Children & Adolescents

OA Sports Medicine
Open Access

Review

Risk factors to sport-related concussion for junior athletes

AL Clacy*, R Sharman, GP Lovell

Abstract

Introduction

As more than just an enjoyable activity, team sport offers a range of invaluable benefits to players and has the potential to provide personal, physical and social growth. Despite the many benefits of team sport participation, these benefits do not come without some cost. Although there are strict rules and guidelines in all contact sports, the risk of injuries such as concussion are impossible to prevent completely. Sport-related concussion is a growing concern in contact sport; however, the underlying risk factors and epidemiology of sport-related concussion in junior athletes is not well understood. The notable cognitive, hormonal and neurophysiological changes occurring during development throughout late childhood and adolescence potentially places paediatric athletes at greater risk of sustaining and experiencing enduring effects of brain injury. The aim of this review is to discuss the risk factors to sport-related concussion for junior athletes.

Discussion

Although research is inconsistent, there have been some suggestions of specific individual variables functioning as possible antecedents that increase risk of sustaining a concussion, such as prenatal testosterone exposure, executive function and sensation seeking behaviour. The growing body of inconclusive and speculative studies on this issue highlights the need for more research into both the prolonged effect of cognitive disruption following concussion as well as what specific factors may place an individual athlete at higher risk of sustaining a concussion in the first place.

Conclusion

There are many variables to consider in assessing concussion, from mode of impact to individual characteristics that may place an individual athlete at a higher risk of sustaining a head injury in the first place (e.g. age, impulsivity and executive function). The 'one size fits all' guidance currently promoted for managing concussion fails to consider the broader contextual variables that may impact upon the underlying risk factors and epidemiology of sport-related concussion in a paediatric and adolescent population. In response to this limitation in current research, the authors of this review are presently undertaking a cross-sectional study to better understand the underlying individual characteristics that place some junior athletes (aged 11–17 years) at more risk of sustaining a concussion than others.

* Corresponding author
Email: aclacy@usc.edu.au

Faculty of Arts and Business, Psychology, University of the Sunshine Coast, Queensland, Australia

Introduction

In Australia, 63% of children aged 5–14 years participate in some form of organised sport, in addition to approximately 27% of Australians aged 15 years and older[1]. There are nearly 850,000 Australians participating in the three main codes of contact football regularly played in Australia: Australian Football League (AFL; 37%), Australian Rugby Union (ARU; 'Rugby'; 38%) and National Rugby League (NRL; 'League'; 24%)[1]. As more than just an enjoyable activity, team sports such as football offer a range of valuable benefits to players, especially children and adolescents[2]. Team sport participation provides the chance for at least four fundamental aspects of development for individuals, including acquisition of motor skills, improved physical fitness, opportunities to learn life skills (e.g. discipline, leadership and self-control) and psychosocial development (e.g. peer interaction, cooperation and mateship)[3]. Despite the many benefits of team sport participation, these benefits do not come without some risk, and the potential for injuries such as concussion are impossible to prevent completely.

Sport-related concussion is a growing concern in contact sport, however, due to inter-sport and international differences in injury reporting along with variations in experimental designs, research populations and operational definitions of concussion (e.g. severity scales), calculating a true incidence of concussion in sport is complicated[4]. Although there is no universally accepted definition proposed in research, concussion or mild traumatic brain injury (mTBI) typically refers to the complex pathophysiological processes induced by biomechanical forces affecting the structure and/or functions of the brain, which may or may not involve a loss of consciousness (LOC)[5–8]. Kelly and Rosenberg[9] presented three features in identifying concussion. These were (a) disturbance of vigilance with heightened distractibility; (b) inability to maintain a coherent stream of thought and (c) inability to carry out a sequence of goal-directed movements. Although concussion is typically associated with blunt trauma to the skull, research has found that concussion can occur following impact to other regions of the body, such as the torso. Following their early research, Ommaya

For citation purposes: *Clacy AL, Sharman R, Lovell GP.* Risk factors to sport-related concussion for junior athletes. OA Sports Medicine 2013 Mar 01;1(1):4.

Competing interests: none declared. Conflict of interests: none declared.
All authors contributed to conception and design, manuscript preparation, read and approved the final manuscript.
All authors abide by the Association for Medical Ethics (AME) ethical rules of disclosure.

OA Sports Medicine
Open Access

and Gennarelli[10] proposed that in a controlled setting, impulsive rotation of the head (e.g. whiplash) produces concussion and concussive symptoms more effectively than blunt impact. In most real-world applications of head injury, it is possible for both 'whiplash' and blunt impacts to occur simultaneously, such as during a scrum or tackle when the athlete may experience rapid deceleration at the same time as blunt head impact with the ground and/or other players. Most symptoms of sport-related concussion resolve within 7–10 days, although for some athletes the recovery time is longer, especially children and adolescents[11]. Moreover, there have been no studies that have directly assessed how susceptible junior athletes are to sustaining a concussive injury during participation in contact sport[12]. This review discusses the susceptibility of junior athletes in sustaining a concussive injury.

Discussion

The paediatric athlete

The present consensus on the epidemiology of concussion in the amateur ranks of child and adolescent athletes throughout literature is meagre and scattered. Although the typical cognitive sequelae of concussion appear comparable for children and adults, the notable cognitive, hormonal and neurophysiological changes occurring during development throughout late childhood and adolescence potentially places paediatric athletes at greater risk of sustaining and experiencing enduring effects of brain injury.

Brain regions, such as the prefrontal cortex, continue to develop throughout childhood and into adolescence through two processes. First, the myelination of axons in the prefrontal cortex and other association regions follows a chronological sequence that continues to develop well into young adulthood[13,14]. Second, there is a proliferation of synapses (called synaptogenesis) in the prefrontal cortex during childhood and again at puberty, followed by a subsequent elimination (or 'pruning') and reorganisation of prefrontal synaptic connections throughout adolescence resulting in an overall decrease in synaptic density[15]. These two processes of maturation culminate in an overall linear increase in cortical white matter as well as a region-specific decrease in grey matter creating a 'sensitive period' for cognitive development[13,16]. Disruptions in development cause brain injuries, such as concussion; therefore, they may have implications in both the 'wiring' and the function of the prefrontal cortex. As the prefrontal cortex is involved in the regulation of emotional behaviour, executive function and fear extinction, the developmental cortical reorganisation of this region of the brain can result in notable changes in the emotional stability, reasoning and behavioural control. Some of the immediate symptoms of concussion (e.g. heightened impulsivity, increased aggression and short term memory loss) reflect a short-term disruption to the effective function of the brain.

Researchers who have tracked symptoms and neuropsychological dysfunction following concussion suggest that age-related differences exist between adolescent and adult athletes[17]. For example, in their age-matched control study Field et al.[18] found that high school athletes (mean age 15.9 years) who sustained a concussion demonstrated prolonged memory dysfunction (3, 5 and 7 days after injury) and performed significantly worse on working memory tasks than the collegiate athletes (mean age 20 years). The findings of Field and colleagues'[18] study may suggest that younger athletes have a longer recovery time following concussion; however, as symptoms were not measured beyond 7 days, it does not address whether concussion has any long-term impacts on memory function. Most developmental models suggest that during childhood cognitive processes such as working memory are rudimentary and not yet localised to the prefrontal cortex. 'Whole-brain' integrity may therefore be essential for succinct cognitive functioning while the brain is still developing, thus head injury causing cognitive disruptions may take longer to stabilise in paediatric athletes compared with older athletes with localised frontal lobe functions.

Despite growing public awareness of the severity of sport-related concussion and the increased volume of research in the area, to date no longitudinal research has been conducted regarding any long-term impact of cognitive disruption following concussion on the developing brain, or whether specific individual characteristics may place an individual athlete at higher risk of sustaining a concussion in the first place.

Individual risk factors and concussion

Prenatal testosterone

Men and women have been found to be dimorphic in athletic abilities consequent of sex differences in both physiological or psychological characteristics such as anaerobic threshold, spatial awareness and competitiveness and sporting aggression[19,20]. Research proposes that the male advantage in sport and athletics can be accounted for, in part, by the prenatal effects of testosterone on the brain and vascular system[19,20]. A suggested correlate of prenatal testosterone is the ratio measurements of the second (index finger) and the forth (ring finger) digits (2D:4D). Research suggests that while testosterone promotes prenatal growth of the fourth digit, oestrogen stimulates the growth of the second digit, therefore a low 2D:4D (i.e. ring finger is longer relative to index finger) is indicative of a uterine environment higher in

For citation purposes: *Clacy AL, Sharman R, Lovell GP.* Risk factors to sport-related concussion for junior athletes. OA Sports Medicine 2013 Mar 01;1(1):4.

Competing interests: none declared. Conflict of interests: none declared.
All authors contributed to conception and design, manuscript preparation, read and approved the final manuscript.
All authors abide by the Association for Medical Ethics (AME) ethical rules of disclosure.

OA Sports Medicine
Open Access

Review

testosterone than oestrogen[19–21]. Using this measure prenatal testosterone exposure has been associated with noted sporting traits such as spatial ability[22]; physical fitness and competitiveness[19]; risk-taking behaviour[23]; physical aggression[24]; cognitive ability[25]; personality[26]; perceived dominance and masculinity[21]; and overall sporting achievement[20].

This interaction raises two interesting questions regarding concussion incidence in contact sport. First, is the reported decrease in concussion in higher grades of sporting competition a function of more practice and experience or is there a biological interaction between higher prenatal testosterone exposure and level of sporting ability? Second, due to the interaction between greater testosterone exposure and sporting performance and competitiveness in men, is the oft-cited 'toughing it out' mentality in Australian sporting culture more a question of individual biology than culture[27]?

Sensation seeking and impulsive behaviour

Risk-taking behaviour may play a significant role in determining the likelihood of injury among children and adolescents who play contact sport, especially in games such as contact football in which tackling and scrumming for possession require some physical risk (e.g. intercepting an opponent, diving for the ball). Although there is a marked increase in risk-taking during adolescence, research suggests that individuals who are more likely to engage in impulsive and/or problematic behaviours exhibit these traits throughout childhood[28,29]. Impulsive traits observed in children as young as 3 years old can predict later problems in behaviour[30–32]. Correlates of risky behaviour in adolescence are the relatively stable personality traits comprising the concept of 'impulsivity'[33,34]. Romer[35] presents impulsivity as a multidimensional trait comprised of three independent concepts; impatience (i.e. selection of a smaller immediate reward over a larger delayed reward; also known as delay discounting), acting without thinking (i.e. uninhibited and hyperactive temperament with limited attention to the environment) and sensation seeking (i.e. experimentation with exciting and novel activities despite the associated risks).

Each of these independent concepts has been found to be associated with deficiencies in executive function[35–37]. Effective executive functioning is necessary for goal directed behaviour, attention, theory of mind and other cognitive processes of the prefrontal cortex[38]. These executive functions are essential for cognitive control, for example developing and executing a plan, filtering out unimportant information and inhibiting impulses. The on-going myelination of axons in the prefrontal cortex and other association regions throughout childhood and adolescence suggests that the cognitive functions orchestrated in these regions, such as attentional control, goal setting and cognitive flexibility (i.e. working memory, problem solving and strategic behaviour), are possibly still developing into young adulthood[16]. The stage and level of an athlete's executive function may therefore have a positive interaction with their risk of sustaining a concussion while playing contact sport. Possessing superior executive function development may not only inhibits an athlete's impulsiveness, but it also increases the likelihood of strategic behaviours such as calculated tackling movements and injury prevention (e.g. avoiding 'rough' plays, wearing headgear).

Headgear

In all codes of contact football in Australia (i.e. NRL, ARU and AFL) players have the option of wearing headgear (i.e. soft-shelled helmet with thin padding) and mouthguards. Although anecdotally it is held that the use of protective wear can prevent head injuries causing concussion, empirical research in this area has found no difference in the incidence of concussion between players who do and do not wear headgear and mouthguards[39]. For example, Knapik and colleagues[40] reviewed the effectiveness of mouthguards in preventing concussion in contact sport, finding an insignificant reduction in rates of concussion. Similarly, in their studies on the effectiveness of padded helmets in preventing concussion for children and adolescents, McIntosh and McCrory[41] and McIntosh et al.[42] found no significant reduction in the incidence of concussion for helmet wearing versus non-helmet wearing athletes. Assessment of headgear efficacy is complicated given the two possible 'modes of impact' that can lead to concussion in contact sport (i.e. whiplash and blunt trauma). Although use of headgear may be effective in preventing superficial head injury caused by blunt impact[43], its role in preventing concussion and other forms of traumatic brain injury remains unproven. The protectiveness of headgear against concussion is further complicated by the possibility of risk compensation, that is wearing headgear might encourage players to adopt a more dangerous style of play based on the misguided belief that they are protected from injury[42,44,45]. This phenomenon has been suggested in a variety of contact sports and may result in a paradoxical increase in injury rates, particularly in younger athletes[42,45].

Return to play guidelines and underreporting

There have been numerous and varying guidelines, consensus statements and position standings developed by different organisations and associations that have led to inter-sport, and even inter-club, variability in the sideline treatment of concussion

OA Sports Medicine
Open Access

and the subsequent return-to-play guidelines implemented. Some of the major revisions include the International Consensus Statement on Concussion in Sport, which is held every 4 years (for latest revision see McCrory et al.[11]), and the National Athletic Trainers' Association (NATA) Position Statement[17]. Despite the new information that these guidelines present, the extent to which these regulation updates are disseminated and implemented remains scarce, especially in amateur and community teams[46]. The majority of these guidelines and guideline changes are publicised through peer-reviewed journals, mostly aimed at medical professionals; however, this information does not appear to be being consistently implemented in community sport[47]. In a sample of Australian Rugby players, Hollis et al.[46] found that 78% of players with experiencing a suspected concussion failed to receive return-to-play advice and those how did receive the correct advice failed to comply with regulations anyway. Furthermore, 23% of community Rugby coaches were either unaware or unsure of the Australian Rugby Union's prescribed concussion treatment guidelines[47]. Trends such as these suggest that the current sideline treatment and return-to-play guideline revisions are not being reliably implemented in amateur and community sport. Finch and colleagues[47] suggest that this may be due to the typically clinical perspective of concussion management, as well as the lack of consideration for the broader contextual variables that may impact upon athlete's attitude towards the value and relevance of injury prevention information.

The major challenge presented by under-reporting is in the sideline judgement of the severity of a head injury, especially when injured players may be intentionally 'toughing out' or 'down playing' their injuries. Sideline evaluation of cognitive function following a head knock is an essential component in the assessment of the injury and subsequent return-to-play decision. Australian Rugby Union[48] along with the International Rugby Board propose a 3-week break from participating in both training and competition following a head injury causing concussion, which is mandatory for players younger than 19 years old. Although 60% of Rugby players (mean age 17 years; SD = 0.96) were aware of and able to recall these rulings[49], 20%–60% of athletes who suspected they may have concussion still fail to report it to their coach, medic or parent/guardian[49,50]. Research has shown that it is less a case of poor education or failure to identify a concussion and more likely the players' attitudes towards the severity of injuries at the time they occur[51] and not wanting to be removed from play[50,51].

Although measures such as the revised Sport Concussion Assessment Tool (SCAT2)[11] and Maddocks' questions (e.g. Where are we? Which team are we playing? Which half is it?)[52] are free for use, there does not appear to be any consistent utilisation of standardised pre–post measures of concussive symptoms in community sport. This may be due to personnel or coach-athlete contact time limitations. This is particularly concerning in youth sport as younger athletes are maturing at a relatively rapid pace, requiring more frequent updates of their baseline measures compared with older athletes[17,53].

Conclusion

Sport-related concussion is a multi-faceted concern that is not well understood. There are many variables to consider in assessing concussion, from mode of impact to individual characteristics that may place an individual athlete at a higher risk of sustaining a head injury in the first place (e.g. age, impulsivity and executive function). While there are some guidelines on the assessment and treatment of concussion, such as those presented by the International Consensus Statement on Concussion in Sport, the implementation and utilisation of these guidelines in amateur sport is inconsistent. As emphasised by Finch and colleagues, this 'one size fits all' guidance for managing concussion fails to consider the broader contextual variables that may impact upon the underlying risk factors and epidemiology of sport-related concussion in a paediatric and adolescent population. In response to this limitation in current research, the authors of this review are presently undertaking a cross-sectional study to better understand the underlying individual characteristics that place some junior athletes (aged 11–17 years) at more risk of sustaining a concussion than others. Specifically our current study is examining at a regional junior rugby union sample and will investigate the impact of variables such as prenatal testosterone exposure, impulsivity, and executive function on an athlete's risk of sustaining a concussion. This study will also form the basis of a 10-year longitudinal study, which will evaluate the specific individual risk factors associated with recovery and possible cumulative or long-term symptoms of concussion. There are no conflicts or competing interests to declare regarding these studies, or the above review. Through the comprehensive assessment of individual characteristics that may contribute to sport-related concussion, it is intended that our understanding of why some athletes are more likely to sustain a concussion; and subsequently why some athletes suffer more adverse and ongoing complications following head injuries in sport might be expanded.

References

1. Childs play: Children's participation in organised sport. No. 4102.0 [http://www.abs.gov.au]. Canberra, ACT: Australian Bureau of Statistics; 2012. [cited 2013 Feb 10].

For citation purposes: *Clacy AL, Sharman R, Lovell GP.* Risk factors to sport-related concussion for junior athletes. OA Sports Medicine 2013 Mar 01;1(1):4.

Competing interests: none declared. Conflict of interests: none declared.
All authors contributed to conception and design, manuscript preparation, read and approved the final manuscript.
All authors abide by the Association for Medical Ethics (AME) ethical rules of disclosure.

2. Solomon GS, Ott SD, Lovell MR. Long-term neurocognitive dysfunction in sports: what is the evidence? Clin Sports Med. 2011 Jan;30(1):165–77.
3. Fraser-Thomas J, Côté J. Youth sports: implementing findings and moving forward with research. Athletic Insight. 2006 Sep;8(3):12–27.
4. Hollis SJ, Stevenson MR, McIntosh AS, Shores EA, Collins MW, Taylor CB. Incidence, risk, and protective factors of mild traumatic brain injury in a cohort of Australian nonprofessional male Rugby players. Am J Sports 5. Med. 2009 Dec;37(12):2328–33.
5. Aubry M, Cantu R, Dvorak J, Graf-Baumann T. Summary and agreement statement of the first International Conference on Concussion in Sport, Vienna 2001. Recommendations for the improvement of safety and health of athletes who may suffer concussive injuries. Br J Sports Med. 2002 Feb;36(1):6–10.
6. Kirkwood MW, Yeates KO, Wilson PE. Pediatric sport-related concussion: a review of the clinical management of an oft-neglected population. Pediatrics. 2006 Apr;117(4):1359–71.
7. Meehan WP III, Bachur RG. Sport-related concussion. Pediatrics. 2009 Jan;123(1):114–23.
8. Poirier MP. Concussions: assessment, management, and recommendations for return to activity. Clin Pediatr Emerg Med. 2003 Sep;4(3):179–85.
9. Kelly JP, Rosenberg JH. Diagnosis and management of concussion in sports. Neurology. 1997 Mar;48(3):575–80.
10. Ommaya AK, Gennarelli TA. Cerebral concussion and traumatic unconsciousness. Correlation of experimental and clinical observations of blunt head injuries. Brain. 1974 Dec;97(4):633–54.
11. McCrory P, Meeuwisse W, Aubry M, Cantu R, Dvorak J, Echemendia RJ, et al. Consensus statement on concussion in sport: The 4th International Conference on Concussion in Sport, Zurich 2012. Br J Sports Med. 2013 Apr;47(5):250–8.
12. Finnoff JT, Jelsing EJ, Smith J. Biomarkers, genetics, and risk factors for concussion. PM R. 2011 Oct;3(10 Suppl 2): S452–9.
13. Blakemore SJ. Imaging brain development: the adolescent brain. Neuroimage. 2012 Jun;61(2):397–406.
14. Yurgelun-Todd D. Emotional and cognitive changes during adolescence. Curr Opin Neurobiol. 2007 Apr;17(2):251–7.
15. Webb SJ, Monk CS, Nelson CA. Mechanisms of postnatal neurobiological development: implications for human development. Dev Neuropsychol. 2001;19(2):147–71.
16. Blakemore S, Choudhury S. Development of the adolescent brain: Implications for executive function and social cognition. J Child Psychol Psychiatry. 2006 Mar–Apr;47(3–4):296–312.
17. Guskiewicz KM, Bruce SL, Cantu RC, Ferrara MS, Kelly JP, McCrae M, et al. National Athletic Trainers' Association position statement: management of sport-related concussion. J Athl Train. 2004 Sep;39(3):280–97.
18. Field M, Collins MW, Lovell MR, Maroon J. Does age play a role in recovery from sports-related concussion? A comparison of high school and collegiate athletes. J Pediatr. 2003 May;142(5):546–53.
19. Hönekopp J, Manning JT, Müller C. Digit ratio (2D:4D) and physical fitness in males and females: evidence for effects of prenatal androgens on sexually selected traits. Horm Behav. 2006 Apr;49(4): 545–9.
20. Manning JT, Taylor R. Second to forth digit ratio and male ability in sport: implications for sexual selection in humans. Evol Hum Behav. 2001 Jan;22(1):61–9.
21. Neave N, Laing S, Fink B, Manning JT. Second to fourth digit ratio, testosterone, and perceived male dominance. Proc Biol Sci. 2003 Oct;270(1529):2167–72.
22. Kempel P, Gohlke B, Klempau J, Zinsberger P, Reuter M, Hennig J. Second-to-fourth digit length, testosterone, and spatial ability. Intelligence. 2005 May–Jun; 33(3):215–30.
23. Hönekopp J. Relationships between digit ratio 2D:4D and self-reported aggression and risk taking in an online study. Pers Individ Dif. 2011 Jul;51(1):77–80.
24. Bailey AA, Hurd PL. Finger length ratio (2D:4D) correlates with physical aggression in men but not in women. Biol Psychol. 2005 Mar;68(3):215–22.
25. Austin EJ, Manning JT, McInroy K, Mathews E. A preliminary investigation of the associations between personality, cognitive ability, and digit ratio. Pers Individ Dif. 2002 Nov;33(7):1115–24.
26. Fink B, Manning JT, Neave N. Second to fourth digit ratio and the 'big five' personality factors. Pers Individ Dif. 2004 Aug;37(3):495–503.
27. Clacy A, Sharman R, Lovell G. Return-to-play confusion: Considerations for sport-related concussion. J Bioeth Inq. 2013 Mar;10(1):127–8.
28. Krueger RF, Hicks BM, Patrick CJ, Carlson SR, Iacono WG, McGue M. Etiologic connections among substance dependence, antisocial behavior, and personality: modeling the externalizing spectrum. J Abnorm Psychol. 2002 Aug;111(3):411–24.
29. McGue M, Iacono WG. The association of early adolescent problem behavior with adult psychopathology. Am J Psychiatry. 2005 Jun;162(6):1118–24.
30. Caspi A, Henry B, McGee RO, Moffitt TE, Silva PA. Temperamental origins of child and adolescent behavior problems: from age three to age fifteen. Child Dev. 1995 Feb;66(1):55–68.
31. Caspi A, Moffitt TE, Newman DL, Silva PA. Behavioral observations at age 3 years predict adult psychiatric disorders: longitudinal evidence from a birth cohort. Arch Gen Psychiatry. 1996 Nov;53(11):1033–9.
32. Tarter RE, Kirisci L, Mezzich A, Cornelius JR, Pajer K, Vanyukov M, et al. Neurobehavioral disinhibition in childhood predicts early age at onset of substance use disorder. Am J Psychiatry. 2003 Jun;160(6):1078–85.
33. Romer D, Betancourt L, Giannetta JM, Brodsky NL, Farah M, Hurt H. Executive cognitive functions and impulsivity as correlates of risk taking and problem behavior in preadolescents. Neuropsychologia. 2009 Nov;47(13):2916–26.
34. Whiteside SP, Lynam DR. The five factor model and impulsivity: using a structural model of personality to understand impulsivity. Person Individ Dif. 2001 Mar;30(4):669–89.
35. Romer D. Adolescent risk taking, impulsivity, and brain development: implications for prevention. Dev Psychobiol. 2010 Apr;52(3):263–76.
36. Reynolds B, Penfold RB, Patak M. Dimensions of impulsive behavior in adolescents: laboratory behavioral assessments. Exp Clin Psychopharmacol. 2008 Apr;16(2):124–31.
37. Shamosh NA, DeYoung CG, Green AE, Reis DL, Johnson MR, Conway ARA, et al. Individual differences in delay discounting: Relation to intelligence, working memory, and anterior prefrontal cortex. Psychol Sci. 2008;19(9):904–11.
38. Lezak MD. Newer contributions to the neuropsychological assessment of executive functions. J Head Trauma Rehabil. 1993 Mar;8(1):24–31.

For citation purposes: *Clacy AL, Sharman R, Lovell GP.* Risk factors to sport-related concussion for junior athletes. OA Sports Medicine 2013 Mar 01;1(1):4.

Competing interests: none declared. Conflict of interests: none declared.
All authors contributed to conception and design, manuscript preparation, read and approved the final manuscript.
All authors abide by the Association for Medical Ethics (AME) ethical rules of disclosure.

OA Sports Medicine
Open Access

39. Cusimano MD, Nassiri F, Chang Y. The effectiveness of interventions to reduce neurological injuries in rugby union: a systematic review. Neurosurgery. 2010 Nov;67(5):1404–8.
40. Knapik JJ, Marshall SW, Lee RB, Darakjy SS, Jones SB, Mitchener TA, et al. Mouthguards in sport activities: History, physical properties, and injury prevention effectiveness. Sports Med. 2007;37(1):117–44.
41. McIntosh AS, McCrory P. Effectiveness of headgear in a pilot study of under 15 rugby union football. Br J Sports Med. 2001 Jul;35(3):167–9.
42. McIntosh AS, McCrory P, Finch CF, Best JP, Chalmers DR, Wolfe R. Does padded headgear prevent head injury in rugby union football? Med Sci Sports Exerc. 2009 Feb;41(2):306–13.
43. Jones SJ, Lyons RA, Evans R, Newcombe RG, Nash P, McCabe M, et al. Effectiveness of rugby headgear in preventing soft tissue injuries to the head: a case-control and video cohort study. Br J Sports Med. 2004 Apr;38(2):159–62.
44. Gilbert F, Partridge BP. The need to tackle concussion in Australian football codes. Med J Aust. 2012 May;196(9):561–3.
45. Hagel B, Meeuwisse W. Risk compensation: a “side effect” of sport injury prevention? Clin J Sports Med. 2004 Jul;14(4):193–6.
46. Hollis SJ, Stevenson MR, McIntosh AS, Shores EA, Finch CF. Compliance with return-to-play regulations following concussion in Australian schoolboy and community rugby union players. Br J Sports Med. 2012 Aug;46(10):735–40.
47. Finch CF, McCrory P, Ewing MT, Sullivan SJ. Concussion guidelines need to move from only expert content to also include implementation and dissemination strategies. Br J of Sports Med. 2013 Jan;47(1):12–4.
48. Annual Report 2011. Off the field: Community rugby report 2011 [http://www.rugby.com.au]. St Leonards, NSW: Rugby Union Australia; 2011. [cited 20 March 2013].
49. Sye G, Sullivan SJ, McCrory P. High school rugby players’ understanding of concussion and return to play guidelines. Br J Sports Med. 2006 Dec;40(12);1003–5.
50. Chrisman SP, Quitiquit C, Rivara FP. Qualitative study of barriers to concussive symptom reporting in high school athletics. J Adol Health. 2013 Mar;52(3):330–5.
51. McCrea M, Hammeke T, Olsen G, Leo P, Guskiewicz K. Unreported concussion in high school football players: Implications for prevention. Clin J Sport Med. 2004 Jan;14(1):13–7.
52. Maddocks DL, Dicker GD, Saling MM. The assessment of orientation following concussion in athletes. Clin J Sport Med. 1995;5(1):32–5.
53. McCrory P. Future advances and areas of future focus in the treatment of sport-related concussion. Clin Sport Med. 2011 Jan;30(1):201–8.

For citation purposes: *Clacy AL, Sharman R, Lovell GP.* Risk factors to sport-related concussion for junior athletes. OA Sports Medicine 2013 Mar 01;1(1):4.

Competing interests: none declared. Conflict of interests: none declared.
All authors contributed to conception and design, manuscript preparation, read and approved the final manuscript.
All authors abide by the Association for Medical Ethics (AME) ethical rules of disclosure.