

lands in the immediate area behind the wicket. The rule is a compromise from the original English proposal that had pushed for automatic slips as well. The ICC refused that request on the grounds that "someone has to go and get the ball when an Australian misses it." An alternative proposal that Australian batsmen field their own misses behind the stumps was firmly rejected by Australia.

(2) Australia is under strict "tip and run" restrictions that require they take a run off every single ball they hit. The Australian captain, Steve Waugh, was apparently happy to accept this rule, as it meant no change to his current game plan. As a compromise, it was agreed that the Australians would also have to shout out the word "wickets" when completing a run to make run out decisions by umpires easier.

(3) Following the performance in the first test, all Australian batsmen now have "six and out" restrictions imposed on them. This particularly applies to wicketkeeper, Adam Gilchrist. In addition, following complaints from the English fieldsmen, Gilchrist will have to get the ball if it goes across the road.

(4) Instead of using a bat, both Adam Slater and Adam Gilchrist will now be obliged to use their arm with their jumper wrapped around it.

(5) Additional rules applicable only for the English team include "one hand, one bounce" while they are fielding, and the provision of "last man carries" when they are batting. Australian captain Steve Waugh has vigorously opposed the "last man carries" rule and has launched an appeal. Waugh says Australia will only agree to the rule if there are "electric wickets" allowing Aussie fielders to throw to the stumps at either end.

(6) In response to a request from the English team, the "can't get out first ball" provision has been amended to "can't get out first ten overs". Although intuitively attractive from a television spectacle standpoint, both the

ICC and the Australian Cricket Board have pointed out that the extra runs gained would hardly be worth the effort.

(7) In response to English batting prowess, any English batsman who has more than three "ducks" in a series cannot get out for a "duck" for the remainder of the series.

(8) All English bowlers, both spinners and slow medium pace bowlers, will also be allowed to scratch the ball with a bottle top, wrap the ball's seam with electrical tape, or use vaseline on the ball at their discretion to improve their chance of taking a wicket.

(9) There will be no LBW decisions given against English batsmen unless "it is really, really obvious." For Australian batsmen, an LBW decision will be allowed if the ball strikes the batsman anywhere on the pad, thigh guard, or arm guard.

(10) Australian bowlers are required to bowl underarm at the English tail end (batsmen from five to eleven in the batting order). Shane Warne has conceded that it is "fair enough" and does not think it will slow his wicket taking considerably.

(11) In the unlikely event of an English batsman remaining at the crease for any significant length of time, any individual score above 70 will be automatically designated a "century" and recorded as such in the official match statistics.

(12) Glenn McGrath is not allowed to bowl at Michael Atherton at any time.

(13) The "front foot rule" for bowlers will only apply to the Australian team.

(14) Shane Warne must nominate the type of delivery before bowling if a wicket is to be claimed. If he fails to nominate the delivery or bowls a different delivery, then the delivery will be deemed a "no ball" by the umpire.

Despite the changes, Australia remain firm favourites for the next series and are at unbackable odds to win "eight in a row".



When to retire after concussion?

The decision to retire after repeated concussive injuries remains a complex and controversial area. For the most part, there are no evidence based recommendations to guide the practitioner. In the absence of scientifically valid guidelines, good clinical judgment and common sense remain the mainstay of management.

It is difficult for a team doctor when an athlete, professional or otherwise, has suffered a number of concussive injuries but has no residual neurological or cognitive symptoms. Concern expressed by the doctor, the patient, and other medical or coaching team members is often raised as the prelude to this decision making process. Far more difficult, and sadly far too common, is the trial "by media" in which anecdotal cases of athletes with poor outcomes following repeated "concussions" are described, often with little or no supporting medical evidence, as the basis for recommendations about the playing future of the player concerned.

Background

There is no scientific evidence that sustaining several concussions over a sporting career will necessarily result in permanent damage. Part of the neuromythology surrounding concussion is the concept of the "three strike rule": if

an athlete has three concussions then, he or she is ruled out of competition for a period of time. On occasions, this can result in permanent curtailment of sporting participation. This anecdotal approach was originally proposed by Quigley in 1945 and subsequently adopted by Thorndike, who suggested that if any athlete suffered "three concussions, which involved loss of consciousness for any period of time, the athlete should be removed from contact sports for the remainder of the season".¹ It is important to remember that this approach has no scientific validity, yet continues to be the rationale underpinning most of the current guidelines on return to play. It may also be worth noting that the definition of concussion used by both Quigley and Thorndike differs considerably from that in current use.

The unstated fear behind this approach is that an athlete suffering repeated concussions will suffer a gradual cognitive decline similar to the so called "punch drunk" syndrome or chronic traumatic encephalopathy seen in boxers.²⁻⁴ Based on published evidence, this fear is largely unfounded, and recent developments suggest that the risk of chronic traumatic encephalopathy in this setting may be largely genetically based rather than simply a manifestation of repeated concussive injury.⁵ Similarly the concept that repeated concussion may predispose an athlete to the

so called second impact syndrome has been largely discredited.⁶

This issue becomes further confused when stories of well known athletes suffering from recurrent head trauma appear in the media and lay press. In some cases, the brain injuries are more severe than the typical sport related concussive injuries, and long term symptoms are not wholly unexpected. In other cases, professional athletes suffer repeated concussions but are not banned from sport, in contrast with the advice given to recreational athletes. Understandably this leads to cynicism in the minds of the public about the differing standards of medical care applied to the elite and non-elite athlete. Far more commonly in my experience, many athletes suffer trauma triggered migraines that are misdiagnosed as episodes of concussion. It is these repeated headache episodes upon which management advice is often erroneously given.

Does repeat concussion result in cumulative damage?

Apart from boxing related head injuries, the most widely cited studies of the cumulative effects of concussion have been of patients with injuries sustained in motor vehicle accidents that were severe enough to warrant presentation to hospital. Generally, concussive injuries suffered in sports such as football involve lower acceleration-deceleration forces than are experienced in motor vehicle accidents.⁷⁻¹⁰ Patients with these sports related injuries typically recover quickly and usually do not require acute hospital admission.

It is widely acknowledged that boxing carries a high risk of neurological injury. Boxing, however, should not be considered as a model for cumulative head injury seen in other sports because it presents unique risks to the athlete in terms of the frequency of repetitive head trauma.^{11 12}

Limitations of retrospective studies on concussion, such as the widely cited studies by Gronwall *et al*⁷⁻¹⁰ on injuries from motor vehicle accidents, include diagnostic uncertainty, relying on both self reported injury recall and medically invalidated injury diagnosis. For example, some head injuries in the cited studies were assessed up to eight years after their occurrence. Although methodological problems flaw this study, it supports the contention proposed by Symonds that cumulative deficits may follow repeated concussive injury, such as is evidenced by the “punch drunk” state of chronic traumatic encephalopathy seen in

boxing.^{4 11} In other studies, specific genetic abnormality has been reported to be the major risk factor for the development of traumatic encephalopathy.^{2 5}

In another series of retrospective studies involving retired Scandinavian soccer players, cognitive deficits were noted.¹³⁻¹⁶ However, considerable methodological problems flaw the results, including lack of data before the injury, selection bias, lack of observer blinding, and inadequate control subjects. About 40% of the control group were found to be cognitively impaired. The authors conclude that the deficits noted in the former soccer players could be explained by repetitive trauma such as heading the ball. However, the pattern of deficits is equally consistent with alcohol related brain impairment, a confounding variable that was not controlled for. To date, these findings have not been replicated by other independent groups.¹⁷⁻²¹

There have been surprisingly few prospective studies of sport related concussion.²²⁻²⁶ In a study of American gridiron football, it was found that, although information processing deficits were evident within 24 hours of injury, neuropsychological function had returned to normal when retested within 5–10 days of the injury.²² Similar findings were reported in studies of Australian Rules footballers.²⁷

Concussive injuries in Australian Rules football tend to be mild, with neuropsychological performance returning to levels found before injury within a few days.²³⁻²⁵ Similarly, post-concussive symptoms such as headache, nausea, poor concentration, and fatigue also resolve within the first few days of injury. The classical “post-concussive syndrome” often seen after motor vehicle accidents and other forms of severe traumatic brain injury is exceedingly rare in sport.

In animal studies of experimental concussion, animals have been repeatedly concussed 20–35 times during the same day and within a two hour period. Despite these unusually high numbers of injuries, no residual or cumulative effect was found.²⁸

Is there a genetic susceptibility to chronic brain injury in sports?

Recent research has suggested that chronic traumatic encephalopathy in boxers may be associated with a particular genetic predisposition. The apolipoprotein E ϵ -4 gene (ApoE), a susceptibility gene for late onset familial and sporadic Alzheimer's disease, may be associated with an increased risk of chronic traumatic encephalopathy in

Table 1 Return to sport guidelines

Severity grade	1st concussion	2nd concussion	3rd concussion
<i>Cantu system</i> ^{25 36}			
Grade 1 (No LOC, PTA <30 min)	RTP after 1 week if asymptomatic	RTP in 2 weeks if asymptomatic for at least 1 week	Terminate season. RTP next season if asymptomatic
Grade 2 (LOC <5 min, PTA >30 min)	RTP after 1 week if asymptomatic for at least 1 week	Minimum of 1 month off sport. RTP if asymptomatic for at least 1 week. Consider terminate season	Terminate season. RTP next season if asymptomatic
Grade 3 (LOC >5 min, PTA >24 h)	Minimum of 1 month off sport. RTP if asymptomatic for at least 1 week	Terminate season. RTP next season if asymptomatic	
<i>Colorado/AAN guidelines</i> ^{32 33 37}			
Grade 1 (No LOC, confusion, no amnesia)	RTP after 20 minutes if asymptomatic	RTP if asymptomatic for at least 1 week	Terminate season. RTP next season if asymptomatic
Grade 2 (No LOC, confusion, amnesia)	RTP after a minimum of 1 week with no symptoms	RTP after a minimum of 1 month with no symptoms for at least 1 week	Terminate season. RTP next season if asymptomatic
Grade 3 (LOC)	RTP after a minimum of 2 weeks with no symptoms.	Terminate season. RTP next season if asymptomatic	Terminate season. RTP next season if asymptomatic
<i>Jordan guidelines</i> ³⁴			
Grade 1	RTP if asymptomatic at rest and with exertion	Not stated	Not stated
Grade 2	RTP if asymptomatic for at least 1 week	Not stated	Not stated
Grade 3	Minimum of 1 month off sport, must then be asymptomatic for at least 1 week	Not stated	Not stated
Grade 4	Minimum of 1 month off sport, RTP if asymptomatic for at least 2 weeks	Not stated	Not stated

PTA, Post-traumatic amnesia; LOC, loss of consciousness; RTP, return to play.

boxers.^{2 5 29 30} In a non-boxing population, ApoE polymorphism was significantly associated with death and adverse outcomes following acute traumatic brain injury seen in a neurosurgical unit.³¹ In a recent prospective study, ApoE genotypes were tested to see if they could be used to predict days of unconsciousness and functional outcome after six months.³² There was a strong association between the ApoE allele and poor clinical outcome.

Published guidelines for return to sport after concussion

Guidelines recommending termination of all contact sport after three concussions during the course of an athletic season need to be considered carefully. In the absence of documented objective evidence of brain injury, there is no scientific support for this generalisation. Athletes excluded from competition on such a basis may consider a medicolegal appeal that would be impossible to defend in a court of law.

There are several anecdotal guidelines available in the literature.³³⁻³⁸ As mentioned above, these are not supported by published scientific evidence and should be considered management "options" at best (table 1).

It would seem that in the absence of a scientifically validated scale for return to sport, we are left to make a decision using either an arbitrary exclusion period or an individualised clinical and neuropsychological assessment of recovery. With new web based computerised neuropsychological test batteries available for screening athletes after injury, such measures are readily and cheaply available for all team doctors involved in the care of recreational as well as professional athletes.³⁹ Before these new developments, access to neuropsychological assessment was a practical and logistical problem for the non-professional athlete, and the evolution of arbitrary exclusion periods was commonplace.

Conclusion

The issue of retirement because of repeated concussion remains controversial. At present, no scientifically validated guidelines exist upon which to base a medical decision. Inappropriate advice, at least at the professional level, may expose the doctor to medicolegal challenge. At present, best practice lies between arbitrary exclusion periods after injury or individualised clinical and neuropsychological assessment. The latter approach should be preferred, and the advent of web based neuropsychological assessment tools makes this a viable and practical option. Recent research suggests that long term chronic complaints resulting from concussion may often have a genetic basis rather than simply being a manifestation of repeated exposure.

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