ORIGINAL ARTICLE

The risk of chronic traumatic brain injury in professional boxing: change in exposure variables over the past century

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Objectives: To determine if boxing exposure has changed over time and hence if current professional boxers are at the same risk of developing chronic traumatic brain injury (CTBI) as historical controls.
Design: Literature review of published studies and analysis of data of active professional boxers.
Subjects: Professional boxers in the United Kingdom and Australia.
Main outcome measures: Boxing history and participation in sparring and professional bouts.
Results: Since the 1930s, the average duration of a professional boxer's career has dropped from 19 years to five years, and the mean number of career bouts has reduced from 336 to 13. This is despite no significant decline in participation rates from 1931 until 2002.
Conclusions: The incidence of boxing related CTBI will diminish in the current era of professional boxing because of the reduction in exposure to repetitive head trauma and increasing medical monitoring of boxers, with preparticipation medical and neuroimaging assessments resulting in the detection of early and potentially pre-symptomatic cases of CTBI.

Professional boxing is associated with a risk of chronic neurological injury. The development of chronic neurological symptoms in this setting was originally referred to as the punch drunk syndrome.[1] This terminology has evolved over time and the entity is now termed chronic traumatic brain injury (CTBI).[2]

Although approximately one third of cases of CTBI are progressive,[3] the clinical evidence does not support the concept that this condition goes through a predictable and sequential series of stages. Rather, it is a constellation of symptoms affecting the pyramidal, cerebellar, and extrapyramidal domains. Cognitive impairment becomes the major neurological feature in the later stages of the condition.[4 5] Neuropsychiatric and behavioural symptoms occur variably throughout the course of the disease.[3 5]

Amateur boxers also show definite neurophysiological and neuroimaging evidence of CTBI. This, however, occurs at a lower incidence than in professional boxers.[6 7] The difference is presumably because of less exposure to repetitive head trauma, through shorter bouts, and the mandatory use of protective headgear.

There are few prospective studies of this condition that enable an epidemiological estimate of the prevalence of chronic boxing related neurological injury in either amateur or professional boxing. Many of the epidemiological studies in this area are retrospective or are case series studying specific radiological or pathological changes in retired boxers. As a result, all of these published studies suffer from major methodological flaws.[8–10]

The best estimate of the prevalence of boxing related CTBI is the prospective study of Roberts[3] in 1969, who randomly sampled 250 retired boxers from a total of 16 781 UK boxers registered between 1929 and 1955. All boxers were traced, and 224 were formally studied (16 died, nine emigrated, and one refused). In 37 (17%), lesions of the nervous system were detected using clinical examination, limited neuropsychological assessment, and the radiological techniques of that era, such as pneumoencephalography.

It is important to note that boxing in that era was unlike boxing today for a number of reasons. The striking feature is the difference in exposure. Boxers' careers in the 1930s to 1950s generally lasted 10–20 years, started in childhood, and often included more than 1000 professional fights. Many boxers after retirement from the professional ranks become professional sparring partners or tent/booth boxers, having up to 30–40 unsupervised bouts a day. Typically boxers had long amateur careers before turning professional. Fighters were not matched by skill or weight, had no medical supervision, and fought with 6 oz gloves. There was less willingness by ring officials to stop bouts when a boxer was overmatched, as well as longer bout duration (up to 40 rounds of two minutes). Furthermore there was no mandatory exclusion after a knockout or head injury. Because of the depression in the 1930s, financial reasons kept many boxers competing for long periods despite the documented onset of neurological symptoms.

The major risk factor cited for CTBI is prolonged exposure to repeated concussive and subconcussive head impact.[1 3 11 12] Hence boxers with long professional careers or boxers with limited defensive skills who repeatedly sustained heavy blows were said to be at the greatest risk of developing this condition. More recent studies suggest that there may be an additional risk factor, the ApoE-ϵ4 genotype.[5 8] It is proposed that the presence of these two risk factors together—exposure and ApoE-ϵ4 genotype—may be multiplicative rather than additive in terms of CTBI risk.[3]

The vast majority of documented CTBI case reports relate to boxers who boxed in the era between 1900 and 1950. Given the evolution in diagnostic neuroimaging sensitivity, one would expect these more sensitive measures to detect much higher rates of CTBI than previous behavioural observations. Further, it is widely noted in the lay press that boxing is less popular as a spectator sport than 50 years ago, yet little is known of boxing participation rates in the current era. If participation in professional boxing is decreasing and the opportunities for head impact exposure is correspondingly reduced, then the risk of CTBI should be minimised. It is therefore hypothesised that current professional boxers will have a lower incidence of boxing related CTBI than their historical counterparts.

Table 1 Boxing exposure from 1900 to 2002

Boxing era	Reference	Estimated era of fighters	N	Career length and boxing history	Average career length (years)	Average no of bouts	Range
1900–1955	Spillane[15]	1900–1930s	5	15–22 years; professional	22.2	287.5	200–350
	Mawdsley & Ferguson[10]	1915–1930s	10	12–36 years; booth and professional	14.3	227	100–600
	Corsellis *et al*[16]	1900–1940	15	11–35 years; amateur and professional	20.7	495	300–700+
	Roberts[3]	1929–1955	224	3–10+ years; professional	NA	NA	<50– 150+
1950–1995	Ross *et al*[17]	1950s–1970s	27	Unknown; professional	NA	27.5	1–100
	Casson *et al*[18]	1950–1970	18	1–22 years; professional	9.6	29	1–128
	Drew *et al*[19]	1980s	19	Unknown; professional	NA	13.7	0–37
	Jordan *et al*[21]	1990–1995	42	4–20 years; professional	9.5	10	0–36
2000–	Ravdin *et al*[20]	2002	18	Unknown; professional	5.3	15.4	1–56
	Hogg[9]	2002	277	1–32 years; professional	4.7	11.2	1–138

NA, Data not available.

The aim of this paper is to determine if boxing exposure has changed over time and hence if current boxers are at the same risk of developing CTBI as historical controls.

METHODS

Relevant studies were identified by searching Medline, PreMedline, Cinahl, SPORTDiscus, Ausport, Austrom, Health & Society, PsychINFO, and the Cochrane database. The search terms used included boxing or boxing and injury or injuries and boxing and head injury or head injuries. The reference lists of identified studies were also searched for relevant studies. Epidemiological studies reported in languages other than English were included where translations were available. Review articles, expert discussion, and bibliographies of major sources were used to provide additional articles.

Australian boxing demographic data were derived from the Australian Boxing Records.[9] This dataset has been compiled on an annual basis since 1996. The current edition provides a full history of all boxers registered and competing in Australia in the year 2002. Population figures for Australia in 2002 were obtained from the Australian Bureau of Statistics.[13]

Current UK professional boxer registration numbers were provided by the British Boxing Board of Control, and recent population figures were obtained from the British Census 2001, available online (www.statistics.gov.uk/census2001/profiles/uk). Historical boxing participant information was obtained from published studies and expressed as a rate of the male population in the relevant UK census years of 1931 and 1951.[14] The years 1931 and 1951 were selected, as there was no population census undertaken in the United Kingdom in 1941 because of the second world war. Information on the change in round numbers over the study period was obtained from the British Boxing Board of Control.

A number of attempts were made to obtain current numbers of professional boxer registrations in the United States. These included website analysis and personal communications with members of the New York State Athletic Commission, the Association of Boxing Commissions (ABC), and the ABC recognised record keeping association, Fight Fax. At present, there appears to be no accurate method of obtaining national boxing registration figures for the United States.

RESULTS

Boxing history

From the search strategy, only nine studies were identified as relating to professional boxing that provided sufficient demographic data for inclusion.[3 15–21] Table 1 summarises the extracted studies, and table 2 summarises them by era.

It can be seen that over the three eras of boxing presented in tables 1 and 2, the average duration of a professional boxer's career has dropped from 19 years to five years, and the mean number of bouts in a career has similarly reduced from 336 to 13. The current boxers[9 20] in table 2 refers to boxers who were registered and professionally active in 2002. This of course will provide an underestimate of total length of careers and boxing exposure, as the boxers had not yet retired at the time of study. Statistical analysis of these data (one tailed Student's *t* test) comparing average length of career from 1900 to 1950 with that of boxers registered and active in 2002 shows a significant difference at the 0.01 level.

Changes to the number of rounds per bout over the study period cannot be measured accurately. It is generally accepted that in the early 1900s to 1929, the number of rounds varied from 20 to 40. From the 1930s onwards, this dropped to 15 three minute rounds. In the early 1980s, the British Boxing Board of Control, in line with many world sanctioning bodies, such as the World Boxing Association, mandated a

Table 2 Summary of change in length of career and bouts across eras

Fight era	N	References	Average career length (years)	Range (years)	Average bouts	Range
1900–1955	254	3, 10, 15, 16	19	3–22	336.5	<50–700+
1950–1995	77	17, 18, 19	9.6	1–22	39.6	0–122
2000 – present	295	9, 20	5	1–32	13.3	1–138

Table 3 Comparison of relative participation in boxing over time

Country/year	Male population	No registered boxers	Boxers per 100 000 male population
UK/1931	22 060 000	592	2.79
UK/1951	24 118 000	481	1.99
UK/2002	28 579 869	814	2.84
Australia/2002	9 908 963	277	2.79

maximum of 12 three minute rounds. This is the maximum number of rounds permitted world wide today. Actual numbers of rounds per fight in current day boxing continues to vary, but presumably this variation occurs across countries.

Boxing participation

The total number of boxers who fought professionally in Australia in 2002 was 277. Of this number, 72% have had less than 11 bouts, 17% 12–25 bouts, 11% 25–50 bouts, and 0.7% more than 50 bouts. Not surprisingly, the two boxers with more than 50 bouts have had careers of 19 and 32 years.

Table 3 illustrates the comparisons for the relative historical boxing participation information where available from the United Kingdom and Australia. This is expressed as the number of registered professional boxers per 100 000 of the male population. Unfortunately, no accurate historical or current registration figures were available from the United States for comparison.

The figures in table 3 suggest that there has been no decline in participation rates from 1931 until 2002. The mean (SD) number of boxers over the entire period is 2.6 (0.4) per 100 000 of the male population.

DISCUSSION

Despite media perception that professional boxing is decreasing in popularity, our review of the available local and international data provides no support for the suggestion that relative participation in professional boxing has declined over the past 70 years. Comparison of registered boxers in the United Kingdom where there is long term documentation available indicates that boxing participation per head of population has not significantly changed over that period. The limited data from Australia on current boxing suggest that participation rates are similar to those in the United Kingdom, but a historical comparison is not possible. Owing to difficulties in determining accurate registration numbers, no equivalent US dataset exists to enable a similar analysis.

On the basis of the data presented in this paper, current exposure rates measured by the number of professional bouts and length of career are comparable across Australia,[9] New York,[20] and California.[19] This suggests a consistency of exposure variables, permitting future comparison and use of Australian figures in determining prevalence rates of chronic boxing related brain injury. Unfortunately, similar demographic data are not available from the United Kingdom.

Boxing exposure, as a surrogate for repetitive concussive and subconcussive head trauma, has long been considered a risk factor for CTBI. It can be seen that career length, round numbers, and the mean number of boxing bouts per career have steadily reduced over time. It follows therefore that the incidence of CTBI should similarly decrease, assuming that this is the only risk factor for this condition. Jordan *et al*[8] have proposed new criteria for high risk professional boxing exposure (12 bouts or more) and low risk boxing exposure (12 bouts or less). Boxers with high exposure are thought to be at greater risk of neurological and cognitive impairment, although this proposition has not yet been adequately tested.

Although a specific genotype has been postulated as an additional risk factor for CTBI, there is no scientific evidence to suggest that the incidence of ApoE-ϵ4 in the at risk boxing population has changed over the course of time.

An additional aspect of boxing exposure and one that is difficult to measure is sparring. There are few data on sparring history in either amateur or professional boxers, and sparring history may need to be factored into risk stratification methods as described above.[20]

Except for the current Australian boxing records, exposure data were obtained from the medical literature. We acknowledge that comparing statistical records with retrospective data has limitations secondary to sample bias in the latter. However, there seems to be little doubt that boxing exposure has declined over the century.

From these results, we conclude that the incidence of boxing related CTBI will diminish in the current era of professional boxers, as their exposure to repetitive head trauma is less in spite of the fact that boxing participation per head of population remains steady. In addition, we presume that, as the preparticipation medical assessments become increasingly sophisticated, detection of early and potentially pre-symptomatic cases of CTBI will be detected and the boxers counselled against future participation in boxing. Already in both the United Kingdom and the State of Victoria, Australia, preparticipation and serial magnetic resonance scans are mandatory, and, in Victoria, both ApoE genotyping and computerised cognitive screening are also required at initial registration and cognitive retesting on a three yearly basis.

Overall, the prevalence of CTBI among currently active and recently retired professional boxers remains to be determined. As has been previously noted, large scale epidemiological studies of well defined boxing populations using modern neurodiagnostic methods to assess the frequency of CTBI are non-existent.[5] Provision of accurate data becomes increasingly important as negative public opinion about boxing grows, along with concerns of long term risks of boxing and the need for boxers to meet ever more stringent registration requirements.

What is already known on this topic

- Professional boxing is known to cause CTBI, and boxing exposure, as a surrogate for repetitive concussion, is considered to be a primary risk factor
- The reported prevalence figures for CTBI are largely based on retrospective studies which have major methodological flaws or are drawn from populations in which exposure to the sport is anecdotally thought to be very different from today

What this study adds

- Boxing exposure, as measured by bouts and length of career, has decreased significantly over the century
- If this is assumed to be a primary risk factor, the incidence of boxing related CTBI should diminish in the current era, despite consistent participation rates

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COMMENTARY

One might expect that professional boxing is a dying art, but this is refuted by the findings of this paper. It is, however, encouraging to note the significant risk reduction in terms of exposure to head injury. This coupled with increased clinical, neuropsychological, radiological, and genetic monitoring and screening should, at least, have a significant effect on the incidence of chronic traumatic brain injury in this sport.

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