Cognitive dysfunction in young men following head injury in childhood and adolescence: a population study

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Objectives: To examine the prevalence of cognitive dysfunction among young men who had suffered a head injury during childhood or adolescence, in particular focusing upon the effects of age and the severity of the injury.

Methods: By cross linkage of Danish national registers for hospital admissions and the draft board, 3091 young men were identified who had been injured before age 18 and tested at age 18 or shortly thereafter: 970 had suffered a single concussion and were in hospital for one day only; 521 had two concussions at separate times and were in hospital for one day only on each occasion; 961 had a cranial fracture; and 639 had a cerebral lesion. For all of these, scores on the draft board's cognitive screening test were obtained, dichotomised as dysfunctional or non-dysfunctional. Prevalences of dysfunctional scores were compared with population base rates (about 20% of all Danish men appearing before the draft board had a score classified as dysfunctional).

Results: For young men who had suffered a single concussion, cranial fracture, or cerebral lesion before 12 years of age, resulting in less than 12 days of hospital admission (n = 376), rates of cognitive dysfunction did not exceed those in the general population (odds ratios < 1.4, NS), but the odds ratios became significant and > 1.4 where the injury occurred after age 11. For those with a cerebral lesion resulting in over 11 days of hospital admission (n = 263), all odds ratios were significant and ⩾ 2.0, irrespective of age at injury. For cases of two concussions, all odds ratios were > 1.4 but were not significant for all age groupings.

Conclusions: For milder forms of single head injury before age 12 there is no evidence of enduring cognitive dysfunction. The apparent effect at later ages may reflect predisposing psychosocial factors. For more serious injury, and for cases with two concussions, the effect is marked and not clearly related to age. For the former, this suggests enduring neurological effects of the injury; for the latter, where the effect is unrelated to time between injuries, predisposing factors may again play a role.

S evere head injury in childhood and adolescence has repeatedly been shown to result in cognitive dysfunction.[1] There remains, however, uncertainty over possible differential effects of age at injury, and earlier perceptions that recovery is better at young ages[2–4] are now questioned.[5–7] There have also hitherto been comparatively few studies that have examined the continuing consequences of pre-adult head injury on cognitive functioning in adulthood, and here too results have been conflicting.[8–10] With regard to mild head injury, most evidence points to substantial recovery of cognitive functioning within at most weeks, regardless of age,[11] although again some studies have suggested enduring consequences.[5 12 13] Especially complex is the not infrequent situation of repeated mild head injury, where cumulative effects have been reported.[14 15]

Most studies have employed comparatively small samples, not usually epidemiologically based. In the present study we have determined the prevalence of cognitive dysfunction in large and population derived numbers of young men who have sustained either severe or mild head injury in childhood or adolescence, including a group who have sustained two separate mild injuries.

METHODS

The study involved cross linking two national Danish registers, one concerning hospital admissions[16] and the other concerning conscription.[17] The link was made possible as both registers employ the same identity number.

Hospital admissions register

The Danish national computer register of hospital admissions has recorded data on all patients discharged from Danish hospitals since 1979. These data include admission and discharge dates, together with discharge diagnoses. Our own database was drawn from live discharges between 1979 and 1993, with any diagnosis indicating head injury. During this time period diagnoses were recorded according to the *International Classification of Diseases*, 8th edition (ICD-8). We defined four groups:

- *Single concussion*: patients who during the 15 year period had been admitted once to hospital for not more than one day and whose sole discharge diagnosis was concussion (ICD-8: 850);

- *Double concussion*: patients who on two separate occasions over the same time period had been admitted to hospital for not more than one day and on both occasions with the sole discharge diagnosis of concussion;

- *Cranial fractures*: patients who had been admitted to hospital with a discharge diagnosis of cranial fracture (ICD-8: 800, 801, 803), with or without concussion but without identified cerebral lesions;

- *Cerebral lesions*: patients who had been hospitalised with a discharge diagnosis of cerebral lesions (ICD-8: 851, 852, 853, 854) with or without cranial fractures or concussion.

Draft board register

There has been conscription in Denmark continuously since Word War II and at age 18 or shortly thereafter Danish men are required to appear before the draft board which assesses their suitability for military service. Uninterruptedly since 1957 the

Table 1 Dysfunctional scores (=fail) in relation to diagnosis group

Group	Age (years)	Admission (days)	Total (n)	Fail (n)	Fail (%)	Population (%)*	Odds ratio	95% CI†
Single concussion	0 to 5		157	31	19.7	19.0	1.05	0.71 to 1.55
	6 to 11		439	93	21.2	19.3	1.12	0.89 to 1.42
	12 to 17		374	97	25.9	19.7	1.42	1.13 to 1.80
Double concussion	Both 0 to 11		298	81	27.2	19.0	1.59	1.23 to 2.05
	0 to 11/12 to 17		162	42	25.9	19.3	1.46	1.03 to 2.08
	Both 12 to 17		61	17	27.9	19.6	1.58	0.90 to 2.78
Cranial fracture	0 to 5		299	63	21.1	18.9	1.14	0.87 to 1.51
	6 to 11		443	102	23.0	19.4	1.24	0.99 to 1.55
	12 to 17		219	60	27.4	20.1	1.50	1.11 to 2.02
Cerebral lesion	0 to 5	1 to 11	75	16	21.3	19.0	1.15	0.66 to 2.01
	6 to 11	1 to 11	166	40	24.1	19.2	1.34	0.94 to 1.91
	12 to 17	1 to 11	135	35	25.9	19.6	1.43	0.97 to 2.11
	0 to 5	12+	23	9	39.1	18.6	2.81	1.21 to 6.49
	6 to 11	12+	106	38	35.8	19.0	2.38	1.60 to 3.54
	12 to 17	12+	134	45	33.6	20.2	2.00	1.40 to 2.87

*Adjusted for secular trends between 1987 and 2001.
†Calculation based on a population of 25 000 (that is, the approximate annual intake of the Danish draft board).
CI, confidence interval.

assessment has included the administration of a group test for cognitive ability, the Børge Prien Prøve. The test comprises four timed subtests measuring logical, verbal, numerical, and spatial reasoning. In each subtest there are about 20 items and a total score 0–78 is computed.[18] Within the draft board's computerised register, a code is recorded indicating whether or not a test performance reached a criterion—namely at least 35 items correctly answered—that is considered adequate for conscription purposes. Performances below criterion are considered dysfunctional. About 10–12% of men are exempted from appearing before the draft board in person and therefore do not take the test, these being those who can document an illness or condition which would disqualify them from military service—for example, chronic asthma, extreme myopia, and various physical and mental handicaps. Danish men are automatically entered into the draft board's register when they become 18, and their records are deleted when they become 32. We conducted our search of the register in December 2001 to January 2002.

Patient selection

We selected our initial four patient groups, as defined above, from hospital admissions in the period 1979 to 1993 of male children and adolescents aged less than 18 years. In order to locate patients in the draft board register, however, we had to confine our groups to men born after 1968 (the records of men born earlier would have been deleted at the time of our search) and not later than 1981 (few men born later would yet have appeared before the draft board). Such men would thus have appeared before the draft board between 1987 and 2001.

Within these constraints we identified 12 172 patients with single concussion, 641 with double concussion, 1227 with cranial fracture, and 1008 with cerebral lesions. As the cross linking of the register had to be done manually, we randomly selected 1176 of the single concussion patients (about 10%). Thus, in all, 4052 patients entered the study. Among the cranial fracture group, 79% had been hospital inpatients for less than one week (median three days). The median period of hospital admission for the cerebral lesion group was 11 days (interquartile range 6 to 28).

Statistical analysis

Annual norm tables were obtained from the Danish draft board showing the percentages of dysfunctional test scores—that is, those falling below the 35 item criterion. Over the 1987 to 2001 period covered by our study there was some fluctuation in these percentages, with a generally declining rate from a high of 21.9% in 1987 to a low of 17.9% in 1998, this decline being consistent with a finding of an overall increase in test scores over that decade, reported elsewhere.[19] For diagnostic and other subgroupings we therefore calculated odds ratios using population rates adjusted for this annual fluctuation.

RESULTS

Of the 4052 patients, no record was found for 184 (4.5%). These would include deaths and emigrations after the injury, and proportions did not vary across the four groups. Of the remainder, 3091 (79.9%) had taken the draft board test, and 777 (20.1%) had been exempted. The overall mean (SD) age at testing was 19.4 (1.2) years and did not differ significantly between the four groups (p > 0.4). More subjects from the cerebral lesion group had been exempted (321, 33%) than from the other three groups (13–18%) ($\chi^2(3) = 151$, p < 0.001), and within the cerebral lesion group the proportion was higher for those who had been admitted to hospital for 12 days or more (229, 46%) than for a shorter period (92, 20%) ($\chi^2(1) = 78$, p < 0.001). However, exemption was unrelated to age at injury ($\chi^2(2) = 1.5$, p = 0.4).

Table 1 shows the odds ratios for dysfunctional test scores among the four diagnostic groups as a function of age at injury and, for the cerebral lesion group, as a function of duration of hospital admission. These are also shown in fig 1. In all cases the odds ratios were above unity, indicating increased rates of cognitive dysfunction scores. For the single concussion group, the odds ratios only reached significance where the injury had been sustained between the ages of 12 and 17 years. A logistic regression confirmed a significant negative association between age at injury and test performance (p = 0.04).

By contrast, the odds ratios for the double concussion group were significant where both injuries had occurred before the age of 12 and where one had occurred before 12 and the other between 12 and 17. The odds ratio for cases where both injuries occurred between 12 and 17 was not less than for the other two age groups, but did not reach significance, possibly owing to reduced statistical power from the smaller sample. A logistic regression revealed no significant relation between age as grouped here and test performance (p > 0.5). We found no effect for the time difference between the two injuries. Among 53 cases where the interval was under six months the odds
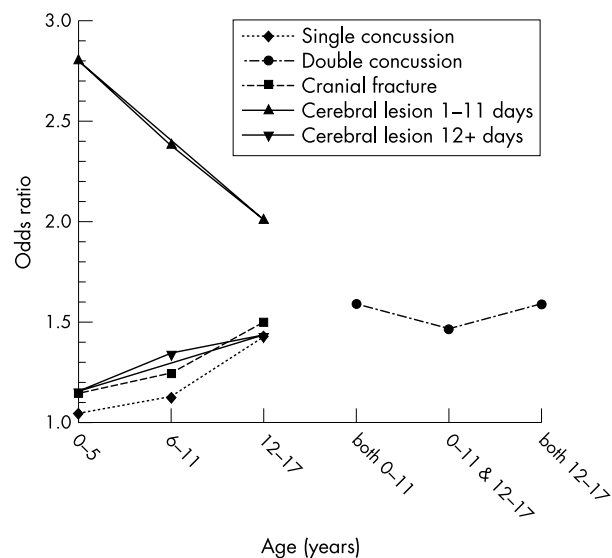
Figure 1 Odds ratios for cognitive dysfunction in relation to age and severity of injury.

ratio was 1.61 (95% confidence interval (CI), 0.89 to 2.94) and for the remaining 568 cases it was 1.54 (1.25 to 1.89).

For the cranial fracture group, only the odds ratio for the 12 to 17 year age range reached significance, and a logistic regression confirmed a significant effect of age (p = 0.02). There was a weak positive correlation between duration of hospital admission and age at injury for this group (Kendall's $\tau = 0.18$, p = 0.01). As shown in table 1, we divided the cerebral lesion group into those above and below the median number of days of hospital admission. For this group also there was a weak positive correlation between duration of hospital admission and age at injury (Kendall's $\tau = 0.15$, p = 0.01). None of the odds ratios for cases admitted to hospital for one to 11 days was significant, irrespective of age group. For those admitted for 12 days or more, all odds ratios were significant and were not less than 2.0. The odds ratio was also highest for the 0 to 5 age group, but there were few cases in this group and the confidence interval was correspondingly wide. Logistic regression analysis for the complete cerebral lesion group revealed a significant effect of duration of hospital stay (p = 0.024) but not of age at injury (p > 0.5).

DISCUSSION

There are two particular strengths of this study. First, it was population based and included all male head injured patients admitted to hospital within the age and calendar year limits. Second, the use of a population administered cognitive test for which full norms are available obviated the often problematic need for control groups. However, there are also some limitations which need to be considered in interpreting our results. First, being based on register data we have only limited information about the nature of the head injury, and for those with cerebral lesions we lack the widely used indices of severity, such as duration of post-traumatic amnesia which is well documented as having strong prognostic value.[20] Duration of hospital admission is only an indirect measure of severity, although we have shown elsewhere that it is a significant predictor of outcome.[21] Second, a high proportion (33%) of the cerebral lesion group was exempted from testing for reasons not available to us. We may thus be underestimating the effect of serious head injury by including only those well enough to be tested. A third limitation concerns the outcome measure. The Børge Prien test has been shown to correlate highly (0.85) with the widely used Wechsler adult intelligence scale,[22] and draft board tables for the last 10 years reveal that among

young men achieving dysfunctional scores, only 8% had attended, or were attending, "gymnasia"—the equivalent of sixth form colleges and the gateway to virtually all higher education in Denmark. For those achieving non-dysfunctional scores during the same period, the corresponding percentage was 54. Nonetheless, it is a global screening instrument and it lacks the discriminatory value of tailored neuropsychological batteries.[23 24] Finally, it should be noted that our study is necessarily limited to male subjects only. We are, however, unaware of any sex differences in the effect of head injury on cognitive dysfunction, and furthermore it should be noted that males account for about two thirds of head injuries during childhood and adolescence.[25]

Within these limitations, it is particularly striking, as shown in fig 1, that the odds ratios for three groupings—namely single concussions, cranial fractures, and relatively moderate cerebral lesions—are almost identical. For all three groupings there is no increase in the rate of cognitive dysfunction as compared with population base rates where the injury occurred before the age of six, and the increase rises to approaching 1.5 where the injury occurred at age 12–17 years. This finding is open to two interpretations. It might be that mild injuries in early childhood have less effect on adult cognitive functioning than injuries in adolescence, possibly because the severity of injury is less in younger children, where the injury typically results from falls, than in older children, where higher velocity injuries—often traffic related—are more common.[25 26] However, in the present study this has been controlled for in the concussion group by uniformly limiting the sample to patients admitted for at most one day, and among both the cranial fracture and the cerebral lesion groups the correlations between age at injury and duration of hospital admission were weak ($\tau < 0.2$). Alternatively, therefore, it might be that pre-injury risk factors for adolescents are more often associated with developmental, educational, and social disadvantage than in cases of childhood injury.[12] We have previously found that rates of cognitive dysfunction in young men sustaining concussion are greater where the injury occurred in their early 20s than where it occurred in their late teens.[27] Reanalysis of these earlier data revealed odds ratios of 1.29 (95% CI, 1.10 to 1.51) for 874 patients injured between ages 16 to19 and 1.85 (1.48 to 2.33) for 346 patients injured between ages 20 and 23. These results are also broadly consistent with a hypothesis of increasing psychosocial risk factors in the association between mild head injury and cognitive dysfunction with increasing age. One example of this would be the increasing involvement of alcohol and alcohol abuse in traumatic injuries with increasing age. Recognition of the potential effects of cognition related risk factors for traumatic brain injury is clearly important, as these can confound the association between the injury and any subsequently identified cognitive dysfunction.

In the case of subjects who had sustained double concussions, there was no relation with age at injuries and all odds ratios were about 1.5. Again two interpretations are possible. It could be, as has been suggested,[14 15] that there is a cumulative neurological effect of repeat concussions. Most recent studies have, however, focused on cases where two concussions have occurred within a few months of each other, as it is hypothesised that the brain recovering from one concussion is especially susceptible to enduring damage if a further concussion occurs.[28] However, we found no effect as a function of time difference between the two concussions, and this might suggest that here too predisposing factors have been operating.[29] This would imply that cognitive dysfunction related risk factors are independent of age among children who have repeated mild head injuries, but such a conclusion would require further supportive data on these comparatively little studied patients.

Regarding cases with severe cerebral lesions involving hospital admissions for longer periods, our study supports others

that suggest that children and adolescents with severe head injury are more likely to have cognitive dysfunction in early adult life.[8–10] Our present evidence also supports other findings indicating that the long term prognosis for cognitive functioning may not be better for children injured at an early age than later.[5–7] To the extent that psychosocial risk contributes to a greater degree with increasing age for severe cerebral lesions as well, our findings may be masking a more marked neurological effect of earlier injuries as compared with later ones.

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