.58) (Schulz, et al., 2004). This is an example of an extrinsic risk factor.

Reports of neck pain and headaches at baseline have also been reported to be risk factors for concussion in male youth athletes (K Schneider, C Emery, J Kang, G Schneider, & W Meeuwisse, 2010). Individuals reporting neck pain at baseline were 1.61 times (95% CI; 1.12, 2.33) more likely to suffer a concussion in the following season and those reporting headaches at baseline were 1.40 times (95% CI; 1.00-1.99) times more likely to suffer a concussion than individuals not reporting a headache. Individuals reporting any two of dizziness, neck pain and headaches on the SCAT were 1.88 times (95% CI; 1.14, 3.09) more likely to sustain a concussion than those individuals not reporting any of these three

symptoms (K Schneider, et al., 2010). These findings appears biologically plausible, as alterations in cervical neuromotor control may alter the body's ability to accept and transmit forces, but no research has currently been performed to examine the mechanism by which this may occur.

Increasing age has been reported to increase the risk of concussion. When compared to Atom (9-10 years of age) players, Pee Wee (11-12 years of age) and Bantam (13-14 years of age) players had an increased risk of concussion (3.13 and 4.04 respectively) (CA Emery & Meeuwisse, 2006). Younger athletes may take longer to recover (Purcell, 2009). Game play has demonstrated a higher rate of concussion than practice(CA Emery, et al., 2010).

Wearing of proper protective equipment has been evaluated in terms of risk reduction (BE Hagel, Pless, Goulet, Platt, & Robitaille, 2005). Helmets have demonstrated a decrease in risk of head injury and evacuation by ambulance for head injury in snowboarders and skiers (Benson, Hamilton, Meeuwisse, McCrory, & Dvorak, 2009; BE Hagel, et al., 2005). Some individuals have hypothesized that the wearing of protective equipment may alter behaviour, instilling a sense of false confidence and thus increasing the likelihood of risk taking behaviours (B Hagel & Meeuwisse, 2004). This has often been termed "risk compensation", but has not been supported by research findings (B Hagel & Meeuwisse, 2004; Russell, Christie, & Hagel, 2010). The use of mouthguards have demonstrated a decrease in orofacial injuries (Knapik, et al., 2007) but there is not any current strong

evidence that mouthguards decrease the risk of concussion (Benson, Hamilton, et al., 2009; Knapik, et al., 2007).

A good understanding of an athlete's intrinsic and extrinsic factors at a particular moment in time is imperative in the prevention of potential injury, in this case specifically concussion. The risk set of an athlete is in a constant state of flux and awareness of potential risk factors may prevent susceptible athletes who encounter a potentially 'inciting' event from becoming injured.

Return to play following a concussion

Return to play guidelines have been presented in the most recent International Consensus Guidelines for Concussion in Sport (Zurich 2008) and involve a graduated exertion protocol for return to play. The initial step following a concussion is rest, both cognitive (school, work, video games, texting, etc) and physical. Once an individual is asymptomatic at rest, in conjunction with their physician and health care team, they may begin a stepwise return to play. If at any point in the progression the symptoms recur, the individual must return to the previous step and rest for a minimum of 24 hours. The steps are as follows:

1. Rest
2. Light aerobic exercise
3. Sport specific
4. Non-contact drills
5. Full contact practice
6. Return to play

Formatted: Bullets and Numbering

Each step should take a minimum of 24 hours (P. McCrory, et al., 2009) .

Differing reports of awareness of return to play guidelines have been reported (Cusimano, Chipman, Volpe, & Donnelly, 2009; Sullivan, et al., 2009), and it is possible that some athletes may return to play with post concussive symptoms. A pilot cross-sectional survey of the parents of high school rugby players found that 96% of parents were aware of risks associated with playing when concussed but only half were familiar with return-to-play guidelines (Sullivan, et al., 2009). Another cross-sectional survey was given to coaches, players, trainers and parents at various levels of competition. When asked to state symptoms of a concussion, the top two symptoms reported by all groups were dizziness and headache. Of interest, many individuals surveyed believed incorrectly that an athlete was able to return to play when feeling "90% better" or "while still experiencing a mild headache for the next game as long as it's at least two days later." (Cusimano, et al., 2009). Although many individuals appear to understand the symptoms of a concussion and the mechanism by which one can occur, an understanding of appropriate return to play guidelines and treatment is lacking and further efforts at knowledge translation are required.

Baseline testing is important to assess if the individual has returned to their personal baseline, as many post concussion symptoms are common in the general population (KJ Schneider, CA Emery, J Kang, GM Schneider, & WH Meeuwisse, 2010). A commonly used post concussion assessment paper neurocognitive tool is the Sport Concussion Assessment

Tool 2 (SCAT2) (P. McCrory, et al., 2009). This tool includes a symptom scale, cognitive assessment, balance examination and a coordination examination (P. McCrory, et al., 2009). The score on the SCAT2 is added up for a score out of 100 (P. McCrory, et al., 2009). Normal growth and development in children and adolescents can confound the repeated assessment of baseline measures and may provide a false sense of improvement so must be taken into account (Purcell, 2009). A learning effect may also occur if measures are administered frequently, especially when only small amounts of time have passed between assessments.

When evaluating the risk of concussion in sport, one must take into account all of the risk factors at hand. Many of the risk factors discussed above are modifiable while others are not. Primary prevention of sport related concussions would involve evaluating the factors that we can modify to minimize the risk of injury. This information must be then translated to the stakeholders-athletes, parents, coaches, associations and governing bodies or it is of little benefit. Studies have shown that many parents are not familiar with the current return to sport guidelines following a concussion (Cusimano, et al., 2009; Sullivan, et al., 2009). Without knowledge of potential risk factors and risk profiles, prevention becomes difficult. Appropriate modification of risk profiles will inevitably lead to a decrease in the number of concussions thus decreasing the overall public health burden from this commonly occurring injury. Physiotherapists play a critical role in primary prevention, ongoing monitoring and return to play decisions along with other health care team

members. An understanding of risk factors and current return to play guidelines are of utmost value in the prevention of concussion

Acknowledgement

The author would like to acknowledge Dr. Carolyn Emery and Geoff Schneider for their assistance in review of the manuscript.

References

Barlow, K., Crawford, S., Stevenson, A., Sandhu, S., Belanger, F., & Dewey, D. (2010). Epidemiology of postconcussion syndromw in pediatric mild traumatic brain injury. *Pediatrics, 126*, e374-e381.

Benson, B., Hamilton, G., Meeuwisse, W., McCrory, P., & Dvorak, J. (2009). Is protective equipment useful in preventing concussion? A systematic review of the literature. *British Journal of Sports Medicine, 43*, i56-i67.

Benson, B., & Meeuwisse, W. (2009). Do initial post-concussion signs, symptoms or physical exam findings predict concussion time loss? The National Hockey League-National Hockey League Players association concussion programme. . *British Journal of Sports Medicine, 43*(Suppl I), i100.

Benson, B., Meeuwisse, W., Burke, C., & Rizos, J. (2009). The NHL-NHLPA Concussion Program: a Prospective Study of 7 Regular Seasons (1997-2004). *Br J Sports Med, 43*, i99-100.

Blair, S., Kohl, H., III, Barlow, C., Paffenbarger, R., Jr., Gibbons, L., & Macera, C. (1995). Changes in physical fitness and all-cause mortality. A prospective study of healthy and unhealthy men. . *Journal of the American Medical Association, 273*, 1093-1098.

Blair, S., Kohl, H., III, Paffenbarger, R., Clark, D., Cooper, KH, & Gibbons, L. (1989). Physical fitness and all-cause mortality. A prospective study of healthy men and women. . *Journal of the American Medical Association, 262*, 2395-2401.

Cusimano, M. D., Chipman, M. L., Volpe, R., & Donnelly, P. (2009). Canadian minor hockey participants' knoledge about concussion. . *Can J Neurol Sci, 36*, 315-320.

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

Emery, C., Kang, J., Shrier, I., Goulet, C., Hagel, B., Benson, B., et al. (2010). Risk of Injury Associated with Body Checking Among Youth Ice Hockey Players. *JAMA, 303*(22), 2265-2272.

Emery, C., & Meeuwisse, W. (2006). Injury Rates, Risk Factors, and Mechanisms of Injury in Minor Hockey. [Prospective Cohort]. *Am J Sports Med, 34*(12), 1960-1969.

Emery, C., Meeuwisse, W., Hagel, B., Shrier, I., Goulet, C., Benson, B., et al. (2009). The risk of injury associated with body checking among Bantam ice hockey players. *Clin J Sport Med, 19*(3), 245-246.

Fait, P., McFadyen, B., Swaine, B., & Cantin, J. (2009). Alterations to locomotor navigation in a complex environment at 7 and 30 days following a concussion in an elite athlete. *Brain Injury, 23*(4), 362-369.

Gavett, B., Stern, R., Cantu, R., Nowinski, C., & McKee, A. (2010). Mild traumatic brain injury: a risk factor for neurodegeneration. *Alzheimer's Research & Therapy, 2*(18).

Gessel, L., Fields, SK, Collins, CL, Dick, RW, Comstock, RD (2007). Concussions among United States high school and collegiate athletes. *J Athl Train, 42*(4), 495-503.

Guskiewicz, K. M. (2001). Postural Stability Assessment Following Concussion: One Piece of the Puzzle. [Review]. *Clinical Journal of Sport Medicine, 11*, 182-189.

Guskiewicz, K. M., McCrea, M., Marshall, S. W., Cantu, R. C., Randolph, C., Barr, W., et al. (2003). Cumulative effects associated with recurrent concussion in collegiate football players: the NCAA Concussion Study.[see comment]. [Research Support, Non-U.S. Gov't]. *JAMA, 290*(19), 2549-2555.

Hagel, B., & Meeuwisse, W. (2004). Risk Compansation A "side effect" of sport injury prevention? *Clinical Journal of Sport Medicine, 14*(4), 193-196.

Hagel, B., Pless, I., Goulet, C., Platt, R., & Robitaille, Y. (2005). Effectiveness of helmets in skiers and snowboarders: case-control and case crossover study. *British Medical Journal*

Helmrich, S., Ragland, D., & Paffenbarger, R., Jr. (1994). Prevention of non-insulin-dependent diabetes mellitus with physical activiry. *Medicine and Science in Sports & Exercise, 26*, 824-830.

Kelly, K. D., Lissel, H. L., Rowe, B. H., Vincenten, J. A., & Voaklander, D. C. (2001). Sport and recreation related head injuries treated in the emergency department. *Clin J Sport Med, 11*, 77-81.

Kelly, K. D., Lissel, H. L., Rowe, B. H., Vincenten, J. A., & Voaklander, D. C. (2001). Sport and recreation-related head injuries treated in the emergency department. *Clin J Sport Med, 11*(2), 77-81.

King, M., Pickett, W., & King, A. (1998). Injury in Canadian youth: a secondary analysis of the 1993-94 health behaviour in school-aged children survey. *Canadian Journal of Public Health, 89*, 397-401.

Knapik, J., Marshall, S., Lee, R., Darakjy, S., Jones, S., Mitchener, T., et al. (2007). Mouthguards in sport activities: History, physical properties and injury prevention effectiveness. *Sports Medicine, 37*(2), 117-144.

Lee, I., & Paffenbarger, R., Jr. (1994). Physical activity and its relation to cancer risk: a prospective study of college alumni *Medicine and Science in Sports & Exercise, 26*, 831-837.

McCrory, P. (2001). Does Second Impact Syndrome Exist? *Clinical Journal of Sport Medicine, 11*, 144-149.

McCrory, P., Meeuwisse, W., Johnston, K., Dvorak, J., Aubry, M., Molloy, M., et al. (2009). Consensus Statement on Concussion in Sport 3rd International Conference on Concussion in Sport Held in Zurich, November 2008. *Clin J Sport Med, 19*, 185-200.

McKee, A., Cantu, R., Nowinski, C., Hedley-Whyte, E., Gavett, B., Budson, A., et al. (2009). Chronic traumatic encephalopathy in athletes: progressive tauopathy after repetitive head injury. *Journal of Neuropathol Exp Neurol, 68*, 709-735.

Meehan W.P., B. R. G. (2009). Sport-Related Concussion. [Review]. *Pediatrics, 123*, 114-123.

Meeuwisse, W. (1994). Assessing Causation in Sport Injury: A Multifactorial Model. *Clinical Journal of Sport Medicine, 4*, 166-170.

Meeuwisse, W., Tyreman, H., Hagel, B., & Emery, C. (2007). A Dynamic Model of Etiology in Sport Injury: The Recursive Nature of Risk and Causation. *Clinical Journal of Sport Medicine, 17*, 215-219.

Pellman, E., Powell, JW, Viano, DC Casson, IR, Tucker, AM, Feuer, H, Lovell, M, Waeckerle, JF, Robertson, DW (2004). Concussion in professional football: Epidemiological features of game injuries and review of the literature-Part 3. . *Neurosurgery, 54*(1), 81-96.

Peterson, C., Ferrara, M., Mrazik, M., Piland, S., & Elliott, R. (2003). Evaluation of neuropsychological domain scores and postural stability following cerebral concussion in sports. *Clinical Journal of Sport Medicine, 13*, 230-237.

Purcell, L. (2009). What are the most appropriate return-to-play guidelines for concussed child athletes? *British Journal of Sports Medicine, 43*, i51-i55.

Rothman, K., Greenland, S., & Lash, T. (2008). *Modern Epidemiology* (3rd Edition ed.). Philadelphia, PA: Lippincott Williams & Wilkins.

Russell, K., Christie, J., & Hagel, B. (2010). The effect of helmets on the risk of head and neck injuries among skiers and snowboarders: a meta-analysis. *Canadian Medical Association Journal 182*(4), 333-340.

Schneider, K., Emery, C., Kang, J., Schneider, G., & Meeuwisse, W. (2010). Examining Sport Concussion Assessment Tool (SCAT) ratings for male and female youth hockey players with and without a history of concussion. *Br J Sports Med, In press*.

Schneider, K., Emery, C., Kang, J., Schneider, G., & Meeuwisse, W. (2010). What is the risk of concussion in pee wee nd bantam male hockey players reporting pre-season

symptoms of neck pain, headaches and dizziness? *Clinical Journal of Sport Medicine, 20*(3), 232-233.

Schulz, M. R., Marshall, S. W., Mueller, F. O., Yang, J., Weaver, N. L., Kalsbeek, W. D., et al. (2004). Incidence and Risk Factors for Concussion in High School Athletes, North Carolina, 1996-1999. [Prospective cohort]. *American Journal of Epidemiology, 160*(10), 937-944.

Slobounov, S., Cao, C., Sebastianelli, W., Slobounov, E., & Newell, K. (2008). Residual deficits from concussion as revealed by virtual time-to-contact measures of postural stability. *Clinical Neurophysiology, 119*, 281-289.

Sullivan, S. J., Bourne, L., Choie, S., Eastwood, B., Isbister, S., McCrory, P., et al. (2009). Understanding of sport concussion by parents of young rugby players: a pilot study. *Clin J Sport Med, 19*(3), 228-230.