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RESEARCH

Amateur boxing and risk of chronic traumatic brain injury: systematic review of observational studies

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EDITORIAL by McCrory

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ABSTRACT

Objective To evaluate the risk of chronic traumatic brain injury from amateur boxing.

Setting Secondary research performed by combination of sport physicians and clinical academics.

Design, data sources, and methods Systematic review of observational studies in which chronic traumatic brain injury was defined as any abnormality on clinical neurological examination, psychometric testing, neuroimaging studies, and electroencephalography. Studies were identified through database (1950 to date) and bibliographic searches without language restrictions. Two reviewers extracted study characteristics, quality, and data, with adherence to a protocol developed from a widely recommended method for systematic review of observational studies (MOOSE).

Results 36 papers had relevant extractable data (from a detailed evaluation of 93 studies of 943 identified from the initial search). Quality of evidence was generally poor. The best quality studies were those with a cohort design and those that used psychometric tests. These yielded the most negative results: only four of 17 (24%) better quality studies found any indication of chronic traumatic brain injury in a minority of boxers studied.

Conclusion There is no strong evidence to associate chronic traumatic brain injury with amateur boxing.

INTRODUCTION

In light of evidence of acute and chronic injuries associated with boxing, the British Medical Association (BMA) has called for boxing to be made illegal.[1 2] Its latest report campaigns for a complete ban on boxing (amateur and professional), mainly because of the purported risk of cumulative brain injury (chronic traumatic brain injury).[2] Severe acute injuries in boxing (including those resulting in fatality), however, are relatively rare compared with other sports, even when professional and amateur boxing are grouped together.[3-5]

A series of important changes in rules and equipment aimed at improving the safety of boxing have been gradually introduced by boxing authorities since the early 20th century.[6 7] Whether such changes have improved safety remains contentious. On the basis of published data available at the time, the BMA 2001 report acknowledged that the evidence for chronic traumatic brain injury in amateur boxing was "far less clear cut" than in professional boxing.[1]

We carried out a systematic review to determine whether amateur boxing leads to chronic traumatic brain injury. We did not consider professional boxing, the incidence of acute injuries, or the moral or legal arguments regarding the sport. A problem with performing such a review is the absence of any clear definition of chronic traumatic brain injury. We clearly needed to consider indicators that may be surrogate markers of chronic traumatic brain injury. In the absence of any ideal standards for this, we took the lowest thresholds —that is, any consistent change in the results of neurological examination, brain imaging, psychometric testing, electroencephalography, including a few other relevant studies for completion. We included studies of amateur boxers (including military and police), with the intervention (exposure) being participation in the sport and from which we could extract data.

METHODS

Two authors carried out a comprehensive search of the literature using Medline and Premedline 1950 to December 2006, Embase, Evidence Based Medicine (EBM) reviews (including the Cochrane database of systematic reviews and the Cochrane central register of controlled trials), and the SPORTDiscus database. We hand searched and cross referenced the bibliographies of relevant papers and three books, and contacted authors when relevant. The figure on bmj.com outlines the study selection process. We included all studies from which we could extract data on outcomes, regardless of study design.

Assessment of study quality—We assessed the quality of all included studies by modifying published checklists[8 9] to accommodate the several types of observational studies, and using the following criteria: prospective study design, groups comparable on all important confounding factors, outcome assessed blind to exposure status, follow-up long enough for outcomes to occur (defined as over one year), relation between outcome and exposure appropriately measured, and appropriate statistical analyses used.

Data extraction and synthesis—When possible, we obtained numerical data, though outcome measures were largely categorical in case series (proportions of participants with positive findings) or expressed as

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group differences in controlled studies. No quantitative data synthesis was performed. Exposure times were collected and expressed as median or mean number of bouts. Accepting that exposure to injury relates to quality, quantity, and length of bouts, we also included the type (level) of boxing where this was recorded. In cohort studies, exposure was presented as length of follow-up in years as well as number of bouts during the study period.

RESULTS

Literature identification, study design, and quality

We identified 943 citations on the basis of initial search terms, of which we included 36 articles. Of the 36 selected, 16 evaluated findings from psychometric tests, 11 from brain imaging, 14 from electroencephalography, and 12 from neurological examination, with several including more than one outcome measure (63 methods in all). We included four cohort studies, four controlled before and after studies, and 11 case-control studies, with the remainder (n=17) being case series. Overall quality was poor (median score 2/6, range 0-6) (see bmj.com). See bmj.com for the characteristics of studies and the main results.

Psychometric testing

The longer duration cohort studies found that, though there were differences from controls in baseline measurements in some psychometric tests (reflecting educational background), there was no longitudinal effect of boxing on psychometric testing, even at nine years.[w1] Indeed in three studies, boxers out-performed controls on some tests.[w1 w2 w6]

Controlled before and after studies observed the acute effects of a boxing bout on performance,[w4 w9] but the durations of altered results on psychometric assessment were not reported as boxers were not followed up long term. The positive findings in the smaller study[w9] were not replicated in the later, larger study, which had a longer exposure and found no overall differences,[w4] though a degree of association with exposure was present on subgroup analysis. One cohort study and two large well controlled series found an isolated abnormality of finger tapping in the non-dominant hand.[w12 w17] A further study with several positive findings used multivariate models to explore the effect of boxing on results of psychometric testing and introduced additional covariates to control for confounding factors.[w11] Although the case series had heterogeneous findings, a large well conducted, albeit uncontrolled, prospective study found no changes in results of psychometric tests from baseline over a two year period.[w5]

Neuroimaging

Though these studies provided the next best evidence after psychometric testing, the overall quality was poor with no cohort studies except that of Butler et al,[w6] who reported in the methods that 67% of the boxers underwent computed tomography but commented no further on this in the results or discussion.

Most of the other studies had small numbers of participants. Most found no consistent abnormalities, and results correlated poorly with findings from other tests when used. For example, Kemp et al, despite identifying abnormalities both on psychometric testing and SPECT, showed no correlation between these findings.[w11] The highest positive yield from a case series was in seven of 13 boxers who underwent computed tomography, though the exact abnormalities were not described.[w22] Other series found abnormalities in individual boxers who had competed in only seven and 14 bouts and were, at the time of study, aged 55 and 57, respectively.[w23 w26]

Electroencephalography and brain evoked potentials

In the 1940s to 1960s researchers extensively explored the potential of electroencephalography to indicate acute injury or chronic traumatic brain injury in amateur and professional boxers with variable results.[10-13] Numerous early studies showed changes in the electroencephalogram in about half of boxers studied,[w22 w24 w26 w27 w29 w31-w33 w35] with more findings immediately after bouts,[w33 w35] although these findings were not followed up longitudinally. Two recent case series found abnormal results on electroencephalography in about half of amateur boxers studied, although results were inversely correlated with advancing age and experience (more findings in younger subjects and with fewer bouts).[w24 w27] A third found some abnormalities in three of 10 amateur boxers,[w22] though two were aged 14 and 16 and the other was aged 53 and all had normal results on psychometric testing, neurological examination, and computed tomography. While case-control studies from the 1960s observed more findings in boxers than controls,[w19 w32] these findings were in stark contrast to more recent case-control series and one prospective series that found no changes compared with controls[w5 w14 w17] or from baseline function,[w5] respectively.

Clinical neurological examination

There are several reports of clinical neurological abnormalities in small numbers of amateur boxers selected on the basis of evident symptoms or recorded acute neurological injury.[10-12] Nine case series that did not select, however, showed a wide variation in prevalence and severity[w18 w30] of findings (from none in 7000 boxers[w24] to 33 of 60[w19]). The widely cited study of McLatchie et al found that seven of 20 amateur boxers had abnormal results on neurological examination that correlated significantly with increasing number of fights,[w21] however, other studies found no correlation with exposure or other methods of testing when used.[w13 w17 w22] Of the three case-control series, two found that non-specific findings such as tremor, nystagmus, slurred speech, and fine movement abnormalities were similarly present in controls.[w13 w17] One large Polish study, however, found significant differences in the incidence of organic neurological dysfunction between high exposure group and controls or lower exposure groups.[w19]

DISCUSSION

In this systematic review we found no evidence for a strong association between amateur boxing and chronic traumatic brain injury. In boxing the head might get hit repeatedly with resultant concussion, though less than in several more popular sports—such as rugby union and equestrian activities[3-5 13]—which may harm cerebral function. Whether clinically measurable long term brain injury occurs is a different and more important question. There is reasonable clinical,[10 14-16] radiological,[10 15 17] and histopathological[11 14 18 19 w28] evidence that this is the case in a proportion of professional boxers (10-20% in most studies), although most studies were performed at a time when safety standards were far less stringent than they are today.[7 20]

Amateur boxing is a different sport from professional boxing, including in its motivation to participate, rules, and equipment, but, most importantly, there is considerably greater exposure to injury in professionals (increased frequency and force of punches over a greater duration of career).[20] We looked at the data for chronic traumatic brain injury in amateur boxing alone. Although no formal synthesis was performed, the data can be described in summary. Overall, 15 of 36 studies (42%) included in the systematic review concluded that relevant abnormalities were present, at least in a proportion of boxers studied. When we expressed this as a function of all methods tested (see bmj.com) we attained a similar figure (28/63, 44%).

Limitations

It would clearly be impossible to perform a double blind randomised controlled trial for amateur boxing, though in general study design and conduct could have been greatly improved. Few studies were of sufficient quality to conclude anything other than a weak association when positive findings were reported, and none was sufficiently powered. There was a definite tendency towards positive findings in studies of poorer quality and design. The importance of using controls was illustrated by several case-control studies that showed that potentially severe abnormalities on clinical neurological examination[w13 w17] as well as neuroimaging[w7] were present equally in the control group.

Methods of selection were rarely adequately explained and occasionally performed on the basis of prior abnormal clinical or investigative findings.[w23] In terms of design, when controls were used these were poorly selected in terms of possible confounding factors. For instance, in one study that used psychometric tests, the controls (rugby and water polo players) were drawn from an undergraduate population, whereas many of the boxers had not completed their full time education.[w6] As no data on IQ had been gathered this factor could not be assessed, and it is acknowledged that education and vocabulary have a large weighting on results of neuropsychometric testing. In respect of performance, remarkably in only two studies were observers blinded.[w1 w7 w12] In studies that sought an association between exposure and outcome, few found an effect, raising the question of false attribution. Conversely, the current range of tests might lack sensitivity to detect subtle changes in neural structure or function. All these tests must be regarded as surrogate markers for the notional concept of chronic traumatic brain injury and clearly no conclusion can be reached on this without an ideal test for comparison or indeed a clear definition of what might constitute clinically relevant injury. Nevertheless, tests regarded as sensitive in general neurological practice have all been used. In particular, psychometric testing, regarded by some as the most sensitive,[w21 21 22] provided the most conclusive negative results.[w1 w2 w4-w6 w15] Similarly, it is generally accepted that magnetic resonance imaging is the best method of determining subtle parenchymal damage and degenerative change. In the six studies that used this, only one case series of four boxers concluded that relevant abnormality was present. This was a cyst in a single boxer, which was possibly congenital.[w23] No abnormalities were found in the single cohort study that used magnetic resonance imaging.[w15]

Finally, because of the short duration or "snapshot" design of nearly all studies (except that of longer follow-up cohort studies in which no detrimental effects were found[w1 w2 w5]), it is impossible to conclude whether or not longer exposure would have eventually led to chronic injury or whether such changes might present in much later life when further neuronal loss occurs with ageing.

Conclusions

Amateur boxing is becoming an increasingly popular participation sport, especially within universities and for both sexes. The safety of boxing is an issue that stimulates emotive responses on both sides of the debate, and calls to ban the sport continue. This review neither seeks to endorse nor oppose the sport of amateur boxing. It is perhaps a question of personal philosophy whether it is incumbent on boxing to prove that it is safe, or on those who oppose it to prove that it is deleterious (although it might be argued that those wanting to alter the status quo have the responsibility to prove this). Nevertheless, on the basis of this systematic review, we conclude that the current evidence, such as it exists, for chronic

WHAT IS ALREADY KNOWN ON THIS TOPIC

The safety of amateur boxing in terms of risk of chronic traumatic brain injury continues to be questioned

No recent or systematic review has been performed to assess the evidence for this

WHAT THIS STUDY ADDS

A systematic review of observational studies indicates that, although the quality of evidence supporting or refuting the hypothesis was poor, the association between amateur boxing and chronic traumatic brain injury is not strong

traumatic brain injury as a consequence of amateur boxing is not strong.

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Effectiveness of physiotherapy exercise after knee arthroplasty for osteoarthritis: systematic review and meta-analysis of randomised controlled trials

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ABSTRACT

Objective To evaluate the effectiveness of physiotherapy exercise after elective primary total knee arthroplasty in patients with osteoarthritis.

Design Systematic review.

Data sources Database searches: AMED, CINAHL, Embase, King's Fund, Medline, Cochrane library (Cochrane reviews, Cochrane central register of controlled trials, DARE), PEDro, Department of Health national research register. Hand searches: *Physiotherapy, Physical Therapy, Journal of Bone and Joint Surgery (Britain) Conference Proceedings*.

Review methods Randomised controlled trials were reviewed if they included a physiotherapy exercise intervention compared with usual or standard physiotherapy care, or compared two types of exercise physiotherapy interventions meeting the review criteria, after discharge from hospital after elective primary total knee arthroplasty for osteoarthritis.

Outcome measures Functional activities of daily living, walking, quality of life, muscle strength, and range of motion in the knee joint. Trial quality was extensively evaluated. Narrative synthesis plus meta-analyses with fixed effect models, weighted mean differences, standardised effect sizes, and tests for heterogeneity.

Results Six trials were identified, five of which were suitable for inclusion in meta-analyses. There was a small to moderate standardised effect size (0.33, 95% confidence interval 0.07 to 0.58) in favour of functional exercise for function three to four months postoperatively. There were also small to moderate weighted mean differences of 2.9 (0.61 to 5.2) for range of joint motion and 1.66 (−1 to 4.3) for quality of life in favour of functional exercise three to four months postoperatively. Benefits of treatment were no longer evident at one year.

Conclusions Interventions including physiotherapy functional exercises after discharge result in short term benefit after elective primary total knee arthroplasty. Effect sizes are small to moderate, with no long term benefit.

INTRODUCTION

The length of hospital stay after joint arthroplasty surgery has markedly and rapidly decreased.[1] Given that patients who undergo knee arthroplasty may still experience considerable functional impairment postoperatively,[2] the effectiveness of physiotherapy after discharge is a valid question. We systematically reviewed randomised controlled trials to determine the effectiveness of physiotherapy exercise after discharge in terms of improving function, quality of life, walking,