Concussion in children

Can we manage sport related concussion in children the same as in adults?

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Evidence based guidelines are required for the management of concussive injury in children

Consensus guidelines for managing sport related concussion in adults have been increasingly widely implemented.[1] So far, there are no guidelines that enable clinicians to manage similar sporting concussive injuries in children. Furthermore, there are a number of important anatomical, physiological, and behavioural differences between adults and children that suggest that adult guidelines will need to be either modified or rewritten to manage injuries in this age group.

EPIDEMIOLOGY OF CONCUSSION IN CHILDREN

The annual incidence of traumatic brain injury (TBI) in adults is remarkably constant worldwide and has been estimated at between 180 and 300 cases per 100 000 population.[2–5] This is believed to be an underestimate of the true incidence as an equivalent number of mild injuries are treated by general practitioners and do not result in hospital admission.[6] Direct sport participation accounts for approximately 15–20% of all such TBI[3 7] and in children a further smaller percentage of TBI is associated with play activities.[8]

In children aged 15 years and under, the estimated incidence rate of TBI is 180 per 100 000 children per year of which approximately 85% are categorised as mild injuries.[7] In the US, it has been estimated that more than 1 million children sustain a TBI annually and that TBI accounts for more than 250 000 paediatric hospital admissions as well as more than 10% of all visits to emergency service settings.[9]

In child and adolescent populations, few well controlled studies exist to identify the age specific frequency and outcome of sport related concussive injuries.

INTRINSIC DIFFERENCES BETWEEN CHILD AND ADULT CONCUSSION

The most common cognitive sequelae of concussive injuries in children are the same as for adults, namely reduced speed of information processing, poor attention, and impaired executive function.[10–14] Concussion may also have a significant negative secondary impact upon educational and social attainment, as these processes are critical for performing common day to day activities in childhood and adolescence, such as acquiring new knowledge and attending to school work. The nature, magnitude, and duration of these post-concussion cognitive impairments are yet to be determined, and the academic and social consequence for the child remains unknown at this time. In addition, it has been reported that children may suffer from a variety of post-concussion behavioural sequelae despite normal neuropsychological testing.[15]

It is also known that brain tolerance to biomechanical forces differs between adults and children.[16] In broad terms, a two to three fold greater impact force is required to produce clinical symptoms in children compared to adults. This is due to a combination of factors, including an age dependent physiological response to mechanical stress, the differing geometry of the skull and brain, and the constitutive structural properties of the head. This means that if a child exhibits clinical symptoms after head injury, then it is reasonable to assume that they have sustained a far greater impact force compared to an adult with the same post-concussive symptoms.

There are rare but well recognised post-traumatic clinical sequelae that occur predominantly in children and teenagers, such as diffuse cerebral swelling.[17–20] The concussive impact, however trivial, sets in train the rapid development of cerebral swelling that usually results in brainstem herniation and death. Its cause is unknown but is thought to involve disordered cerebral vascular autoregulation. Although repeated concussive injuries have been proposed as the basis for this syndrome (the so called second impact syndrome), the evidence for repeated concussion as a specific risk factor is not compelling.[21] It is more likely that a single impact of any severity may result in this rare complication; however, participation in sport simply draws attention to incidental concussive injuries in this setting. There is also limited published evidence that a specific genetic abnormality predisposes to brain swelling following mild head injury in children.[22]

NEUROPSYCHOLOGICAL DIFFERENCES BETWEEN CHILDREN AND ADULTS

Over and above any cognitive effects of concussion, there is an additional issue that makes assessment difficult, namely the fact that the brain is cognitively maturing during this period. This has two major implications. Firstly, the child's brain potentially may be more vulnerable to the impact of head injury than the more mature adult brain due to the disturbances of neuronal maturation caused by brain trauma.[14] Secondly, unlike adults where cognitive function is relatively stable over time, children's cognition continues to develop. Thus any assessment of baseline or post-injury cognitive function needs to factor in the normal maturation in cognition that is occurring over this period. Pilot unpublished cross sectional data collected in 180 healthy children using a computerised cognitive test paradigm (CogSport) indicates substantial improvement in performance between the ages of 9 and 18 years on tests of simple and choice reaction time, working memory, and new learning. The largest improvements in test performance occur between the ages of 9 and 15, with minimal changes after this age paralleling adult performance (fig 1).

These developmental changes are of comparable magnitude to post-concussive impairments observed on computerised cognitive post-injury assessment in adults.[23 24] This has the potential for confusion in assessment given that maturational improvements occurring between baseline and post-concussion testing may offset any injury related cognitive impairment in concussed children and adolescents.

RISK FACTORS FOR SEQUELAE AND POOR RECOVERY AFTER CONCUSSION IN CHILDREN

It has been argued that individuals are not at equal risk for symptoms and cognitive dysfunction following concussion, and also that some individuals may be at higher risk of sustaining concussion than others. There is circumstantial evidence that a prior history of brain injury is a risk factor for subsequent concussive injury in children.[15 25]

Other potential risk factors that may predict more severe neurobehavioral

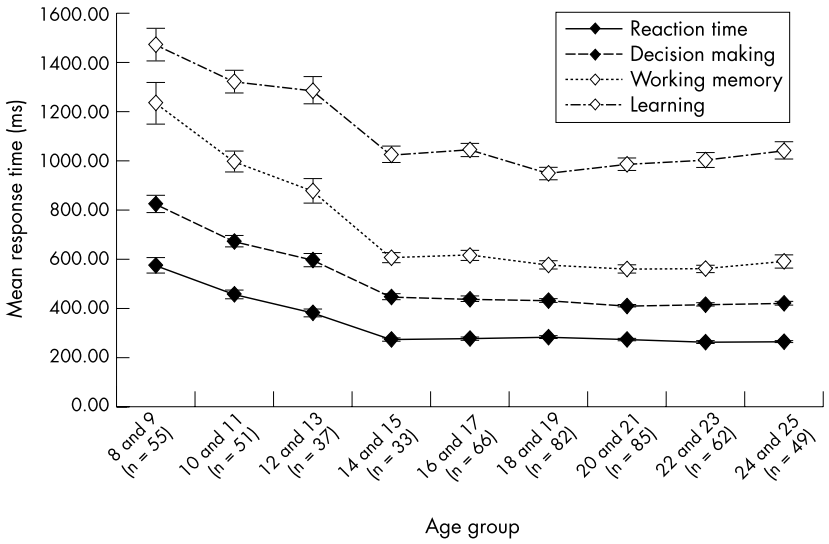

Figure 1 Mean (and standard error) response speed on four cognitive tasks in nine different age bands, from 8 to 25 years of age.

sequelae following injury, especially in younger children where the brain is less mature, include the presence of premorbid cognitive, attention, and behavioural impairments.[15 26]

It has also become a widely held belief that having sustained a sport related concussive injury, an athlete is then more prone to future concussive injury. The evidence for this in sport is limited with most studies being methodologically flawed.[27–29] It has been suggested that individuals with more aggressive playing styles may be at the greatest risk of concussion.

Although helmet use may be effective in preventing superficial head injury in children, its role in preventing concussion and other forms of traumatic brain injury remains unproven. Furthermore, recent studies have shown a differential behavioural response of children to protective equipment with some adopting increased risk taking behaviour and hence paradoxically increasing their risk of sustaining a concussive injury by wearing a ''protective'' helmet.[30 31]

There is also evidence that an individual's genetic make up may predict outcome from head injury. In particular, an association has been identified between the apolipoprotein E ϵ4 allele and poor clinical outcome in adult patients with mild head injury.[32] Although only in the early stages of understanding, the interaction between genetic and environmental factors may be critical in the development of post-concussive phenomena. These data suggest that it may be possible to identify individuals who are at greater risk for poor outcomes from concussion and in the future management practices may need to be tailored to incorporate such information.

CAN WE USE ADULT CONCUSSION RETURN TO PLAY STRATEGIES IN CHILDREN?

There have been numerous attempts in the past to formulate evidence based concussion management guidelines,[33] with that developed at the recent Vienna Consensus Conference[1] being most widely accepted today. In broad terms, this approach recommends baseline cognitive testing to enable accurate individual assessment of recovery, in order to guide return to play following concussion.

There are no current guidelines for diagnosis and management of concussion in children beyond generic recommendations for observation and neuroimaging following childhood mild head injury.[34] This is also reflected in the variable specialist clinical management that may be offered in this situation. In a recent pilot study of paediatric neurosurgical management of sport related concussive injury in children, there was no consensus between the surgeons being studied as to the significance of specific clinical symptoms or on recommendations regarding hospitalisation, time off school and sport, or the use of protective equipment following injury.[35]

The ''comparison to own baseline'' model of assessment remains a powerful method of assessing change in cognitive function after concussion, and in the absence of conflicting evidence, should be adopted as a conservative approach to identifying post-concussion cognitive deficits in children as it is in adults. The central issue is how often baseline testing should be conducted. During the period of rapid cognitive maturation (8–15 years of age), baseline testing would have to be performed at least 6 monthly to enable accurate comparison for serial testing. Apart from elite junior athletes, such regular testing would be beyond the resources of most sports and individuals. For any child or adolescent athlete participating in collision sport or where there is a significant risk of concussion, annual cognitive testing should be considered. Any statistical decision about whether cognition has changed from baseline following concussion must also include an adjustment for developmental changes in cognition. This in turn requires knowledge of how performance changes on specific tests over time. Figure 1 demonstrates the cognitive maturation process that is maximal between 8 and 15 years of age and gives an estimate of the degree of this change. Beyond 15 years of age an annual baseline test would be suitable, as for adult athletes, and be applied in the same fashion as for adults and without any developmental increment.

THE CLINICAL MANAGEMENT OF CONCUSSION IN CHILDREN

Current adult management of concussion involves an initial diagnosis using a validated assessment tool such as the Maddocks questions[36] or the Standardized Assessment of Concussion[37]. Neither tool has been specifically tested or validated in children with concussion.

One preliminary study suggests that high school aged children (14–18 years) may also have prolonged cognitive recovery when compared with young adults (18–25 years), but that symptom recovery is equivalent between these groups.[38] This finding raises the possibility that symptom ratings and cognitive testing may be differentially sensitive to concussion in minors and adults; however, there is no such information available for younger children. This in turn raises concern as to how sport related concussion assessment may be performed in these age groups and the validity of existing assessment tools.

Return to play concussion guidelines recommend baseline cognitive evaluation of all individuals participating in contact and collision sport.[1] The heterogeneity of concussion ensures that individual comparison to baseline allows more sensitive identification of post-concussion symptom elevation and cognitive dysfunction than arbitrary classification according to a retrospective grading scale.[39 40]

Statistical models used to determine the significance of any observed post-concussion cognitive change require knowledge of how cognitive test performance and symptom ratings change in

healthy, uninjured individuals.[41] In adult populations (and potentially children aged 16 years and over) available data suggest that cognitive performance remains relatively stable over time on tests commonly used in concussion management.[42]

These findings support the need for prospective serial investigation of cognitive and behavioural function in healthy and concussed children and adolescents, including specific assessment of how cognitive processes (including response variability) change within individuals. Such data will be invaluable in informing the development of concussion management guidelines in this population, and the interpretation of post-concussion cognitive test data.

The issue of neuroimaging is often raised for children following mild head injury. With young patients, this issue is often problematic given that they may require a general anaesthetic in order to obtain adequate images, although new generation spiral CT scanners are able to perform extremely rapid imaging sequences. If imaging is desired by the health practitioner in this setting or by the subsequent development of symptoms of intracranial pathology, then CT scanning is the imaging modality of choice in the emergency setting. The American Academy of Paediatrics guidelines state that there is no indication for routine use of skull *x* ray in paediatric concussion and ''no data are available that demonstrate that children who undergo CT scanning early after minor closed head injury with loss of consciousness have different outcomes compared with children who receive observation alone after injury''.[34]

In broad terms, a previously neurologically healthy child with a concussive injury who has normal mental status, no abnormal or focal abnormalities on neurological exam, and no physical evidence of skull fracture simply requires observation by a competent caregiver. The risk of clinically significant intracranial pathology in this setting is less than 0.02%[34 43] although earlier studies had suggested higher figures.[44 45] It is likely that many of these early studies suffered from selection bias and over estimated this risk in this situation.[34]

SUMMARY

At the present time, there are no evidence based guidelines using which sport related concussive injury in childhood and adolescence can be scientifically managed. There are significant differences between adults and children in this regard and a child who is symptomatic following head injury is likely to have sustained a far greater impact force as compared to an adult with the same post-concussive symptoms.

The extent and duration of the cognitive effect on children with acute concussive injuries is variable and there may be persistent effects on scholastic performance and behaviour long after the clinical concussive symptoms and measurable neuropsychological impairment have resolved. Even subtle and transient impairments in attention and information processing skills can have a dramatic effect on the young person's capacity to cope with school demands, with these issues being particularly critical for those at later secondary school levels.

Based on pilot data, cognitive maturation is greatest in those under 15 years of age and beyond this time plateaus to an adult level of performance. Although comparison to baseline cognitive performance remains a powerful method of assessing function following a concussion injury, its application in children under 15 years of age is problematic given the rapid cognitive maturation that is occurring in this period. With regular baseline testing, an ''adult'' management strategy could be adopted in this age group, whereas in its absence only an estimate of normal age related cognitive function can be made. Beyond 15 years of age, it would be reasonable to follow the adult concussion management consensus guidelines utilising a ''return to baseline'' approach.

It is suggested that concussive symptoms take longer to resolve than in adults although this may be a surrogate marker of the biomechanical differences between child and adult concussion as outlined above. It is critical therefore that concussed children and adolescents not resume sport, school, or training until all the physical symptoms fully resolve. This is important also because of the risk of diffuse cerebral swelling that may occur in children after a single head injury no matter how trivial the impact may be. The adoption of a conservative adult management strategy with a thorough assessment of symptom resolution followed by ''return to baseline'' cognitive function remains the most appropriate management strategy in this age group.

Further research is required to characterise the duration and nature of the subclinical cognitive impairment that may exist during this recovery period in children. Increased awareness of these issues by those involved in the management of a child with concussion may assist in avoiding problems caused by this putative impairment.

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Sport psychology and concussion

Sport psychology and concussion: new impacts to explore

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In recent years, there has been great interest in examining the psychological effects of athletic injuries. This has also extended to interventions in which coping strategies have been suggested to enhance recovery. Concussive injuries, which are common to many sports, hold particular problems in this regard. For example, a concussed athlete may be prone to experience isolation, pain, anxiety, and disruption of daily life as a result of the injury. This may be a problem for individual sport athletes—for example, professional skiers—who do not have the support of team mates to help them through their rehabilitation and recovery, as well as team sport athletes whose team mates may inadvertently pressure them to return to play.

Besides the physical loss resulting from an injury, there may also be psychological distress. Commonly reported emotion responses resulting from athletic injury have included anger, denial, depression, distress, bargaining, shock, and guilt.[1–5] These are particularly seen in career ending injuries. Such emotional distress can negatively affect the athletes' recovery process.

> ''…concussed athletes in team sports seem to have fewer long term problems''

Injured athletes have also reported feelings of isolation and loneliness. Researchers found that athletes prevented from participating in their activity have lost contact with their team, coach, and friends.[6 7] For example, Gould *et al*[6] examined the emotional reactions of US national team skiers to season ending injuries and found that 66.6% cited lack of attention and isolation as a source of stress during their injury. In another study of injured athletes, Brewer *et al*[2] surveyed 43 sports medicine practitioners to discover side effects of psychological distress. These side effects included exercise addiction, weight control problems, family adjustment, and substance abuse. These problems have been reported individually as well as being associated with depression and anxiety and have been shown to cause severe health complications.[7]

Injured athletes have reported different levels of satisfaction with the social support they have received after injury. In particular, team mates have been shown to have a greater affect on the emotional state of injured athletes than coaches or medical professionals.[8] This leads one to speculate that individual sport athletes may experience different adjustment difficulties while recovering from a concussion. This may also suggest why concussed athletes in team sports seem to have fewer long term problems, such as persistent post-concussive symptoms. In an environment in which team mates are likely to have experienced similar injuries, there is a greater corporate memory of such injuries and hence more reassurance as to the likely recovery time frame and validation of subjective symptoms experienced by the injured athlete.

UNIQUENESS OF CONCUSSION INJURIES

A number of unique characteristics of concussion injuries exist. Firstly, a concussion is an ''invisible injury''. This