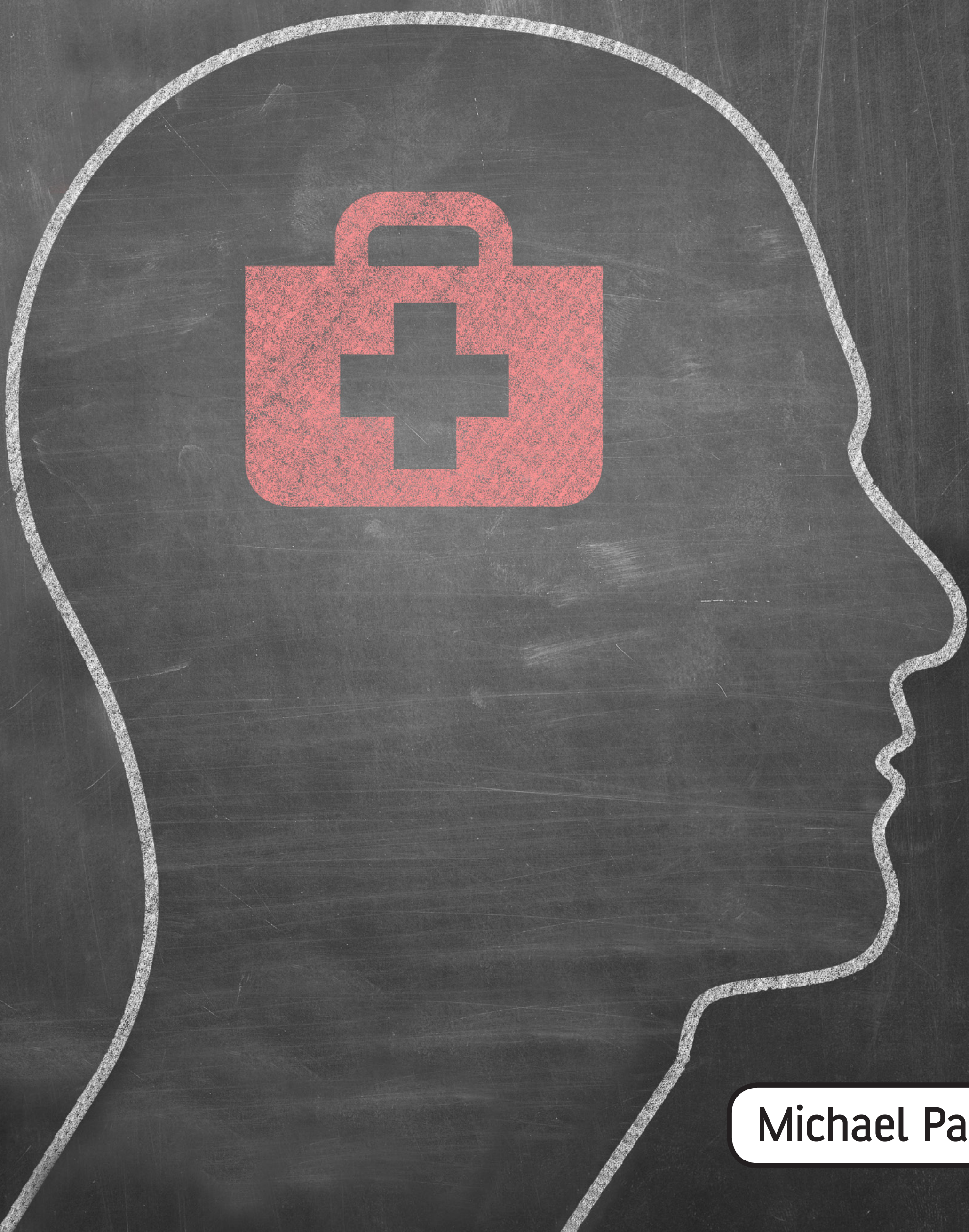
REPORT

Centre for Mental Health

Traumatic brain injury and offending

An economic analysis



Barrow Cadbury Trust

Michael Parsonage

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About the funder

The Barrow Cadbury Trust is an independent charitable foundation, committed to bringing about socially just change. We provide grants to grassroots community groups and campaigns working in deprived communities in the UK, with a focus on Birmingham and the Black Country. We also work with researchers, think tanks and government, often in partnership with other grant-makers, to overcome the structural barriers to a more just and equal society.

Executive Summary

Over a million people in this country live with the consequences of traumatic brain injury, at a cost to the economy of around £15 billion a year.

Funded by the Barrow Cadbury Trust as part of its Transition to Adulthood programme, this report presents an analysis of the costs of traumatic brain injury, with particular reference to the links between head injury and crime.

Traumatic brain injury (TBI), also described as head injury, is any injury to the brain caused by impact, for example a direct blow to the head or a force that causes the brain to move around inside the skull. Common causes are falls, road accidents, collisions and violence.

Head injuries vary greatly in severity, depending on whether and for how long they result in a loss of consciousness or post-traumatic amnesia. About 10-15% of all TBIs are classified as moderate or severe and the remaining 85-90% as mild.

The scale of traumatic brain injury

Population-wide estimates of the annual incidence of TBI in this country are based largely on hospital data, including numbers of attendances at A&E and numbers of inpatient admissions.

It is estimated that A&E departments in the UK see about 900,000 head injury presentations a year, including around 100,000 classified as severe.

Numbers of inpatient admissions in the UK are currently running at around 160,000 a year, with males accounting for the majority (62%). Rates of admission are highest among people aged 75+, but are also elevated among children, adolescents and young adults.

A significant proportion of head injuries result in continuing problems and it is estimated that there are up to 1.3 million people in the UK living with a TBI-related disability.

The consequences of traumatic brain injury

TBI is the leading cause of death and disability in people aged 1-40 in the UK. Possible non-fatal consequences include a wide range of physical, cognitive, emotional and behavioural effects, often of long duration and leading on to high unemployment, financial hardship, loss of independence and difficulties in maintaining relationships.

Outcomes vary greatly between individual cases, depending on the severity and frequency of injury, the area of the brain affected and the age of the patient. Injury at a young age can result in serious and long-lasting impairments in brain development.

A number of studies show that the risk of premature death among people with TBI remains elevated well beyond the initial post-injury period. One study found that 40% of all patients admitted to hospital for head injury were dead 13 years later. People aged 15-54 experienced a death rate nearly eight times the population average in years 2-13 after injury. Those with a mild injury were just as likely to die in years 2-13 as those with a moderate or severe injury.

Evidence from a range of sources shows a strong association between TBI and mental health problems, including substance misuse. To some extent this reflects a line of causation running from mental ill-health to head injury; for example, people dependent on alcohol are particularly prone to falls and other causes of TBI.

But equally it is clear that causation runs the other way as well, i.e. head injury is an important risk factor for poor mental health, roughly doubling the likelihood that someone with no prior psychiatric history will go on to develop a diagnosable mental health problem following an incident of TBI.

The costs of traumatic brain injury

Good-quality studies of the aggregate costs of TBI are few and far between, whether in this country or elsewhere, and those that are available vary considerably in methodology, coverage and findings. Because of major gaps in data availability, particularly relating to the large numbers of mild head injuries that do not result in hospital admission, these studies are also likely to result in the underestimation of aggregate costs, rather than the reverse.

Subject to these qualifications, analysis of cost estimates for the US, Australia and Europe suggests that in broad terms the overall annual cost of TBI in developed countries is equivalent to about 0.8% of annual GDP. Applying this ratio to the UK, the aggregate cost of TBI in this country may be estimated at around £15 billion a year.

Most of this cost takes the form of output losses in the economy resulting from the adverse impact of TBI on people's ability to work. Some of these losses are associated with premature mortality and some with continuing disability in survivors. The costs of health and social care for the victims of head injury are the next most important component in the total.

The estimate of £15 billion does not include any allowance for the human costs of TBI, corresponding to the negative effects of injury on people's wellbeing and quality of life. On any reasonable metric this is the biggest cost of head injury, but it is inherently difficult to quantify and value in monetary terms.

The links between traumatic brain injury and offending

There is much evidence to show that traumatic brain injury can in some cases lead to cognitive and behavioural changes such as impaired judgement, reduced impulse control and increased aggression which are well established as risk factors for involvement in criminal activity, including violent crime.

In terms of supporting evidence, studies from around the world show beyond doubt that the prevalence of TBI is far higher among convicted offenders than in the general population.

Central estimates are that about 60% of adult offenders (those aged 18+) and around 30% of young offenders (those aged under 18) have a history of TBI, often involving multiple injuries which evidence shows to have a cumulative impact.

These studies also show that offenders with a history of TBI are more likely than those with no such history to be prolific offenders and to have committed crimes involving violence.

The high prevalence of TBI in offending populations is clearly suggestive of a causal link between TBI and crime, but other mechanisms may also be at work, including the possibility that both head injury and offending have common underlying determinants.

Further evidence is therefore needed from longitudinal studies, particularly where these allow the identification of individuals whose first conviction occurred after rather than before a diagnosis of TBI, who can then be compared with matched controls in the general population.

Such studies confirm that traumatic brain injury is indeed causally implicated in offending to some degree, increasing the likelihood of crime by at least 50%. Effective measures to reduce the prevalence of TBI would therefore contribute to crime reduction as well as improvements in health and wellbeing.

The costs of crime

The overall level of crime in this country has been decreasing since the mid-1990s but continues to impose huge costs on individuals, taxpayers and society as a whole. Based on Home Office data, it is estimated that the aggregate economic and social cost of crime is currently around £70 billion a year (England and Wales only). Violent crime accounts for about 40% of the total.

Most crime is perpetrated by a small minority of prolific offenders who typically start their 'criminal careers' at an early age. Defining prolific offenders as those who commit six or more offences, it may be estimated that the lifetime cost of crime committed by a single prolific offender is in the range £1.3 – 2.3 million.

It was recently found that, due to high levels of reoffending, on average each young offender cost £8,000 a year to the criminal justice system and each of the 10% most prolific or serious offenders cost £29,000 a year.

Costs to the criminal justice system account for only about a fifth of the total costs of crime, most of which fall on victims. Allowing for this, the total societal cost of crime over the full ten-year period reaches nearly £1.5 million per young offender in the most costly 10%.

Pulling the threads together

Adolescence is a peak period for both offending and head injury, and it is also established that prolific offending, which accounts for the bulk of crime at the aggregate level, usually starts at a relatively young age. Adolescence thus provides a key opportunity for early intervention, covering both preventive measures and the early provision of evidence-based treatment for head injury, particularly among young people in the criminal justice system.

Two broad estimates are therefore provided of the long-term costs of TBI for an injury incurred at age 15. The first of these relates to cost per case for a representative 15-year-old in the general population and may be interpreted as a broad measure of the potential benefits of preventing a case of head injury at this age. In contrast, the second relates to cost per case for a 15-year-old with TBI who comes into contact with the criminal justice system and can be seen as providing a measure of the potential benefits of effective treatment and rehabilitation.

The long-term cost of traumatic brain injury is estimated at around £155,000 per case among 15-year-olds in the general population and at around £345,000 per case among young offenders. The big difference between the two numbers is entirely explained by differences in crime costs, which are much higher among those who have already embarked on a criminal career.

Non-crime costs are estimated at around £95,000 per case and are assumed to be the same in both groups.

It should be emphasised that because of limitations in data availability, all the cost estimates given in this report are subject to wide margins of error. They nevertheless suggest that effective measures to address head injury in young people, especially young offenders, have the potential to generate very significant benefits, both for individuals and for wider society.

Traumatic brain injury and offending

Key findings from the report

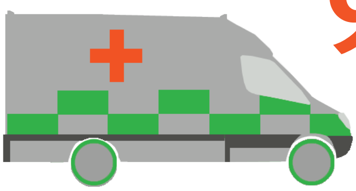
Having a head injury increases the risk of offending by at least **50%**

Head injuries cost the UK around **£15 bn** a year

X2

Having a head injury doubles the risk of developing a mental health problem

60% of adults in prison and **30%** of young offenders have a history of head injury.



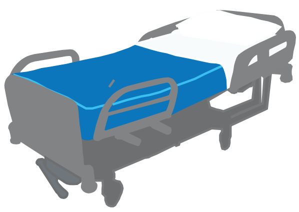
900,000

attendances a year at A&E for head injury

&

160,000

hospital inpatient admissions a year.



Chapter 1: Introduction

This report presents an analysis of the costs of traumatic brain injury (TBI), with particular reference to the links between TBI and crime. Traumatic brain injury, also described as head injury, is any injury to the brain caused by impact, for example a direct blow to the head or a force that causes the brain to move around the inside the skull. The work has been funded by the Barrow Cadbury Trust, as part of its Transition to Adulthood programme on young people in the criminal justice system.

A number of topics are covered in the report. First, Chapters 2 and 3 set out information on the scale and consequences of traumatic brain injury, highlighting such features as the relatively young age of many victims and the wide-ranging and long-lasting nature of the various disabilities that may result. Evidence is also presented on the extent to which TBI is a risk factor for premature mortality and for the development of mental health problems in survivors.

Chapter 4 then looks at the aggregate economic costs of TBI, focusing particularly on the losses of output that may result from the adverse impact of head injury on people's ability to work and on the costs to health and social services in relation to treatment, rehabilitation and long-term care.

The focus of attention shifts towards crime in the next two chapters. Chapter 5 explores the links between traumatic brain injury and offending, drawing on such evidence as studies reporting on the very high prevalence of head injury in offending populations and longitudinal surveys which allow further analysis of the complex causal relationships involved. For example, is head injury a cause of crime or is the high prevalence of TBI among convicted offenders rather explained by the fact that both head injury and crime have common underlying determinants?

Chapter 6 sets out some relevant information on the costs of crime, not just to the criminal justice system but to society as a whole. Particular attention is given to the very high costs of the 'criminal careers' pursued by persistent and prolific offenders, most of whom start offending at a young age.

Finally, Chapter 7 presents estimates of the long-term costs of a case of head injury: first, for a 15-year-old in the general population; and second, for a 15-year-old coming into contact with the criminal justice system. The first of these provides a broad estimate of the potential benefits of preventing a case of head injury in the adolescent population at large, while the second can be interpreted as a measure of the potential benefits to society of the effective treatment and rehabilitation of a young offender with head injury.

Chapter 2: The scale of traumatic brain injury

Introduction

Traumatic brain injury (TBI), also described as head injury, is any injury caused to the brain by impact and is distinguished from other forms of brain damage that result from natural causes such as strokes, tumours and meningitis. TBI may take the form of a direct blow to the head or penetration of the skull, for example by a bullet or knife, or a force that causes the brain to move around inside the skull. The most common causes of TBI are falls, road accidents, collisions and violence.

Traumatic brain injuries are conventionally categorised as mild, moderate or severe. A very mild injury, resulting in a brief concussion, rarely leads to any lasting brain changes, but the risk of permanent damage increases with signs of more severe injury such as being knocked out for a longer period of time or a deeper level of unconsciousness. The latter is usually measured by the Glasgow Coma Scale which assesses the extent to which a patient is able to respond to different stimuli. Severity may also be measured according to the duration of post-traumatic amnesia (the period of time after an injury that a patient is alert but unable to take in new information), while the extent of actual physical damage to the brain after an injury can be assessed by neuro-imaging.

In broad terms, a severe head injury may be defined as a condition in which the patient is unconscious for six hours or more, or experiences post-traumatic amnesia for 24 hours or more; a moderate injury is loss of consciousness for between 15 minutes and six hours or a period of post-traumatic amnesia of between one hour and 24 hours; and a mild injury is loss of consciousness for less than 15 minutes or post-traumatic amnesia of less than an hour. Again in very broad terms, the available data suggest that about 10-15% of all TBIs may be classified as moderate or severe and the remaining 85-90% as mild (Cassidy *et al.*, 2004).

Scale

Estimates of the overall scale of TBI can be made in two main ways, depending on whether they relate to incidence or prevalence. Incidence measures the numbers of recorded incidents of TBI which have occurred in a given period of time, usually one year but sometimes over longer periods such as all of childhood. In contrast, prevalence measures the overall numbers of people in the population who at a given date are experiencing disability caused by TBI, whenever the injury may have occurred.

Another relevant distinction is between the numbers of incidents of TBI and the numbers of individuals who are affected. The two are not necessarily the same, as some individuals experience multiple incidents. Indeed, a single TBI roughly doubles the risk of experiencing another injury and two TBIs increase the risk of a third injury eight-fold (Gaultieri and Cox, 1991). There is also evidence that multiple TBIs have a cumulative impact, implying that significant disability may result from repeated incidents even if each individual injury is relatively mild (Wrightson *et al.*, 1995).

Estimates of the scale of TBI vary between studies because of different case definitions of TBI and because of the use of different sources of data, the main distinction being between estimates based on hospital records (A&E attendances, inpatient admissions) and those based on population surveys. The former are likely to be more reliable in the coverage of moderate and severe injuries but less so in the case of mild injuries, as it is known that many individuals with minor concussion do not seek hospital treatment. Population surveys offer the prospect of broader coverage but suffer from problems of faulty recall, and findings may also be very sensitive to the way in which questions on brain injury are framed.

Population-wide estimates of the annual incidence of TBI in this country rely largely on hospital data. Dealing first with the numbers presenting at A&E, a recent NICE guideline on head injury cites an annual figure of 1.4 million attendances in England and Wales (NICE, 2014). Relative to population size, this looks to be on the high side when compared with equivalent figures in the US and in other European countries, and what appears to be the original source for the estimate (Machonochie and Ross, 2007) gives no details on how it was derived.

An alternative figure can be calculated from a detailed study of A&E attendances over a six-year period at the Royal Devon and Exeter Hospital (Yates *et al.*, 2006), which found that head injury presentations accounted for 3.4% of all attendances per year, of which 10.9% were classified as moderate or severe. Assuming that this is broadly representative of the national picture and relating it to a total of 22.4 million A&E attendances for all causes in England in 2014/15 (NHS England, 2015), the proportion of 3.4% implies a current figure of around 760,000 head injury presentations at A&E a year in England, including around 83,000 classified as moderate or severe. (Grossing up by population numbers, the equivalent figures for the UK as a whole would be around 900,000 and 100,000 respectively.)

Detailed data on hospital inpatient admissions for TBI covering the period 2000/01 to 2013/14 have recently been collated and analysed by Headway – the brain injury association (2015). Although less comprehensive than the data on A&E attendances, this source provides valuable information on trends over time and also gives detailed breakdowns by age and gender. Major findings are as follows:

- A total of 162,544 hospital admissions for TBI were recorded in the UK in 2013/14, equivalent to 254 cases per 100,000 population. Males accounted for 62% of these admissions and females for 38%.
- Rates of admission are highest among those aged 75+, but are also elevated among children, adolescents and young adults. The lowest rates are found among people in their 40s and 50s.
- Based on data for England only, admissions for TBI increased by 35% between 2000/01 and 2013/14. Adjusted for population growth, the overall rate of admissions per 100,000 population rose by 23%.
- Most of the increase in admissions occurred in the first part of the period, rising to a peak in 2009/10 with little change in the following years.
- There were striking differences in the pattern of change over time both by gender and by age. Concerning the first of these, the rate of admissions among males increased by just 10% over the period whereas among females it rose by 53%. Males still account for the majority of admissions, but their share of the total fell from 69% in 2000/01 to 62% in 2013/14.
- In relation to age, rates of admission among children and young people fell by around a quarter over the period; among adults of working age they remained broadly constant; and among people aged 65+ they more than doubled. Put another way, all of the overall increase in admissions for head injury recorded between 2000/01 and 2013/14 can be explained by higher rates of admission among older people, particularly those aged over 75.

The reasons for these major changes by gender and age do not appear to be well understood and they merit further research.

Concerning the incidence of TBI over periods longer than a year, a number of studies are available in the international literature, but with widely differing findings. For example, a cohort study of about 12,000 children born in Finland in 1966/67 found that, during the period from birth until the age of 15, 2.7% of male children in the cohort and 1.9% of the females had sustained a TBI (Timonen *et al.*, 2002). The estimates were based on the numbers who were admitted to hospital or visited an outpatient clinic and had a confirmed TBI in their medical records.

In contrast, a smaller birth cohort study in New Zealand, covering 1,265 children born in 1977, found incidence rates for TBI during the period from birth to age 25 of no less than

38.5% among males and 24.4% among females (McKinlay *et al.*, 2008). The data covered any head injury for which medical attention was sought, whether in primary or secondary care (i.e. covering GP visits as well as hospital A&E attendances and inpatient admissions), and were based on a combination of parent recall (up to age 16) and patient recall (age 16-25), cross-checked with medical records.

This study also found that:

- Based on the duration of loss of consciousness, 10% of all head injuries were classified as moderate or severe.
- A third of all recorded cases of TBI were admitted to hospital for observation or inpatient care.
- Males accounted for 71% of injuries that led to hospital admission and for 63% of those that did not.
- The incidence of TBI up to age 25 was lowest at ages 5-10 and highest at ages 15-25.
- Among all those with any TBI, 29% suffered two or more injuries.
- Falls were responsible for 67% of all injuries at ages 0-14 but for only 10% at ages 15-25, with sporting injuries, assaults and road accidents being the most common sources of injury in the older age range.

A third study has looked at the long-term incidence of head injuries in a community sample of just over 5,000 people aged 18+ living in New Haven, Connecticut (Silver *et al.*, 2001). All those in the sample were asked 'Have you ever had a severe head injury that was associated with a loss of consciousness or confusion?' No information was collected on when the injury occurred, whether medical attention was sought or whether the individual had suffered multiple injuries. On this basis it was found that, after adjustment for the over-sampling of elderly people in the study, 8.5% of the group had experienced a TBI at some time in their lives.

Finally, reference may be made to a prevalence study by the US National Center for Injury Prevention and Control which estimated that in 1996 some 5.3 million Americans (2.0% of the national population) were living with a TBI-related disability (Thurmann *et al.*, 1999). The figure was based on a statistical model incorporating data on incidence (numbers admitted to hospital for TBI each year), severity of injury and likelihood of disability, given a specific level of injury severity.

The estimate thus shows the numbers of people alive in the US in 1996 who had ever had a TBI that required hospitalisation and resulted in long-term disability. It is acknowledged in the study that this figure may be too low, as it does not account for disability among people with a TBI who were not admitted to hospital. Subject to this qualification, it may be calculated that if the population prevalence of 2.0% in the US were broadly the same in the UK, the numbers of people in this country living with a TBI-related disability would currently total around 1.3 million.

Chapter 3: The consequences of traumatic brain injury

Introduction

Traumatic brain injury is the leading cause of death and disability in people aged 1-40 in the UK (NICE, 2014). Possible non-fatal outcomes include a range of physical, cognitive, emotional and behavioural effects, reflected in such adverse consequences as deficits in memory, concentration, flexibility of thinking, problem-solving and planning, and increased levels of impulsivity, irritability, aggression, impatience, poor judgement, impaired insight and lack of concern for others. TBI is also an important risk factor for most forms of psychiatric disorder and substance misuse. The lifestyle changes that may in turn result from these various problems include unemployment, financial hardship, loss of independence and difficulties in maintaining relationships, together with a heavy burden on families and also on the exchequer in terms of the costs of treatment, rehabilitation and ongoing care.

Traumatic brain injury is a heterogeneous disorder, with many different forms of presentation, and outcomes vary greatly between individual cases. Such variation is most obviously explained by differences in the severity of injury, but other factors are also relevant, including:

- The area of the brain affected (for example, injury to the frontal lobes may be particularly damaging in its wider consequences, as this is where processes of high-level executive functioning are mainly located);
- The frequency of injury (as already noted, there is evidence that multiple incidents of TBI have a cumulative impact); and
- The age of the patient (in particular, the brain is rapidly growing during childhood, adolescence and early adulthood, and injury at a young age can result in serious and long-lasting impairments in brain development (Williams, 2013)).

Severity of injury is clearly a critical determinant of outcomes, particularly as an immediate cause of death, but the relationship is not always straightforward and there is growing evidence that the adverse consequences of mild injury may be more serious and persistent than previously thought.

To illustrate this, reference may be made to a study in Scotland which looked at levels of disability one year after head injury in a sample of 549 patients aged 14+ admitted to hospital with TBI (Thornhill *et al.*, 2000). Initial severity of injury was measured according to the Glasgow coma scale, while overall outcome at one year was assessed using a scale in which people rated as ‘severely disabled’ were unable to support themselves, those rated as ‘moderately disabled’ had significant restrictions in lifestyle or work capacity or both, and those rated as ‘good recovery’ had resumed their previous lifestyle.

Rates of good recovery one year after injury were estimated at 14% among those admitted to hospital with a severe head injury, 38% among those with a moderate injury, and 45% among those with a mild injury. As expected, good recovery was least common in those patients with the most severe injuries, but there was surprisingly little difference in outcomes between those with moderate and mild injuries, and the finding that over half of all patients admitted to hospital with an apparently mild head injury were suffering from moderate or severe disability a year later was not anticipated.

Follow-up studies of this sample at 5-7 years and 12-14 years after injury showed continuing high levels of disability among survivors (Whitnall *et al.*, 2006; McMillan *et al.*, 2012). Some individuals improved over time, but broadly equal numbers deteriorated, and in neither case was there any clear association with the initial severity of injury.

The remainder of this chapter looks in more detail at two specific risks associated with TBI, namely premature mortality and psychiatric disorder. The following chapter, on the costs of head injury, provides further information on the impact of TBI on employment and public expenditure, while the links between head injury and criminal activity are separately examined in detail in Chapter 5.

Premature mortality

It is well established that mortality after head injury, particularly severe injury, is high during hospital admission and in the following 6-12 months, but there is now evidence to show that the risk of premature death remains elevated well beyond this initial post-injury period. For example, a study based on longitudinal population-based registers in Sweden found that, among all those who survived a TBI for six months or more, the odds of premature mortality were 3.2 times higher than in a control group from the general population matched by age and gender (Fazel *et al.*, 2014).

The increased mortality risk persisted for many years after the TBI, still being three times higher than in the general population five years later. Risks of mortality from external causes, including suicide, injuries and assault, were particularly elevated and indeed about half of all the deaths that occurred more than six months after a diagnosis of TBI were due to these causes. There were strong associations between premature death and both psychiatric disorder and substance abuse.

Long-term mortality outcomes are also reported in a study of patients admitted to hospital for head injury in Glasgow in 1996/7, the main finding being that more than 40% of these patients were dead 13 years later (McMillan *et al.*, 2011). Not surprisingly the mortality rate was particularly high in the first year after injury, but still remained more than double the average among a matched community sample in years 2-13. Younger adults (those aged 15-54) were at particularly high risk, with a death rate nearly eight times the community average in years 2-13. A striking finding was that there was no association between the severity of head injury and survival outcomes beyond the first year after injury. In other words, patients with a mild injury were just as likely to die in years 2-13 as those with a moderate or severe injury.

A further study of the Glasgow sample focusing just on those with mild head injury has reported on outcomes 15 years after hospital admission and confirms that the risks of premature mortality among this group were much higher than in the general population, particularly among younger adults where the risk over the whole 15-year period was 4.2 times greater than among matched community controls (McMillan *et al.*, 2014). Repeated head injury was found to be a risk factor for death in the mild injury group, confirming the importance of cumulative effects.

Finally, mention may be made of a study of head injury and mortality among homeless people, again in Glasgow (McMillan *et al.*, 2015). This found that the occurrence of hospitalised head injury among homeless people was five times higher than in the general population. Hospitalised head injury was associated with a mortality rate over a seven-year period that was not only more than four times higher than in the general population, but also twice as high as in homeless people who had not experienced hospitalised head injury. The risk of death among younger homeless adults with head injury was no less than 17 times higher than in people aged 15-34 in the general Glasgow population.

Mental health problems

Evidence from a range of sources shows a strong association between traumatic brain injury and mental health problems. For example, the Connecticut study cited above on the lifetime prevalence of TBI provides similar data on the prevalence of various types of mental illness and this shows that 43% of all members of the sample who had a history of TBI also had at least one diagnosed mental health problem at some time, compared with only 20% among matched controls with no history of TBI (Silver *et al.*, 2001). In addition, 8.1% of the TBI group had made at least one suicide attempt compared with 1.9% of the comparison group. The lifetime prevalence of depression was 2.4 times higher than average in those with TBI, 2.1 times higher for obsessive compulsive disorder, 2.8 times higher for panic disorder, 1.8 times higher for drug abuse, 2.2 times higher for alcohol abuse, 1.8 times higher for schizophrenia and 1.4 times higher for bipolar disorder.

A similar picture is found in other studies, with estimates of the prevalence of mental health problems among patients with TBI ranging from 18% to 63% (Max *et al.*, 1998; Deb *et al.*, 1999). There is also evidence of high proportions with personality disorders - up to 39% (van Reekum *et al.*, 1996) - and high rates of psychiatric comorbidity - up to 44% of individuals with a TBI having two or more mental health diagnoses at the same time (Hibbard *et al.*, 1998).

The main limitation of such findings is that, although they establish a clear link between TBI and psychiatric disorder, they do not necessarily explain or clarify the nature of the underlying causal relationships. In particular, is mental ill-health mainly a consequence of brain injury or is it rather the case that those individuals who already have a psychiatric disorder are for one reason or another more likely to experience TBI? The latter explanation might be particularly plausible, for example in relation to alcohol abuse, as it is well established that people who drink heavily are prone to falls and to become involved in fights, both of which are major causes of TBI.

Further information is therefore needed on the temporal sequencing of events, in order to establish whether a high prevalence of mental health problems among patients with TBI is already apparent before injury or largely follows afterwards. If the latter, a number of mechanisms could explain the greater frequency of psychiatric illness, including the effects of the injury on brain functioning, the psychological effects of the accident (for example, post-traumatic stress disorder), or a reaction to the effects of other disabilities resulting from TBI.

A number of studies are available showing rates of psychiatric illness both before and after an incident of traumatic brain injury, and perhaps the main conclusion to be drawn is that causation runs in both directions. In other words, TBI is an important risk factor for psychiatric disorder, but equally pre-existing psychiatric illness is an important risk factor for TBI.

Two relevant studies may be cited. The first relates to a three-year follow-up study of a sample of patients aged 15+ living in Washington State who received hospital treatment for TBI occurring in 1993 (Fann *et al.*, 2004). This showed that the prevalence of psychiatric illness in the first year after injury was 49% among those with moderate to severe TBI, 34% among those with mild TBI and 18% in a matched comparison group. This confirms the strong association between TBI and psychiatric illness. However, it was also found that the relationship was significantly affected by whether the individual had experienced pre-injury mental health problems. Thus for those with no prior mental ill-health, the risk of such illness in the 12 months after TBI was 3.4 times higher than in matched controls for moderate to severe injury and 2.1 times higher for mild injury. In comparison, the risks for those with prior psychiatric illness were only 1.6 and 1.4 times higher respectively. Another interesting finding of this study is that while moderate to severe TBI was associated with a higher initial risk, the three-year follow-up data suggested that mild TBI may be associated with more persistent psychiatric illness.

Further relevant information is provided in the Swedish longitudinal study already cited in relation to the links between TBI and premature mortality, as this also gives data on psychiatric disorders over a 41-year period, distinguishing between diagnoses which preceded TBI and those which came afterwards (Fazel *et al.*, 2014). This found that, among all those with TBI, 9.3% had a mental health diagnosis which preceded their injury, compared with a rate of 3.9% in matched controls. In other words, among people with any pre-existing psychiatric diagnosis the risk of experiencing TBI was more than twice as high as in the rest of the population. (The increase in risk was nearly five-fold among those diagnosed with alcohol abuse, confirming this as a particularly potent risk factor for head injury.) However, it was also found that, compared with the rest of the population, those with TBI were at much higher risk of mental health problems after their injury – the rates of new diagnoses were 8.2% among those with TBI and 4.6% in the controls. (The equivalent numbers for alcohol abuse were 3.1% and 0.8%, indicating that just as alcohol abuse is a major risk factor for TBI, so TBI is a major risk factor for alcohol abuse.)

Finally, it is worth noting that even mild traumatic head injury experienced early in life may be associated with an increased prevalence of mental health problems which persist not only during childhood and adolescence but also into adult life. Three relevant studies may be cited, dealing with the mental health outcomes of childhood TBI in the short, medium and long term respectively.

The first is a follow-up study of a US sample of nearly 500 children aged 14 or under who sustained a mild TBI in 1993 (Massagli *et al.*, 2004). This found that diagnosable mental health problems were very common in the first three years after injury, occurring in 26% of those with no prior psychiatric history, compared with 16% in a matched control group not exposed to TBI. There was a particularly high risk of hyperactivity problems in the first year after injury.

The second study analysed data, collected in a New Zealand birth cohort study, on the mental health outcomes at ages 7-13 of mild traumatic brain injury experienced by children in their pre-school years (McKinlay *et al.*, 2010). This found that, especially among those who were hospitalised, mild TBI was associated with a range of negative effects on mental health persisting into adolescence, including increased numbers with conduct disorder, ADHD, substance abuse and mood disorders.

Finally, the third study used data collected in a Finnish birth cohort study to show the association between traumatic brain injury experienced in childhood (up to age 15) and psychiatric illness in adult life (up to age 31) (Timonen *et al.*, 2002). This found that, after controlling for other possible influences such as socio-economic background, TBI during childhood more than doubled the risk of psychiatric disorder in adulthood.

Chapter 4: The costs of traumatic brain injury

Introduction

As with the scale of traumatic brain injury, the aggregate economic costs of TBI can be measured in two main ways, corresponding to the distinction noted earlier between incidence and prevalence. An incidence-based approach takes all incidents of TBI occurring in the current year and then seeks to estimate the cumulative value of costs that are associated with these injuries, including not only costs incurred this year but also those arising in future years as a result of continuing disability. In contrast, a prevalence-based approach measures only those costs relating to TBI which are incurred in the current year, but relates this assessment not just to injuries occurring this year but also to all those which happened in the past to the extent that these have resulted in ongoing disability.

In effect, the distinction is between a forward-looking approach and a backward-looking one, with both methods seeking to capture a key dimension of TBI, namely that its adverse consequences and hence its economic costs may extend over many years, even a lifetime in the case of severe injuries suffered in early childhood. Under certain rather restrictive assumptions, the two approaches will give the same answer, although in practice this is unlikely. There is no strong theoretical reason to prefer one method over the other, but it is worth noting that the incidence-based approach provides cost information that is more directly relevant to the economic evaluation of interventions addressing TBI through prevention or improved treatment.

To take a simple example, suppose it is proposed to introduce a new road safety programme costing £X million a year, which is forecast to reduce the national incidence of TBIs by 1% a year. Whether the programme is good value for money from an economic perspective will depend on whether 1% of the aggregate cost of TBI is more than £X million. As this example shows, estimates of the economic costs of TBI may be useful not only as an indicator of the overall scale and burden of the problem, but also as a measure of the potential benefits of effective intervention, on the logic that a cost saved is a benefit gained.

Whichever method of calculation is used, the main categories of cost covered in the estimates include some or all of the following.

- The costs of health and social care associated with the treatment, rehabilitation and on-going support of people with TBI; in some cases this may include an imputed value of the costs of informal care provided by family and friends.
- Output losses in the economy resulting from the adverse impact of TBI on people's ability to work, with a distinction often drawn between output losses associated with premature mortality and those linked to disability in survivors.
- Any other costs linked to the wider consequences of TBI such as increased prevalence of mental health problems.
- The human costs of TBI, i.e. the adverse effects of injury on people's wellbeing and quality of life.

Most people would say that the last of these is the most important cost of TBI, but it is rarely included in costing studies, mainly because of difficulties of valuation. Only one of the studies described below has sought to address these difficulties and interestingly it finds that human costs are indeed the largest single component, accounting for well over half of total costs. (A similar finding has been reported in studies of the aggregate costs of mental illness; see, for example, Centre for Mental Health, 2003.)

The costs of TBI may also be categorised according to the groups or sectors in society which bear these costs. The usual breakdown is between: costs falling on the individuals directly affected by TBI, such as reduced quality of life and lower earnings; costs to the exchequer, including not only increased spending on health and other public services but also lower tax receipts and higher spending on social security benefits (mainly linked to the adverse effects of TBI on employment); and costs falling on the rest of society, such as the costs of informal care.

A search of the published literature reveals that good quality studies of the aggregate costs of TBI are few and far between. The findings of four such studies are summarised below, two relating to the US, one to Australia and one to Europe which includes separate figures for the UK. All of these except the last are incidence-based.

US studies

The aggregate costs of TBI in the US have been estimated at $38 billion in 1985 (Max *et al.*, 1991) and $60 billion in 2000 (Finkelstein *et al.*, 2006). Both studies use very similar methods and they also produce very similar results, because if the earlier estimate is increased to allow for general inflation between 1985 and 2000 it comes out very close to $60 billion.

Focusing on the first of these studies, this based its cost estimates on a total of nearly 333,000 cases of head injury occurring in 1985 which resulted in hospitalisation or death. In terms of severity, 65% of cases were classified as minor, 14% as moderate and 10% as severe, with the remaining 11% being fatalities.

Two main components of cost were estimated, namely health care and output losses. This resulted in the following breakdown of total costs: health care 12%, output losses resulting from premature mortality 34%, and output losses linked to short- and long-term disability among survivors 54%.

Average lifetime cost per case of head injury was estimated at $115,000 in 1985 dollars. Converting to 1985 £s using a purchasing power parity exchange rate and then increasing in line with average earnings in the UK since 1985, the figure is equivalent to just over £250,000 in today's value in this country. (The increase in line with earnings is justified because nearly all the estimated costs take this form.) Measured on the same basis, the average lifetime cost of health care per case of head injury comes out at around £30,000.

In relation to severity, cost per case was estimated at $77,000 for minor head injury, $81,000 for moderate injury and $141,000 for severe injury, while the cost of a fatality was put at $357,000.

In relation to age, cost per case ranged from a high of $172,000 among those aged 15-44 to a low of $28,000 among those aged 75+. People in the age range 15-44 made up half the number of cases but accounted for three-quarters of total costs.

Finally, a comparison was made with the costs of other types of injury and this found that head injury accounted for 13% of all injuries in the US in 1985 but for 29% of all injury-related costs. The high proportion of overall costs attributable to head injury reflected a number of factors, including the relatively young age of many victims, a high fatality rate compared with most other injuries and the long-lasting nature of disability among survivors.

Various limitations were acknowledged in this study. First, the estimated costs of mild head injury are too low because they relate only to the minority of cases which result in hospitalisation. Second, the costs of health care are also underestimates, as they relate very largely to immediate treatment costs, with very little information being available on the longer-term costs of rehabilitation, residential care and community support. And third, no allowance is made for the costs of informal care.

Australian study

This is a detailed study of the costs of moderate and severe TBI in Australia in 2008, based on an analysis of 2,493 cases (Access Economics, 2009). Around 60% of these cases were classified as moderate, but even among this group nearly a quarter died within a year of injury, suggesting that the sample as a whole was very much towards the severe end of the spectrum. The coverage of costs is broader than in the US study just described, including detailed estimates of the costs of long-term care including informal care, and also an estimate of quality-of-life costs.

Converting the cost figures from 2008 Australian dollars to 2008 UK £s using a purchasing power parity exchange rate, it is estimated in this study that the average lifetime cost of moderate/severe TBI was around £1.5 million per case. In proportionate terms this breaks down as follows:

- Quality-of-life costs 60%;
- Costs of health and social care including informal care 25%;
- Output losses resulting from disability and premature mortality 15%.

Leaving aside the quality of life component, average lifetime costs come to around £600,000 million per case. This is clearly much higher than the equivalent US figure noted above (around £250,000 in today's prices) and there is also a major difference in the relative importance of health and social care costs on the one hand and output losses on the other. A large part of the explanation for these differences is that 65% of the US sample were classified as having mild injury against none in the Australian sample. This clearly increases average cost in the latter, particularly in relation to the costs of health care.

Another reason is that the Australian study included detailed estimates of the long-term costs of informal care, which are largely ignored in the US study. This turns out to be an important omission, as the Australian data suggest that long-term care accounts for about three-quarters of all health and social care costs for moderate/severe TBI.

Concerning output losses, the proportion of the total attributable to premature mortality is higher in the Australian study, because of the higher rate of mortality in the first year, while among survivors it was found that the likelihood of employment after injury in this group was 28%, compared with an employment rate of 64% in the general population of working age in Australia.

Quality of life costs were assessed by estimating the total number of quality-adjusted life-years (QALYs) that were lost because of TBI, covering both premature death and disability among survivors, and then multiplying this by a monetary value of a life-year estimated at $158,000 in 2008 Australian dollars, equivalent to around £72,000 in 2008 UK £s. This looks to be very much on the high side, for example when compared with the value of £20,000-30,000 used in this country by NICE when assessing the cost-effectiveness of health service interventions.

Finally, it may be noted that the total costs of TBI, including quality-of-life costs, were estimated to be distributed between different groups in society as follows: costs to individuals at 65%, costs to the public sector at 30% and costs to the rest of society at 5%.

European study

Estimates of the costs of traumatic brain disorder in the UK in 2010 are available as part of a much wider study of the costs of all brain disorders in Europe, commissioned by the European Brain Council. Findings of this study are summarised in Olesen *et al.* (2012) and described in more detail in Gustavsson *et al.* (2011).

The main distinguishing feature of this study is that it uses a prevalence-based approach to costing. Thus, in contrast to the estimates given above, which show the cumulative lifetime costs of all incident cases of TBI in a given year, the figures in the European study show the costs of TBI incurred in a single year (2010), relating to both new and past cases where the latter have resulted in continuing disability. The European estimates thus cover a larger number of cases but at lower average cost per case, as only one year's costs are included. In terms of the coverage of costs, the figures include the costs of health and social care (including informal care) and of output losses resulting from short- and long-term disability but not from premature mortality.

Results for the UK show that, after conversion from euros to £s, the aggregate cost of TBI in 2010 amounted to £5.1 billion. This is based on 452,000 cases of TBI, including 145,000 occurring in 2010 ('incident cases') and 307,000 occurring over the previous 20 years with continuing disability ('prevalent cases'). The estimate for incident cases appears to be based on the numbers admitted to hospital for TBI.

Average cost per case in 2010 works out at £11,340. A breakdown of this by category of cost is not available for the UK, but figures for Europe as a whole indicate that the costs of health care account for 31% of the total, other care costs including informal care for 10% and output losses for 59%.

Again using figures for Europe as a whole, it appears that average cost per case is much the same comparing incident and prevalent cases. This is however rather misleading, as more detailed analysis shows that at any given level of severity (mild/moderate/severe), average cost per case for incident cases is about twice as high as for prevalent cases. This is mainly because the costs of health care are heavily concentrated in the year of injury. For example, among those with severe injury, health costs account for 68% of total costs among incident cases but for only 16% among prevalent cases. On the other hand, taken as a whole, the group of prevalent cases contains a relatively higher proportion with moderate or severe injuries, as these are the ones most likely to cause continuing disability, and this serves to push up the group's average cost.

Analysis

It is clear from this brief review that estimates of the aggregate cost of TBI vary greatly between studies in terms of methodology, coverage and findings. It may also be argued that, in so far as all studies have their limitations, these are likely to result in the underestimation of costs rather than the reverse. One obvious reason for this is the incomplete coverage of mild head injuries in the data sources commonly used, such as hospital records. Another relates to premature mortality, where the usual convention is to record all TBI-related deaths in the first year after injury but then to assume that the mortality rate among survivors reverts to the general population average. As seen in Chapter 3, there is now good evidence to show the risk of premature death remains elevated well beyond the initial post-injury period, especially among people in the younger age groups.

The three studies reviewed above produce the following estimates of the aggregate cost of TBI: in the US, $38 billion in 1985; in Australia $8.6 billion (Australian dollars) in 2008 if quality-of-life costs are included and $3.7 billion if they are excluded; and in the UK £5.1 billion in 2010. Clearly these numbers cannot be directly compared, as they relate to very different population sizes as well as different time periods and currencies. It is however possible to make a simple adjustment for all these factors by expressing the cost of TBI as a percentage of national income in each country for the year concerned.

To make the figures on this basis as comparable as possible, it is proposed to focus just on financial costs and thus exclude the quality-of-life costs estimated in the Australian study. This is not to downplay the importance of these costs, which are clearly central to any assessment of the overall burden of TBI. Rather, it is an acknowledgement that there is not yet an international consensus on how these costs should be valued in monetary terms. The figures on aggregate cost given below should therefore be interpreted as a measure of the costs of TBI over and above the profound negative impact of this condition on the quality of life of those affected and their families.

The aggregate financial costs of TBI expressed as a percentage of GDP in the year concerned for each country are as follows: US 0.815%, Australia 0.351%, UK 0.328%. The figures for Australia and the UK are thus very similar but both are less than half the US equivalent. Given that the focus of this report is on TBI in the UK, does this finding imply that the estimate of cost for the UK given in the European study is broadly acceptable or does the US evidence suggest that it is too low?

It is beyond the scope of this study to undertake a detailed reconciliation of the three estimates, but it is worth noting that differences between them are of two broad types: those relating to the number of cases of TBI (relative to population size) and those relating to average cost per case. Following on from this, it also appears that the higher GDP ratio found in the US estimate is mainly because of differences of the first type rather than the second. Indeed, concerning the latter, there are good reasons for thinking that the US figures for average cost per case are in some respects too low, for example because of the omission of long-term care costs including informal care.

Concerning the numbers of cases of TBI, the Australian figure is clearly an underestimate to the extent that this study focuses just on moderate and severe cases. But even on these terms the numbers are very low and it turns out that they are based not on the incidence of TBI in Australia as a whole but on incidence in the state of Victoria. (The reason for this choice of data is that the costing study was commissioned by the state government of Victoria, even though the findings are presented as national estimates.)

Information given in the report shows that the incidence of moderate and severe cases of TBI in Victoria in 2008 was only 45% of the national average. If the national figures are used instead, as indeed they should be, the estimated GDP ratio in Australia increases to 0.78%, which is now close to the US equivalent.

Concerning the UK cost estimate, it was noted above that this is based on a total of 452,000 cases of TBI, including 145,000 incident cases (new cases in 2010) and 307,000 prevalent cases (past cases from 1991-2009 with continuing disability). The first of these is based on numbers of hospital admissions for TBI, which is the same approach as used in the US costing study. However, the estimate of prevalent cases looks very low, implying rates of recovery from head injury which look implausibly high in the light of some of the evidence reviewed in this report. For example, reference was made earlier to a Scottish study showing that over half of all patients admitted to hospital with mild head injury were suffering from moderate or severe disability a year later, with even higher rates among those with moderate and severe injury.

The total of 452,000 cases in the UK may be compared with the estimate of 1.3 million given in Chapter 2 above as a broad measure of the overall prevalence of TBI in this country including new cases in the current year. This was derived from a US prevalence study and would clearly be too high if other evidence suggests that the frequency of head injury is higher in the US than in this country. In fact, the opposite appears to be the case, as recorded rates of emergency department attendances and hospital admissions for TBI per 100,000 population in the US are both well below those in the UK.

If the UK cost estimate is adjusted so that it is based on 1.3 million cases, the GDP ratio increases to 0.934%, which again is fairly close to the corresponding figure in the US. Revised ratios for the three studies are therefore: US 0.815%, Australia 0.78%, UK 0.934%.

As a final step, it may be noted that the Treasury's latest out-turn estimates indicate that the total value of GDP for the UK in 2015 is £1,882 billion (HM Treasury, 2015). The UK ratio of 0.934% would thus imply an estimate of £17.6 billion for the aggregate cost of TBI in 2015, while application of the other two ratios would give figures of £15.3 billion and £14.7 billion respectively. A conservative central figure of around £15 billion seems appropriate as a broad order of magnitude for the aggregate cost of TBI in the UK.

It should be emphasised that for many reasons this is at best a rough ball-park figure. If anything, it is probably an underestimate, for the reasons given above, but much more analysis and much better data are needed to produce a more reliable figure.

Chapter 5: The links between traumatic brain injury and offending

Introduction

Evidence from individual case studies going back to the early 19th century shows that traumatic brain injury can sometimes lead to cognitive and behavioural changes such as impaired judgement, reduced impulse control and increased aggression which are well established as risk factors for involvement in criminal activity, including violent crime. This chapter explores in more detail the nature of the relationship between TBI and offending, drawing on two main types of evidence.

The first of these is evidence on the prevalence of head injury among convicted offenders, which shows beyond doubt that a history of TBI is far more common in this group than in the general population. A strong association is thus demonstrated by such evidence, but not necessarily a direct causal link running from TBI to crime. For example, it is possible that there are common underlying factors such as personality traits or socio-economic deprivation which result in the same individuals being simultaneously at increased risk of experiencing head injuries and becoming involved in criminal activity.

Further evidence, drawn from birth cohort studies or other longitudinal data sets relating to representative population samples, is therefore needed to analyse the relationship between TBI and offending in more detail, taking into account the temporal sequencing of events and the influence of potential confounding variables such as family background.

Rates of traumatic brain injury among offenders

Dealing first with adult offenders (i.e. those aged 18+), published prevalence studies from around the world show that between 25% and 87% of offenders report having sustained a traumatic brain injury at some time in their lives. This is a wide range, partly reflecting different definitions of TBI, and a central estimate is provided by a recent meta-analysis of 20 studies that meet pre-established criteria for inclusion (Shiroma *et al.*, 2010).

The analysis finds an overall estimated prevalence of TBI in adult offender populations of 60.2%. Seventeen of the 20 studies include a definition of TBI as head injury with loss of consciousness and the overall prevalence of TBI among offenders measured on this basis is put at 50.2%. For comparison, perhaps the best available estimate of prevalence in the general population is the figure of 8.5% given in the US study by Silver *et al.* (2001) cited in Chapter 2 above. Using these figures, the prevalence of TBI among offenders thus appears to be six or seven times higher than in the population generally.

The majority of studies included in the meta-analysis are from the US, so it may also be helpful to refer to two individual studies which relate specifically to the UK. The first of these analysed information on a sample of 196 prisoners in a local Category C prison in the West Country and found that 60.7% reported a history of head injury, very close to the international average (Williams *et al.*, 2010). It was also found that in comparison to the rest of the sample, those with head injuries were significantly younger when first convicted of a criminal offence and they reported higher rates of reoffending and more time spent in prison during the previous five years.

The other UK study relates to a sample of 613 men screened on admission to HMP Leeds and found that 47% reported a history of TBI (Pitman *et al.*, 2015). Of these, 76% had experienced more than one TBI and 30% had experienced more than five TBIs. It was also found that:

- 70% of those with a history of TBI experienced their first injury before they committed their first offence;
- 41% of those who reported TBI were under the age of 18 when they committed their first offence, compared with 20% of those with no TBI;
- 44% had been in prison on five or more occasions; and
- 60% reported having committed a violent offence, compared with 38% among those with no history of TBI.

Turning to young offenders, less information is available on the prevalence of TBI in this group, but the findings from nine available studies (seven from the US, two from the UK) have been brought together in a meta-analysis, covering 1,524 juveniles with an average age of 15.7 years (Farrer *et al.*, 2013). A history of TBI was reported in 30.7% of the combined sample.

This is only half the average rate found among adult offenders, the most obvious explanation being that younger offenders have simply had less time to sustain a head injury. There is, however, a further possibility relating to the evidence noted above, that offenders with TBI report higher rates of re-offending than those with no such history. Adolescence is the peak age for involvement in criminal activity, but many young people who offend do so only once or twice. The fact that young offenders with TBI are more likely to become persistent offenders implies that the prevalence of head injury in offending populations is likely to rise with age.

As noted, two of the nine studies covered in the meta-analysis relate to the UK. One of these is based on a very small sample, but the second is a larger study covering 186 young male offenders aged 11 to 19 years (Williams *et al.*, 2010). This found that the prevalence of TBI with loss of consciousness was 46%. Other findings include the following:

- Repeat injury was common, with 32% of the sample reporting more than one injury with loss of consciousness.
- Frequency of self-reported TBI was associated with more convictions.
- Three or more self-reported TBIs were associated with greater violence in offences.
- Those with self-reported TBI had more convictions than those with no history of head injury.

Evidence from longitudinal studies

The high prevalence of head injury in offending populations is clearly suggestive of a causal link between TBI and crime, but – as noted above – other mechanisms may also be at work, including the possibility that both head injury and offending have common underlying determinants. Evidence from longitudinal studies which are rich in relevant contextual data such as demographic background provides a further means of exploring the relationship. The findings from three such studies are summarised below.

The first of these is the Finnish birth cohort study cited in Chapter 3 which collected data on traumatic brain injury experienced in childhood and related this to a range of outcomes in later life including psychiatric illness and offending (Timonen *et al.*, 2002). As already seen, this found that, after controlling for a range of other possible influences such as socio-economic background, TBI during childhood more than doubled the risk of psychiatric disorder in adulthood. The risk of becoming involved in criminal activity was increased by a factor of 1.6, and there was also found to be a four-fold increase in the risk of being part of a sub-group of adults with mental health problems and co-existing criminality. In addition, those who had a head injury earlier than age 12 were found to have started committing crimes significantly earlier than those who had a head injury later, indicative of a causal link between TBI and crime.

The second study used whole-population data linkage to identify individuals born in Western Australia between 1980 and 1985 who were treated in hospital for a TBI between 1980 and 2006 and then to compare these cases with matched individuals in the general population with no history of TBI (Schofield *et al.*, 2015). In order to analyse the links with offending, the study included only those individuals whose first conviction occurred after their first diagnosis of TBI. Comparisons were also made with same-sex siblings with no record of head injury, as a way of allowing for family-related factors such as genetic susceptibility and early environmental effects.

Relative to general population controls, TBI was found to increase the likelihood of subsequent conviction for any type of criminal offence by a factor of 1.58 for males and 1.52 for females. For violent offences, the corresponding increases in risk were 1.65 and 1.73 respectively. The comparisons with siblings produced broadly similar results, with slightly higher increases in the likelihood of offending among males but not among females. The study concludes that these findings are "consistent with a causal relationship between TBI and subsequent criminal convictions, and convictions for violence in particular, in both sexes".

The third study used combined data in Swedish population registers from 1973 to 2009 and examined associations between traumatic brain injury and subsequent violent crime, defined as convictions for homicide, assault, robbery, arson, any sexual offence and illegal threats or intimidation (Fazel *et al.*, 2011). As in the Australian study, comparisons were made both with matched controls in the general population and with siblings. The study found that 8.8% of all individuals with traumatic brain injury committed violent crime after diagnosis, corresponding to a more than threefold increase in risk compared with population controls. In contrast to the Australian study, this increase was significantly reduced when TBI cases were compared with unaffected siblings, with the likelihood of violent crime increasing by a factor of 2.0.

A limitation of the published Swedish study is that it relates only to violent crime, and it is also the case that individuals were not excluded from the analysis if they had been convicted of a crime before the occurrence of TBI, although only convictions after the injury were counted. Further analyses of the Swedish data have therefore kindly been undertaken by Professor Fazel and his colleagues specifically for this report, relating to all types of offending committed by individuals who experienced a traumatic brain injury in childhood or adolescence.

Three measures of offending were analysed: prolific offending (committed four or more offences); ever imprisoned (as an indicator of serious crime); and ever convicted of violent crime. Relative to matched population controls, the likelihood of offending by people with TBI exceeded the expected level by the following factors: prolific offending 1.96, ever imprisoned 2.17 and ever convicted of violent crime 2.36. In terms of offending rates, it was found that 8.9% of all those who experienced TBI in childhood or adolescence subsequently became prolific offenders, 1.8% were imprisoned at some point, and 8.3% were ever convicted of violent crime.

Conclusions

Taken as a whole, the evidence summarised in this chapter establishes that traumatic brain injury is causally implicated in offending behaviour to some degree, particularly in relation to persistent offending and crimes involving violence. At the same time the relationship is a complex one and difficult to quantify with any precision. Wider research on criminal behaviour points to multiple, probably interacting, causal factors and the role of head injury is best seen in this context. As already discussed, TBI is often linked to other problems such as mental illness and alcohol and drug misuse which may themselves contribute to crime risk, and the interaction between these problems is likely to have a compounding effect.

Also important is the young age at which head injury is often first experienced, as there is good evidence that this puts those affected at increased risk of long-term trajectories characterised by a range of adverse outcomes, including persistent offending. For example, an Australian study found that one in every four young people with a history of childhood TBI demonstrated behavioural disorders which persisted into adulthood, often interacting with a pre-existing vulnerability to create a double hazard (Ryan *et al.*, 2015). Interestingly, this study also found that there was no clear association between the severity of behavioural problems and the severity of TBI; in other words, people with mild injury were as much at risk of persistent behavioural problems as those with severe injury.

A major policy conclusion to be drawn from the available evidence is that effective measures to reduce the incidence of traumatic brain injury, particularly among children and young people, would contribute to crime reduction as well as improvements in health and wellbeing.

Chapter 6: The costs of crime

Aggregate costs

The overall level of crime in this country reached a peak in about 1995 and has since been falling steadily at around 2-3% a year. All major types of offending have declined at broadly comparable rates, including both violent and non-violent crime. Despite this welcome fall in offending, crime continues to impose huge costs, most obviously on individual victims but also on the rest of society. To the extent that there is an established causal link between traumatic brain injury and crime, this constitutes a further element in the overall costs of TBI which has been altogether ignored in previous costing studies.

Comprehensive estimates of the costs of crime in England and Wales were first published by the Home Office in 2000 (Brand and Price, 2000) and partially updated five years later (Dubourg *et al.*, 2005). The figures are calculated by combining data on the total number of offences committed, disaggregated by type of offence, with separate estimates of unit costs for each category. The unit costs cover not just costs falling on the criminal justice system (police, courts, prisons etc.) but also – and much more importantly in quantitative terms – costs falling on the victims of crime, including the value of stolen or damaged property, losses in earnings resulting from crime-related injuries, and an imputed value of the emotional and physical impact of crime on victims.

According to these estimates, the total economic and social cost of crime in England and Wales in 1999/2000 was £59.9 billion, or more than £1,000 per head of population. Just over half of this total (£32.2 billion) was accounted for by crimes against individuals and households (homicide, assault, sexual offences, robbery etc.) and the remainder by other types of offending such as shoplifting, fraud and forgery, drug offences and traffic offences. The value of stolen or damaged property accounted for 31% of total costs, the emotional and physical impact on victims for 30% (but also for 53% of the total cost of crimes against individuals and households) and costs to the criminal justice system for 19%. The update of the figures carried out by the Home Office in 2005 related just to crimes against individuals and households and produced a revised total of £36.2 billion for the value of this component in 2003/04.

As noted, the overall volume of crime has been falling steadily since the mid-1990s, which obviously serves to bring down the aggregate cost. On the other hand, the unit costs of crime have been rising because of general inflation and other cost increases, and a broad assessment is that these two opposing influences have largely cancelled each other out, implying that the total cost of crime is much the same now as in 1999/2000, i.e. around £60 billion a year.

Two qualifications should, however, be noted. The first is that there is good evidence that the scale and cost of domestic violence are under-recorded in the Home Office figures, as documented in an analysis produced in 2004 for the government's Women and Equality Unit (Walby, 2004). And second, there is also more recent evidence that the available sources of data on the numbers of crimes committed each year understate the scale of fraud and cyber-crime (ONS, 2015). A rough allowance for these two factors suggests that the current aggregate cost of crime in England and Wales is of the order of £70 billion a year.

The costs of violent crime

According to an estimate produced for the Department of Health in 2010, the total cost of violent crime in England and Wales in 2008/09 was £29.9 billion (Parsonage, 2010). This breaks down as follows:

	Number of offences '000	Unit cost £	Total cost £ million
Homicides	1.1	1,748,080	1,933
Wounding	1,328	9,950	13,213
Sexual offences	221	37,647	8,320
Common assault	2,287	1,620	3,706
Robbery/mugging	322	8,583	2,764
Total	**4,159**	-	**29,936**

The estimates are based on figures for 2003/04 produced by the Home Office (Dubourg *et al.*, 2005), adjusted for change in the volume and unit costs of violent crime between 2003/04 and 2008/09, and for the under-recording of domestic violence mentioned above.

The figures show that there were around 4.1 million incidents of violent crime in 2008/09 and that about half the costs associated with these incidents resulted from violence against the person (homicides and wounding combined) and a further 28% from sexual offences. On the assumption that falls in the volume of violent crime since 2008/09 have been broadly offset by increases in the unit cost of offences, the total cost of violent crime in England and Wales today may be put at around £30 billion a year, equivalent to more than 40% of the aggregate cost of all types of offending.

Prolific offending

Research evidence indicates that while a significant proportion of the general population have a criminal record by the time they reach their mid-forties, most crime is perpetrated by a small minority of prolific offenders. These prolific offenders typically start their 'criminal careers' at an early age.

A Home Office study of criminal careers has shown that, among all people born in 1953, 33% of males and 9% of females had been convicted of at least one offence (excluding minor traffic offences etc.) before the age of 46 (Prime *et al.*, 2001). However, more than half of these offenders were convicted on only one occasion. At the other end of the scale, 25% of male offenders and 8% of female offenders had four or more convictions and these prolific offenders accounted for the majority of all recorded crime. Thus, among males, two-thirds of all convictions were attributable to the one quarter of offenders, equivalent to 8% of the total male population, who had four or more convictions. And only about 1 in 5 male offenders and 1 in 20 female offenders had received a custodial conviction by age 46, again suggesting that persistent or serious crime is concentrated in a relatively small minority.

Further information on patterns of offending is given in the Cambridge Study in Delinquent Development, which has been tracking a sample of 411 boys born in inner London in 1953. Broadly in line with the Home Office findings, follow-up data show that, while 41% of this sample had obtained a criminal record by age 50, over half of all offences were committed by 7% of the sample (Farrington *et al.*, 2006).

The Cambridge study also provides information on patterns of offending by age. This shows that 20% of those with a criminal record committed their first offence at ages 10-13 and a further 30% at ages 14-16. Taken together, these early-starting offenders were responsible for 77% of all crime committed by the sample. Among those who committed their first offence at ages 10-13, 91% became repeat offenders, compared with only 37% of those who first offended at ages 21-30, and this group of very young offenders, representing 8% of the overall sample, accounted for 39% of all crime recorded in the study.

A number of studies have sought to measure the long-term costs of criminal careers, particularly among prolific offenders. One of these is a detailed US study which defines prolific offenders as those who commit six or more offences (Cohen and Piquero, 2009). Longitudinal evidence in the US suggests that this group represents about 15% of all offenders and is responsible for half of all recorded crime. Crime costs in this study include criminal justice costs, costs to victims and lost productivity of offenders who are imprisoned.

Measured on this basis, it is estimated that lifetime crime-related costs for a single prolific offender are in the range $2.1-3.7 million (2007 US dollars) when discounted back to birth. This is equivalent to about 45-80 times annual GDP per head in the US. Applying the same multiples to UK GDP per head, it may be calculated that in this country the lifetime costs of crime committed by a single prolific offender are in the range £1.3-£2.3 million.

Estimates of the long-term costs of crime for offenders serving custodial sentences are given in a report by the Matrix consultancy group on the economic case for and against prison (Matrix, 2007). This uses an economic modelling approach based on two-year reconviction data extrapolated into the future in order to generate estimates of the lifetime costs of crime committed after an offender has been released from prison. These figures vary according to the type of offence for which the offender was imprisoned, but on average it is estimated that because of the scale of persistent reoffending in this group the long-term cost of crime after release from prison is around £260,000 per offender in today's prices. This understates the full cost of the criminal careers of released offenders, as it makes no allowance for the costs of their index offence or any other offences committed before they were imprisoned.

Finally, it has already been seen that most prolific offenders start offending at a young age and the high cost of adolescent crime is highlighted in a recent report by the National Audit Office on the cost to the criminal justice system in England of a cohort of young offenders (NAO, 2011). This examined 83,000 young offenders who committed their first offence in 2000 and analysed their subsequent offending behaviour for the period 2000-2009. It found that on average each young offender cost £8,000 a year to the criminal justice system and that each of the 10% most prolific or serious offenders cost £29,000 a year.

As noted earlier, costs to the criminal justice system account for only about a fifth of the total costs of crime. Allowing for this, the total societal costs of crime accumulated over the 10 years of the NAO study work out at around £400,000 per average young offender and around £1.45 million per offender in the most costly 10%. Again this understates the full cost of criminal careers, as it makes no allowance for crimes that may be committed after the end of the 10-year cut-off.

The various estimates given in this chapter are intended to show the extremely high costs imposed on society by offenders, particularly prolific or persistent offenders and also those who commit violent crimes. One implication is that only a small reduction in offending or reoffending may be needed to support a value-for-money case for investment in services and programmes which seek to promote this objective.

Chapter 7: Pulling the threads together

Introduction

Previous chapters have established:

- First, that traumatic brain injury is a common and costly condition, with a range of adverse long-term consequences including increased risks of psychiatric disorder and premature mortality.
- Second, that there is a causal link between TBI and offending.
- Third, that crime also imposes very high costs on society, although this has not previously been recognised in studies of the overall costs of TBI.

The purpose of this chapter is to pull the threads together, by providing broad estimates of the costs of TBI including costs associated with crime. The focus will be on young offenders, partly because adolescence is a peak period for both offending and head injury, but also because of the clear evidence that persistent or prolific offending, which accounts for the bulk of crime at the aggregate level, almost invariably starts at a relatively young age.

Adolescence thus provides a key opportunity for early intervention, covering both preventive measures and the early provision of evidence-based treatment and rehabilitation for head injury, particularly among young people in the criminal justice system. It is beyond the scope of this report to assess the economics of intervention in any detail, but the cost estimates set out below are nevertheless relevant in this context, as they provide a measure of the potential benefits of effective intervention, following the line of argument mentioned earlier that a cost saved is a benefit gained.

The long-term costs of a head injury at age 15

We start by providing an estimate of cost per case of TBI, initially excluding any costs related to crime, for an injury incurred at age 15. The analysis in Chapter 3 suggested that as a broad order of magnitude the aggregate cost of TBI in the UK is currently around £15 billion a year. Using the incidence-based approach, this provides a measure of the present value of long-term costs that result from all new cases of TBI occurring in the present year. In practice the estimate relates only to those cases of head injury that result in hospital admission and as the latest available data indicate that there are currently about 162,500 such admissions a year in the UK, the implied average cost of TBI is around £92,000 per case.

A number of adjustments need to be made to this figure to suit the requirements of this chapter. First, the estimate of £92,000 per case is an average across all ages, but the focus here is on the long-term cost of an injury incurred at age 15. Use is therefore made of age-specific data given in the US study of the costs of TBI reviewed in Chapter 3 (Max *et al.*, 1991) in order to generate an estimate of cost per case specifically for 15-year-olds.

Second, because the cost estimate is particularly intended to be used in relation to young offenders, an adjustment has also been made to the gender balance of the figures, to take into account the fact that most offending is committed by males. Thus, among all young people aged 10-17 who were arrested for notifiable offences in England and Wales in 2013/14, 83% were male and 17% were female (Home Office, 2015). The cost figures have been re-weighted in line with these proportions, which serves to increase the average cost.

Third, an adjustment going the other way has been made to allow for the fact that cost estimates based on cases admitted to hospital are likely to be too high when related to offender populations, as the great majority of head injuries among the latter will be towards the mild rather than severe end of the spectrum. Similarly, any costs relating to fatalities are not relevant, as the figures are to be related to living populations. Again using data from the US study, average cost per case has therefore been re-calculated so that it relates solely to surviving cases of head injuries classified as mild in the US figures.

Finally, at a more technical level, an adjustment has been made to ensure that all future costs incorporated in the figures are given a present value based on the standard public sector discount rate of 3.5% a year in real terms which is used in this country. For costs arising in the near future, the choice of discount rate makes relatively little difference, but it is important for those costs which are spread over many years, most notably any reductions in future lifetime earnings which may result from head injury. The US study by Max *et al.*, which is the main source of data on lost earnings, bases its estimate of present value on a discount rate of 6%. Use of a lower rate of 3.5% has the effect of significantly increasing the cost of lost earnings in present value terms.

Partly because these various adjustments go in different directions, their combined impact is relatively small and overall it is estimated that in broad terms the average long-term cost of a mild head injury incurred at age 15 which entails a hospital admission is around £94,000 per case. The main reason why this comes out slightly higher than the earlier all-cases average of £92,000 is because of the impact of using a lower discount rate for future earnings losses.

Long-term costs including the costs of crime: 15-year-olds in the general population

Two further calculations may be made based on the estimate of cost per case just described. The first is to include an allowance for the future costs of crime for a representative 15-year-old in the general population and the second is to include a similar allowance for a 15-year-old who is already in contact with the criminal justice system.

The first of these measures may be seen as providing an indication of the potential benefits of preventing head injury in the general population of young people, and the second in indicating the potential benefits to be derived from the effective identification and treatment of head injury in a young person who has already offended. Combined with further information on the costs and effectiveness of specific interventions, these estimates provide key building blocks for the economic evaluation of the prevention and treatment of head injury in adolescent years.

The first calculation requires an estimate of possible future crime costs that may result from a head injury incurred by a 15-year-old with no previous offending history, to be added to the figure of £94,000 per case for non-crime costs as estimated above. Taking into account the causal links between TBI and crime as discussed in Chapter 5, two questions need to be addressed: first, what is the average long-term cost of crime committed by a general member of the population, and second, how much is this likely to be increased in someone with a head injury?

Concerning the first of these, an obvious starting point is the estimate given in Chapter 6 that the total cost of crime in England and Wales is currently around £70 billion a year, which on average works out at about £1,200 per head of population. However, this relates to the cost of crime in a single year and, while the majority of people never offend at all, it is also the case that a small minority become persistent offenders, committing crimes over a number of years during the course of a criminal career. The average length of a criminal career, even among persistent offenders, is nevertheless relatively short, as crime is very strongly age-related, with the bulk of offences being committed in adolescence and early adulthood.

Building on this last point, suppose as an extreme example that all crime is committed by 20-year-olds, i.e. criminal careers last just one year. It then follows that the average lifetime cost of crime per head of population is simply the total cost of crime committed in any one year divided by the total number of people in the one-year cohort who are aged 20 during the year in question. Population data indicate that each one-year cohort of young people in this country includes around 700,000 people, so if the total cost of crime is about £70 billion a year, then it follows that the average lifetime cost of crime is of the order of £100,000 per head of population.

Obviously it is unrealistic to say that people only commit crimes when they are aged 20, but this does not in practice affect the estimate of lifetime costs. For example, suppose that all crime is committed by people aged 20 and 21. This doubles the number of cohorts involved but it also doubles the number of years in which crime is committed, meaning that the cost per cohort is unchanged and so too is average lifetime cost per head in the population as a whole. Similarly, if all crime is committed by people aged 15-25, ten cohorts are involved in ten years of crime, again equivalent to one year of crime per cohort. On this logic, and assuming that the aggregate cost of crime remains broadly constant over time as it has done in recent years, then the average lifetime cost of crime may be put at around £100,000 per head of population.

At one level this average figure is misleading, as it conceals a highly skewed distribution, with the majority of the population imposing zero costs and at the other extreme a small minority each costing the rest of society £1-2 million or more because of their serious and persistent offending. Subject to this qualification, a population-wide average is nevertheless appropriate and indeed necessary in the present context.

The remaining step is to determine how much crime over and above the national average is likely to be committed by people with head injury. As discussed in Chapter 5, the best available evidence suggests that, after taking account of other possible influences, TBI increases the likelihood of offending by a factor of between 1.5 and 2.0. The odds of persistent and violent offending appear to be somewhat higher than this, but to ensure that the estimates remain on the conservative side, it is proposed to ignore this and to use a central figure for the odds ratio of 1.75. On this basis the costs of crime over and above the national average that may be attributed to TBI are of the order of £75,000 per case.

As before, allowance needs to be made for the fact that these costs may be incurred over a number of years, depending on the length of criminal careers, and thus need to be discounted at 3.5% a year so as to give a present value. For this purpose it is assumed that on average a criminal career starting at age 15 lasts for around 10 years, resulting in an adjusted estimate of around £60,000 per case for the additional costs of crime attributable to TBI.

Adding to this the non-crime costs of TBI as calculated above gives an overall estimate of around £155,000 for the long-term costs of a head injury suffered by a 15-year-old in the general population. Such a figure may be interpreted as a broad measure of the potential benefits of preventing one case of head injury in this age group.

By way of comparison, reference may be made to recent estimates of the long-term costs of two childhood mental health problems, namely conduct disorder (persistent disobedient, disruptive and aggressive behaviour) and attention-deficit hyperactivity disorder (ADHD). Both of these are conditions which typically start early in life with a strong tendency to persist into adolescence and beyond, and are associated with a range of adverse long-term outcomes. In particular, conduct disorder is a major risk factor for future involvement in criminal activity.

It is estimated that the lifetime cost of early onset conduct disorder (i.e. before age 10) is around £260,000 per case (Parsonage *et al.*, 2014). Costs relating to crime account for about 70% of this total. The corresponding lifetime cost of ADHD, again assuming onset early in childhood, is put at about £100,000 per case (Khong, 2014). An estimate of £155,000 for the long-term cost of a head injury suffered at age 15 thus falls between these two figures for persistent mental health problems.

Long-term costs including the costs of crime: young offenders

For this calculation, the best available source of information is the study reviewed in Chapter 6 of the cost to the criminal justice system of a cohort of first-time young offenders published by the National Audit Office in 2011 (NAO, 2011). This covered a large sample of offenders who committed their first offence in 2000, when their average age was 15, and found that their subsequent offending over the next 10 years cost the criminal justice system £8,000 a year on average. Grossing up to take into account the wider costs of crime, particularly costs falling on victims, it is estimated that the overall costs of offending over the 10-year period come to around £400,000 per average young offender.

Two adjustments are needed to this figure for present purposes. The first is to reduce the estimate by £100,000 in order to take account into the average long-term cost of crime committed by a 15-year-old in the general population. This ensures that the resulting figure of £300,000 provides a genuine measure of additional crime costs, i.e. over and above those that would have occurred anyway.

The second adjustment is to discount these additional costs at the standard public sector rate of 3.5%, which has the effect of reducing the costs over ten years to a present value of around £250,000 per average young offender.

Adding this figure to the earlier estimate of £94,000 per case for the long-term non-crime costs of head injury at age 15 gives a total cost of around £345,000 per case. It should be noted that this estimate is not meant to imply that all future offending carried out by a 15-year-old already in contact with the criminal justice system is directly caused by their head injury. Rather, it is intended to provide a broad measure of the total future costs likely to be imposed on society by a young offender with a head injury, on the assumption that their future offending behaviour will be much the same as among young offenders generally. To that extent, the figure is probably an underestimate, as the limited available evidence suggests that, compared with other young offenders, those with a head injury are more likely to become persistent offenders and also to commit more crimes involving violence.

The relevance of the estimate of £345,000 per case depends to some degree on the context in which it is used. If, for example, the choice is a narrow one of deciding whether or not to invest more resources in supporting one group of young offenders (those with head injury) rather than another (those without head injury), then it may reasonably be argued that some or all of the crime costs should be ignored, as they are common to both groups. On the other hand, taking a broader view and asking the general question of whether society should invest more resources in young offenders with head injury as against some completely different purpose, then future additional crime costs are clearly relevant and should always be included in any overall assessment of the potential benefits to society of effective intervention for this group.

Concluding comments

To end on a cautionary note, it must be emphasised that all the cost estimates for TBI given in this chapter, as in Chapter 4, are subject to wide margins of error. Little information of good quality is available on the costs of traumatic brain injury and, while there is a larger literature on the costs of crime, some of the best studies in this area are now increasingly out of date. A number of difficulties have also been encountered in seeking to combine cost figures from the two fields.

In response to these problems, the general approach taken in this study has been that whenever judgements or assumptions are required to take the analysis forward, these should be pitched on the conservative side. Combined with gaps in data availability which have precluded quantification in some important areas of analysis, the end-result of this approach is that, if anything, the cost estimates set out in this chapter are more likely to be underestimates rather than the reverse.

To give an example, it was noted in Chapter 3 that there is now good evidence to show that traumatic brain disorder is strongly associated with a number of adverse outcomes such as psychiatric disorder and substance misuse, and also premature mortality from a range of causes not directly linked to the original injury. All of these are likely to result in increased costs, including greater use of health and other public services as well as reduced earnings, but few if any costing studies of brain injury have yet been able to capture these additional costs to a significant degree. Much of the difficulty lies in the complexity of the underlying relationships in these areas, with causation often running in both directions and so complicating the appropriate attribution of costs to one outcome rather than another.

Finally, it is important to reiterate a point highlighted in Chapter 4, namely that on almost any metric the biggest cost of traumatic brain injury is the intangible cost associated with its adverse impact on the quality of life and wellbeing of the individuals directly affected and their families. This is inherently difficult to measure and value and has been largely set to one side in this study, as it has in nearly all other studies in this field. It should nevertheless be seen as central to any overall assessment of the case for more investment in the prevention and treatment of traumatic brain injury.

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Traumatic brain injury and offending

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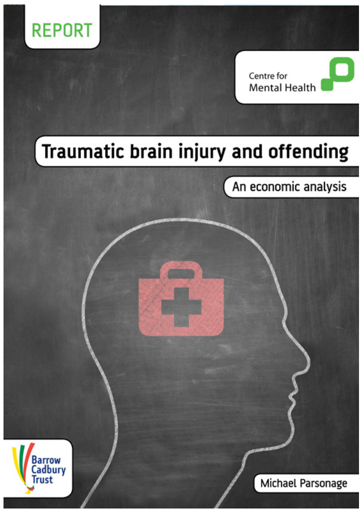

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