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Traumatic brain injury, collision sports participation, and neurodegenerative disorders: narrative power, scientific evidence, and litigation

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The present and future burden of neurodegenerative disorder, particularly dementia, for individuals, society, and health care systems has been extremely well documented. Dementia currently directly affects around 50 million people globally and, owing to demographic expansion, its prevalence is expected to triple over the following three decades.[1] The disappointing results of trials of drug treatments for dementia, motor neuron disease (amyotrophic lateral sclerosis), and Parkinson's disease – particularly curative therapies – brings into sharp focus the need to identify modifiable risk factors. Head injury has been advanced in this regard,[2] is common[3] and, in principle, has the potential for amelioration via advances in safety legislation and protective technologies.

Operationalising head impact

Head injury severity might be operationalised as a continuum. The traumatic insults occurring at the higher end of this spectrum result from vehicular accidents, assaults, and falls in civilian populations and bomb blasts in the military. Direct trauma to the head is not, however, a pre-requisite for a significant brain injury; it can also result from rapid acceleration-deceleration as seen as in whiplash-type episodes. Severe head injury may also occur in selected sports, most obviously boxing, mixed martial arts (so called 'cage fighting'), and professional wrestling,[4 5] where the infliction of head trauma is a key objective. In other sports such as soccer, while trauma to the head may also occur, typically in elbow-on-head collisions,[6] head impact – as it is perhaps most usefully termed – is most likely to result from contact with equipment. Typically, this would be the seemingly innocuous sub-concussive 'heading' of the ball for its redirection. Of the non-sport activities, similar low intensity neurological insults might be the product of the percussive movement of the head in accompaniment to contemporary music – so called 'head banging'.[7]

Traumatic head injury and dementia

While the influential 2020 report of the Lancet Commission on dementia – an asystematic, selective, narrative overview of the field – lists traumatic brain injury as one of twelve modifiable risk factors,[2] position statements from prominent organisations such as the World Health Organization[8] and the US National Academies of Sciences[9] make no mention of it. This may be a reflection of the discordant

literature. There is evidence, for instance, from large scale, retrospective and prospective cohort studies of the general population of an approximate doubling in the rate of dementia in people who experienced head trauma severe enough to warrant hospitalisation relative to the unaffected.[10-13] In selected analyses, there is also a suggestion that risk is elevated in the months immediately following exposure but wanes thereafter.[12] These studies, generated from linkages of administrative datasets, seem to reveal stronger effects than conventional, field-based cohort studies.[14,15] This may be explained by the greater availability of confounding factors in the field-based studies. Equally likely, physician-corroborated head injury assessment in data linkages studies may be less subject to misclassification than when captured by self-report in the field-based investigations.[16]

Collison sports participation and dementia: 'consistent' anecdotal evidence

Media coverage is a powerful force in forming public opinion and behaviours in a variety of areas, including health and disease prevention.[17] Press reports of the consequences for brain health of participation in collision-heavy sports often comprise a mix of heart-rendering accounts of understandably distressed relatives of retired athletes who live(d) with the condition, who are convinced of the very singular dementia-causing effect of such activities,[18-20] sometimes interwoven with mention of film dramatisation.[21] Indeed, the recently convened UK Parliament cross-party Committee on Concussion in Sport was notable for its focus on anecdotal accounts of the affected patients, carers, relatives, or treating physicians but light on scientific representation.[22] While any disease entity is under the control of a multitude of genetic and environmental risk indices rather than a single factor,[23] for the lay population, these anecdotal accounts make for a powerful and often definitive narrative, and one that is typically more persuasive than the inevitably less consistent picture drawn using empirical data.

Collison sports participation and dementia: inconsistent empirical evidence

In the scientific literature also, case reports, often of a solitary athlete,[24,25] can be misrepresented as evidence of cause and effect, even by scientists. While case series have historically provided important descriptive medical insights – most obviously for past[26] and present[27] pandemics – in failing to offer cross-

group comparisons of disease rates in exposed and unexposed, they do little to advance understanding of disease causation. The counter-factual, such as accounts of sprightly centenarians who have consumed cigarettes, cake, and soap opera reruns on a daily basis since kindergarten[28] are rarely advanced as evidence for the health-enhancing effects of tobacco, saturated fat, and a dedication to sedentarism.

Despite estimates of the occurrence of head trauma in Ivy League college football,[29] and debates over its links with dementia in boxers (so called *dementia pugilistica*[30]) first appearing a century ago, the long term impact on brain health of membership of athletic groups has been relatively little-scrutinised in an epidemiological context. Most studies have examined the association between participation in American football and dementia in samples which, unsurprisingly, are exclusively based on retired athletes from that country. Similarly, with the exception of one study,[31] former Italian soccer players comprise the other large body of work linking engagement in that sport with amyotrophic lateral sclerosis[32,33] (the origins of this focus stem from an judicial investigation of illicit drug use in these athletes).[34] In these studies, membership of professional athletic groups is used as a proxy for exposure to brain trauma. Rates of death ascribed to neurodegenerative disease in aggregate have been reported as being higher in American football players relative to comparison groups comprising baseball players[35] and the general population,[36] both of whom are likely to have a much lower period prevalence of brain injury. These results are not universal however – in long-term follow-up of football-playing University students, for instance, the occurrence of degenerative disorders as alumni was essentially the same as the general population.[37 38] A major methodological shortcoming of these studies is their extremely low statistical power: in a recent review, a single report aside,[31] the frequency of neurodegenerative disease cases across studies ranged between 17 and 55, while for dementia/Alzheimer's disease it was 7 and 26. As such, these studies may simply not have the capacity to detect a relationship should one exist, nor rebut one if it does not.

In studies of soccer, although no better powered, results are more consistent: quantitative aggregation of studies featuring retired soccer players suggest around a 6-fold increase in risk relative of amyotrophic lateral sclerosis versus less exposed groups.[32] The magnitude of this association is unusually high by the

standards of modern epidemiology, potentially elevating soccer participation, and its cumulative head trauma, to risk factor status.

In other sports, investigators have also used cognitive function as a quasi-dementia endpoint.[39-42] In these studies, a single baseline measure, as opposed to serial measurement which captures cognitive decline, may in fact provide more insights into intelligence differences between sporting and non-collision sporting/general population groups as opposed to cognitive impairment. Thus, where cognition is higher in non-collision sports participants,[41] it may be that these individuals had sufficiently high perception of risk to simply avoid potentially injurious activities.

Confounding in studies of collision sports and dementia

While the results suggesting higher rates of degenerative disorders in retired American football and soccer athletes are intriguing and provide the highest level of epidemiological evidence to date, instinctively, concerns are raised about the limited array of confounding factors in the published studies. With most studies relying on employment or pension records, beyond age, gender, and career duration, very little else is known about the study members. As is rarely the case, however, confounding may have minimal impact in this context. Putting aside the key exposure of head injury and also specific athletes whom, for instance, high body weight – and all its negative consequences for health – is prized (e.g., linemen in American football,[43] professional wrestlers[44]), retired athlete groups, relative to general population controls, typically have a more favourable risk factor profile for dementia. This includes a lower prevalence of hypertension, diabetes, and other co-morbidities, smoking, and overweight.[45] Accordingly, rates of total mortality and cardiovascular disease in former elite sports participants are typically lower than the general population[31,46,47] – an exemplar of the so called 'healthy worker' effect.[48] Thus, dementia rates in the general population are more likely to be higher than athletic groups. Adjustment for these factors in analyses of collision sports participation would then increase any group difference in dementia risk (positive confounding), not attenuate it.

Potential mechanisms

The mechanisms linking brain insults to neurodegenerative disorders is likely to vary according to the disease endpoint in question. Of the collision sports, most mechanistically-orientated research has again been conducted in American football and soccer, in former participants of which there are autopsy reports of chronic traumatic encephalopathy-type neuropathological change.[49] There is also evidence that heading of a soccer ball produces a measurable if temporary lowering of cognitive function,[50] while potentially more permanent structural changes to the brain are evident upon imaging.[51] Head impact, particularly when severe, has been implicated in the occurrence of stroke,[52] and stroke is itself related to the development of dementia.[53]

Future research directions in collision sports

Aside from the generally trivial number of events in existing studies, methodological advances might include a version of the randomised controlled trial. Clearly, the notion of an experiment where head injury was administered to one group and not to another, and then both groups were followed for ascertainment of neurodegenerative outcomes is as ridiculous as it is unethical. The converse may be plausible, however, whereby, for instance, collision sports participants are randomised to the wearing of head gear in training and competition versus none, and then followed for an array of intermediary markers for dementia (e.g., cognitive decline) or proxies (e.g., brain atrophy from computerised tomography scanning). Rather like amateur boxing, the assumption is that the deleterious impact – acute and long-term – would be mitigated by the wearing of such gear – a point not shared by the International Boxing Association.[54] An alternative study would be a quasi-experimental investigation whereby cognition is assessed pre- and post-issuance of legislation designed to protect the players, such as this withdrawal of head protection in boxing and also recent World Rugby guidance to limit full-contact training, and, in soccer, the restriction of heading in certain levels of the sport.[20]

Lastly, notion of sensitive or critical periods may have relevance to the study of the implications for brain health of a history of sports-acquired head impacts. Defined as a narrow period of time in which an

exposure can have positive or negative effects on brain development and disease outcome, on the one hand, earlier life exposure to head impact may be plausibly compensated by neurological plasticity.[55] The opposite is also conceivable: exposure in early life could lead to 'programming', whereby an insult during a specific period has long-standing effects on brain architecture and physiology. Well characterised cohort studies with data captured across the life course are required for examination of critical and sensitive periods.

Epidemiology and workplace injury litigation

Alongside other scientific evidence, epidemiological data have long been cited in industrial litigation.[56,57] On both sides of the argument, epidemiological findings have been central to legal action for: asbestos exposure and the risk of mesothelioma;[58] specific tampons brands ('Rely') and toxic shock syndrome;[59] silicone gel breast implants and connective tissue disease;[60] and passive smoking and lung cancer,[61] amongst others. In 2011, multiple class (group) and individuals law suits were brought against the National Football League by retired American football players and a no-liability (no-guilt) settlement was reached in 2013[62] (a dedicated website to process the claims of affected former players was subsequently established[63]). Media reports in the UK[64] indicate that claims of negligence have been made by former rugby union and soccer players against their respective governing bodies.

Conclusions

Taken together, the low quality, paucity, and inconsistency of the evidence base for engagement in collision sports as a potential risk factor for specific neurodegenerative disorders does not facilitate the formulation of many clear conclusions. One exception might be the strong suggestion of an elevated risk of amyotrophic lateral sclerosis in former soccer athletes. These findings suggest that concussion is not a prerequisite for there to be a deleterious influence on brain health. Moreover, while data are generally sparse, they also exclusively comprise men. The population impact of head injury may in fact be greater in women given its apparent higher prevalence relative to males in the same sports.[65]

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