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Acquired brain injury, violence, and anti-social behaviour: Disentangling cause and effect

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ACQUIRED BRAIN INJURY, VIOLENCE, AND ANTI-SOCIAL BEHAVIOUR: DISENTANGLING CAUSE AND EFFECT

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Declaration

I hereby declare that this thesis is the results of my own investigations, except where otherwise stated. All other sources are acknowledged by bibliographic references. This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree unless, as agreed by the University, for approved dual awards.

Yr wyf drwy hyn yn datgan mai canlyniad fy ymchwil fy hun yw'r thesis hwn, ac eithrio lle nodir yn wahanol. Caiff ffynonellau eraill eu cydnabod gan droednodiadau yn rhoi cyfeiriadau eglur. Nid yw sylwedd y gwaith hwn wedi cael ei dderbyn o'r blaen ar gyfer unrhyw radd, ac nid yw'n cael ei gyflwyno ar yr un pryd mewn ymgeisiaeth am unrhyw radd oni bai ei fod, fel y cytunwyd gan y Brifysgol, am gymwysterau deuol cymeradwy.

Signed .....

Print name ..... ALUED BLANCH .....

Date ..... 21/5/2020 .....

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At the risk of going the full Oscar, there are lots of people without whom this research would not have been possible, or anything like as much fun. Thanks therefore go to:

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My daughters, Freya, Charlotte, and Romilly aka The Cool Chick Crew: giving the world you will always be the greatest thing I ever do. I hope some of what I've written helps make it a bit safer for you.

Finally, I dedicate this thesis to Grandpa Batchelor, who was the Hippocratic Oath made flesh. Genetically, I am 25% you. If I can be a quarter of the human being you were, well, that's good enough. I miss you Grandpa, very much.

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Thesis Summary

ACQUIRED BRAIN INJURY, VIOLENCE, AND ANTI-SOCIAL BEHAVIOUR: DISENTANGLING CAUSE AND EFFECT

Since Cain killed Abel with a rock to the skull, brain injury, violence, and anti-social behaviour have been entangled. This thesis attempts to disentangle them.

Chapter One systematically reviews the clinical outcomes of non-fatal strangulation in domestic and sexual violence. 27 studies met inclusion criteria. Together they evidence potentially severe medical consequences: loss of consciousness, seizures, motor and speech disorders. Psychological outcomes include suicidality, dissociation, and PTSD. There was less evidence for cognitive and behavioural sequelae, but memory deficits and compliance were reported. We propose further research, using standardised neuropsychological assessment to build cognitive and behavioural profiles. We also discuss broader implications: the 'rough sex' defence, issues of consent, and chokeholds within mixed martial arts.

Chapter Two explores the temporal sequencing of childhood brain injury and anti-social behaviour, using prospective sampling. We hypothesised that brain injury would come first and, controlling for confounds, causation could be inferred. 476 members of the Millennium Cohort Study (CLS, 2019) have had accidents resulting in loss of consciousness; we compare them to 3,964 children with orthopaedic injuries. Using interrupted time series regression, we explore post-injury changes to behavioural trajectories, measured by the SDQ (Goodman, 2001). Modelling did not demonstrate any significant alteration in the short or long term, and thus we could not infer causation. Moreover, there was neither a significant effect of age at injury, nor a dose response. We discuss study limitations which may have obscured effects,

but highlight the difference made by using prospective sampling, and injured control groups, in a field used to clinical samples, cross-sectional analysis, and retrospective report.

The final chapter suggests theoretical development for both papers, further research, and clinical implications, before concluding with personal reflections on the research process.

List of Abbreviations

ABI	Acquired Brain Injury
ACT	Acceptance & Commitment Therapy
ADHD	Attention Deficit Hyperactivity Disorder
CTE	Chronic Traumatic Encephalopathy
CTS2	Revised Conflict Tactics Scale
IPV	Intimate Partner Violence
ITS	Interrupted Time Series
JBI	Joanna Briggs Institute
LOC	Loss of consciousness
MCS	Millennium Cohort Study
MMA	Mixed Martial Arts
mTBI	Mild Traumatic Brain Injury
OI	Orthopaedic injury
PTSD	Post-Traumatic Stress Disorder
REC	Research & Ethics Committee
RMI	Rutter Malaise Inventory
SAIL	Secure Anonymised Information Linkage
SARC	Sexual Assault Referrals Centre
SDQ	Strengths & Difficulties Questionnaire
TBI	Traumatic Brain Injury
TTF	Target Trial Framework

Chapter One

Systematic Literature Review

The neuropsychological outcomes of non-fatal strangulation in domestic and sexual violence: A systematic review

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…when I have pluck'd the rose,

I cannot give it vital growth again.

It must needs wither: I'll smell it on the tree.

[He kisses her]

Ah balmy breath, that dost almost persuade

Justice to break her sword…

[He strangles her]

Othello, Act V Scene II

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This paper is under consideration by *Neuropsychological Rehabilitation*, and therefore follows the journal's guidelines; see https://www.tandfonline.com/action/authorSubmission?show=instructions&journalCode=pnrh20

Abstract

This paper reviews the clinical outcomes of non-fatal strangulation in domestic and sexual violence and, given shared physiological mechanisms, asks whether the hypoxic-ischaemic literature can serve as a proxy. 27 empirical, peer-reviewed studies were found which met the inclusion criteria. Medical consequences included loss of consciousness, indicating at least mild acquired brain injury, stroke, seizures, motor and speech disorders, and paralysis. Psychological outcomes included PTSD, depression, suicidality, and dissociation. Cognitive and behavioural sequelae were described less frequently, but included memory deficits and compliance. Overall, the evidence suggested strangulation can share all the serious consequences of hypoxic-ischaemic injury, but carries additional neuropsychological burden. However, no papers used formal neuropsychological assessment: the majority were medical case studies, or based on self-report. There is therefore a need for further neuropsychological research, focusing on cognitive and behavioural outcomes, using standardised tools, and control groups where possible. This is urgent, given societal normalisation of strangulation, and consent to 'rough sex' being used as a legal defence. We also discuss broader implications: the popularity of the 'choking game' with teenagers, and carotid injuries within mixed martial arts.

Keywords

Intimate partner violence; sexual assault; choking; hypoxic-ischaemic; neurobehavioural

Introduction

Brain injury within domestic and sexual violence is belatedly gaining academic, medical, and legal attention. This is welcome, given the scale of the problem. More than one in three women are victims of intimate partner violence (IPV; WHO, 2019), 44% report sexual assault, and 20% rape (McQuown et al., 2016). In the majority of sexual assaults, the perpetrator is the victim's partner, so there is a significant overlap between the two areas, termed Intimate Partner Sexual Violence (Bagwell-Grey, Messing & Baldwin-White, 2015). Corrigan and colleagues (2003) reported loss of consciousness in 30% of IPV cases in emergency rooms, indicating at least a mild brain injury, and 67% presenting with residual problems that could be neurological. This is perhaps unsurprising, given evidence showing over 90% of IPV survivors have injuries to the head, neck, and face (Banks, 2007). The risk of brain injury within IPV thus appears significantly higher, both in terms of percentage, and absolute numbers, than the risk in contact sports and military action, despite not having benefitted from the same degree of clinical and academic focus (Chapman & Diaz-Arrastia, 2014; Koh, Cassidy & Watkinson, 2003).

Within this new field, the research emphasis has been on traumatic brain injury (TBI). However, strangulation has emerged as a "hidden epidemic" (Taliaferro, Mills & Walker, 2001, p.294). A systematic review reported the lifetime prevalence of strangulation to be between 3.0% and 9.7% in community-living adults; amongst women who are victims of systematic abuse, this rises to 50-68% (Kwako et al., 2011; Sorenson, Joshi, & Sivitz, 2014; Wilbur et al., 2001). Evidence indicates up to 17% of those strangled lose consciousness, indicating at least a mild TBI (Wilbur et al., 2001). Incidence is also high: in a US study of IPV/sexual assault health encounters, strangulation was reported in 23% of the assaults (McQuown et al., 2016). A similar UK audit noted strangulation in one in five cases

presenting at a sexual assault referral centre (White, 2018). For incidence to be so high versus lifetime prevalence is suggestive of repeated injuries and, indeed, the literature confirms this, with studies showing half of survivors reporting being strangled between three and 20 times (Vella, 2013; Wilbur et al., 2001).

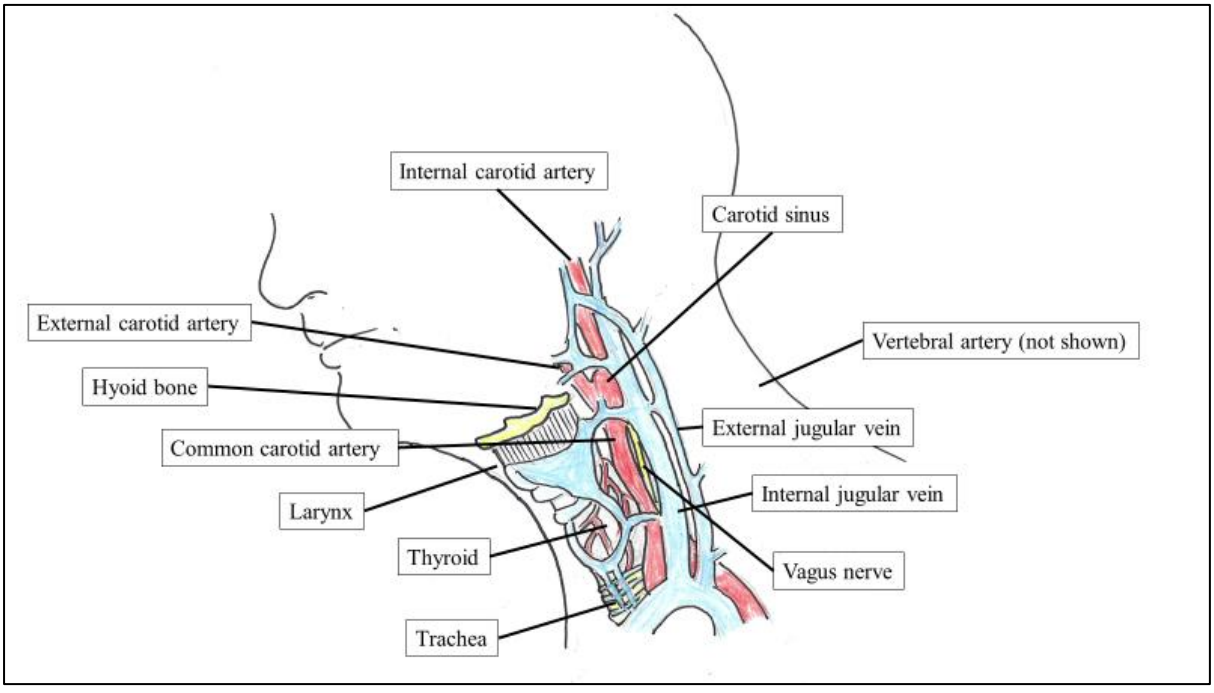
Although it is possible for a woman to strangle a man, as it can take more pressure to open a canned drink than to occlude the jugular vein (Green, 2017), strangulation appears to be a gendered crime. Sorenson and colleagues (2014) reports lifetime discrepancy between four and eleven-fold. In a review of 300 cases within the San Diego City Attorney's Office, 298 involved a male perpetrator and a female victim (McClane, Strack & Hawley, 2001). In White's SARC audit (2018), only two out of 70 victims were male. Indeed, a meta-analysis reviewing gender differences in violence stated strangulation "is very clearly a male act" (Archer, 2000, p. 327). There may be anatomical reasons behind this, in terms of hand and neck span, but the literature also suggests a power dynamic, often triggered by Othello-like jealousy, and a desire to assert control (Joshi, Thomas & Sorenson, 2012; Sorenson et al., 2014). Thomas and colleagues (2014) describe strangulation's role as "setting the stage" (p.125): ensuring that it is understood that the main actor can or will kill.

Although strangulation can result in blunt force trauma to the neck, the method and physiological impact on the brain is different from most TBI. Strangulation can be defined as the external compression of the airway and/or blood vessels, leading to restricted oxygenated blood flow to, and deoxygenated blood from, the brain. This can be achieved with a ligature (garrotting), by body weight (throttling, or positional strangulation), or manually. Evidence largely gleaned from autopsies, and from assessing the risk of the 'choke hold' carotid restraint used by police, has been able to show the pathophysiology of strangulation, as set out below (Clarot, Vaz, Papin & Proust, 2005; de Boos, 2019; Hawley, McClane & Strack,

2001; Monahan, Purushotham & Biegon, 2019). Figure 1 serves as reference for the location of the relevant anatomical structures.

- Obstruction of the larynx cutting off airflow to the lungs (i.e. asphyxiation, leading to hypoxia), which may continue after pressure has been lifted if the neck structure has been damaged (e.g. hyoid fracture);
- Occlusion of the jugular veins, leading to venous congestion, increased intracranial pressure, decreased respiration, and possible pinpoint haemorrhage (petechiae);
- Occlusion of the internal carotid artery, restricting blood flow to the brain (i.e. ischaemic). This is more likely to happen when the attacker is facing the victim. If pressure is at base of neck, vertebral arteries may also be occluded. Again, this may continue once pressure has been removed if there has been arterial dissection;
- Triggering of the carotid sinus reflex, leading to dysrhythmia, possible cardiac arrest, and thus further lack of blood to the brain (hypoxic-ischaemic);
- Damage to the thyroid gland, resulting in possible 'thyroid storm', in which acute hyperthyroidism can cause congestive heart and multi-organ failure.

Figure 1. Schematic illustration of neck anatomy, indicating main structures vulnerable in strangulation



Any or all of these mechanisms could damage the brain, and quickly. In the notorious Red Wing studies (Kabat & Anderson, 1943), in which psychiatric inmates and prisoners were strangled in order to increase the US military's understanding of why wartime airmen were blacking out, consciousness (and therefore memory of, and control over, events) was lost within four to ten seconds of arterial pressure, followed by anoxic seizures at six to eight seconds. Bladder control can be lost after 15 seconds, and bowels after 30, with decerebrate posturing after 20 seconds, indicating damage at a brain stem level, and, finally, brain death at between one and six minutes (de Boos, 2019). For asphyxiation only (so breathing prevented, but blood still flowing to the brain), the course depends on how much oxygen is present in the blood and lungs. Memories will still be formed while the person retains consciousness. Panic-induced struggling against the attacker may cause its own injuries. Eventually consciousness will be lost as the brain runs out of oxygen.

A relatively small amount of pressure is required to affect the various injuries: 4.4lbs for the jugular, 11lbs for the carotid arteries, 33lbs for the trachea, and 66lbs for the vertebral arteries (Shields, Corey, Weakley-Jones & Stewart, 2009). Figure 1 also highlights the proximity of the key structures; one can infer how difficult it would be to affect one in isolation. For those who survive strangulation, different brain areas react to a different time scale. Some parts of the brain stem and the hippocampus are known to be particularly vulnerable to lack of blood flow, along with the dentate nucleus, and the cerebellum (Hawley et al., 2001). Some cells may survive for days before dying, and the wider literature contains reports of stroke delayed by almost two weeks following other methods of carotid bisection (Levack, Pettitt, & Winston, 2009). In fact, in a large study (n = 300) only 39% had symptoms on the day of the injury (Strack, McClane & Hawley, 2001). That Shakespeare depicts Desdemona regaining

consciousness, and pleading with her assailant, before finally succumbing, is therefore not as ridiculous as literary critics have historically suggested (Cooper, 1949).

In addition to the neurological damage, leading to possible cognitive and behavioural changes, there is also the risk of significant psychological trauma. Strangulation has been called "the edge of homicide" (Strack & Gwinn, 2011, p.32). If a woman has been strangled by her partner, the risk of attempted murder increases sevenfold, and death by a factor of eight (Glass et al., 2008). Not being able to breathe – air hunger – is a primal fear, experienced even in controlled laboratory tests (Banzett, Lansing, Evans & Shea, 1996). In the uncontrolled IPV/sexual assault situation, the perpetrator, literally, has the woman's life in his hands; a woman who could well be his wife or girlfriend. He dictates whether she takes her next breath or not, and may, like Othello, have his gaze locked on her as she struggles. Strangulation is a uniquely intimate act of terrorism (Johnson, 2010), and it is not difficult to see why it could leave more than physical marks, such as PTSD and other trauma reactions.

Attempts have already been made to synthesise our understanding of this new and important area. Pritchard and colleagues (2017) produced a narrative review, outlining the history of the subject, with particular focus on the US legal response, where strangulation has now been reclassified as a felony. However, the search was not systematic, and the paper does not reference outcomes. An integrative review (Patch, Anderson and Campbell, 2018) did follow PRISMA guidelines, but excluded studies before 2000, and was undertaken from a nursing perspective, requiring there to have been an emergency healthcare interaction. Given we know there is significant under-reporting, and the San Diego study suggested as few as 5% of women will seek medical attention (Strack et al., 2001), it was felt that a more liberal and transdisciplinary approach might yield fuller findings.

This review therefore aims to map the knowledge currently held within the medical, legal, social work, policing, and psychological literature. Specifically, what evidence do we have for the neurological, cognitive, behavioural, and psychological impact of strangulation within IPV and sexual assault? Secondly, given the similar mechanics, is this any different from the documented outcomes of hypoxic-ischaemic brain injury (e.g. cardiac arrest), or can that body of literature be used as a proxy?

Method

The review was carried out according to PRISMA guidelines (Moher, Liberati, Tetzlaff & Altman, 2009). It was registered in advance with PROSPERO, reference CRD42019160487.

Search sources and strategy

A deliberately wide selection of databases was used, given the transdisciplinary nature of the topic: PubMed, PsycINFO, CINHAL, Proquest, ASSIA, Web of Science, and WestLaw. The initial search consisted of paired combinations, based on titles and key words from other studies, reflecting the injury (strangulation) and the outcomes (brain injury and its sequelae). This was then joined with terms reflecting the context (IPV and sexual assault). The ProQuest script was:

> ((strangl* OR strangulation OR chok* OR "breath play" OR throttl* OR ligature OR garrot*) AND (neuro* OR asphyxi* OR cardiac OR Aneurysm OR stroke OR vascular OR "brain injury" OR "brain damage" OR hypox* OR anox* OR cogniti* OR psych* OR "mental health" OR emotion* OR dementia OR encephalopathy OR behavio* OR ischaemi*)) AND ("sexual assault" OR "sexual abuse" OR "spouse abuse" OR "spousal abuse" OR "partner abuse" OR "domestic violence" OR "sexual violence" OR "intimate partner violence" OR "intimate terrorism" OR "situational couple violence" OR batter* OR rape OR "rough sex" OR "dating violence")

The search was conducted on the 17th December, 2019.

Eligibility criteria

To qualify for inclusion, articles needed to be published, peer-reviewed, empirical papers, in order to indicate quality of research and reporting. Studies needed to refer to neurological, psychological, behavioural, or cognitive outcomes of strangulation (manual, ligature, or throttling) within domestic or sexual violence. No date limits were set, given the need for breadth. Exclusion criteria were: general violence not limited to IPV or sexual assault; focus on perpetrator; strangulation not separated out from other forms of violence; fatal; non-neurological outcomes only (e.g. neck lacerations, bruising); limited to policing or legal process; not adult or human; self-inflicted (e.g. auto-erotic asphyxia or hanging); no English version available.

Quality assessment

Based on specialist librarian advice, all studies were assessed using the suite of critical appraisal tools from the Joanna Briggs Institute (2017). Analytical cross sectional studies were measured against an eight item checklist, e.g. were confounding factors identified and controlled for, were outcomes measured in a valid and reliable way, and was appropriate statistical analysis undertaken. Case reports were appraised against a different eight item checklist, e.g. was there clear description of the patient's demographic characteristics and history, and were diagnostic tests and assessment methods specified. There was a 10-item checklist for qualitative research, e.g. congruity between research objectives and methodology, addressing the influence of the researcher on the research, and whether the conclusions drawn flowed from the analysis of the data. These are all checklists for inclusion in reviews, and are not intended to provide a formal grading system, or cut-off scores. However, our appraisal against the checklists has been included in the data extraction tables,

with a higher score indicating that the authors have more closely adhered to methodological best practice.

Risk of bias

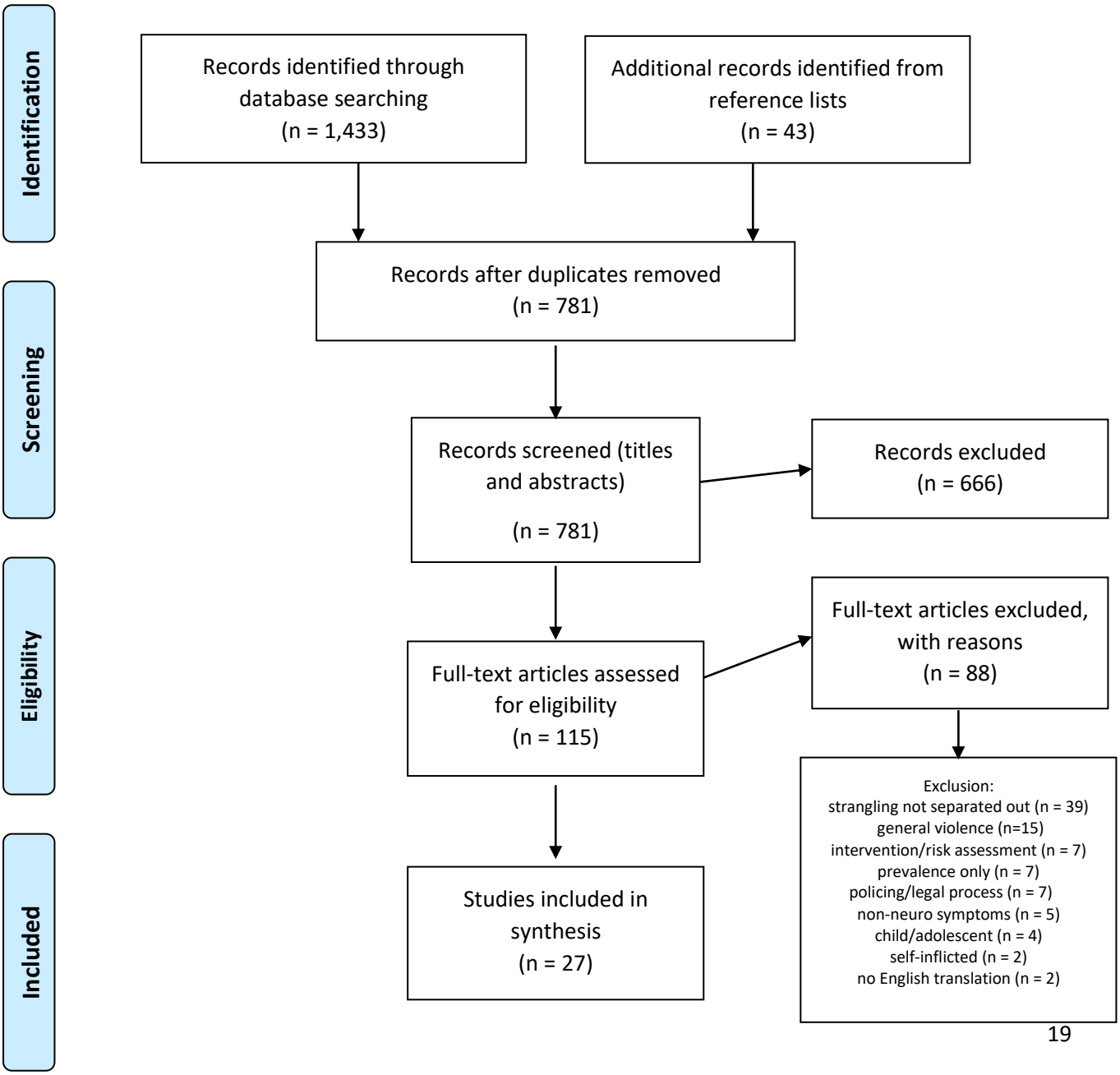
The first author conducted the search, and results were reviewed against these criteria and refined by the second author. Data on outcomes were extracted, and recorded in Table 1 by the first author. Comparison was made with the sequelae of hypoxic-ischaemic injuries as outlined by the International Brain Injury Association (Arciniegas, 2012). Again, outcome data and quality assessments were inspected and refined by the second author, and then the whole review was checked by the remaining authors, who were available in case of disagreement, but this was not necessary.

Results

Information extraction

The initial search yielded 1,433 articles, with a further 43 added from reference lists. Subsequent selection involved four main phases; see Figure 2. A total of 27 articles were included in the final sample.

Figure 2. PRISMA Flow Diagram



Analysis of the articles

Table 1 provides key features of the final list of articles. They were published between 1980 and 2019 across 10 countries, with the USA being the main contributor, with 16/27.

Characteristics of samples

There were no randomised, population, or prospective samples. People were identified through their contact with the healthcare, police, or justice systems, or had been helped by IPV organisations. Sample size was bimodal, with nine case reports (N = 1 to 3), and eleven large retrospective analyses of existing records (N = 102 to 1,064). 21/27 studies had entirely female samples, and one study interviewed heterosexual couples with a male attacker. Of those studies where men had also been victims, they were in the minority, ranging from 2/14 (Yen et al., 2007) to 2/300 (Strack et al., 2001). Most studies reported a mean age in the early thirties. There were no controls. Joshi et al. (2012) and Thomas et al. (2014) tried to recruit IPV survivors who had not been strangled, but were unable. In the majority of studies (19/29) strangulation was in the context of IPV. 4/27 involved sexual assault, with partners being the assailant in two of those, and 4/27 recruited both IPV and sexual assault victims. Ralston and colleagues (2019) specifically excluded sexual assault.

Study design and methodological considerations

There was marked heterogeneity of design. All studies were cross-sectional, although three case reports cited GP follow-up after several years. Alongside the nine clinical case reports written by the treating clinicians, there were another five analyses of hospital records, written by ED medics, forensic nurses, or radiologists, and three analyses of police and legal reports. There were no studies written from a neuropsychological perspective. These retrospective analyses depend on the depth and breadth of what was documented at the time, and who was

doing this: for example, Strack et al. (2001) emphasise the inconsistency and paucity of symptom reporting by police, limited largely to visible injury. Similarly, using imaging data will be limited to what can be identified on a scan. Five studies were survey-based, and could therefore generate additional, transdisciplinary data. Of those studies which used statistical analysis, this was largely descriptive. Only four studies used inferential analysis, including t tests and odds ratios, chi-square, binomial/multinomial logistic regression, and risk ratios (Davins-Pujols et al., 2014; Messing et al., 2014 and 2018; Mittal et al., 2019). Where method was stated in the five qualitative studies, this was based on grounded theory. One used mixed methods, combining analysis of police records and follow-up depth interviews (Farr, 2002). The others used focus groups, and found this successful, despite the sensitivity of the topic.

Assessment

None of the studies used formal neuropsychological assessment. The majority of cognitive and psychological outcomes were based on participants' spontaneous self-reports. Shields et al. (2010) suggest this may underestimate complaints, given participants' tendency towards minimisation and denial, and possible memory impairment resulting from strangulation. Where objective assessment was undertaken, this was guided by profession, and varied significantly. For example, Plattner and colleagues (2004) analysed hospital records of imaging results and clinical presentation, but note no evidence of neurological examination. There was no standard strangulation assessment tool identified, in either the medical or policing fields.

Two survey-based studies developed their own questions to record symptoms (Smith et al., 2001; Wilbur et al., 2001). Messing and colleagues (2014, 2018) and Mittal and colleagues (2019) were the only authors to used validated psychometrics, although none of these were

strangulation-specific: Revised Conflict Tactics Scale (CTS2; Strauss et al., 1996), Danger Assessment Scale (Campbell et al., 2009), Women's Experience of Battering Scale (Smith, Earp, & DeVellis, 1995), Primary Care Post-Traumatic Stress Disorder Screen (Cameron & Gusman, 2003), Abuse Behaviour Inventory (Zink et al., 2007), Rosenberg Self-Esteen Scale (1965), and the Centre for Epidemiologic Studies Depression Scale (Radloff, 1977).

The timing of assessment differed. Case reports and retrospective record analyses tended to be based on immediate outcomes. There is therefore the risk that symptoms may not have developed, and victims were not yet in a position to report more specific difficulties. Where studies were delayed, by contrast, this relied on participants' recall, which may have been compromised by time, and short-term memory impairment, and many of the physical symptoms may have receded.

Quality of evidence

Qualitative researchers, despite intending to, found it difficult to recruit comparison groups who had not been strangled, given the high prevalence and incidence figures (Joshi et al., 2012; Thomas et al., 2014). However, Davins-Pujols et al. (2014), Messing et al. (2014, 2018), and Zilkens et al. (2016) were able to identify IPV victims not reporting strangulation to act as a comparison, and were the only studies thereby to attempt to control for confounding factors. Smith and colleagues (2001) were able to compare multiple to single strangulation events. There were only two clinical follow-ups by authors (Clarot et al., 2004; Malek et al, 2000), and one anecdotal report from the patient's GP after several years (Milligan & Anderson, 1980). Only 3/27 studies used standardised psychometrics (Messing et al., 2014 & 2018; Mittal et al., 2019). Overall therefore, the quality of the evidence would have been low if measured by standard grading tools. Using the JBI critical appraisal tools

Table 1. Key features of studies documenting the outcomes of non-fatal strangulation in Intimate Partner Violence and sexual assault

Reference	Country	Study Design	Sample	Quality	Neuropathology	Clinical outcomes (neurological, cognitive, emotional, behavioural)	Additional to hypoxic-ischaemic?
Clarot, Vaz, Papin, & Proust (2004)	France	Case report (hospital)	N = 2, only 1 IPV-related 42 year old woman strangled by husband	JBI Case Reports: 6/8 Nil for 4/6	Bilateral common carotid artery dissection with 40% stenosis CT scan normal	Discharged from Emergency Department following strangulation; returned two days later, with severe headaches. No neurologic sequelae at 5 month follow-up	Pathological: Arterial dissection
Davins-Pujols, Salamero, Aznar-Martinez, Alegret, & Perez-Testor (2014)	Spain	Retrospective, cross sectional analysis of client assessment data	N = 161 in specialised psychology outpatient service for abused women; 41 women had been strangled; mean age 38.9	JBI Cross Sectional: 7/8 Nil for 6		Women who were strangled significantly more likely to experience feeling of danger (OR 9.74, $p < 0.001$) than other forms of physical violence.	Psychological: feeling of danger, threat to life from other
De Boos (2019)	Australia	Case report (hospital)	N = 1 21 year old woman strangled 3 times over 20 minutes by partner	JBI Case Reports: 7/8 Nil for 4	Tracheal perforation	Pain Dysphonia Dysphagia Confusion Short-term memory impairment – could not articulate events Nausea Potential loss of consciousness Feeling of being 'choked to death' Lost to follow-up	Pathological: Perforated trachea Neurological: Pain Dysphonia Nausea Psychological: Existential threat
Eiskovits & Winstok (2002)	Israel	Qualitative	N = 48 24 in-depth interviews with heterosexual couples who had stayed together despite IPV; one woman describes strangulation.	JBI Qualitative Research 7/10 Nil for 2/6/7		Realisation of imminent death, and battle for survival vs attacker: "Then I knew it's either him or me" (p. 695)	Psychological: Existential fear and survival response vs attacker
Farr (2002)	USA	Mixed – content analysis of police reports, qualitative interviews	N = 30 survivors (all female) of attempted homicide; mean age 34; 11 were choked/strangled; 3 describe strangulation	JBI Qualitative Research 8/10 Nil for 6/7		"Being killed and watching it" (p. 275) – dissociation? Belief that they are about to die, one survivor referring to having been "killed" when "choked" (p. 275) "Traumatic immobility" (p.275)	Psychological: Existential fear Belief that did actually 'die' Dissociation Traumatic immobility

						Two survivors taken into public after strangulation and no attempt made to escape, either due to fear, or because it never occurred to them that they could (p. 276)	Cognitive: Agnosia/lack of initiation?
Funk & Schuppel (2003)	USA	Case report (hospital)	N = 1 24 year old woman strangled three times by partner whilst 7 months pregnant	JBI Case Reports: 7/8 Nil for 6	Right sub-conjunctival haemorrhage Petechiae right frontal region	"I thought I would die" Lightheaded Loss of consciousness Headache Ptosis Pain Dysphagia Difficulty breathing No follow-up	Pathological: Petechiae, conjunctival haemorrhage Neurological: Ptosis Pain Dyspnoea Psychological: Existential fear
Joshi, Rahill, Lecano, & Jean (2014)	Haiti	Qualitative	N = 27 8 survivors of sexual assault (age 19-45 years)	JBI Qualitative Research 9/10 Nil for 7		"Dappiyanmp" used to describe sexual assault (translates as 'strangled like a chicken'; p. 1635) Headache Tinnitus Vision changes Insomnia Hypervigilance Depression Feelings of worthlessness and hopelessness Suicidality "I'm traumatised…I black out; you can be talking to me right now and I can't see you, can't hear you" (p. 1636) - dissociative seizures?	Neurological: Tinnitus Insomnia Psychological: Hypervigilance Depression Feelings of worthlessness and hopelessness Suicidality Trauma reaction Dissociative seizures?
Joshi, Thomas, & Sorenson (2012)	USA	Qualitative	N = 17 Women attending domestic violence shelter. Age 21-47, 14 self-identified as African American. All strangled, 15/17 multiple times.	JBI Qualitative Research 9/10 Nil for 7	Petechiae Stroke	14/17 lost consciousness; 2 close to blacking out Near death experience "life flashing before eyes…saw my own face" (p. 9) Dysphasia Dysphagia Pain Incontinence Tinnitus Physical weakness Nightmares Insomnia	Pathological: Petechiae Stroke Neurological: Incontinence Tinnitus Insomnia Pain Psychological: Nightmares

						Anxiety Suicidality Heightened and persistent fear Exacerbation of existing mental health problems Triggering in new relationships Minimisation of severity Lack of medical help-seeking	Anxiety Fear Exacerbated existing mental health difficulties Interpersonal difficulties Suicidality Minimisation Lack of help-seeking
Le Blanc-Louvry, Papin, Vaz, & Proust (2013)	France	Case reports (hospital)	N = 3, only 1 IPV-related 29 year old woman strangled twice within a few minutes by spouse. First attempt manual, front on; second was 'chokehold' from behind.	JBI Case Reports: 5/8 Nil for 3/4/6	Brain CT: wide temporal hypodensity in left middle cerebral artery area Doppler: left carotid artery thrombosis due to major dissection	Dysesthesia right hand and foot Headache Facial paralysis Right-side hemiplegia Broca-like aphasia Lateral homonymous hemianopia Symptoms all persistent and worsening after 3 weeks; discharged to neurorehabilitation, further deteriorated with seizures	Pathological: Arterial dissection and thrombosis Neurological: Aphasia Headache
Malek et al. (2000)	USA	Case reports (hospital)	N = 3 Age 24-43, all victims of strangulation by partner	JBI Case Reports: 7/8 Nil for 6	1. Left posterior frontal lobe stroke, delayed by 3 months 2. Right opercular stroke, delayed by 3 months 3. Bilateral frontal infarcts in watershed distribution of MCA & ACA.	1. Dysarthria; Residual right hand and digit weakness and numbness; no symptoms at 8 month follow-up 2. Left hand and arm paresis. Asymptomatic at 20 months 3. Strangulation witnessed 6/12 months prior to admission; delayed coma. 3 months after treatment, persistent paralysed right upper extremity, weak left arm and hand, dysphasia.	Pathological: Stroke Bilateral, symmetrical, high cervical CA dissection NB all cases had hyperthyroidism described as 'coexisting medical problem'. However, the thyroid can be damaged by strangulation. Neurological: Dysarthria Dysphasia
Meel (2015)	South Africa	Case report (hospital)	N = 1 23 year old woman sexually assaulted by colleague	JBI Case Reports: 5/8	Symptoms of venous congestion: bilateral sub-conjunctival haemorrhage CT neck-only: hyoid fracture	Loss of consciousness (GCS 3/15) Seizures, suggesting cerebral hypoxia Discharged after a week "with no neurological deficits"	Pathological: Venous congestion Hyoid fracture

				Nil for 4/5/6		No follow-up	
Messing, Patch, Wilson, Kelen, & Campbell (2018)	USA	Analytical cross-sectional	N = 1,008 Community-living women recruited through contact with police for IPV; mean age 32; 803 (80%) reported strangulation; 38% multiple strangulation attempts	JBI for Cross Sectional: 8/8		More likely than non-strangled IPV survivors to: - believe partner capable of killing them (ARR, 1.81) - have suffered miscarriage due to abuse (ARR, 2.95) - have lost consciousness for over an hour (ARR, 5.08) - feel powerless (ARR, 2.62) 27% reported loss of consciousness Multiple strangulation significantly associated with miscarriage	Psychological: Existential fear Powerlessness Other: Miscarriage
Messing, Thaller, & Bagwell (2014)	USA	Analytical cross-sectional	N = 432 Women recruited at scene of police-involved IPSV incidents; age range 18-62 315 (73%) reported strangulation	JBI Cross Sectional: 7/8 Nil for 6		Strangulation significantly associated with sexual abuse (OR, 2.74) and rape (OR, 2.19) Women experiencing forced sex more likely to experience strangulation, PTSD, and shame (direction of interactions not analysed)	Psychological: PTSD Shame
Miao et al. (2008)	China	Case report (hospital)	N = 1 21 year old woman strangled in IPV	JBI Case Reports: 4/8 Nil for 3/4/6/7	Bilateral basal ganglia lesions	No respiration for 3 minutes but heart continued with CPR Unconscious for 24 hours No symptoms 5 days later, resting left hand tremor and mild dysarthria. After 8 days, bradykinesia, severe tremor, rigidity of all extremities; delayed Parkinsonism. Treated with hyperbaric oxygen and asymptomatic at 12 months	Neurological: Dysarthria

Reference	Country	Study Design	Sample	Quality	Neuropathology	Clinical outcomes (neurological, cognitive, emotional, behavioural)	Additional to hypoxic-ischaemic?
Milligan & Anderson (1980)	UK	Case reports (hospital)	N = 2 Women strangled by husbands (37 & 28)	JBI Case Reports: 7/8 Nil for 6	Partial occlusion of left carotid artery 1.5cm distal to bifurcation. Diagnosis: stroke due to ICA lesion Large infarct left fronto-parietal. Tapering occlusion of internal carotid 2cm distal to bifurcation. Diagnosis: stroke due to ICA lesion	3 days following strangulation: Confusion Headache Right-sided weakness and sensory loss Dysphasia Ptosis, then Horner's syndrome Hyperreflexia 8 year GP review asymptomatic Day after strangulation: Collapsed but conscious Severe dysphasia Right hemianopia Right hemiplegia Right sensory deficit 2 year GP review, speech hesitancy	Pathological: Arterial lesion and stroke Neurological: Headache Dysphasia and speech hesitancy
Mittal et al. (2018)	USA	Analytical cross-sectional using secondary data (from RCT)	N = 175 Participants in trial for HIV-IPV prevention intervention for abused women Majority (*n* = 103) reported strangulation. Age range 18-49; 41% African American.	JBI Cross Sectional: 8/8		Strangulation significantly correlated with depression In logistic regression, significant factor (OR = 2.40, 95% CI 1.29-4.50)	Psychological: Depression
Plattner, Bolliger, & Zollinger (2004)	Switzerland	Retrospective, cross sectional analysis of clinical examination data	N = 134 Hospital records 114 (85%) victims female. All male victims assaulted by men. In 47 (35%) cases strangulation inflicted during rape. 4/134 were strangled from behind ("carotid sleeper") with severe effects.	JBI Cross sectional: 5/8 Nil for 6/7/8	21% had petechial haemorrhages	20% dyspnoea 10% "nearly" fainted 11% lost consciousness 3% incontinent	Pathological: Petechiae Neurological: Incontinence

Reference	Country	Study Design	Sample	Quality	Neuropathology	Clinical outcomes (neurological, cognitive, emotional, behavioural)	Additional to hypoxic-ischaemic?
Pritchard, Reckdenwald, Nordham, & Holton (2018)	USA	Retrospective, cross sectional analysis of police records	N = 591 cases charged as IPV 68 explicit strangulation cases and 101 possible cases. 13% choke hold, 6% pinned against wall/floor.	JBI Cross sectional: 5/8 Nil for 6/7/8	16% petechiae	22% cognitive symptoms (e.g. memory problems, slurred speech) 2% dysphagia 2% voice changes 25% breathing difficulties	Neurological: Petechiae
Purvin (1997)	USA	Case report (hospital)	N = 1 30 year old woman strangled by boyfriend	JBI Case Reports: 7/8 Nil for 6	Carotid artery dissection with pseudoaneurysm formation and high-grade narrowing	Severe left-sided headache Followed after two weeks by left-sided post-glandionic Horner's Syndrome	Pathological: CA dissection
Ralston, Rable, Larson, Handmaker, & Lifshitz (2019)	USA	Retrospective analysis of symptom self-report in forensic nursing records	N = 19 Patients presenting with IPV injuries 17/19 female; mean age 32 100% reported strangulation Excluded those who had also been sexually assaulted	JBI Cross sectional: 6/8 Nil for 6/7	21.1% petechiae	84% dizziness 79% headache 79% breathing difficulty 68% pain 16% nausea and vomiting 26% loss of consciousness 37% confusion and lack of orientation 11% sleepiness 58% visual changes 5% incontinence 58% voice changes 11% loss of hearing	Pathological: Petechiae Neurological: Pain Incontinence Breathing difficulty
Shields, Corey, Weakley-Jones, & Stewart (2010)	USA	Retrospective analysis of medicolegal evaluations records	N = 102 101/102 female 79% strangled by intimate partner, 7% by stranger; 9% pregnant at time of attack. Age 17-68 (M = 31). 30% African American.	JBI Cross Sectional: 6/8 Nil for 6/7	Petechiae Stroke Right vertebral artery dissection Left cerebral infarction of distal posterior cerebral artery	38% loss of consciousness Miscarriage Incontinence Coma Difficulty breathing Dysphagia Pain Dizziness Short-term memory impairment Minimisation/lying about event due to fear, shame, embarrassment Experienced verbal threats to kill "He's going to kill me if not the baby" (p. 321); "I could have killed you. You're lucky I didn't" (p. 323)	Pathological: Petechiae Stroke Vertebral artery dissection Neurological: Pain Incontinence Breathing difficulty Psychological: Minimisation/lying about event due to fear, shame, embarrassment, existential threat

							Miscarriage
Smith, Mills, & Taliaferro (2001)	USA	Cross-sectional survey-based study	N = 101 Recruited from women's refuges and ED patients including 57/102 strangled twice or more	JBI Cross Sectional Studies 4/8 Nil for 2/5/6/7		Multiple strangulation vs one incident increases risk of (* for significant difference): Personality change Depression, suicidality Nightmares*, insomnia Anxiety Diagnosed PTSD Dizziness/light-headedness* Pain*, headache Memory loss* Vision changes Tinnitus* Ptosis Weakness* Facial droop Paralysis Loss of sensation Muscle spasms* Voice changes* Multiple strangulation subjects more frequently report neurological and psychological symptoms than single attack subjects	Neurological: Muscle spasms Tinnitus Psychological: Personality change Depression Nightmares Insomnia Suicidality Anxiety PTSD
Strack, McClane, & Hawley (2001)	USA	Cross sectional analysis of prosecution files for domestic violence	N = 300 strangulation victims 99% female Only two were female offender and male victim. Mean age 32. 10 were pregnant at time of attack.	JBI Cross Sectional Studies 6/8 Nil for 6/7	Delayed presentation – only 39% had symptoms on day of incident Only 15% had symptoms sufficiently visible to be photographed for evidence Petechiae Bilateral sub-conjunctival haemorrhage	Pain Short-term memory impairment Ataxia Uncontrollable shaking Defecation Hyperventilation Light-headness Visual changes ("black and white" or "black spots", p. 305) Loss of consciousness Headache Nausea and vomiting (inc. blood) Dysphagia Difficulty breathing Voice changes Experienced threats to kill: "I can easily cut off your air supply by shutting off your	Neurological: Incontinence Uncontrollable shaking Hyperventilation Vomiting blood Voice changes Delayed presentation Psychological: Existential threat Miscarriage

						carotid artery"; "I am going to commit an OJ on you and leave no visible marks"; "Dear God, please forgive me for what I am about to do"; "I'm going to pop your neck"; "I'm going to choke you to death"; "Die, die" Miscarriage within 24h	
Thomas, Joshi, & Sorenson (2014)	USA	Qualitative	N = 17 female shelter residents who had experienced strangulation, aged 21-47, 14/17 African American, 13/17 experienced multiple strangulation, 4/17 pregnant	JBI Qualitative Research 9/10 Nil for 7		Shock Intense vulnerability/powerlessness Pain Loss of consciousness Experienced death threats Belief in imminent death (16/17) "I thought I was going to die, I really did, because I got real clammy and everything just got real dark" (p. 130) "painful to watch the man who so-called loves you try to kill you" (p. 130) Immediate and lasting fear Subsequent compliant/submissive behaviour Aggression towards perpetrator Not leaving house	Psychological: Shock Vulnerability Existential fear Powerlessness Emotional pain Behaviour: Compliant Submissive Aggressive Not leaving house
Wilbur et al. (2001)	USA	Analytical cross sectional (survey-based)	N = 62 Women's shelters and hospital-based violence prevention centre 42 (68%) had been strangled by partner. 42% Hispanic and 16% African American. Average length of abuse before strangulation 3 years.	JBI Cross Sectional Studies 6/8 Nil for 6/7	54% petechiae	61% dizziness 17% loss of consciousness 28% visual changes 36% tinnitus 45% voice changes 44% dysphagia 68% pain 85% breathing difficulties 11% miscarriage 11% incontinence 20% ptosis 10% facial droop 23% weakness/paralysis 31% loss of sensation 31% memory loss 81% depression 31% suicidality 67% insomnia 70% nightmares 83% anxiety PTSD (no figure given)	Pathological: Petechiae Neurological: Tinnitus Voice change Pain Breathing difficulties Incontinence Psychological: Depression Suicidality Insomnia Nightmares Anxiety PTSD Miscarriage

Reference	Country	Study Design	Sample	Quality	Neuropathology	Clinical outcomes (neurological, cognitive, emotional, behavioural)	Additional to hypoxic-ischaemic?
Yen et al. (2007)	Austria, Switzerland	Case reports from forensic examination (using existing radiological findings)	N = 14 2 men, 12 women Mean age 33	JBI Case Reports: 6/8 Nil for 6/7	Petechiae Extensive infarction of both cerebellar hemispheres Haemorrhage of lymph nodes Patients reported significant, understandable distress having to wear neck coil for MRI, which may have caused motion artefacts and reduced quality of diagnostics	Loss of consciousness/"blackout" Incontinence Dizziness Pain Hallucinations before losing consciousness Impaired vision: seeing "black void" (p.116) reported by 50% Anxiety	Pathological: Cerebellar infarction Petechiae Haemorrhage of lymph nodes Neurological: Incontinence Pain "Black void" in vision Psychological: Hallucinations Anxiety
Zilkens et al. (2016)	Australia	Analytical cross-sectional study using existing routine admissions data	N = 1,064 women referred to a sexual assault centre, 79 of whom had been strangled. Mean age 29. 5% were pregnant. Odds of strangulation were 8.4 times more likely for someone sexually assaulted by intimate partner vs stranger.	JBI Cross Sectional Studies 6/8 Nil for 6/7	27.8% petechiae 3.8% subconjunctival haemorrhage	46.8% pain 34.2% dysphagia 15.2% voice changes 8.9% breathlessness 8.9% loss of consciousness 8.9% dizziness 2.5% blurred vision 1.3% incontinence Deprivation of liberty & verbal threats more likely than in non-strangulation assaults	Pathological: Petechiae Neurological: Breathlessness Incontinence Pain Psychological: Impact of deprivation of liberty and verbal threats

the median score for both cross sectional studies and case reports was 6/8. Quality was higher, albeit against different criteria, for the qualitative studies, although there was a widespread failure to frame the research in terms of relevant theory, or address the influence of the researcher on the research.

Summary of main findings

This review's main objective was to ascertain what evidence we have for the neurological, cognitive, behavioural, and psychological impact of strangulation within IPV and sexual assault.

Clinical outcomes

21/27 studies reported potentially serious medical outcomes. Loss of, and alterations to, consciousness, were widespread, suggesting at least mild brain injury per the Mayo classification system (Malek et al., 2007). For those studies reporting incidence, loss of consciousness ranged from 8.9% (Zilkens et al., 2016) to 38% of strangulation attempts (Shields et al., 2010). Importantly, figures were higher when taken from medical settings, where consciousness was assessed objectively. When women self-reported at a later date, lower figures may be due to memory loss, or not understanding what 'blacking out' or 'passing out' signify. Other widely reported consequences, with number of articles in parentheses, include: changes to vision, including hemianopia (9); pain (9); dysarthria, dysphonia, and other voice changes (9); headache (8); dyspnoea or breathing difficulty (7); facial or limb paralysis (7); dysthesia or loss of or changes to sensation (7); swallowing difficulty or dysphagia (6); lightheaded or dizzy (6); urinary or faecal incontinence (6); limb weakness (6); tinnitus (4); dysphasia (4); spasms/tremor/shaking (3); seizures (2); confusion (2); nausea and vomiting (2); ptosis and Horner's Syndrome (2); coma (2); ataxia (2); facial droop (2); hyperreflexia (1). In the eight studies that reported follow-up outcomes, or were

based on surveys or interviews with survivors at a later date, ongoing symptoms, with number of articles in parentheses, included: pain, tinnitus, vision changes, paralysis (4); headache, sensory and voice changes (3); swallowing difficulty, ptosis, incontinence, facial droop (2); seizures, dizziness, breathing difficulty, and muscle spasm (1).

Cognitive outcomes

Only one case report mentioned an immediate cognitive outcome, which was having no memory of the strangulation incident (De Boos, 2019). Five studies reported delayed cognitive outcomes, all of which cited memory loss. Farr (2002) reported two victims having been taken into public by the attacker afterwards and making no attempt to escape, which is deemed to be "traumatic immobility" (p. 276). This may have had a psychological basis – fear – but could also be cognitive, e.g. agnosia or lack of initiation. Pritchard et al. (2018) reported 22% of police records mentioning "any psychological symptoms", but then refers to "memory problems, slurred speech etc" (p. 171), which seem to be more neurocognitive, and are, unfortunately, not separated out.

Psychological outcomes

Only four studies reported on psychological distress in the immediate aftermath of the strangulation, which all hinged on a sense of existential threat, the firm conviction that they were about to die (De Boos, 2019; Funk & Schuppel, 2003; Shields et al., 2010; Strack et al., 2001). A further 13 studies reported on delayed psychological outcomes. These included (with number of articles in parentheses): existential threat (7); depression, anxiety, suicidality, and nightmares (4); insomnia, PTSD (3); generalised fear and feelings of danger, powerlessness and vulnerability, dissociation at the time of the attack, and ongoing, including possible dissociative seizures, minimisation and denial of events (2); and then single articles reported increased shame, hypervigilance, participants believing they had actually died,

interpersonal difficulties, personality change, feelings of worthlessness, further unspecified trauma reaction, and exacerbation of existing mental health difficulties.

The verbal threats to kill made by attackers were mentioned in three studies, and give substance to the existential fear reported by victims (Shields et al., 2010, Strack et al., 2001; Zilkens et al., 2016). Examples include: “I am going to commit an OJ on you and leave no visible marks” or “Die, die” (Strack et al., 2001, p. 307). Messing et al. (2018) found that IPV victims who were strangled had significantly increased odds of believing their partner could and would kill them (ARR, 1.81). Both studies by Joshi et al (2014 & 2018) reported dissociative reactions at the time of the strangulation, seeing life flashing before their eyes, and possible non-epileptic absence seizures as a long-term consequence: “I black out, you can be talking to me right now and I can’t see you, can’t hear you (p. 1,636). One of Farr’s participants (2002) describes the sense of “being killed and watching it” (p. 275). In Yen et al. (2007) 7/14 of forensic examinations contain reports of seeing a “black void”. Thomas et al. (2014) draw attention to the highly personal nature of the crime, as well as this dissociative element, with a victim stating it is “painful to watch the man who so-called loves you try to kill you” (p. 130)

An incidental finding in several of the studies was miscarriage following the strangulation event. Messing et al. (2018) reported increased odds (ARR, 2.95) for strangled versus non-strangled IPV survivors, and that this increased for those who had experienced multiple incidents. Wilbur and colleagues (2001) reported an 11% incidence amongst women in refuges who had been strangled. Although miscarriage does not directly fall within immediate psychological outcomes, the potential effect does, as large effects have been shown elsewhere for depression, guilt, and complicated grief (Adolfsson, 2011).

Behavioural outcomes

One qualitative study (Thomas et al., 2014) mentioned behavioural changes after strangulation, indicative of power dynamics. These included increased compliant and submissive behaviour, self-isolation and not leaving the house, and, for one participant, increased aggression towards her partner. Another qualitative study discussed the survivalist mode the victim entered following the realisation that death was imminent: "then I knew it's either him or me" (Eiskovits & Winstok, 2002, p. 695). Several studies drew attention to the lack of help-seeking behaviour by strangulation victims (Joshi et al, 2012; Pritchard et al., 2018; Ralston et al., 2019). Only 39% of women at a refuge who had been strangled had sought medical attention, despite more than half having been strangled twice or more (Smith et al., 2001). This dropped to 5% in a study of 300 prosecution files (Strack et al., 2001).

Is there a distinction between strangulation and hypoxic-ischaemic outcomes?

Our second review question was the extent to which these reported sequelae differed from typical symptoms of other hypoxic-ischaemic injuries such as cardiac arrest, given the similar mechanisms, not least that the sinus reflex can be triggered in strangulation. Table 2 compares outcomes, using the International Brain Injury Association's delineation of neurological and neurobehavioural outcomes (Arciniegas, 2012), compared to the findings from our literature review.

Table 2. Clinical outcomes of hypoxic-ischaemic injury versus strangulation

	Specific to hypoxic-ischaemic injury?	Shared outcomes	Specific to strangulation?
Neurological		Loss of consciousness Seizures Movement disorders Weakness Paralysis Changes to vision	Pain Dysphonia Nausea Ptosis Breathing difficulties, hyperventilation Tinnitus Incontinence

			Voice changes Delayed presentation (weeks after index event)
Cognitive	Attention and processing speed Executive function	Memory loss Disorders of language Agnosia?	Lack of initiation?
Psychological		Personality change Disorders of mood and affect regulation (depression, anxiety)	Existential threat Persisting fear, sense of danger Sense of vulnerability and powerlessness Dissociation Hypervigilance Suicidality PTSD Trauma reaction Nightmares Insomnia Exacerbation of existing mental health difficulties Interpersonal difficulties Minimisation and denial Hallucinations Shame Impact of verbal threats and deprivation of liberty Indirect effect of miscarriage
Behavioural		Behavioural disturbance, including aggression	Compliant and submissive behaviour Self-isolating Lack of help-seeking

The information in Table 2 is clearly limited by the data reported in the studies available for our review. Some strangulation events result in complete occlusion of both air and blood flow, can trigger the carotid sinus reflex, and would therefore include all hypoxic-ischaemic outcomes, by definition. Given the lack of reporting on cognitive outcomes in the studies we reviewed, we cannot state that strangulation does not lead to difficulties with attention, speed of processing, or executive function. In fact, several case reports outlined frontal lobe and basal ganglia damage (Malek et al., 2000; Miao et al., 2008; Milligan & Anderson, 1980).

Unfortunately, these studies were limited to anatomical changes. Similarly, some of the neurological outcomes reported in the strangulation literature are doubtless present in hypoxic-ischaemic cases, although speech does appear to be a resistant function (Lu-Emerson & Khot, 2010). For example, incontinence has been reported in rare cases of posthypoxic demyelination (Thacker, Asthana & Sarkari, 1995).

Perhaps Table 2 might be most helpfully seen as a preliminary attempt at providing a general profile of strangulation outcomes. As such it spotlights the severity of the crime. Strangulation can result in the majority of expected clinical outcomes of cardiac arrest, hanging, carbon monoxide poisoning, or drowning, but with additional trauma-based psychological distress, significant neurological damage, behavioural change, and the risk of miscarriage. Despite this severity, the data suggest strangulation victims may receive less intervention, partly due to delayed symptom development, and the observation that as few as 5% of victims seek medical assistance (Strack et al., 2001).

Discussion

Our systematic literature search identified 27 empirical, peer-reviewed studies which documented the outcomes of non-fatal strangulation in IPV and sexual assault. There was heterogeneity of design, from medical case reports, to large scale cross-sectional analyses of police records. This is both a strength of the review, in that it was able to draw together evidence from disparate disciplines, but also a limitation as regards comparison. Almost all victims were female. 18 studies reported on the pathology of the attack, which included severe, life-threatening injuries: delayed stroke, arterial bisection, basal ganglia, frontal lobe, and cerebellar lesions, hyoid fractures, tracheal perforations, and signs of venous congestion, including petechial haemorrhage. 23 described the clinical outcomes, with loss of

consciousness reported in up to 38% of strangulation events (Shields et al., 2010), strongly suggestive of acquired brain injury, and other serious sequelae including changes to vision and voice, limb weakness and paralysis, sensory loss, and movement disorder. 17 studies described the psychological outcomes, indicative of a profound trauma reaction: PTSD, existential fear, depression, anxiety, suicidality, personality change, insomnia, dissociation, and shame. Markedly fewer studies reported on cognitive and behavioural changes. Impaired memory for events was mentioned in six papers, and one was suggestive of executive difficulties. One study described subsequent compliant and submissive behaviour, and two reported survivalism and aggression towards the attacker. Five studies drew attention to the lack of help-seeking behaviour by the victims, even when there had been multiple strangulation attempts. There were no studies conducted from a neuropsychological perspective: the majority of papers found in our search were hospital-based case reports, or retrospective analyses of police and legal records. As such, they tended to focus on physical and visible (including via imaging) injury.

One study which had used standardised, blinded neuropsychological assessment, and demonstrated strangulation accounted for one-third the variance in cognitive function, as well as a dose effect, had to be excluded due to not having been peer-reviewed (Pierquet, 1997). Similarly, another unpublished study showed a 10-15 fold increased risk of stroke amongst young female IPV survivors, three-quarters of whom had been strangled (n = 237).

Lack of peer review meant it could not be included, but it does lend more substance to the warnings in the studies that were, namely that strangulation may be the second most common cause of stroke in women under 40, and should be included in the differential diagnosis of younger patients (Malek et al., 2000). Seven papers we found diagnosed haemorrhagic or ischaemic stroke, often significantly delayed.

This systematic review highlights four main points. Firstly, that strangulation within IPV and sexual assault is a highly gendered crime. Secondly, that strangulation may share all the consequences of hypoxic-ischaemic injury, such as cardiac arrest, but could have additional, severe, clinical outcomes, many of which are due to the highly traumatising nature of this particularly intimate terrorism (Johnson, 2010). Thirdly, that these women are unlikely to present to healthcare services, despite the severity of their injuries. Finally, and related to our original questions, that, despite growing interest, we still do not know enough about the clinical outcomes of strangulation in IPV and sexual assault, and that therefore potentially those women who do present to medical settings are being discharged with no real understanding of long-term consequences, nor receiving appropriate neuropsychological intervention.

This last point is important, because we need this evidence base in order to build public and institutional understanding of the gravity of strangulation. In a recent British legal case, a prostitute had been strangled by a client (Armstrong, 2012). With her losing consciousness, he had panicked, believed her to be dead, and was in the process of abandoning her body by the roadside when she regained consciousness. The victim then went to her attacker's house, where they drank wine together. Her behaviour after the event was used to undermine the severity of the attack, he was found guilty of the lesser charge of grievous bodily harm, and sentenced to two years. Based on the literature we have reviewed, her behaviour could have been due to existential fear, and therefore displaying compliance in order to survive. Having lost consciousness she would not remember that portion of the attack, but she could also have wider retrograde memory loss. It could be the result of damage to brain areas involved in executive function - she could not problem-solve or plan an escape – and general hypoxic

confusion. But if none of this is systematically evidenced, then victims' behaviour will not be seen as the product of a strangled brain.

This lack of appreciation for the severity of strangulation has other far-reaching consequences. The campaign group We Can't Consent To This (https://wecantconsenttothis.uk/) has collated 250 cases of women fatally strangled by men during sexual intercourse, in which the legal defence team argued that the victim consented, that therefore the death was accidental, and consequently the assailant not guilty of murder. But from a neuropsychological perspective, cognitively consent hinges on two factors: it must be informed, and there needs to be capacity to withdraw it at any point. If strangulation – its mechanics, its severity – is not understood, then the victim is not informed. The Red Wing studies (Kabat & Anderson, 1943) undermine the second point. The prisoners and psychiatric inmates who were fitted with the mechanical strangulation cuffs were also given an emergency release button. The lead investigator, when testing the equipment on himself, described being close to losing consciousness and finding himself unable to press the button (Smith, Clayton & Robertson, 2011). The potential onset of dyspraxia, memory impairment, and unconsciousness itself (in as little as four seconds) are disabling: the very organ that is needed to withdraw consent is compromised by the activity to which that consent applies. The term 'consenting kink' is therefore a potentially fatal misnomer.

This is of concern, in the context of strangulation having become normalised (Edwards, 2016). In a recent UK survey (N = 2,002) 38% of women under 40 had experienced strangulation during sex, with 42% of those saying it was unwanted, and that they had felt pressured, coerced, or forced (BBC, 2019). Strangulation is a pornographic trope, and features within popular mainstream literature, such as the *Fifty Shades* series. At the time of writing this paper the Google search algorithms would autocomplete 'choke' with 'someone

safely' and '…a girl meme', and online shops to buy accessories for 'breath play' are promoted. A recent systematic review calculated a median 7.4% prevalence amongst teenagers for the 'choking game', in which ligatures are used to strangle oneself, with this filmed and shared on social media, and 99 deaths reported in the literature (Busse, Harrop, Gunell, Kipping, 2015). Although many police forces have abandoned the use of carotid restraint following deaths in custody, it is still used in many countries, and by the military (Stellpflug, Menton, Corry, & Schneir, 2020). 'Near chokes', 'chokes', and 'submission holds' are also legitimate and widely utilised tactics in mixed martial arts (MMA).

To put this into context, waterboarding has now been internationally outlawed as a form of torture, correctly considered inhumane and unacceptably dangerous, even when its stated objective is to prevent multiple deaths. In waterboarding, however, it is only the airway which is occluded. Strangulation is more lethal: not only is breathing interrupted, but also blood flow to and from the brain. We have shown how it can carry all the consequences of hypoxic-ischaemic injury such as cardiac arrest, and more besides. There is something societally flawed about banning the waterboarding of terrorists, whilst ignoring the intimate terrorism (Johnson, 2010) of those millions of women around the world who are regular victims of strangulation.

Review limitations

The neuropsychological sequelae of strangulation is an embryonic field, it straddles different disciplines, and multiple terms are used to describe strangulation. Despite our best efforts, it is therefore extremely likely that our search missed studies. We limited ourselves to published studies, as a quality assurance, but therefore may have unintentionally excluded good work, including theses, which had not been submitted to peer review. It is also worth noting that, given this review was part of a doctoral thesis, we did not test inter-rater

reliability for inclusion criteria at the title/abstract level. In those papers we did find, few controlled for confounding factors. It was therefore sometimes difficult to separate out what outcomes were specific to strangulation as opposed to the general traumatising effects of IPV and sexual assault. This is particularly relevant for those instances where PTSD was reported, given associations have been demonstrated elsewhere between PTSD and hippocampal volume, speed of processing, and reasoning performance (Twamley, Allard, Thorp & Norman, 2009).

The JBI suite of critical appraisal tools were appropriate given heterogeneity of study design, but they do not enable weighting of evidence, and potentially mask the issue of low quality in the field. Linked to this, theabsence of consistent, validated assessment tools rendered between-study comparisons difficult, and meta-analysis impossible. Finally, the lack of high quality literature is an important finding in itself, and means any conclusions drawn are tentative.

Further research

In our opinion, it is imperative that new, peer-reviewed, high quality studies add to our neuropsychological understanding of strangulation, by investigating the cognitive, psychological, and behavioural outcomes, measured with standardised assessment tools, set against control groups. This will help in terms of isolating the effects of strangulation. It will also be important to recruit from non-hospital or IPV settings (given the majority of victims do not seek assistance). This lack of help-seeking behaviour merits exploration in its own right. The majority of studies were from the USA: does this pattern still exist in countries where healthcare is free at the point of need? What barriers prevent women from presenting? For those who do receive intervention, although it was not the objective of this search, little

was found in the literature which evidences best practice and treatment outcomes for holistic, long-term recovery, beyond acute medical care.

Again, although not the aim of this study, the societal normalisation of strangling we observed is concerning. There would be merit in trying to understand the attraction of, and possible pressure to partake in, 'breath play' and the 'choking game'. Similarly, the use of 'chokes' (loss of consciousness) and 'submission holds' (in which respiration is blocked) in MMA. Other sports, based on the evidence, have banned repeated heading of balls by young people, given the cumulative effect of multiple concussions on cognitive function, and the future risk of developing chronic traumatic encephalopathy (Stein, Alvarez & McKee, 2014). There are emerging case reports and studies on choking and carotid injury in MMA (Lim, Ho & Ho, 2019; Powell et al., 2018). There was a recent systematic review on TBI in MMA (Lockwood, Frame, Lin & Ackerley, 2018), but it focused on 'knockouts' rather than strangulation.

One of the strangulation mechanisms described in the Introduction is thyroid storm: thyrocytosis resulting from damage to the gland, which can cause multiple organ failure, including lethal arrhythmias. Malek et al. (2001) reported hyperthyroidism in their cases but stated this was pre-morbid. Given hyperthyroidism's non-fatal effects can include anxiety, insomnia, and several other strangulation outcomes attributed to the psychological impact, there may be merit in exploring further this interaction, as its incidence may be under-reported.

Finally, the high incidence of miscarriage and delayed stroke were notable. Further epidemiological investigation could be conducted to substantiate a call to healthcare providers to consider strangulation a differential diagnosis for both events. These could be

rare and critical moments in which to identify IPV victims, who may have no other physical signs of strangulation, and provide life-saving intervention.

Conclusion

This systematic review found 27 empirical, peer-reviewed studies on the outcomes of strangulation within IPV and sexual assault. Although the field is embryonic and, consequently, research tends to be of low quality, provisional evidence suggests that these outcomes can be severe. Given the mechanisms, involving potential occlusion of the airway, blood flow to and from the brain, and the triggering of the carotid sinus reflex, the neurological consequences can include all those associated with hypoxic-ischaemic injury, such as cardiac arrest. But there are other psychological outcomes linked to this uniquely intimate terrorism and its traumatising nature: the pain of watching "the man who so-called loves you try to kill you" (Thomas et al., 2014, p. 130). The majority of studies we found were based on hospital case reports, or existing police and legal records. At present there is less evidence for strangulation's cognitive and behavioural sequelae, and none based on objective, neuropsychological testing. There is therefore a need to build the evidence base, and this work should use control groups, and standardised assessment tools.

Perhaps more importantly, however, is the need to use the science to inform institutions and the public; to reposition strangulation from being a game, to serious criminal assault. Othello believed that Justice would be breaking her sword if he did not strangle Desdemona. In our view, Justice needs to keep her sword firmly raised until the millions of Othellos and Desdemonas around the world understand, as our review of the current evidence begins to show, that strangulation – even for seconds – could potentiallycause lifechanging damage to the mind, and the brain.

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References

Adolfsson A. (2011). Meta-analysis to obtain a scale of psychological reaction after perinatal loss: focus on miscarriage. *Psychology Research and Behavior Management*, *4*, 29–39.

Archer, J. (2002). Sex differences in physically aggressive acts between heterosexual partners: A meta-analytic review. *Aggression and Violent Behavior*, *7*(4), 313-351.

Arciniegas, D. (2012). Hypoxic-Ischaemic Brain Injury. *International Brain Injury Association*. Retrieved from https://www.internationalbrain.org/articles/hypoxicischemic-brain-injury/.

Armstrong, (2012). Man choked prostitute after watching Billie Piper in Secret Diary of a Call Girl. The Mirror. Retrieved from https://www.mirror.co.uk/news/uk-news/man-choked-prostitute-after-watching-145613

Bagwell-Gray, M. E., Messing, J. T., & Baldwin-White, A. (2015). Intimate partner sexual violence: A review of terms, definitions, and prevalence. *Trauma, Violence, & Abuse*, *16*(3), 316-335.

Banks, M. E. (2007). Overlooked but critical: Traumatic brain injury as a consequence of interpersonal violence. *Trauma, Violence, & Abuse*, *8*(3), 290-298.

Banzett, R. B., Lansing, R. W., Evans, K. C., & Shea, S. A. (1996). Stimulus-response characteristics of CO2-induced air hunger in normal subjects. *Respiration Physiology*, *103*(1), 19-31.

British Broadcasting Corporation (2019). Savanta ComRes survey. Table with full results retrieved from https://www.comresglobal.com/wp-content/uploads/2019/11/Final-BBC-5-Live-Tables_211119cdh.pdf

Busse H, Harrop T, Gunnell D, *et al.* Prevalence and associated harm of engagement in self-asphyxial behaviours ('choking game') in young people: A systematic review. *Archives of Disease in Childhood, 100***,** 1106-1114

Cameron, R. P., & Gusman, D. (2003). The primary care PTSD screen (PC-PTSD): development and operating characteristics. *Primary Care Psychiatry*, *9*(1), 9-14.

Campbell, J. C., Webster, D. W., & Glass, N. (2009). The danger assessment: Validation of a lethality risk assessment instrument for intimate partner femicide. *Journal of Interpersonal Violence*, *24*(4), 653-674.

Chapman, J. C., & Diaz-Arrastia, R. (2014). Military traumatic brain injury: a review. *Alzheimer's & Dementia*, *10*, S97-S104.

Clarot, F., Vaz, E., Papin, F., & Proust, B. (2005). Fatal and non-fatal bilateral delayed carotid artery dissection after manual strangulation. *Forensic Science International*, *149*(2-3), 143-150.

Cooper, I. S. (1949). Medical Aspects of the Death of Desdemona. *Postgraduate Medicine*, *5*(6), 520-525.

Corrigan, J. D., Wolfe, M., Mysiw, W. J., Jackson, R. D., & Bogner, J. A. (2003). Early identification of mild traumatic brain injury in female victims of domestic violence. *American Journal of Obstetrics and Gynaecology*, *188*(5), S71-S76.

Davins-Pujols, M., Salamero, M., Aznar-Martínez, B., Aramburu-Alegret, I., & Pérez-Testor, C. (2014). Acts of intimate partner violence and feelings of danger in battered women seeking help in a Spanish specialized care unit. *Journal of Family Violence*, *29*(7), 703-712.

De Boos, J. (2019). Tracheal perforation from non-fatal manual strangulation. *Journal of Forensic and Legal Medicine*, *66*, 1-3.

Edwards, S. (2016). Assault, strangulation and murder – challenging the sexual libido consent defence narrative, in A. Reed & M. Bohlander, with N. Wake & E. Smith (eds), *Consent: Domestic and Comparative Perspect*ives. Abingdon, UK: Routledge.

Eisikovits, Z., & Winstok, Z. (2002). Reconstructing intimate violence: The structure and content of recollections of violent events. *Qualitative Health Research*, *12*(5), 685-699.

Farr, K. A. (2002). Battered women who were "being killed and survived it": Straight talk from survivors. *Violence and Victims*, *17*(3), 267-281.

Funk, M., & Schuppel, J. (2003). Strangulation injuries. *WMJ-MADISON-*, *102*(3), 41-45.

Glass, N., Laughon, K., Campbell, J., Block, C. R., Hanson, G., Sharps, P.W., & Taliaferro, T. (2008). Non-fatal strangulation is an important risk factor for homicide of women. *The Journal of Emergency Medicine*, *35*(3), 329-335.

Green, S. (2017). Strangulation is a powerful tool of violence that often leaves no physical mark. Training Institute on Strangulation Prevention. Retrieved at: https://www.strangulationtraininginstitute.com/strangulation-is-a-powerful-tool-of-violence-that-often-leaves-no-physical-mark-officials-in-king-county-want-it-noticed-prosecuted/

Hawley, D. A., McClane, G. E., & Strack, G. B. (2001). A review of 300 attempted strangulation cases part III: injuries in fatal cases. *The Journal of Emergency Medicine*, *21*(3), 317-322.

Joanna Briggs Institute (2017). Critical Appraisal Tools. Retrieved from https://joannabriggs.org/ebp/critical_appraisal_tools

Johnson, M. P. (2010). *A typology of domestic violence: Intimate terrorism, violent resistance, and situational couple violence*. Northeastern University Press: Upne.

Joshi, M., Rahill, G. J., Lescano, C., & Jean, F. (2014). Language of sexual violence in Haiti: perceptions of victims, community-level workers, and health care providers. *Journal of Health Care for the Poor and Underserved*, *25*(4), 1623-1640.

Joshi, M., Thomas, K. A., & Sorenson, S. B. (2012). "I didn't know I could turn colors": Health problems and health care experiences of women strangled by an intimate partner. *Social Work in Health Care*, *51*(9), 798-814.

Kabat, H., & Anderson, J. P. (1943). Acute arrest of cerebral circulation in man: Lieutenant Ralph Rossen. *Archives of Neurology & Psychiatry*, *50*(5), 510-528.

Koh, J. O., Cassidy, J. D., & Watkinson, E. J. (2003). Incidence of concussion in contact sports: a systematic review of the evidence. *Brain Injury*, *17*(10), 901-917.

Kwako, L. E., Glass, N., Campbell, J., Melvin, K. C., Barr, T., & Gill, J. M. (2011). Traumatic brain injury in intimate partner violence: A critical review of outcomes and mechanisms. *Trauma, Violence, & Abuse*, *12*(3), 115-126.

Le Blanc-Louvry, I., Papin, F., Vaz, E., & Proust, B. (2013). Cervical arterial injury after strangulation—different types of arterial lesions. *Journal of Forensic Sciences*, *58*(6), 1640-1643.

Levack, M. M., Pettitt, B. J., & Winston, A. D. (2009). Carotid artery thrombosis and delayed stroke associated with the use of a shoulder belt in a teenager. *Journal of Pediatric Surgery*, *44*(8), e29-e33.

Lim, L. J., Ho, R., & Ho, C. S. (2019). Dangers of mixed martial arts in the development of chronic traumatic encephalopathy. *International journal of environmental research and public health*, *16*(2), 254.

Lockwood, J., Frape, L., Lin, S., & Ackery, A. (2018). Traumatic brain injuries in mixed martial arts: A systematic review. *Trauma*, *20*(4), 245-254.

Lu-Emerson, C., & Khot, S. (2010). Neurological sequelae of hypoxic-ischemic brain injury. *NeuroRehabilitation*, *26*(1), 35-45.

Malec, J. F., Brown, A. W., Leibson, C. L., Flaada, J. T., Mandrekar, J. N., Diehl, N. N., & Perkins, P. K. (2007). The Mayo classification system for traumatic brain injury severity. *Journal of Neurotrauma*, *24*(9), 1417-1424.

Malek, A. M., Higashida, R. T., Halbach, V. V., Dowd, C. F., Phatouros, C. C., Lempert, T. E., ... & Stoney, R. (2000). Patient presentation, angiographic features, and treatment of strangulation-induced dissection of the internal carotid artery: Report of three cases. *Journal of Neurosurgery*, *92*(3), 481-487.

McClane, G. E., Strack, G. B., & Hawley, D. (2001). A review of 300 attempted strangulation cases Part II: clinical evaluation of the surviving victim. *The Journal of emergency medicine*, *21*(3), 311-315.

Mcquown, C., Frey, J., Steer, S., Fletcher, G. E., Kinkopf, B., Fakler, M., & Prulhiere, V. (2016). Prevalence of strangulation in survivors of sexual assault and domestic violence. *The American journal of emergency medicine*, *34*(7), 1281-1285.

Meel, B. L. (2015). A case report on near manual strangulation and Glasgow coma scale. *African Health Sciences*, *15*(3), 1038-1040.

Messing, J. T., Patch, M., Wilson, J. S., Kelen, G. D., & Campbell, J. (2018). Differentiating among attempted, completed, and multiple nonfatal strangulation in women experiencing intimate partner violence. *Women's Health Issues*, *28*(1), 104-111.

Messing, J. T., Thaller, J., & Bagwell, M. (2014). Factors related to sexual abuse and forced sex in a sample of women experiencing police-involved intimate partner violence. *Health & Social Work*, *39*(3), 181-191.

Miao, J., Su, C., Wang, W., Lin, H., Li, H., Lei, G., ... & Li, Z. (2009). Delayed parkinsonism with a selective symmetric basal ganglia lesion after manual strangulation. *Journal of Clinical Neuroscience*, *16*(4), 573-575.

Milligan, N., & Anderson, M. (1980). Conjugal disharmony: a hitherto unrecognised cause of strokes. *Br Med J*, *281*(6237), 421-422.

Mittal, M., Resch, K., Nichols-Hadeed, C., Stone, J. T., Thevenet-Morrison, K., Faurot, C., & Cerulli, C. (2018). Examining associations between strangulation and depressive symptoms in women with intimate partner violence histories. *Violence and Victims*, *33*(6), 1072-1087.

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Annals of Internal Medicine*, *151*(4), 264-269.

Monahan, K., Purushotham, A., & Biegon, A. (2019). Neurological implications of nonfatal strangulation and intimate partner violence. *Future Neurology*, *14*(3), FNL21.

Patch, M., Anderson, J. C., & Campbell, J. C. (2018). Injuries of women surviving intimate partner strangulation and subsequent emergency health care seeking: an integrative evidence review. *Journal of Emergency Nursing*, *44*(4), 384-393.

Pierquet, L. (1997). *Neuropsychological consequences of the domestic battering of women*. Doctoral thesis submitted to the Wisconsin School of Professional Psychology. Retrieved via Inter-Library Loan from UMI, Ann Arbor, Michigan.

Plattner, T., Bolliger, S., & Zollinger, U. (2005). Forensic assessment of survived strangulation. *Forensic Science International*, *153*(2-3), 202-207.

Powell, T., Fullam, T., Hammett, J., Nettlow, D., & Harris, J. (2018). Vertebral Artery Dissection in Active-Duty Soldier Due to Mixed Martial Arts Choke Hold. *Federal Practitioner*, *35*(7), 12.

Pritchard, A. J., Reckdenwald, A., & Nordham, C. (2017). Nonfatal strangulation as part of domestic violence: A review of research. *Trauma, Violence, & Abuse*, *18*(4), 407-424.

Pritchard, A. J., Reckdenwald, A., Nordham, C., & Holton, J. (2018). Improving identification of strangulation injuries in domestic violence: Pilot data from a researcher–practitioner collaboration. *Feminist Criminology*, *13*(2), 160-181.

Purvin, V. (1997). Unilateral headache and ptosis in a 30-year-old woman. *Survey of Ophthalmology*, *42*(2), 163-168.

Radloff, L. S. (1977). The CES-D scale: A self-report depression scale for research in the general population. *Applied Psychological Measurement*, *1*(3), 385-401.

Ralston, B., Rable, J., Larson, T., Handmaker, H., & Lifshitz, J. (2019). Forensic nursing examination to screen for traumatic brain injury following intimate partner violence. *Journal of Aggression, Maltreatment & Trauma*, *28*(6), 732-743.

Rosenberg, M. (1965). Rosenberg self-esteem scale (RSE). *Acceptance and commitment therapy: Measures package*, *61*(52), 18.

Shields, L. B., Corey, T. S., Weakley-Jones, B., & Stewart, D. (2010). Living victims of strangulation: a 10-year review of cases in a metropolitan community. *The American Journal of Forensic Medicine and Pathology*, *31*(4), 320-325.

Smith, Y. (2009). Exploring psychosocial risk factors for stroke in young women exposed to domestic violence. Dissertation submitted to Queen Margaret University, UK. Retrieved from http://europepmc.org/article/ETH/500505.

Smith, B. A., Clayton, E. W., & Robertson, D. (2011). Experimental arrest of cerebral blood flow in human subjects: the red wing studies revisited. *Perspectives in Biology and Medicine*, *54*(2).

Smith, P. H., Earp, J. A., & DeVellis, R. (1995). Measuring battering: development of the Women's Experience with Battering (WEB) Scale. *Women's Health: Research on Gender, Behavior, & Policy*.

Smith Jr, D. J., Mills, T., & Taliaferro, E. H. (2001). Frequency and relationship of reported symptomology in victims of intimate partner violence: The effect of multiple strangulation attacks. *The Journal of Emergency Medicine*, *21*(3), 323-329.

Sorenson, S. B., Joshi, M., & Sivitz, E. (2014). A systematic review of the epidemiology of nonfatal strangulation, a human rights and health concern. *American Journal of Public Health*, *104*(11), e54-e61.

Stein, T. D., Alvarez, V. E., & McKee, A. C. (2014). Chronic traumatic encephalopathy: a spectrum of neuropathological changes following repetitive brain trauma in athletes and military personnel. *Alzheimer's Research & Therapy*, *6*(1), 4.

Stellpflug, S. J., Menton, T. R., Corry, J. J., & Schneir, A. B. (2020). There is more to the mechanism of unconsciousness from vascular neck restraint than simply carotid compression. *International Journal of Neuroscience*, *130*(1), 103-106.

Strack, G. B., & Gwinn, C. (2011). On the edge of homicide: Strangulation as a prelude. *Crim. Just.*, *26*(32).

Strack, G. B., McClane, G. E., & Hawley, D. (2001). A review of 300 attempted strangulation cases Part I: Criminal legal issues. *The Journal of Emergency Medicine*, *21*(3), 303-309.

Straus, M. A., Hamby, S. L., Boney-McCoy, S., & Sugarman, D. B. (1996). The revised conflict tactics scales (CTS2) development and preliminary psychometric data. *Journal of Family Issues*, *17*(3), 283-316.

Taliaferro, E., Mills, T., & Walker, S. (2001). Walking and talking victims of strangulation. Is there a new epidemic? A commentary. *The Journal of Emergency Medicine*, *21*(3), 293-295.

Thacker, A. K., Asthana, A. B., & Sarkari, N. B. S. (1995). Delayed post-anoxic encephalopathy. *Postgraduate Medical Journal*, *71*(836), 373.

Thomas, K. A., Joshi, M., & Sorenson, S. B. (2014). "Do you know what it feels like to drown?" Strangulation as coercive control in intimate relationships. *Psychology of Women Quarterly*, *38*(1), 124-137.

Twamley, E. W., Allard, C. B., Thorp, S. R., Norman, S. B., Cissell, S. H., Berardi, K. H., ... & Stein, M. B. (2009). Cognitive impairment and functioning in PTSD related to intimate partner violence. *Journal of the International Neuropsychological Society*, *15*(6), 879-887.

Vella, S. A. (2013). *Cognitions and behaviors of strangulation survivors of intimate terrorism*. Alliant International University.

White, C., & Majeed-Ariss, R. (2018). Non-fatal strangulation amongst clients attending Saint Mary's SARC. Manchester University NHS Foundation Trust. Retrieved from https://www.stmaryscentre.org/application/files/5815/6439/0323/White2018.pdf.

Wilbur, L., Higley, M., Hatfield, J., Surprenant, Z., Taliaferro, E., Smith Jr, D. J., & Paolo, A. (2001). Survey results of women who have been strangled while in an abusive relationship. *The Journal of Emergency Medicine*, *21*(3), 297-302.

World Health Organisation (2019). Violence against women - Evidence brief. Retrieved from https://www.who.int/reproductivehealth/publications/vaw-evidence-brief/en/.

Yen, K., Vock, P., Christe, A., Scheurer, E., Plattner, T., Schön, C., ... & Dirnhofer, R. (2007). Clinical forensic radiology in strangulation victims: forensic expertise based on magnetic resonance imaging (MRI) findings. *International Journal of Legal Medicine*, *121*(2), 115-123.

Zilkens, R. R., Phillips, M. A., Kelly, M. C., Mukhtar, S. A., Semmens, J. B., & Smith, D. A. (2016). Non-fatal strangulation in sexual assault: A study of clinical and assault characteristics highlighting the role of intimate partner violence. *Journal of Forensic and Legal Medicine*, *43*, 1-7.

Zink, T., Klesges, L. M., Levin, L., & Putnam, F. (2007). Abuse behavior inventory: Cutpoint, validity, and characterization of discrepancies. *Journal of Interpersonal Violence*, *22*(7), 921-931.

Chapter Two

Empirical Study

Which came first, playing chicken or the egg on the head? Examining the temporal relationship of paediatric traumatic brain injury and anti-social behaviour using a national birth cohort study.

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Abstract

Childhood traumatic brain injury (TBI) has been shown to increase the risk of behavioural difficulties (Li & Liu, 2012). However, most studies are cross-sectional, use a healthy control, and recruitment is retrospective. Associations are therefore correlational. Our objective was to quantify a causal relationship between TBI and anti-social behaviour.

We used the Millennium Cohort Study (N = 19,517; 2019) to identify 476 British children who have sustained a TBI since birth, and an orthopaedic injury control group (*n* = 3,964). Parents have completed the Strengths and Difficulties Questionnaire since the children were three (Goodman et al., 1998). These data show a significant association between TBI and behavioural difficulties at 14. Children also reported actual behaviours, including offending, and again likelihood was increased for our TBI group. However, taking a longitudinal approach, this difference disappeared when we controlled for pre-school behaviour. Moreover, when we used interrupted time series regression to look at behavioural trajectories since three, controlling for socioeconomic factors, there was no significant alteration following TBI. Nor was there an effect of age at, or repeated, injury. The only significant predictors of behaviour were sex, and maternal factors. Our causal hypothesis was therefore not supported.

Study limitations may obscure the behavioural impact of TBI: using loss of consciousness as a proxy variable, and comparing group means, when the majority of TBIs are mild. But our findings do highlight the difference made by using a valid control, and taking a prospective approach in a field more used to clinical samples.

Keywords: *Interrupted time series; causal inference; concussion; child; adolescent*

Introduction

Traumatic brain injury (TBI) is the leading cause of death and injury in young people worldwide (WHO, 2006). Despite this, traditionally childhood TBI has been seen as less problematic than in adults. Historically, it has been assumed that more generalised functionality in the young brain resulted in ease of operational transfer, i.e. neuroplasticity (Anderson, Northam & Wrenall, 2017). However, this belief is being increasingly challenged, with evidence that there are certain moments of vulnerability in the cognitive and emotional development necessary for adaptive functioning which, if interrupted by TBI, can result in failure to acquire age-expected skills (Anderson, Catroppa, Morse, Haritou, Rosenfeld, 2005; Williams, 2012). This phenomenon, in which the sequelae of early childhood experiences do not manifest until later, seems particularly pertinent for executive function and social cognition (Best, Miller & Jones, 2009).

There is a growing body of literature looking at the maladaptive behaviours associated with these formative brain insults. A systematic review of 50 papers showed roughly half of children are at risk of presenting with anti-social behaviour after even mild TBI (mTBI; Li & Liu, 2013). Studies show significant differences in alcohol and drug use, aggression, hyperactivity, oppositional defiant and conduct disorders, delinquency, bullying, violence, criminal activity and arrest, prosocial behaviour, self-regulation, and interpersonal skills (Connolly & McCormick, 2019; Gerring et al., 2009; Gordon, Spielman, Hahn-Ketter & Sy, 2017; Ilie et al., 2014; Ilie et al., 2016; Jones et al., 2018; Kennedy, Heron & Munafò , 2017b; McKinlay, Corrigan, Horwood & Fergusson, 2014).

However, the relationships demonstrated in the literature are associational; causation cannot be inferred. Limitations inherent in the research designs typically employed in the field explain this. Recruitment is largely retrospective. Longitudinal studies tend to gather samples from hospital, thereby suffering key challenges to validity. They are not representative, given the majority of mTBI cases will not even attend hospital, much less be admitted (Carroll et al., 2004). There is questionable use of controls. Although some studies compare orthopaedic trauma, often the control is non-injured children. This means causal inference can be challenged with the idea of temperamental or environmental differences which make some children more likely to be injured, and which are also risk factors for adverse outcomes. Being in an accident *per se*, regardless of the physical sequelae, may also have its own impact, which is difficult to control for. Samples are drawn from the hospital's geographical catchment area, so not generalizable. They are also relatively small: medians of 58 and 76 in recent systematic reviews (Bellesi et al., 2019; Kennedy et al., 2017). Additionally, attempts are often made to match controls on certain confounds (Catroppa et al., 2017). However, this can sometimes lead to selection bias and, despite the objective, negative confounding (Costanza, 1995; Rothman & Greenland, 1998).

Due to the pragmatic nature of these studies, time-points are few. Typically data on the child are collected shortly after the TBI, and then once or twice afterwards. Very few contain long-term follow-up. This matters, because of the potential delay in symptom manifestation. We are limbically-driven creatures in childhood; it is not until adolescence that the frontal lobes begin to come online (Williams, 2012). So, for example, if TBI were to lead to attentional difficulties, then

skills acquisition would be hampered across the board, but this may not be apparent until the greater academic and social demands of high school and beyond. In fact, one study picked up comparative difficulties in social perception in young adulthood, some 16 years post-childhood TBI, suggesting early cracks in the cognitive foundations may underpin future global social impairment (Rosema et al., 2014). Moreover, not only are the observations time-limited, but they also tend to be based on parental report (usually the mother), and not substantiated by the young person themselves. A significant lack of inter-rater reliability has been demonstrated in other studies, suggesting that these behavioural reports are not interchangeable (Gagner, Dégeilh, Bernier & Beauchamp, 2019; Jones et al., 2018).

But perhaps the biggest limitation of previous research in this area is the absence of a valid behavioural baseline. There has been some longitudinal investigation using a New Zealand cohort study (McKinlay et al., 2009; McKinlay et al., 2014), but the first paper only used pre-injury behaviour to predict risk of TBI (concluding it was not a risk factor), and the second controlled for pre-school behaviour, but with a simple binary measure of whether there had been any problems with management, tantrums, or aggression (range 0-3). To our knowledge, all other studies to date have used parental recall of how the child was before the injury.

Relying on retrospective data in this area can be error-prone (Catroppa et al., 2017). Perhaps there is an idealisation of pre-morbid functioning, a belief that everything was perfect before the accident. This recall bias has been shown to exist for parents of children with TBI (Brooks, Kadoura & Turley, 2013). Secondary gain – financial compensation, sympathy - may be an issue. Conversely, the narrative could

become one in which the injury was an inevitable point on a behavioural trajectory, and the child's current poor psychosocial functioning is simply its continuation. The (untested) hypothesis present in much of the literature is that the child with existing behavioural issues may be unable to predict or care about consequences, and therefore be more accident-prone (Li & Liu, 2013). Certainly, there is a widespread assumption that "post-injury sequelae may reflect premorbid…disturbances rather than injury-specific impairment" (Anderson et al., 2017, p.320).

The research limitations which leave these opposing views untested have been recognised, with the quality of evidence currently deemed "very low" (Kennedy et al., 2017a, p. 431). The same author used the longitudinal ALSPAC cohort to add to the evidence base, but applied a cross-sectional approach (Kennedy et al., 2017b). Recent systematic reviews (Bellesi et al., 2019; Emery et al., 2016) have instead called for further work to explore the temporal sequencing of childhood TBI and behavioural problems.

Obviously, ethical considerations prevent us from taking an experimental approach to TBI, randomly assigning children to TBI/control groups, but the prospective sampling offered by cohort studies suggests a quasi-experimental solution. The Millennium Cohort Study (MCS; Centre for Longitudinal Studies, 2019) has followed over 19,000 randomly sampled children born at the start of this century across Wales, Scotland, Northern Ireland, and England. There have been regular data sweeps since the children were nine months old. Initially, biopsychosocial data were taken from the parents, but the cohort members have provided their own reports from 11. Sadly, since the MCS began, parents have reported over 500 losses of consciousness (LOC) as a result of an accident or injury, which indicates those

children have suffered at least a probable mild TBI (Malec et al., 2007). This allows us to plot the child's behavioural trajectory and see if this was altered by the injury, with sufficient statistical power to observe effects if they exist.

It also lets us compare this with an orthopaedic control group, as almost 4,000 young people who were already in the study have suffered accidental bone fractures not involving the head, thus accounting for possible temperamental factors. Importantly, they are drawn from the same prospective sample, which aids validity. Pre-morbid functioning, albeit still subjective, is not influenced by retrospective bias. There is also the chance to assess more objective outcomes, including the beginnings of offending behaviours and police involvement.

Evidence shows 30-72% of young offenders have a history of TBI (Farrer, Frost & Hedges, 2012; Hughes et al., 2015), and meta-analyses put prevalence in adult prisoners at 41-87% (Farrer & Hedges, 2011; Shiroma, Ferguson & Pickelsimer, 2010). Answering the question of which comes first is therefore not just clinically, but also legally and morally vital. This study aimed therefore to test the following hypotheses:

1. In line with the literature, there would be a significant association between paediatric TBI and behavioural difficulties. We would see this in increased parent-reported SDQ scores by adolescence, as well as the children's own reports of anti-social behaviour.
2. This effect would also be present when allowing for potential confounds, and it would be possible to infer a causal relationship, as there would be an interaction with pre/post injury status (stepwise change), and with time (slope-wise change).

3. There would be a dose effect.
4. There would also be an effect of age at injury, with early TBI manifesting later.
5. That all these effects would be smaller in the orthopaedic control.

Methods

Participants

The Millennium Cohort Study (MCS; Centre for Longitudinal Studies, 2019) recruited 19,517 children born in the UK in 2000-2001, from 19,243 families, and is managed by the Centre for Longitudinal Studies. The data themselves are freely accessible upon registration with the UK Data Service (https://www.ukdataservice.ac.uk/). To date, there have been six sweeps released, from when the children were nine months, then three, five, seven, 11, and 14 years old. A seventh sweep was conducted in 2017-18 when the children were 17, but unfortunately data were not yet available for this analysis.

Approval for the MCS was granted for each sweep by National Health Service (NHS) Multi-Centre Research Ethics Committee [CLS, 2019] and a Code of Practice developed to which all researchers using the data adhere. Approval for this particular study was obtained from the Bangor University School of Psychology Ethics Committee.

Measures

Independent variable: Injury groups. At each sweep parents were asked if their children had been in any accidents since the last interview, with a maximum of five recorded for each child. Parents were asked about 'the most serious injury' resulting from each accident, with options including 'loss of consciousness/knocked out' and 'head injury'. The former was used as an indicator of having sustained at least a probable mild traumatic brain injury (TBI), in line with the Mayo classification system (Malec et al., 2007).

A proportion of those who had a head injury but did not lose consciousness may also have suffered brain damage. Their parents may have missed signs of altered consciousness indicative of TBI. However, given there was no reliable way of using objective data to identify them with an acceptable level of confidence, they were not included. Our brain injury group is therefore conservative in allocation, which is substantiated by the literature. TBI incidence amongst 0-14s is estimated to be 100-300/100,000 (Jones et al, 2018), which would predict 270-820 TBIs over the course of the study. At 520, incidence in this cohort is comfortably within that range, and provides further reassurance that the LOC variable is a reasonable proxy for having sustained at least a mild TBI, although see Study Limitations below.

The control group comprised all cohort members who had a bone fracture. The 135 children who suffered both an orthopaedic injury (OI) and a LOC were allocated to the latter group. This assumes that the LOC has a greater effect, and it is therefore possible that for some in the LOC group it was actually the OI that led to observable change; see Study Limitations. All other children were used to provide norms where useful. In some studies, a 'healthy control' is used but, given the

longitudinal nature of this study, children who had received no injury at all in 14 years would potentially have been outliers.

Dependent variable: Anti-social behaviour. From the second sweep (aged three) parents completed the Strengths and Difficulties Questionnaire (SDQ; Goodman, Meltzer & Bailey, 1998).The SDQ is a brief behavioural screening instrument. There are five derived index scores for specific areas of difficulty: Conduct Problems, Hyperactivity/Inattention, Emotional Symptoms, Peer Problems, and a reversed scale for Prosocial Behaviour. Internal consistency is acceptable (mean Cronbach's α = .73); test-retest reliability at four-six months is lower, at .62 (Goodman, 2001).

The SDQ has been measured against the Child Behaviour Checklist (Achenbach, 1991) which has been used in other studies of paediatric TBI, and is as good at detecting conduct and emotional problems, and better for inattention and hyperactivity (Goodman & Scott, 1999). Dimensionality has been tested against a large (*n* = 18,415) sample of UK children and adolescents who received multi-informant clinical diagnosis. Children with higher total difficulty scores on the SDQ had greater psychopathology, with no evidence of threshold effects (Goodman & Goodman, 2009). SDQ scores have previously been shown to be higher in cross-sectional samples following TBI (Pastore et al., 2018; Kennedy et al., 2017b).

Finally, in the two most recent sweeps, when the children were 11 and 14, they also completed self-reports about anti-social behaviour, including offending activity and encounters with the police.

Confounders. Models were adjusted for confounders that have previously been shown to be associated with brain injury and anti-social behaviour. Those

available from the MCS and considered included: sex; age at injury; multiple TBIs; maternal age at child's birth; and socio-economic status, expanded on below. The MCS deliberately over-sampled amongst less well-off communities, and thereby stratified households into groups they labelled Advantaged/Disadvantaged/Ethnic. Stratum was used as a possible area-level confounder, together with individual income quintile, and overall poverty, using the OECD definition of household income being below 60% of the national median. The main respondent's highest educational level by sweep one was also included. Attachment has been used in other studies, and is measured in the MCS. However, this is done using a novel selection of six items from the 19 item Condon Maternal Attachment Scale (Condon & Corkindale, 1998), some responses have sparse endorsement, and a recent paper has found poor internal validity ($\alpha = .51$; St Clair, Forrest, Yew & Gibson, 2019). The decision was therefore made not to include attachment in the model, and instead we used parental mental health at the first sweep, as measured by the Rutter Malaise Inventory (1970). This is a shortened version of the original 24-item questionnaire which measures psychological distress, using the nine items with the highest loading onto the first factor, and with acceptable reliability (Cronbach's $\alpha \geq 0.70$; CLS, 2019). In contrast to most scales, the lower the score, the worse the distress.

Statistical analysis

This study is an attempt to infer causation. Given children cannot be prospectively and randomly allocated to an injury group, the quasi-experimental nature of interrupted time series is arguably 'the next best thing' (ITS; Bernal, Cummins & Gasparini, 2017). ITS is typically used to examine the effect of legislative or policy changes, such as the introduction of bike helmets (Dennis et al., 2013), or

for one-off clinical interventions, like initiatives to reduce infection in hospital (Derdre et al., 2014). Regression analysis, which examines the interaction with time (as represented by the child's age in our study), reveals the impact of the 'interruption' on the expected trajectory. In this case, the brain injury is the 'interruption' in the child's behavioural development: a negative intervention. It is a necessarily more complex use of ITS in that the 'interruption' happens to different people at different times, thereby creating multiple baselines. It is also a *controlled* time series, in that there is a group who have a different interruption with a different predicted effect. The maximum six observation time-points are fewer than might be traditionally seen (see Study Limitations below). However, the sample (*N* =4,440, with 476 in the TBI group) is large compared to most studies, where convenience samples are drawn from the ward, and the use of a control enables more confidence in the trend lines.

Secondary analysis was also undertaken to look at the effect of sustaining multiple TBIs, and the effect of age at injury.

Results

Participant characteristics

Incidence and prevalence data for the sample are shown in Table 1. There were 520 injuries involving loss of consciousness (LOC), sustained by 476 children, i.e. 44 of the injuries were repeats. The temporal spread is in line with the literature, namely a peak when the children were toddlers, and again in mid-adolescence (McKinlay, Grace & Harwood, 2008). Those children experiencing a LOC were then assigned to the traumatic brain injury (TBI) group. As expected, the orthopaedic

injury (OI) group is much larger, and does not have the same bi-modal distribution. Table 1 also shows how many children who had or would go on to have an injury were present for each round of data collection, and then how many individuals in total sustained the two types of injury.

Table 1 Loss of consciousness and orthopaedic injuries

Sweep (age)	LOC incidents (n)	TBI group present in sweep (n)	OI incidents (n)	OI group present in sweep (n)
1 (9 months)	7	457	29	3,950
2 (3 years)	124	449	497	3,714
3 (5 years)	71	436	580	3,806
4 (7 years)	63	423	705	3,658
5 (11 years)	119	416	1,729	3,657
6 (14 years)	136	373	1,770	3,395
Total	520 incidents	476 individuals	5,310 incidents	3,964 individuals

LOC loss of consciousness; *TBI* traumatic brain injury; *OI* orthopaedic injury; *LOC Ever present in sweep* i.e. data given at this sweep by those who have lost or will go on to lose consciousness by 14; *OI Ever present in sweep*, as before, for orthopaedic injury

Table 2 shows the socioeconomic characteristics of the groups close to birth, and the average sweeps of data available. The MCS interviews a ‘main respondent’. Given in 99.98% of cases the main respondent was the natural mother, the label ‘maternal’ is used. There was no significant group difference with regard to maternal education, mental health, sweeps available, or likelihood of living in a disadvantaged area. However, the TBI group was significantly more likely than the control to be male, with household income below the poverty line, and maternal income in the lowest quintile. Maternal age was also slightly, but significantly, lower for the TBI group.

Table 2 Descriptive statistics in Sweep One, by injury group: chi-square and t-tests

	Group			
	TBI (n=457) N (%)	OI (n=3,833) N (%)	χ^2 (degrees freedom)	*p* value
Male	275 (60.18)	2,104 (54.89)	4.61 (1)	0.032*
Disadvantaged area[a]	223 (48.80)	1,934 (50.46)	8.70 (8)	0.368
Below OECD poverty marker[b]	173 (37.86)	1,210 (31.57)	8.09 (2)	0.017*
Maternal income, lowest quintile	131 (28.67)	827(21.58)	14.63 (5)	0.009*
Maternal qualifications, none to level 2[c]	245 (53.61)	1,911 (49.86)	3.66 (7)	0.818
	M (SD)	M (SD)	*t* (degrees freedom)	
Maternal age[d]	27.99 (6.27)	28.67 (5.87)	-2.35 (4,288)	0.019**
Maternal mental health[e]	16.14 (1.89)	16.30 (1.74)	-1.84 (4,195)	0.066
Sweeps available[f]	5.40 (1.04)	5.45 (0.95)	-0.94 (4,288)	0.347

**p < 0.05 ** p < 0.01 (rounded to three decimal places)*
TBI traumatic brain injury*, OI* orthopaedic injury
a MCS stratum (MCS, 2017)
b below 60% of UK median household income
c National Vocational Qualification equivalents, from none, to 1-3, which represent levels of secondary education, to 4-5 for tertiary education
d specific variable on mother's age at child's birth
e 9 item Rutter Malaise Inventory
f sweeps (out of 6) that cohort member/family were present for

Cross-sectional association between injury and behaviour

Cross-sectional data are presented first, replicating the existing literature. Additionally, in order to aid comparison with other studies, we have treated SDQ scores as continuous data for this stage of the analysis.

There was no difference between the groups at aged 14 with regards to strengths, as measured by the Prosocial Behaviour index, nor Conduct Problems, but there were significant differences when it came to all other sub-scales: the TBI group scored significantly higher by mid-adolescence than the orthopaedic group, including at a Total Difficulties level, $t(8,868) = 2.39$, $p = 0.008$; see Table 3.

Table 3 Strengths and Difficulties by group at Sweep 6 (aged 14), reported by parent

	Group			
SDQ Scale	TBI (n=356) M (SD)	OI (n=3,199) M (SD)	*t* (degrees freedom)	*p* value[a]
Conduct Problems	1.56 (1.80)	1.47 (1.65)	0.93 (3,553)	0.175
Emotional Symptoms	2.28 (2.33)	1.99 (2.13)	2.34 (3,553)	0.009**
Hyperactivity/inattention	3.37 (2.61)	3.13 (2.44)	1.79 (3,553)	0.037*
Peer Problems	1.85 (2.00)	1.66 (1.78)	1.88 (3,556)	0.030*
Prosocial Behaviour[b]	8.31 (1.84)	8.33 (1.85)	-0.24 (3,555)	0.406
Total Difficulties	9.05 (6.86)	8.24 (5.98)	2.39 (3,551)	0.008**

*$p < 0.05$ ** $p < 0.01$ (rounded to three decimal places)
TBI traumatic brain injury, *OI* orthopaedic injury
a one-tailed hypothesis, as per literature
b positively worded questions to assess strengths, rather than difficulties, not included in Total Difficulties score

We then looked at behaviour at 14 again, but this time using regression to control for pre-school SDQ scores (sweep two, aged three), replicating McKinlay and colleagues' work with the New Zealand cohort (2009, 2014); see Table 4. When we do this, the significant difference between the TBI and orthopaedic groups disappears, and it is pre-school behaviour which predicts mid-adolescent behaviour.

Table 4 SDQ Total Difficulties at Sweep 6 (aged 14), by group, controlling for pre-school behaviour

	β estimate	SE	Z value	*p* value
Group (TBI)	0.26	0.23	13.62	0.705
Pre-school behaviour[a]	0.48	0.02	23.98	0.001***
Interaction	0.02	0.06	0.27	0.788

*$p < 0.05$ ** $p < 0.01$ *** $p < 0.001$ (rounded to two decimal places)
LOC loss of consciousness, *OI* orthopaedic injury
a SDQ Total Difficulties score at Sweep 2 (aged 3)

The SDQ scores are parental reports of general behavioural difficulties. The children also completed their own questionnaires on actual behaviours from the fifth

sweep. By aged 14, the TBI group was more likely than the orthopaedic group to have engaged in each and every anti-social behaviour, although the only two significant responses were smoking cannabis (OR 1.52, 95% CI 1.01-2.31), and gambling (OR 1.62, 95% CI 1.14-2.31); see Table 5.

Table 5 Anti-social behaviour by group at Sweep 6 (aged 14), reported by cohort member

	Group			95% confidence interval	
	TBI (n=364) %	OI (n=3,192) %	Odds Ratio	Lower bound	Upper bound
Ever truanted	11.26	9.81	1.17	0.83	1.65
Ever had alcohol	51.11	50.83	1.01	0.81	1.26
Ever had cannabis	7.78	5.24	1.52*	1.01	2.31
Gambled money (with friends)	11.14	7.19	1.62*	1.14	2.31
Been complained about for causing public nuisance	16.39	14.36	1.17	0.87	1.57
Ever shoplifted	4.44	3.71	1.21	0.71	2.06
Ever carried knife or other weapon	2.78	2.51	1.11	0.57	2.16
Used or hit someone with weapon in fight	34.54	32.79	1.08	0.86	1.36
Stolen something	2.23	1.11	2.04	0.94	4.42
Been given formal warning/caution by Police	17.60	16.19	1.11	0.83	1.48
Ever been arrested	1.67	1.27	1.32	0.56	3.13

TBI traumatic brain injury, *OI* orthopaedic injury
* significant (95% confidence intervals exclude 1)

Longitudinal association between injury and behaviour

The cross-sectional results are in line with the literature in which there appear to be significant behavioural differences associated with having had a brain injury apparent by mid-adolescence, albeit this effect disappears after accounting for pre-school SDQ scores. However, using a birth cohort study allows us to look at this

longitudinally, to analyse changes over time to behavioural trajectories. Linear mixed effects models were fitted to the data, predicting SDQ Total Difficulties score. These models were constructed using the glmmTMB package (Brooks et al., 2017) for R (R Core Team, 2017). Fixed effects of group (TBI or OI), injury status (pre vs post TBI or OI), and time-point (using the child's age in years) were examined, together with group by injury status, and group by injury status by time interactions. Random intercepts were included for cohort member nested within household. Three separate models were fitted. Model 1 assumes no confounds. Model 2 includes child's sex, and the material circumstances of the family (being in a disadvantaged area, household income below 60% of the median). Model 3 adds maternal factors, namely age at child's birth, individual income quintile, highest educational level, and psychosocial distress.

Table 6. Time Series Regression, using SDQ Total Difficulties score, whole sample (N = 4,440)

		β estimate	SE	Z value	*p* value	VIF
Model 1	Group (TBI)	0.55	0.27	2.05	0.041*	1.42
	Pre/post-injury	0.21	0.10	2.16	0.032*	2.51
	Time	-1.75	0.08	-23.03	<0.001***	5.95†
	Group by Pre/post-injury	0.67	0.28	2.37	0.024*	2.48
	Group by Pre/post-injury by Time	-0.23	0.28	0.83	0.413	5.86†
Model 2	Group (TBI)	0.42	0.28	1.52	0.134	1.67
	Pre/post-injury	-0.28	0.16	2.39	0.024*	2.82
	Time	-1.76	0.09	-20.22	<0.001***	7.08†
	Sex (male)	0.90	0.13	6.70	<0.001***	1.00
	Stratum (disadvantaged)	1.25	0.14	8.84	<0.001***	1.05
	Stratum (ethnic)	1.31	0.26	5.08	<0.001***	
	Household poverty	1.28	0.11	11.91	<0.001***	1.06
	Group by Pre/post-injury	0.78	0.33	2.40	0.022*	2.88
	Group by Pre/post-injury	-0.38	0.31	-1.21	0.229	6.54†

	by Time					
Model 3	Group (TBI)	0.26	0.27	0.96	0.329	1.73
	Pre/post-injury	0.15	0.12	1.31	0.191	2.79
	Time	-1.73	0.09	-19.59	<0.001***	7.02†
	Sex (male)	0.97	0.13	7.59	<0.001***	1.00
	Stratum (disadvantaged)	0.29	0.14	2.08	0.041*	1.18
	Stratum (ethnic)	0.05	0.26	0.20	0.838	
	Household poverty	0.38	0.17	2.28	0.023*	2.57
	Maternal education	See Supplementary Table 1 in Appendix				1.41
	Maternal mental health	-0.67	0.04	-18.09	<0.001***	1.03
	Maternal age at birth	-0.09	0.01	-7.30	<0.001***	1.19
	Maternal income quintile	See Supplementary Table 1 in Appendix				3.06
	Group by Pre/post-injury	0.60	0.33	1.83	0.066	2.93
	Group by Pre/post-injury by Time	-0.22	0.32	-0.70	0.480	6.57†

TBI traumatic brain injury, *OI* orthopaedic injury
* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$
† moderate collinearity (VIF ≥ 5.00)

As would be expected in a model involving interactions of pre/post and time, there was moderate collinearity for time (child's age in years), and the three-way group/injury/time interaction. Similarly, the significant negative impact of time on behavioural difficulties is in line with published norms for the SDQ, in which mean scores trend down by age (Meltzer et al., 2000).

The first model demonstrates group, pre/post status, and the interaction between the two all significantly contribute to increased behavioural difficulties, suggesting a stepwise behavioural change following a TBI. However, the lack of a significant three-way interaction with time suggests there is no alteration to the slope. In Model 2, time, injury status, being male, and in a household below the poverty line significantly increase behavioural difficulties. The effect of group is no longer significant, but there is still evidence for a stepwise behavioural change following a

TBI. This disappears in the third model, when maternal factors, all of which appear significant, are included. In this more complex model significant interactions disappear, although the stepwise behavioural change following TBI is close to significance (p = 0.066). The RMI used to assess maternal mental health is reverse scored, so the model indicates that the less distressed the mother, the fewer behavioural difficulties in the child. Similarly, difficulties decrease in line with increasing maternal age at birth, maternal income, and maternal education (see Supplementary Table 1 in Appendix, as both education and income have too many levels to include in the main table).

Models 1-3 do not take account of the absence of pre-morbid data for any children injured in the first two sweeps, nor post-morbid attrition. Taking a more conservative approach, and excluding those cohort members for whom we do not have both pre- and post-injury data, reduces our TBI and orthopaedic groups to 334 and 3,328 respectively. We re-ran the models with this new dataset; see Table 7.

Table 7. Time Series Regression, using SDQ Total Difficulties score, restricted to children with pre/post-injury measures (N = 3,662)

		β estimate	SE	Z value	*p* value	VIF
Model 4	Group (TBI)	0.46	0.28	1.65	0.099	1.19
	Pre/post-injury	-0.30	0.12	-2.50	0.012**	3.68
	Time	-1.71	0.08	-22.63	<0.001***	5.18†
	Group by Pre/post-injury	0.09	0.38	0.24	0.808	3.66
	Group by Pre/post-injury by Time	0.16	0.33	0.48	0.633	5.41†
Model 5	Group (TBI)	0.37	0.29	1.30	0.193	1.35
	Pre/post-injury	-0.50	0.15	-3.22	0.001**	4.91
	Time	-1.72	0.09	-19.97	<0.001***	6.15†

	Sex (male)	0.83	0.14	5.76	<0.001***	1.00
	Stratum (disadvantaged)	1.18	0.15	7.78	<0.001***	1.05
	Stratum (ethnic)	1.45	0.28	5.15	<0.001***	
	Household poverty	1.18	0.12	10.16	<0.001***	1.06
	Group by Pre/post-injury	0.27	0.49	0.55	0.581	5.04†
	Group by Pre/post-injury by Time	-0.05	0.40	-0.13	0.900	6.85†
Model 6	Group (TBI)	0.24	0.28	0.86	0.390	1.38
	Pre/post-injury	-0.52	0.16	-3.33	<0.001***	4.89
	Time	-1.70	0.09	-19.36	<0.001***	6.11†
	Sex (male)	0.88	0.14	6.37	<0.001***	1.01
	Stratum (disadvantaged)	0.26	0.15	1.75	0.081	1.17
	Stratum (ethnic)	0.22	0.29	0.77	0.442	
	Household poverty	0.17	0.18	0.93	0.352	2.57
	Maternal education	See Supplementary Table 2 in Appendix				1.39
	Maternal mental health	-0.64	0.04	-15.69	<0.001***	1.03
	Maternal age at birth	-0.08	0.01	-6.35	<0.001***	1.17
	Maternal income quintile	See Supplementary Table 2 in Appendix				3.05
	Group by Pre/post-injury	-0.15	0.51	-0.30	0.763	5.32†
	Group by Pre/post-injury by Time	0.28	0.41	0.68	0.497	7.13†

TBI traumatic brain injury, *OI* orthopaedic injury
* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$; † moderate collinearity (VIF ≥ 5.00)

Again, there was moderate collinearity for time, and the three-way interaction, as would be expected. There is no significant effect of group. Being male, and below the poverty line significantly increases difficulties, although not when maternal factors are included. The significant maternal confounds are mental health and age at birth: the less maternal distress and the older the mother, the fewer behavioural difficulties for the child. Under this conservative approach, only including those cohort members for whom we had both pre- and post-morbid SDQ scores, there is

neither a stepwise effect of brain injury on behaviour compared to the orthopaedic control, nor a significant alteration to the trend, even in the basic model.

Finally, models 1-6 assume that the SDQ scores can be treated as interval data. Examination of the residuals indicated slight skewedness, so we felt dichotomising the scores, and calculating odds ratios, might be appropriate. SDQ author Goodman (2001) found that, in large community samples, children scoring in the top 10% were 15.7 times more likely to be assessed by an independent clinician as having psychiatric difficulties, and described this band as 'abnormal'. Given these are developmental data, we calculated the 90th centile on a sweep-by-sweep basis, and used these as our cut-off scores. Rendered binomial, model residuals were less skewed.

Table 8. Binomial Regression, using SDQ Total Difficulties cut-off (90th centile per sweep), restricted to children with pre/post-injury measures (N = 3,662)

			Confidence Intervals		
		Odds Ratio	Lower Bound	Upper Bound	VIF
Model 7	Group (TBI)	1.32	0.77	2.25	1.30
	Pre/post-injury	1.40*	1.09	1.81	3.30
	Time	0.76*	0.64	0.90	5.07†
	Group by Pre/post-injury	1.52	0.72	3.20	3.27
	Group by Pre/post-injury by Time	0.90	0.45	1.80	5.15†
Model 8	Group (TBI)	1.30	0.76	2.22	1.58
	Pre/post-injury	1.48*	1.09	2.03	4.39
	Time	0.72*	0.59	0.87	6.68†
	Sex (male)	1.54*	1.20	1.98	1.00
	Stratum (disadvantaged)	2.01*	1.54	2.63	1.07
	Stratum (ethnic)	2.47*	1.53	4.00	
	Household poverty	2.72*	2.21	3.36	1.07
	Group by Pre/post-injury	1.92	0.80	4.60	4.30
	Group by Pre/post-injury by Time	0.65	0.30	1.41	6.48†

Model 9	Group (TBI)	1.17	0.69	1.98	1.64
	Pre/post-injury	1.46*	1.06	2.01	4.39
	Time	0.73*	0.60	0.90	6.61†
	Sex (male)	1.65*	1.29	2.11	1.01
	Stratum (disadvantaged)	1.15	0.88	1.50	1.14
	Stratum (ethnic)	1.11	0.68	1.81	
	Household poverty	1.24	0.90	1.72	2.62
	Maternal education	See Supplementary Table 3			1.37
	Maternal mental health	0.69*	0.64	0.74	1.02
	Maternal age at birth	0.96*	0.94	0.98	1.14
	Maternal income quintile	See Supplementary Table 3			3.13
	Group by Pre/post-injury	1.45	0.58	3.66	4.56
	Group by Pre/post-injury by Time	0.80	0.35	1.81	6.76†

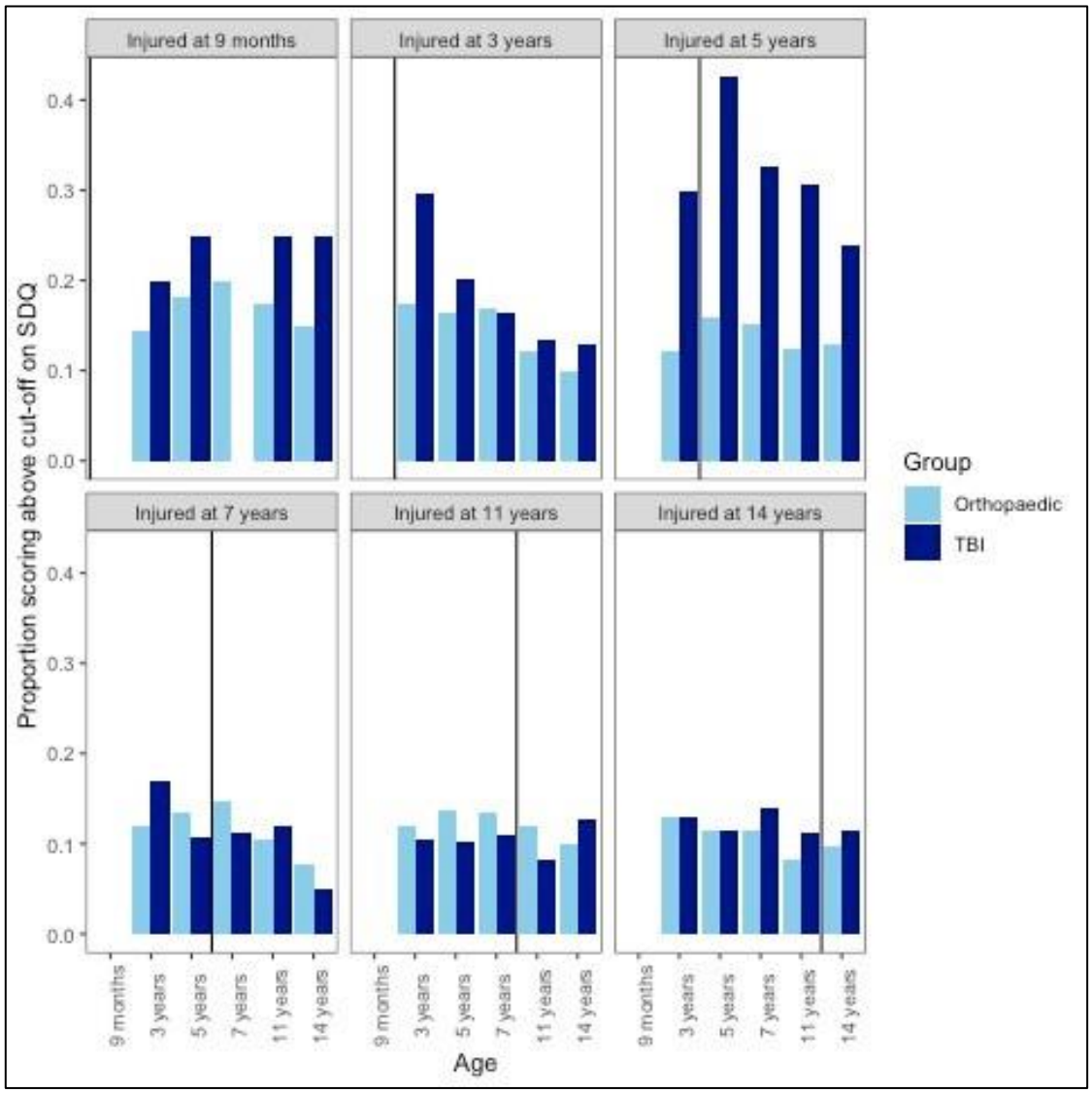
TBI traumatic brain injury, *OI* orthopaedic injury
* significant (95% confidence intervals exclude 1)
† moderate collinearity (VIF ≥ 5.00)

Again, there is moderate collinearity for time, and the three-way group/time/injury status interaction. The effect of group is not significant. Injury status and time are significant: children are more likely to fall within the clinical range for behavioural difficulties following their injury, and less likely as they get older. Being male, from a disadvantaged area, and a poor household also significantly increase the odds of caseness. Material circumstances become insignificant, however, when maternal factors are included. In the final model, having a mother who is less distressed, older, better educated, and with a higher individual income, all significantly decrease the odds of a child being within the clinical range for behaviours. None of the models indicated a significant stepwise contribution of TBI, nor any alterations to the behavioural trajectory.

Effect of age at injury

Neurodevelopmental models suggest there would be an effect of age at injury, and that the sequelae of some pre/primary school injuries would not manifest until the greater cognitive and social demands of adolescence and high school (Williams, 2012). Figure 1 below plots the proportion of each injury group falling within the abnormal range on the SDQ Total Difficulties score at each sweep, by the age at which the injury occurred.

Figure 1. Proportion of each group meeting criteria for caseness (above 90th centile on SDQ Total Difficulties score for age group), faceted by age at injury. Black line shows injury happening.



It is worth noting that in general SDQ scores trend downwards with age, both in the published norms (Meltzer et al., 2000) and the MCS: the whole cohort has a mean Total Difficulty score of 9.64 (*SD* 5.31) at aged 3 (*n* = 14,408) but has dropped to 8.19 (*SD* 5.99) at aged 14 (*n* = 11,471).

Those children sustaining an injury in sweep one (9 months) show a spike in behavioural difficulties at 14, suggestive of delayed manifestation, however, *n* = 7. There does seem a difference for the children injured at three years old, but there is no pre-morbid behavioural rating. The picture for sweep three injuries (five years old) is striking: they seem to have more difficulties both before and after the injury. Injuries at seven seem to have the least effect. There may be a small increase in difficulties for injuries at 11. The other sweeps appear flat. There appears to be a stark difference between the children who are injured before and after seven, in terms of both pre/post behaviours.

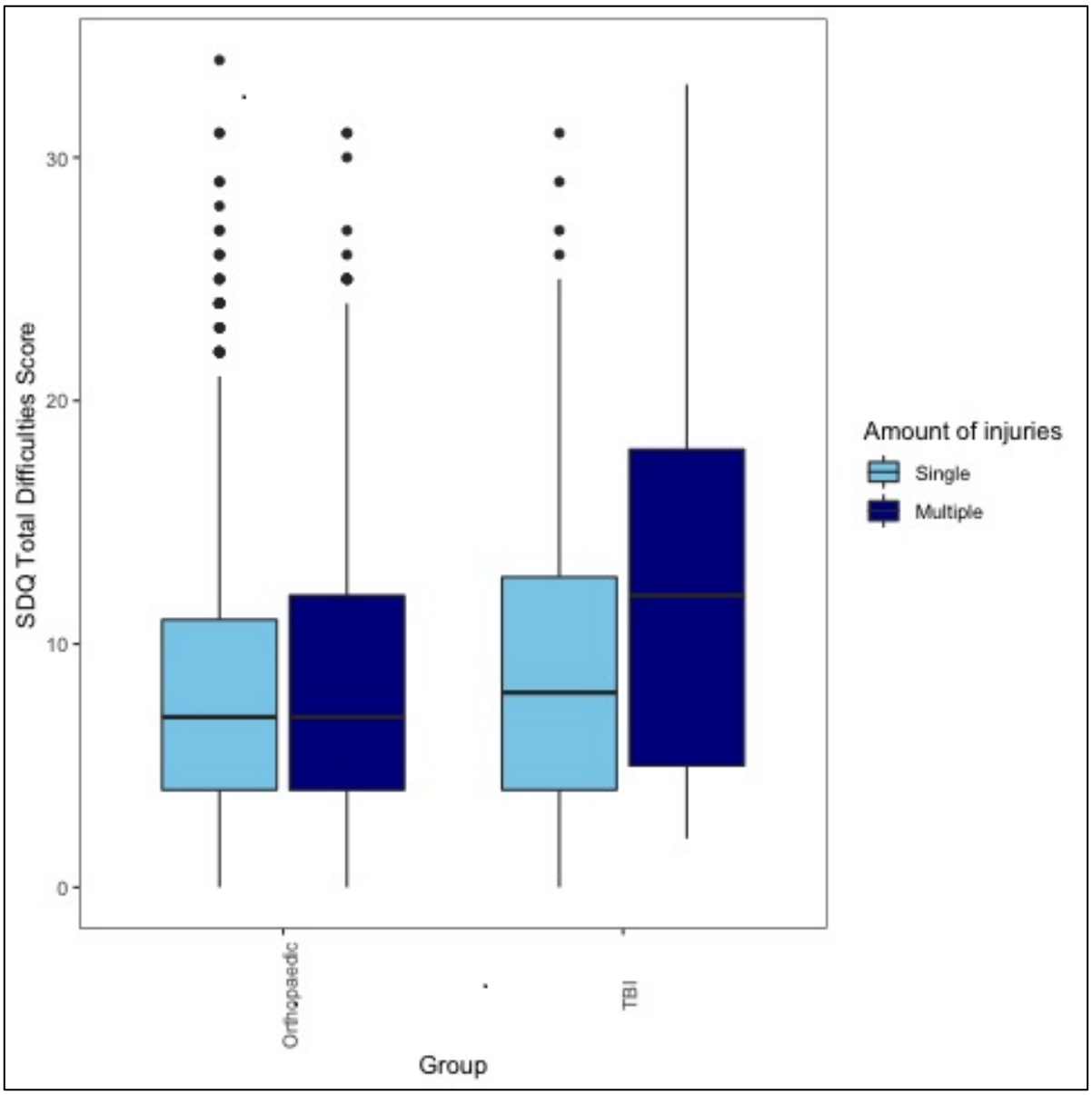
To test for a significant effect of age at injury on behaviour, logistic mixed effects models were fitted to the data, predicting caseness (dichotomised data showing whether children were above the 90th centile on the SDQ Total Difficulties score for their age group). The models were again constructed using the glmmTMB package (Brooks et al., 2017) for R (R Core Team, 2017). Fixed effects of group (TBI or OI), and age at injury were calculated. Random intercepts were included for cohort member nested within household. A basic model was fitted, looking at the interaction, and then two further models adjusting for sex and material circumstances. Children for whom we had no behavioural baseline were excluded, so we only looked at those injured aged five or older.

From this analysis, it appears that being injured from seven onwards decreases the odds of experiencing clinical behavioural difficulties, versus injury at five. Those children injured at seven are actually the least likely to meet the criteria for caseness by 14, which is in line with Figure 1. This pattern persisted even when adjusting for sex and material circumstances. However, none of the age bands approached significance. The problem encountered was that the upper bounds of the confidence intervals were extremely high, likely the result of multicollinearity (although VIF was not >5). Because of this we cannot be confident as to the true odds ratios, and therefore have not presented the output in the main paper, although see Supplementary Table 4 in the Appendix.

Effect of multiple injuries

Finally, 31 children had multiple TBIs (range 2-4, mode 2). The literature suggests a dose effect for TBI, particularly in childhood (Iverson, Gaetz, Lovell, & Collins, 2004). Figure 2 demonstrates a significant within-group difference in behaviour by 14 between those having one versus multiple TBIs: $t(340) = 1.99$, $p = 0.024$. However, although there are fewer behavioural difficulties for the OI group, there is also a significant within-group difference between children sustaining single and multiple fractures: $t(3,052) = 3.58$, $p < 0.001$. Moreover, there was no significant interaction between group and amount of injuries, using two-way independent ANOVA: $F(2) = 0.48$, $p = 0.618$, $np^2 < 0.01$. This suggests the dose effect is not unique to TBI, and that it is the factors pre-disposing a child to multiple injuries that matter, rather than the type of injury.

Figure 2. Effect of number of injuries on behavioural difficulties, by injury group



Discussion

Our first hypothesis was supported. In line with previous studies, childhood TBI is associated with significantly increased behavioural difficulties by mid-adolescence. A strength of this study was that this remained the case when compared to another injury group, rather than a healthy control. Children with a TBI

were given significantly higher total SDQ scores than those with orthopaedic injuries, and specifically for emotional symptoms, hyperactivity or inattention, and peer problems (see Table 3). This was also reflected in the children's self-reports of actual behaviours, with the TBI group more likely to agree they had engaged in each anti-social behaviour, including offences and police encounters, and significantly so for drug use and gambling (Table 5).

Interestingly, although the TBI group scored slightly higher than the orthopaedic group for conduct problems in the SDQ, this difference was not significant. The Conduct subscale includes questions about disobedience, fighting or bullying, lying or cheating, and stealing. This is counter to the literature, but highlights the fact that many previous comparisons have been with non-injured controls, and TBI samples have been hospital-based, and therefore perhaps more severely injured. One could also make an argument that the components of the Conduct scale require a degree of intent and malice, and are therefore qualitatively different from the dysregulation, inattention, and interpersonal difficulties represented by the other sub-scales.

However, when we analysed the data longitudinally, these differences began to disappear, contrary to our second and third hypotheses. Behaviour at 14 was significantly predicted by pre-school behaviour, not by injury group (Table 4). Time series regression allowed us to look at interactions, test for significance, and include other confounds, including time itself. Brain injury did appear to increase behavioural difficulties in the short term, versus children who had an orthopaedic injury, and allowing for socioeconomic factors (Models 1-3). But the sample was all injured children, including those pre-school children for whom we did not have behavioural

baselines. When we used a more conservative sample, including only those children for whom we had pre-injury scores (Models 4-6), there was no significant difference. One interpretation is that, in line with the literature, pre-school is a particularly vulnerable period for brain development, for laying down the cognitive building blocks needed for future executive function and social cognition (Best, Miller & Jones, 2009). By excluding children injured by three from the model, we effectively cancel this effect. However, the fact that the children injured at five years old already had increased pre-morbid difficulties suggests this may be a statistical artefact (see Fig.1).

The initial models had assumed the SDQ could be treated as interval data. However, dichotomising the scores to look instead at the likelihood of being within the clinical range for behavioural difficulties did not change the picture: children sustaining a TBI were no more likely than their orthopaedic peers to fall within the clinical range for antisocial behaviour following their accident (Models 7-9).

Moreover, none of the models had a significant three-way interaction between group, time, and injury status: there was no slope-wise effect. In other words, contrary to our hypothesis, these data do not suggest that TBI alters a child's behavioural trajectory. In fact, in Models 7-9, odds ratios for the interaction were all <1, suggesting that having a TBI might, for some, actually have a subduing impact on the behavioural trajectory, albeit this was not significant.

These models examined all children with TBI, split into pre/post-injury. The literature suggests the age of the brain that is injured is important, and that there may be delayed visibility fo sequelae, with the behavioural consequences of early childhood injury not manifesting until later. We therefore analysed outcomes by the

age at which the injury was sustained, in case this showed an effect. There did seem to be some differences in outcomes by adolescence for those children aged five or under when injured (Fig. 1). However, no conclusions could be drawn due to small samples, and lack of behavioural baselines. When we used regression modelling, age at injury did not significantly predict whether or not a child would fall into the abnormal range for behaviours.

The literature also suggests a dose–response for TBI, with a cumulative growth in negative outcomes associated with repeated concussions, hence the move by several countries to ban the heading of balls by schoolchildren, or mandatory helmets (Mackay et al., 2019). We did indeed identify a within-group dose effect, with those children sustaining multiple TBIs having significantly more behavioural difficulties by adolescence than their single injury peers (Fig. 2). However, given this effect was also present for those children sustaining multiple bone fractures, and that there was no significant interaction between group and injury count, we cannot infer causation.

Where we did see a consistently significant contribution to behavioural difficulties was sex (p <0.01 in all models), maternal mental health close to child's birth, and maternal age at child's birth (both $p < 0.001$ in all models). Material circumstances – living in a disadvantaged area, and having a household income below the poverty line – were no longer significant when maternal factors were included. The only consistently significant socioeconomic contributions were the mother's educational level and the income from her own employment.

The lack of effect was surprising: we know that up to 72% of young offenders have a history of TBI (Hughes et al., 2012). But perhaps we should also find it

reassuring: childhood concussion does not appear to lead inexorably to poor behavioural outcomes. This is consistent with other studies which have followed hospital samples into young adulthood, and found no link between childhood TBI and self-reports of externalising and rule-breaking behaviour (Rosema et al., 2014; Rosema et al., 2015). In fact, there is a suggestion in our data that it may in some cases have a dampening effect. Nor, seemingly, do reduced financial circumstances drive maladaptive behaviours, when allowing for factors specifically related to the mother. In fact, from these data, the most important risk factors for anti-social behaviour are being male, and having a mother who has experienced psychosocial distress, is younger, less educated, and in a less well-paying job; significantly more so than sustaining a brain injury. This suggests that the reason cross-sectional analyses show increased behaviours for children with TBI is that those gender and maternal risk factors for behaviours are also the risk factors for sustaining a TBI. Our results also highlight the difference that using a valid control, and prospective sampling, can make. But before we declare support for neuroplasticity's protective role in children, there are some key study limitations to consider.

Study Limitations

The available data only followed children up to early adolescence. Important brain regions such as the dorsolateral prefrontal cortex, involved in judgement and decision-making, have not reached maturity by this point (Williams et al., 2012). There was therefore less opportunity to witness any sleeper effect from damage to these areas on executive function, social cognition, and hence maladaptive behaviours.

Using secondary data from a birth cohort study has all the advantages outlined in the Introduction, but there are major drawbacks due to specific objectives not being addressed in its design. The first is to do with our independent variable. We have had to use loss of consciousness as a proxy for having sustained a brain injury. As argued previously, this seems reasonable, and is in line with the Mayo classification, but it may therefore include some children with no brain injury, and our comparison groups may include some children who do have an injury. Moreover, the OI group was much larger than the TBI group, and followed a different age distribution. This raises questions over comparability.

Secondly, there is no measurement of severity, which has been an important factor in other studies. Scott and colleagues (2015) found a significant effect of severity on offending outcomes. Ong et al. (1998) demonstrated no difference in behavioural outcomes between children with mild TBI and orthopaedic injury; only the severe group had significantly more problem behaviours than the control. Hughes et al. (2015) showed that, when severity is taken into account, the relationship between TBI and imprisonment is even starker. However, in the MCS we do not know whether loss of consciousness was fleeting, or lasted days. There are questions about hospital attendance and admission, but they are not connected to a specific accident. Likewise, there is a variable for having a diagnosed neurological condition but, again, this cannot be linked to an accident. There is therefore no opportunity to classify the children into mild, moderate or severe TBI. Given we are comparing group means, and we know up to 91% of TBIs in population cohort studies can be mild (McKinlay et al., 2014) they could be overshadowing a "miserable minority" (Ruff, Camenzuli, & Mueller, 1996). It does seem to be the case,

looking at the self-reported behaviours at 14 (Table 5), that 2-18% of the LOC group are engaging in the more troublesome behaviours; might these be our “miserable minority”?

There are also inherent difficulties with our dependent variable. The SDQ is only used from when the child is three. We know there is a pre-school spike in TBI incidence, we suspect this is a window of developmental vulnerability, and our data suggested this, but the lack of a behavioural baseline for any child injured before five means we cannot be confident that this is not just a statistical artefact. Critically, this also threatens the validity of the interrupted time series, as we do not have the three pre- and three post- observation points recommended by Cochrane, although this may be balanced out by the large sample.

There are other limitations connected to the SDQ. We do not know when the injury happened within interview time periods. Data sweeps were conducted every two to four years, and the accident could have happened at any point. Therefore, when the parent is reporting on behaviour, it could be post-injury if the LOC was at the start of the period, or pre-injury, if it has only just happened. The MCS did not consistently ask the SDQ questions about impact on functioning, and therefore this could not be included. The impact sub-scale has been shown in the literature to be the SDQ’s best predictor of psychological caseness (Stringaris & Goodman, 2013).

As with any longitudinal study there are missing data, albeit our TBI and OI groups were present respectively for an average of 5.40 and 5.45 sweeps out of six. Imputation was considered, but it was felt this would overly reduce the variance. There is the possibility that attrition might lead to bias, and systematically disguise

large effects. For example, parents of children who had suffered severe injuries might have been less likely to continue with the study.

Finally, there were some potential factors which we could or did not include. Attachment has been shown elsewhere to be an important moderator, and would seem a likely candidate here given the significant effect of other maternal factors, but the measurement scale used by the MCS was not reliable. Parenting style has been explored in other studies, but was not directly measured in the MCS. The children underwent cognitive assessment in some of the sweeps, but this currently only provides a baseline, with no repeated measures. Those variables that we did include frequently displayed multicollinearity, so it is difficult to disentangle effects.

Further research

This is very much the first stage in an ongoing project. The release of data from sweep seven (aged 17) will allow us to comply with Cochrane recommendations for interrupted time series in that, for those children injured at 11 years old, we will have three pre- and three post-injury behavioural scores. This will increase the validity of any observable step or slope-wise change to their behavioural trajectories. The literature suggests mid-late adolescence will coincide with increased incidence and impact. With more cognitive and social demands, and frontal lobe development, executive dysfunction will likely become more noticeable. The measurement of variables including not gaining qualifications, leaving school, unemployment, and convictions may allow us to ‘join the dots’ with the prison literature.

A mixed methods approach could be utilised in order to isolate the “miserable minority” (Ruff et al., 1996) and ensure they do not get lost in the mean. The MCS is

in the process of being joined with Welsh health records through the Secure Anonymised Information Linkage service (SAIL; Sedakis & Fitzsimons, 2017). This would allow us to identify Welsh cohort members who reported a LOC and then extract more detailed data about the nature of their injury and its sequelae. Perhaps, ethical considerations permitting, there may even be the opportunity to conduct follow-up interviews, understanding more about the family's journey post-TBI but, unlike with other qualitative research, having an unbiased and contemporaneous account of the pre-injury narrative to compare.

There were significant differences between the TBI and OI children with regard to hyperactivity and attentional difficulties (see Table 3). Elsewhere in the MCS parents are asked about ADHD diagnoses and interventions, as are the children's teachers. It would be interesting to contrast children diagnosed before and after brain injury, and those with no injury. Are those children receiving later ADHD diagnoses simply being given another label for the normal effects of TBI?

Limitations notwithstanding, we hope this study serves as proof of principle for the use of big data to emulate experiments within brain injury, and for the use of interrupted time series (ITS) as a statistical method. Symbolically, this is precisely what brain injury represents for many survivors: life is moving in one direction but then abruptly changes, forever. The use of ITS in brain injury is more complicated than the historical events or new policies it traditionally measures, in that it does not simultaneously strike a whole cohort.

There is another epidemiological method which can potentially get closer to this: the target trial framework (TTF; Hernan & Robins, 2016). When randomised studies are ethically impossible, the TTF proposes designing the experiment you

would have conducted, and then systematically demonstrating how you have applied statistical analysis to observational data in order to mimic as best as you can each component of this 'target trial'. In our case, in a true experiment we would want a randomly selected group of children, hitherto healthy, who would then be randomly assigned to receive a brain or bone injury at the same time, with a full set of pre-injury behavioural data for which you could control. We chose not to follow this approach as it would have reduced our total TBI sample to 85 (those injured at 11), with only one or two sweep's worth of post-injury observations, and we would have sacrificed important data from the younger children. In the future though, and for other questions, the TTF has the potential to substantiate causal inference.

Conclusion

In a national birth cohort study, using prospective sampling, childhood TBI is significantly associated with anti-social behaviour by mid-adolescence, compared to children sustaining orthopaedic injuries. But this analysis was cross-sectional. When we controlled for pre-school behaviour, the relationship was no longer significant. When we went further into the longitudinal approach, using interrupted time series regression, there was neither an immediate nor a long-term alteration to the child's behavioural trajectory following TBI, once we excluded those children with pre-school injuries for whom we did not have a behavioural baseline. Nor was it possible to establish a significant effect of age at injury, compared to the orthopaedic control, nor a dose-response. The only consistently significant contributors to behavioural outcomes by mid-adolescence were sex, and factors to do with the mother. Our hypothesis, that childhood brain injury has a causal relationship with anti-social behaviour, was not supported.

There were limitations to the study which might have obscured any effect, not least comparing the means of large samples, and being restricted to a proxy variable for measuring brain injury. However, it does provide reassurance that childhood brain injury does not lead inevitably to behavioural difficulties.

This is the first stage in what we hope will be ongoing data-mining. We plan to update the study with the data from the cohort members at 17, when we might expect to see more of a sleeper effect from the impact of executive dysfunction. There is also an opportunity to look deeper into the relationship between brain injury, attentional difficulties, and anti-social behaviour. Finally, it is our hope that this paper highlights how big data, epidemiological methods, and prospective sampling, in a field more used to small, clinical studies, can help us edge closer to answering questions of cause and effect.

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References

Achenbach, T. M., & Edelbrock, C. (1991). Child behavior checklist. *Burlington (Vt)*, *7*, 371-392.

Anderson, V., Catroppa, C., Morse, S., Haritou, F., & Rosenfeld, J. (2005). Functional plasticity or vulnerability after early brain injury? *Pediatrics*, *116*(6), 1374-1382.

Anderson, V., Northam, E., & Wrennall, J. (2017). *Developmental Neuropsychology: A clinical approach*. Routledge: London, UK.

Bellesi, G., Barker, E. D., Brown, L., & Valmaggia, L. (2019). Pediatric traumatic brain injury and antisocial behavior: are they linked? A systematic review. *Brain Injury*, *33*(10), 1272-1292.

Bernal, J. L., Cummins, S., & Gasparrini, A. (2017). Interrupted time series regression for the evaluation of public health interventions: a tutorial. *International Journal of Epidemiology*, *46*(1), 348-355.

Best, J. R., Miller, P. H., & Jones, L. L. (2009). Executive functions after age 5: Changes and correlates. *DevelopmentalRreview*, *29*(3), 180-200.

Brooks, B., Kadoura, B., & Turley, B. (2013). Perception of recovery after paediatric mild traumatic brain injury is influenced by the “good old days” bias: Tangible implications for clinical practice and outcomes research. *Archives of Clinical Neuropsychology, 29*(2), 186-193.

Brooks, M. E., Kristensen, K., van Benthem, K. J., Magnusson, A., Berg, C. W., Nielsen, A., ... & Bolker, B. M. (2017). glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling. *The R Journal*, *9*(2), 378-400.

Cassidy, J. D., Carroll, L., Peloso, P., Borg, J., Von Holst, H., Holm, L., ... & Coronado, V. (2004). Incidence, risk factors and prevention of mild traumatic brain injury: results of the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. *Journal of Rehabilitation Medicine*, *36*(0), 28-60.

Catroppa, C., Hearps, S., Crossley, L., Yeates, K., Beauchamp, M., Fusella, J., & Anderson, V. (2017). Social and behavioral outcomes following childhood traumatic brain injury: what predicts outcome at 12 months post-insult?. *Journal of Neurotrauma*, *34*(7), 1439-1447.

Centre for Longitudinal Studies (2019). The Millennium Cohort Study. *University College London Institute of Education*. Retrieved from https://www.cls.ucl.ac.uk/cls-studies/millennium-cohort-study/.

Condon, J. T., & Corkindale, C. J. (1998). The assessment of parent-to-infant attachment: Development of a self-report questionnaire instrument. *Journal of Reproductive and Infant Psychology*, *16*(1), 57-76.

Connolly, E. J., & McCormick, B. F. (2019). Mild traumatic brain injury and psychopathology in adolescence: evidence from the Project on Human Development in Chicago Neighborhoods. *Journal of Adolescent Health*.

Costanza, M. C. (1995). Matching. *Preventive Medicine*, *24*(5), 425-433.

Dennis, J., Ramsay, T., Turgeon, A. F., & Zarychanski, R. (2013). Helmet legislation and admissions to hospital for cycling related head injuries in Canadian provinces and territories: interrupted time series analysis. *BMJS*, *346*, f2674.

Emery, C. A., Barlow, K. M., Brooks, B. L., Max, J. E., Villavicencio-Requis, A., Gnanakumar, V., ... & Yeates, K. O. (2016). A systematic review of psychiatric, psychological, and behavioural outcomes following mild traumatic brain injury in children and adolescents. *The Canadian Journal of Psychiatry*, *61*(5), 259-269.

Farrer, T. J., Frost, R. B., & Hedges, D. W. (2013). Prevalence of traumatic brain injury in juvenile offenders: a meta-analysis. *Child Neuropsychology*, *19*(3), 225-234.

Farrer, T. J., & Hedges, D. W. (2011). Prevalence of traumatic brain injury in incarcerated groups compared to the general population: a meta-analysis. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, *35*(2), 390-394.

Gagner, C., Dégeilh, F., Bernier, A., & Beauchamp, M. H. (2019). Persistent changes in child behavior after early mild traumatic brain injury. *Journal of Pediatric Psychology*.

Gerring, J. P., Grados, M. A., Slomine, B., Christensen, J. R., Salorio, C. F., Cole, W. R., & Vasa, R. A. (2009). Disruptive behaviour disorders and disruptive symptoms after severe paediatric traumatic brain injury. *Brain Injury*, *23*(12), 944-955.

Goodman, R. (2001). Psychometric properties of the strengths and difficulties questionnaire. *Journal of the American Academy of Child & Adolescent Psychiatry*, *40*(11), 1337-1345.

Goodman, R., Ford, T., Simmons, H., Gatward, R., & Meltzer, H. (2000). Using the Strengths and Difficulties Questionnaire (SDQ) to screen for child psychiatric disorders in a community sample. *The British Journal of Psychiatry*, *177*(6), 534-539.

Goodman, A., & Goodman, R. (2009). Strengths and difficulties questionnaire as a dimensional measure of child mental health. *Journal of the American Academy of Child & Adolescent Psychiatry*, *48*(4), 400-403.

Goodman, R., Meltzer, H., & Bailey, V. (1998). The Strengths and Difficulties Questionnaire: A pilot study on the validity of the self-report version. *European child & adolescent psychiatry*, *7*(3), 125-130.

Goodman, R., & Scott, S. (1999). Comparing the Strengths and Difficulties Questionnaire and the Child Behavior Checklist: is small beautiful?. *Journal of Abnormal Child Psychology*, *27*(1), 17-24.

Gordon, W. A., Spielman, L. A., Hahn-Ketter, A. E., & Sy, K. T. L. (2017). The relationship between traumatic brain injury and criminality in juvenile offenders. *Journal of Head Trauma Rehabilitation*, *32*(6), 393-403.

Hernán, M. A., & Robins, J. M. (2016). Using big data to emulate a target trial when a randomized trial is not available. *American Journal of Epidemiology*, *183*(8), 758-764.

Hughes, N., Williams, H., Chitsabesan, P., Davids, R., & Mounce, L. (2012). Nobody made the connection: The prevalence of neuro-disability in young people who offend. *Office of the Children's Commissioner*. Retrieved from https://www.childrenscommissioner.gov.uk/publication/nobody-made-the-connection/

Hughes, N., Williams, W. H., Chitsabesan, P., Walesby, R. C., Mounce, L. T., & Clasby, B. (2015). The prevalence of traumatic brain injury among young offenders in custody: a systematic review. *Journal of Head Trauma Rehabilitation*, *30*(2), 94-105.

Ilie, G., Mann, R. E., Boak, A., Adlaf, E. M., Hamilton, H., Asbridge, M., ... & Cusimano, M. D. (2014). Suicidality, bullying and other conduct and mental health correlates of traumatic brain injury in adolescents. *PloS One*, *9*(4), e94936.

Ilie, G., Mann, R. E., Boak, A., Adlaf, E. M., Hamilton, H., Asbridge, M., ... & Cusimano, M. D. (2016). Cross-sectional examination of the association of co-occurring alcohol misuse and traumatic brain injury on mental health and conduct problems in adolescents in Ontario, Canada. *BMJ Open*, *6*(11), e011824.

Iverson, G. L., Gaetz, M., Lovell, M. R., & Collins, M. W. (2004). Cumulative effects of concussion in amateur athletes. *Brain Injury, 18*(5), 433-443.

Jones, K. M., Starkey, N. J., Theadom, A., Gheorghe, A., Willix-Payne, D., Prah, P., & Feigin, V. L. (2018). Parent and child ratings of child behaviour following mild traumatic brain injury. *Brain Injury*, *32*(11), 1397-1404.

Kennedy, E., Cohen, M., & Munafo, M. (2017a). Childhood traumatic brain injury and the associations with risk behavior in adolescence and young adulthood: a systematic review. *The Journal of Head Trauma Rehabilitation*, *32*(6), 425.

Kennedy, E., Heron, J., & Munafò, M. (2017b). Substance use, criminal behaviour and psychiatric symptoms following childhood traumatic brain injury: findings from the ALSPAC cohort. *European Child & Adolescent Psychiatry*, *26*(10), 1197-1206.

Li, L., & Liu, J. (2013). The effect of pediatric traumatic brain injury on behavioral outcomes: a systematic review. *Developmental Medicine & Child Neurology*, *55*(1), 37-45.

Mackay, D. F., Russell, D. R., Stewart, K., MacLean, J. A., Pell, J. P., & Stewart, W. (2019). Neurodegenerative disease mortality among former professional soccer players. *New England Journal of Medicine, 381*, 1801-8.

McKinlay, A., Corrigan, J., Horwood, L. J., & Fergusson, D. M. (2014). Substance abuse and criminal activities following traumatic brain injury in childhood, adolescence, and early adulthood. *The Journal of Head Trauma Rehabilitation*, *29*(6), 498-506.

McKinlay, A., Grace, R., Horwood, J., Fergusson, D., & MacFarlane, M. (2009). Adolescent psychiatric symptoms following preschool childhood mild traumatic brain injury: evidence from a birth cohort. *The Journal of Head Trauma Rehabilitation*, *24*(3), 221-227.

McKinlay, A., Grace, R., Horwood, L., Fergusson, D., Ridder, E., & MacFarlane, M. (2008). Prevalence of traumatic brain injury among children, adolescents and young adults: Prospective evidence from a birth cohort. *Brain Injury, 22*(2), 175-181

Malec, J. F., Brown, A. W., Leibson, C. L., Flaada, J. T., Mandrekar, J. N., Diehl, N. N., & Perkins, P. K. (2007). The Mayo classification system for traumatic brain injury severity. *Journal of Neurotrauma*, *24*(9), 1417-1424.

Ong, L. C., Chandran, V., Zasmani, S., & Lye, M. S. (1998). Outcome of closed head injury in Malaysian children: neurocognitive and behavioural sequelae. *Journal of Paediatrics and Child Health*, *34*(4), 363-368.

Pastore, V., Galbiati, S., Recla, M., Colombo, K., Beretta, E., & Strazzer, S. (2018). Psychological and behavioural difficulties following severe TBI in adolescence: a comparison with a sample of peers with brain lesions of other origin and with a control group. *Brain Injury*, *32*(8), 1011-1020.

R Core Team (2017). R: A language and environment for statistical computing. *R Foundation for Statistical Computing, Vienna, Austria*. Retrieved from: https://www.R-project.org/.

Rosema, S., Muscara, F., Anderson, V., Godfrey, C., Eren, S., & Catroppa, C. (2014). Agreement on and predictors of long-term psychosocial development 16 years post-childhood traumatic brain injury. *Journal of Neurotrauma*, *31*(10), 899-905.

Rothman, K. J., Greenland, S., & Lash, T. L. (1998). Types of epidemiologic studies. *Modern Epidemiology. 2nd ed: Lippincott Raven*, 74-5.

Ruff, R. M., Camenzuli, L., & Mueller, J. (1996). Miserable minority: emotional risk factors that influence the outcome of a mild traumatic brain injury. *Brain Injury*, *10*(8), 551-566.

Rutter, M., Tizard, J., & Whitmore, K. (1970). Malaise inventory. *Education, Health and Behaviour*, 339-340.

Scott, C., McKinlay, A., McLellan, T., Britt, E., Grace, R., & MacFarlane, M. (2015). A comparison of adult outcomes for males compared to females following pediatric traumatic brain injury. *Neuropsychology*, *29*(4), 501.

Sedakis, E., & Fitzsimons, E. (2017). Millennium Cohort Study: A Guide to the NHS PEDW (inpatient and day case) Linked Administrative Data Sets: ICD-10 codes in Continuous Spells. *UCL Institute of Education*. Retrieved from http://doc.ukdataservice.ac.uk/doc/8302/mrdoc/pdf/mcs_pedw_linkage_icd10_data_document_final.pdf.

Shiroma, E. J., Ferguson, P. L., & Pickelsimer, E. E. (2010). Prevalence of traumatic brain injury in an offender population: A meta-analysis. *Journal of Correctional Health Care*, *16*(2), 147-159.

St Clair, M. C., Forrest, C. L., Yew, S. G. K., & Gibson, J. L. (2019). Early risk factors and emotional difficulties in children at risk of developmental language disorder: A population cohort study. *Journal of Speech, Language, and Hearing Research*, *62*(8), 2750-2771.

Stone, S. P., Fuller, C., Savage, J., Cookson, B., Hayward, A., Cooper, B., ... & Roberts, J. (2012). Evaluation of the national Cleanyourhands campaign to reduce Staphylococcus aureus bacteraemia and Clostridium difficile infection in hospitals in England and Wales by improved hand hygiene: four year, prospective, ecological, interrupted time series study. *BMJ*, *344*.

Stringaris, A., & Goodman, R. (2013). The value of measuring impact alongside symptoms in children and adolescents: a longitudinal assessment in a community sample. *Journal of Abnormal Child Psychology*, *41*(7), 1109-1120.

Williams, H. (2012). Repairing shattered lives. *Transition to Adult Alliance, Barrow Cadbury Trust*.

Williams, T. C., Bach, C. C., Matthiesen, N. B., Henriksen, T. B., & Gagliardi, L. (2018). Directed acyclic graphs: a tool for causal studies in paediatrics. *Pediatric Research*, *84*(4), 487-493.

World Health Organization. (2006). *Neurological disorders: Public health challenges*. Retrieved from: https://www.who.int/mental_health/neurology/neurodiso/en/.

Appendix

Supplementary Table 1. Time Series Regression, using SDQ Total Difficulties score, whole sample (N = 4,440)**;** maternal education and income quintiles close to child's birth

			β estimate	SE	Z value	*p* value	VIF
Model 3	Maternal Education	NVQ Level 1	-0.32	0.30	-1.07	0.292	1.41
		NVQ Level 2	-1.52	0.23	-6.55	<0.001***	
		NVQ Level 3	-1.81	0.26	-6.89	<0.001***	
		NVQ Level 4	-2.60	0.25	-10.43	<0.001***	
		NVQ Level 5	-2.76	0.39	-7.03	<0.001***	
		Overseas qualification only	-0.23	0.48	-0.49	0.624	
	Maternal income quintile	2	-0.03	0.15	-0.17	0.871	3.06
		3	-0.22	0.21	-1.02	0.309	
		4	-0.59	0.22	-2.69	0.011**	
		5	-0.73	0.23	-3.18	<0.001**	

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$
† moderate collinearity (VIF ≥ 5.00)

Supplementary Table 2. Time Series Regression, using SDQ Total Difficulties score, restricted to children with pre/post-injury measures (N = 3,662)**;** maternal education and income quintiles close to child's birth

			β estimate	SE	Z value	*p* value	VIF
Model 6	Maternal Education	NVQ Level 1	-0.29	0.33	-0.87	0.384	1.39
		NVQ Level 2	-1.56	0.26	-6.03	<0.001***	
		NVQ Level 3	-1.80	0.29	-6.22	<0.001***	
		NVQ Level 4	-2.58	0.27	-9.49	<0.001***	
		NVQ Level 5	-2.71	0.41	-6.55	<0.001***	

		Overseas qualification only	-0.20	0.51	-0.40	0.689	
	Maternal income quintile	2	-0.08	0.17	-0.46	0.643	3.05
		3	-0.42	0.23	-1.82	0.069	
		4	-0.82	0.24	-3.46	<0.001***	
		5	-1.01	0.25	-4.03	<0.001***	

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$
† moderate collinearity (VIF ≥ 5.00)

Supplementary Table 3. Binomial Regression for step/slope-wise effect of brain injury, using SDQ Total Difficulties 90th centile cut-off, restricted to children with pre/post-injury measures (N = 3,662)**;** maternal education and income quintiles close to child's birth

				Confidence Intervals		
			Odds Ratio	Lower Bound	Upper Bound	VIF
Model 9	Maternal Education	NVQ Level 1	0.98	0.58	1.64	1.37
		NVQ Level 2	0.43*	0.28	0.65	
		NVQ Level 3	0.38*	0.24	0.61	
		NVQ Level 4	0.22*	0.14	0.35	
		NVQ Level 5	0.21*	0.09	0.48	
		Overseas qualification only	1.14	0.50	2.57	
	Maternal income quintile	2	0.95	0.71	1.27	3.13
		3	0.43	0.51	1.18	
		4	0.22*	0.32	0.79	
		5	0.21*	0.26	0.68	

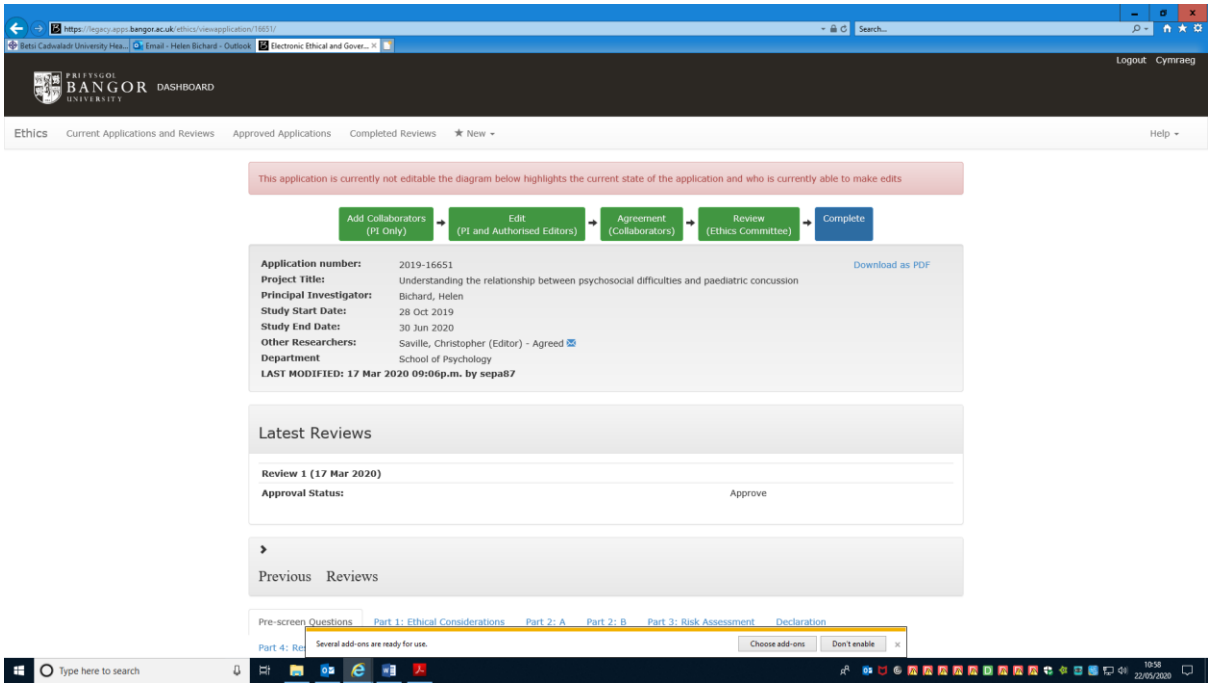
* significant (95% confidence intervals exclude 1)

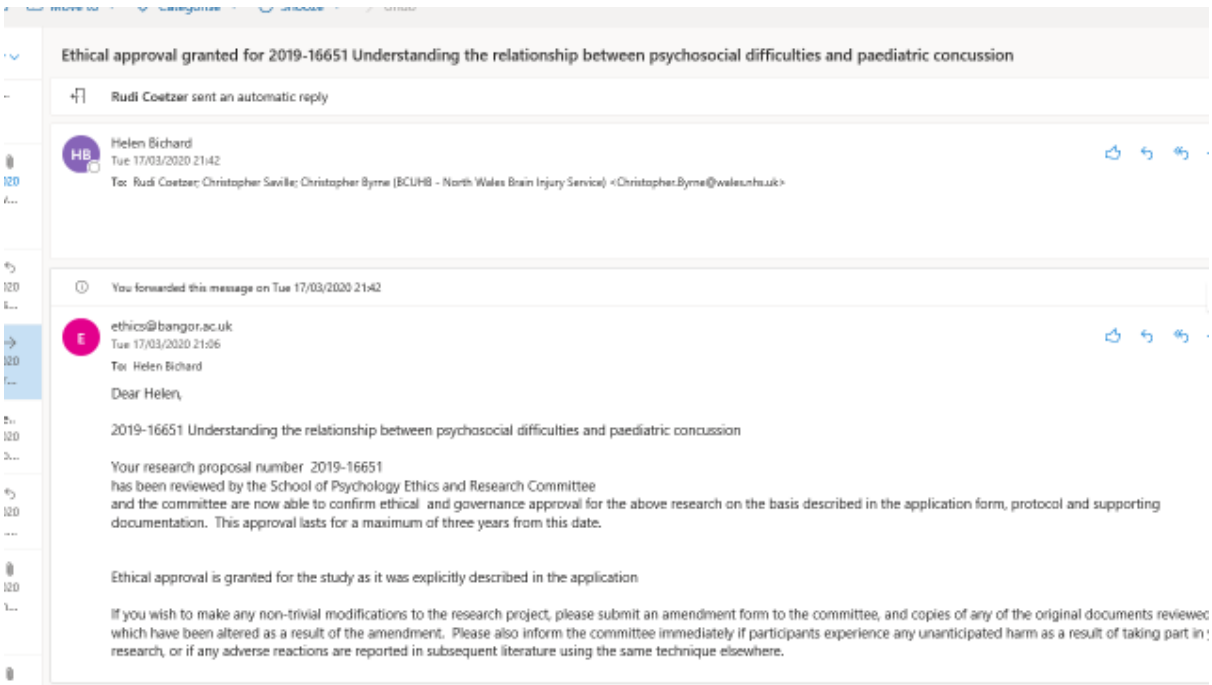
Supplementary Table 4. Logistic Regression, examining effect of age at injury, using dichotomised SDQ scores; restricted to children with pre/post-injury measures (N = 3,662)

				Confidence Intervals		
			Odds Ratio	Lower Bound	Upper Bound	VIF
Model 10	Group (TBI)		1.39	0.19	10.28	1.00
	Age at injury (vs. 5)	7	0.49	0.04	6.60	1.00
		11	0.70	0.10	5.01	
		14	0.67	0.10	4.77	
Model 11	Group (TBI)		2.77	0.05	160.61	4.12
	Age at injury (vs. 5)	7	0.60	0.04	9.71	1.49
		11	0.79	0.09	6.94	
		14	0.77	0.09	6.77	
	Group by age at injury	7	0.21	0.00	2,074.83	4.90
		11	0.48	0.00	119.60	
		14	0.44	0.00	77.73	
Model 12	Group (TBI)		2.71	0.05	160.86	4.16
	Age at injury (vs. 5)	7	0.53	0.03	8.83	1.51
		11	0.79	0.09	6.95	
		14	0.75	0.09	6.64	
	Sex (male)		1.17	0.32	4.30	1.01
	Stratum (disadvantaged)		1.24	0.29	5.29	1.19
	Stratum (ethnic)		0.67	0.05	9.49	
	Household poverty		3.23	0.80	12.96	1.18
	Group by age at injury	7	0.19	0.00	1,889.32	4.98
		11	0.45	0.00	114.34	
		14	0.45	0.00	80.01	

TBI traumatic brain injury, *OI* orthopaedic injury
* significant (95% confidence intervals exclude 1)

Study approval by School of Psychology Ethics





Chapter Three

Contributions to Theory and Clinical Practice, and Personal Reflections

Contributions to Theory and Clinical practice

In this paper I set out the implications for theory development and further research arising from both studies, in addition to what has already been discussed. I also suggest considerations for us as practising clinicians in North Wales. The thesis concludes with some personal reflections on the process of conducting the research.

Systematic review

It is customary for strangulation to be included as an example of hypoxic-ischaemic injury, together with cardiac arrest, near-drowning, and hanging, which could imply a degree of interchangeability. Based on the data our review found, many sequelae are shared, but strangulation has its own additional consequences. However, there needs to be further investigation, particularly for cognition and behaviour, using standardised neuropsychological assessment. Essentially, this is about replicating Pierquet's unpublished thesis (1997), at scale, to establish a neuropsychological profile of strangulation in intimate partner violence (IPV) and sexual assault, to build norms, and explore correlations e.g. length and frequency of events. Having more robust, strangulation-specific data would allow clinicians to conduct hypothesis-based, deductive testing.

It might also contribute to wider societal understanding of relationship dynamics in IPV and provide one answer to the typical question, 'why does she not just leave?', so often asked by those who do not find themselves in chronic, abusive relationships. As we saw in the review, existential fear may play a part, and submissive behaviour. But in any biopsychosocial formulation, we would hope the possibility of brain injury and resulting cognitive challenges will increasingly now be considered (St Ivany & Schminkey, 2016). Escape would be difficult, if memory of the attack has been compromised, along with ability to make judgements and decisions, and to plan. For this same reason, it is worth considering recruitment location in future research. Arguably someone who has managed to flee with their children to a refuge has already 'passed' an assessment of executive function.

Our review focused on the neuropsychological impact on the victim, but other parties are involved. Disturbingly, children were often witnesses: Strack and colleagues (2001) reported their presence in 41% of the 300 cases. This might underestimate incidence, given (understandable) reluctance to report, or failure to record by police. We can hypothesise what

immediate and long-term effects witnessing one's mother being strangled might have. In fact, some have speculated there might be generational social learning (Taliaferro, Hawley, McClane & Strack, 2009). There is, however, little empirical study in this area. Nor is there consensus on how to best care for these children. This is an important and sensitive topic, not least because reporting to child protection services might be seen as risking the 'punishment' of the mother by removal of her children.

We excluded studies which focused on the perpetrator, but we know from the literature that a high proportion will have had a history of TBI themselves. In fact, a meta-analysis calculated that 53% of offenders had a brain injury, significantly higher than the general population ($p < 0.0001$; Farrer, Frost & Hedges, 2012). This begins to suggest a dyadic model in which perpetrator and victim are united by brain injury, and its interpersonal dynamics. For example, the perpetrator may have difficulties with self-regulation following his TBI, which contribute to the attack, which then results in executive and memory difficulties in the victim, which further antagonise the partner, and so on. To our knowledge, this area has not been researched.

Strangulation is one aspect of the bigger field that is TBI within IPV. It has belatedly gained interest. In fact, a systematic scoping review on the topic was published recently (Haag, Jones, Joseph & Colantonio, 2019). However, the research is embryonic, and there is much still to explore. This includes the long term consequences of receiving multiple mild TBIs from battery. The literature suggests many women are being hit weekly, over a period of years (Valera & Kucyi, 2017). Jackson and colleagues (2002) found 25% of subjects had sustained blows to the head over 20 times in the previous five years, and were able to evidence a dose effect with regard to symptoms. In another study, 72% of women who had received IPV-related TBI reported multiple events (Valera & Berenbaum, 2003). We know there is an association between repeated concussion from boxing or football and chronic traumatic encephalopathy (CTE; McKee et al., 2009). There have not, as yet, been similar studies conducted amongst battered women. Part of the issue is that CTE is currently diagnosed post-mortem, at autopsy. Footballers and boxers are easy to identify, because the activity that put them at risk is known. It is different with IPV victims: they may not understand the risk themselves, and the violence may have been unnoticed by those around them. However, these women, unlike footballers and boxers, are not putting themselves at risk by choice, they do not get periods of respite, nor a team of therapists to aid recovery. But

until we can show the damage sustained it is unlikely the risk will receive the same academic and clinical attention, despite the numbers being potentially significantly higher. To put this into context, a recent study claimed there are up to 85 times more women living with IPV-sustained TBI in the US than military veterans, and 37,000 times more than American Football players who have had repeated concussion (St Ivany & Schminkey, 2016). One solution might be adopting a similar Big Data approach as in our empirical paper: identifying a national cohort study which has been operating for long enough to let us explore the relationship between domestic violence and dementia. Given such high prevalence and incidence figures for IPV, and TBI within IPV, it does not feel too outlandish to ask whether this is one explanation for the increased risk of Alzheimer's in women (Andersen et al., 1999).

In terms of clinical practice, the main issue from the review is that these women do not routinely present to services. Relying on the current model, whereby community ABI teams passively receive referrals from hospital wards and GPs, will almost certainly not provide strangulation victims with the neuropsychological intervention they need and deserve, as currently referrals are unlikely. In our service, there is one IPV strangulation victim that we know of, but she has only come to our attention because of a later TBI as a result of a fall. As if to support our point, she did not report the strangulation during history-taking, when asked about any previous brain injury. She only mentioned it during later trauma processing, and was surprised when the possibility of having sustained a brain injury was raised, despite reporting attending hospital at the time. This therefore suggests a more active role for ABI services in this area: building professional awareness and understanding, in order to drive future referrals. Potential targets would be A&E colleagues, GPs, sexual assault referral centres, and refuge workers. In this, it would be similar to the work of the training institute created by the authors of the San Diego studies cited in our paper, which they established following their own review of the evidence (https://www.strangulationtraininginstitute.com/; Strack et al., 2001).

This more active positioning for ABI services brings to mind a paper written about Cambodian survivors of the Pol Pot regime (Mollica, Henderson & Tor, 2002). The authors demonstrated that symptoms of depression and PTSD often masked an underlying brain injury; in fact brain injury was more predictive of PTSD symptoms than warlike conditions and violence to others. The authors recommended active clinical identification of ABI;

deliberately going out to find it. Similarly in IPV, funding permitting, there might be an opportunity for clinical in-reach e.g. regular brain injury screening clinics at refuges, in order to mitigate against this diagnostic overshadowing amongst a similarly traumatised population. This equally applies to our colleagues in mental health. Yes, psychological trauma will almost certainly play a large part in someone's presentation, but to be fully biopsychosocial in our approach, brain injury does need to be considered within any formulation.

There is also a potential upstream role, and that is to focus on prevention. Two amendments have been tabled to the new Domestic Abuse Bill in the UK. One aims to outlaw the use of the 'rough sex' defence in fatal strangulation, and the other to make non-fatal strangulation a specific offence, as it can currently be tried as common assault. We have shared our review with both lobby groups, and the MPs sponsoring the amendments. Following consultation with our corporate communications colleagues, we have also circulated the review to all 10 MPs who have constituencies served by the local health board, and at the time of writing three had already replied to confirm they would support the amendments, including advocating with the Home Secretary. It has been submitted as evidence to the Domestic Abuse Bill committee, and has been cited eight times in others' submissions. In order to do this, a pre-print had to be uploaded to the Centre for Open Science platform so that it could be cited (https://psyarxiv.com/c6zbv/). Encouragingly, in the eight days since appearing online, the full text has been downloaded 71 times. Our target journal has a green SHERPA/RoMEO rating, so this is permitted, but if they do not accept the paper and we need to try elsewhere, having shared a pre-print may jeopardise our chances. On balance, we felt the kind of 'impact' which really mattered was getting it in front of decision-makers. Please see Appendix for examples of this impact.

When it comes to decision-makers, that applies to the public too. The women who might have been strangled, notice memory problems afterwards, but do not connect the two, just like our service user. The couple researching 'breath play' for fun. If someone had been repeatedly hit about the head, and then noticed cognitive changes, the association would likely be much clearer. It is hard to imagine a couple exploring 'how to waterboard someone safely'. We need the public to have the information necessary to appreciate strangulation's potential lethality. To this end, we are also contributing to a BBC Disclosure documentary on the growing popularity of choking, and are drafting a lay version of our review for

mainstream dissemination by https://wecantconsenttothis.uk/, as part of their social media campaign.

Empirical study

Frustratingly, the data from our empirical study could equally be used as evidence for the sleeper effect, or for the Kennard Principle, despite their being effectively contradictory. Those children injured by the age of three seemed to display greater difficulties at 14, which could support the theory that childhood TBI causes frontal lobe damage which does not become apparent until the greater socio-cognitive demands of adolescence. However, the samples were small, and there was some suggestion of pre-morbid disturbance. Overall, the lack of significant step-wise or slope-wise changes to behavioural trajectories following TBI could also evidence neuroplasticity in the young. However, we were comparing means, and we know that up to 90% of our samples may have had a mild TBI, with many not attending hospital. Based on our clinical experience, we know that there will be a portion of children for whom this has devastating consequences: the miserable minority identified elsewhere. In our study, this might be those reporting the most extreme anti-social behaviours. But we cannot state anything more confidently at this point in the project. Analysing the data from when the children were 17 will give us valuable information. It is also our intention to work with the MCS team to find ways to 'fill in the gaps', such as indicators of injury severity. This might be possible for the Welsh cohort members through the SAIL project although, when we enquired about basic hospital attendance data, the cost was prohibitive.

From a broader perspective, the lack of significant findings means we cannot yet answer the concluding question posed by Bellesi and colleagues in their systematic review of paediatric TBI and anti-social behaviour (2019): does TBI cause anti-social behaviour, or vice versa, or does it moderate existing difficulties, or is one a risk factor for the other. Addressing this remains critical, because the literature is still divided. On the one hand, there are those who believe that the increased prevalence of TBI in offenders is due to pre-morbid behavioural difficulties that were themselves risk factors for sustaining a TBI (Anderson et al., 2017, p.320; (Li & Liu, 2013). On the other, we have Williams, Hughes and colleagues making the connection between neurodisability and children who offend (Hughes, Williams, Chitsabesan, Davids, & Mounce, 2012; Williams, 2012). Harris' theory of criminal offending

and psychopathy (2001) likewise contains one pathway which is via neurodevelopmental insult. Interestingly, the MCS did include the Callous-Unemotional Scale in sweep five (when the children were 11), so this may merit further investigation.

Moving from what the data do not tell us, to what they do, there is evidence for the power of the parental relationship, i.e. indirect support for Attachment Theory (Bowlby, 2005), although, as explained in our paper, test validity meant we could not assess this directly. Consistently, maternal wellbeing was more predictive of the child's behaviour than material circumstances or even brain injury. This seems an obvious point, but has implications for the system around the child. In some cases, this means reassurance can be given to parents. For others, where there are attachment difficulties, it allows agencies to identify those children who may struggle, brain injury notwithstanding.

Perhaps the most important clinical take-home message so far is, as with the strangulation study, the importance of explicit questions about TBI when history-taking, including with adults. The MCS does not ask 'have they had a brain injury?' It would be interesting to include that question now, so we could see what proportion of those whom we know have experienced loss of consciousness associate that with TBI. The hypothesis being that most people will not self-report childhood TBI despite satisfying criteria. Yet we know that one of the strongest predictors of TBI is having sustained a previous TBI (Dams-O'Connor et al., 2013; Saunders et al., 2009). It may be that those injured aged three or younger and/or those reporting the most serious anti-social behaviours, including offending, are our future adult clients. What this means for us as clinicians is not expecting spontaneous report: we should be asking about any losses of consciousness, or accidents when they 'blacked out' or were 'knocked out' as a child.

Finally, as we add more data, and can get closer to being able to 'join the dots' with the criminal population, where we know TBI is over-represented, it is worth remembering that we have the largest prison in the UK within our catchment area. This has research and clinical implications. From a research perspective, narrative studies could look specifically at childhood TBI, albeit that will have the recall bias that our prospective sampling avoids. Understanding, from a qualitative perspective, how trajectories alter after paediatric brain injury would add human colour to our numbers. Clinically, we understand charity BIRT have tendered to provide brain injury services within HMP Berwyn. This seems counterintuitive, given the proximity of world class, publicly-funded expertise. Legally it is also questionable,

as it means prisoners are not receiving equity of provision. As an aside, rule 20(1) of the Prison Rules 1999 (UK Legislation, amended 2009) contains an obligation: "the governor must work in partnership with local health care providers to secure…access to the same quality and range of services as the general public receives". Breaching this rule could be enforced by a damages action for breach of statutory duty, or by public law litigation (i.e. a claim for judicial review).

A reflective commentary

But Mousie, thou are no thy-lane,
In proving foresight may be vain:
The best laid schemes o' Mice an' Men,
Gang aft agley,
An' lea'e us nought but grief an' pain,
For promis'd joy!

Robert Burns (1785)

This was not the LSRP I had intended writing, and nor has it been the process I imagined. Like Burns' mousie, my best laid schemes have often been in vain. Plan A was rejected by the Research and Ethics Committee (REC). Plan B became unpractical because it depended on other agencies. Having adopted Plan C – Big Data – my hypotheses were unsupported. I did not get the job I had, frankly, expected. And then there was the small matter of a global pandemic. Throughout it all, therefore, I have had to practice the psychological flexibility that is at the centre of Acceptance and Commitment Therapy (ACT), and which I often preach to clients. It transpires this can be rather hard!

My original research proposal was an interpretative phenomenological analysis of sex after ABI. I had intended to speak to the female partners of male ABI survivors. Although there has been some work on the interpersonal impact of ABI, and many interviews with couples about the behavioural and psychological difficulties, they usually shy clear of the subject of sex. When sex is covered, the research is more often with the brain injury survivor themselves (notwithstanding the potential lack of insight, communication difficulties, and the cognitive changes that may make it difficult to consider the other party), or with the couple,

which will have an impact on what is shared, and what is not. This reticence is often replicated in the clinical environment. We seem to be comfortable asking about other basic functions like sleep, diet, and even bowel movements, but sex is skipped over. However, we know that the majority of clients are concerned and want to discuss it (Moreno et al, 2015). Similarly, in a recent study 60% of clinicians agreed it was important, yet only 6% had raised it proactively (Arango-Lasprilla et al., 2017).

There is a growing body of research on sex after ABI, largely coming out of Jennie Ponsford's lab in Australia (e.g. Downing & Ponsford, 2018), but it tends to be quantitative and survey-based, not permitting a richness of understanding, and physiological, concentrating on the biological changes which may make the sexual act itself more challenging, rather than more psychosocial aspects such as role transition, personality and behaviour change, anger, fatigue, and aggression. And what about unspeakable emotions such as disgust, guilt, and shame? Given the association between marital quality and rehabilitation outcomes (Godwin, Kreutzer, Arango-Lasprilla, & Lehan, 2011), to me this had seemed like an important area to explore.

We knew that it was a sensitive theme, and the consensus was that the REC would likely suggest changes, but I was reassured that no trainees' proposals had ever been rejected outright. However, at the REC, concerns were professed about confidentiality and risk, and we were asked to get informed consent from the male ABI survivors for their female partners to take part in the research. I understood their point: it was by dint of their being our patients that we would have access to their partners. How would they feel if they found out their partner had been discussing their sex lives? Would there be repercussions for the partner? For our service? I had already discussed this at length with supervisors and with our People Panel, comprised of service users. The People Panel had, in fact, roundly endorsed the project, and given me four written pages of input. Several of the members were married to people with dementia and, given the similarities, felt strongly that this was a topic which should be explored. Supervisors and service users had all believed that the decision was up to the research participant, just as if they were having individual psychotherapy in which they discussed their relationships and their sex lives. Indeed, clinically, we have often provided interventions for families and carers. Asking female participants to get their male partners' consent therefore suggested an antiquated attitude towards relationships, was likely to skew the sample towards those whose partners had remained 'reasonable' despite the injury, and

actually potentially put my participants at increased risk of provoking an angry reaction. This was all put to the REC, but they were not swayed, and the application was rejected, making me something of a trailblazer for the Programme.

A recent article provided some validation and normalisation of my experience. Della Sala and Cubelli (2020) gathered examples of questionable decisions by RECs to make the point that what was created to be a collaborative process can too often be combative. The ethics process should be about protecting the public, yes, to prevent atrocities like the Red Wing studies cited in our literature review (Kabat & Anderson, 1943). But there is also a role in terms of promoting and improving clinical research. Instead, their response seemed to me a blocking one, and the result of a lack of nuanced understanding and expertise in either ABI or qualitative research.

Given it had taken so long to get to this point – five months to get through the School Ethics process even before the REC's rejection – it was now October, and I only had seven months before submission. An official ethics appeal could have taken up to 120 days. Plan B was therefore hastily constructed: to take my literature review topic – at that point ABI in sexual violence – and transform it into an empirical study. I proposed replicating some small scale studies conducted in other countries whereby residents in women's refuges who had been victims of sexual violence were screened for ABI, in order to build prevalence data, and possibly combining that with auditing to what extent the Health Board complied with NICE guidelines by screening for domestic violence when women attended A&E with head and neck trauma. However, this hinged on cooperation from various NGOs, the Informatics department, and local authorities. Having made initial contact with charity Women's Aid, they then had funding cut by government, and a change of CEO. My research project was therefore, rightly, a low priority. Without their help, the study would have been extremely difficult, certainly within my timings.

Plan C was therefore adopted, which involved scouring all the national cohort studies in order to post-rationalise a research question, depending on what data were available. This had to involve brain injury, as I wanted my empirical paper to count towards any future entry for the post-doctoral Qualification in Clinical Neuropsychology. The issue was that very few of the datasets contained any reliable measure of brain injury, and there was therefore no way of combining this with experience of domestic violence in order to construct a research question that still fitted with my Plan B. The Millennium Cohort Study measured incidences of loss of

consciousness, but this was within a child population. I therefore had to change topic, and mine the paediatric literature for possible research questions, at speed. This also entailed having to modify my literature review, to form a pairing. It is a huge credit to my academic supervisor Chris Saville that, from receiving the REC rejection in the first week of October, we managed to submit an application for School Ethics by the end of October, albeit that this was not formally approved until March, two months before submission!

I had previously been aware of the data showing increased prevalence of ABI amongst the prison population, and decided this would form the background of my project. In my mind, I would be able to 'prove' that typically developing, law-abiding, Sunday School attendees got hit on the head, life changed in a heartbeat, and thus began a long descent which ended inexorably, and unfairly, in a life of crime. However, science intervened, and my hypotheses were not supported. Yet again I was having to let go of tightly held plans and predictions. I remember falling silent the moment when we first pressed ctrl + enter on our R model, and there was no star of significance beside the three-way interaction that popped out the other end. I actually began to have something of an internal moral tussle with the findings. My supervisor was keen to push ahead on publication, whereas I worried that our study could be misinterpreted and add to the 'born bad' narrative.

And then Covid-19 happened. I have contributed to a paper elsewhere about how this affected our clinical work (Coetzer & Bichard, 2020). I felt a strong – possibly grandiose – sense of duty to be where I was most needed, and therefore moved from a community role to working on the acute stroke wards. There is an already evidenced interaction between stroke and coronavirus, with frail stroke patients being vulnerable to hospital-acquired infection, and the coagulant effect of the virus increasing the risk of stroke (Klok et al., 2020; Wu et al., 2020). We saw this on our wards. Patients died. Four colleagues were infected, although thankfully all recovered quickly. It was hard against this background to retain emotional commitment to the LSRP: it suddenly seemed trivial. I found myself 'dropping in' to the wards on my study days to check on colleagues and patients.

It brought practical difficulties too. My academic supervisor, having been on strike for three weeks, was in quarantine for a further two, before the country was then locked down. I had two young children being home schooled. This made working from home difficult logistically, but also I wanted to spend evenings and weekends ensuring they continued to feel safe and settled, when previously I might have sat at the computer. My partner, who had

been so supportive, was rightly focused on keeping our fledgling family business afloat. My eldest daughter struggled with the isolation and, breaking lockdown, fled to London one day when I was at work. I worried about her, a lot.

Finally, I failed to get the brain injury job I had been working towards for six years. I went through a brief but uncharacteristically visceral grief reaction, as well as suffering a dent to the self-efficacy necessary to get through a process like thesis-writing. Unhelpful secondary emotions and cognitions reared their heads. I felt guilty, that I was crying about not getting a job, when people were dying. I would not allow myself to feel angry, as these were my colleagues, whom I admired hugely, so to be angry felt disrespectful. In hindsight, although I was aware it was a competitive process, I had developed a degree of expectation, and therefore this rejection served as yet another upending of predictions. The door was shut on a long-imagined future.

So, with an ethics application, a clutch of hypotheses, and now me, all rejected – presumably the research process has been one of pain, rather than the promised joy? Perhaps counterintuitively, I have found it galvanising, and confirmatory. In my previous career, we used to talk about 'strong opinions, weakly held'. To me, that seems the corporate equivalent of ACT's psychological flexibility construct. Whatever framework used, there is something important about learning not to hold onto ideas and predictions too rigidly; by letting go, we bounce back. In life, as in science. The research process has been a three year test of this resilience and is, I believe, a test I have passed.

In so doing, I have come to some realisations.

I am an English graduate and ex-adman. As such, the world of statistics seemed alien. Art versus science; words versus numbers. I would have never naturally chosen a Big Data project. However, there is something fundamental shared by books and regression models. They are both about *stories*: stories that attempt to further our understanding of the human condition. Having spent many hours grumbling to my supervisors about statistics, and that doing it in R was the equivalent of writing my thesis in Mandarin (and backwards, and in heels), I now find myself intrigued by the possibilities offered by Big Data. There are jewels waiting to be mined. I have also reached the point where – sometimes – I see the simple beauty in the maths, and find the number-crunching soothing. Sometimes.

Beyond this, the process has confirmed that, put simply, I like research, and want to do more of it. At 46 I am significantly older than the mode but, if anything, this helps focus: I only have 20 years to write everything I need to write! I therefore want to concentrate on issues-based research; hard but important areas where I can help make a difference. Again, maybe grandiosity is at play, but with grandiosity comes the self-belief that gets things done. I have outlined above potential next steps in the domestic violence field, and using the MCS. I want to find a way to make the sex after ABI study happen. But there are other wrongs I want to right. These include building our understanding of functional neurological disorders: a group of people who are still too often systemically mistreated as frauds and hysterics, who lack services, and evidence-based interventions, and find themselves trapped in a revolving door, shunted between clinicians and investigations. I am also interested in women and ABI, whether there is any difference in outcome between genders, and potential moderators, including hormones. I think there may be a niche for me: feminist neuropsychology.

I could continue, as I am building an ever-growing bucket list of interesting questions. My curiosity is activated: I have become a scientist. And so, as I end this thesis, I do it in the grateful knowledge that it is only the beginning. Yes, there has been grief and pain. In hindsight, yes, my schemes have gone as ‘agley’ as the wee mousie’s house. But the one prediction I never made was that this process would be joyful, and, in its own peculiar way, it has. I intend, therefore, to keep going.

References

Andersen, K., Launer, L. J., Dewey, M. E., Letenneur, L., Ott, A., Copeland, J. R. M., ... & Lobo, A. (1999). Gender differences in the incidence of AD and vascular dementia: The EURODEM Studies. *Neurology*, *53*(9), 1992-1992.

Arango-Lasprilla, J. C., Olabarrieta-Landa, L., Ertl, M. M., Stevens, L. F., Morlett-Paredes, A., Andelic, N., & Zasler, N. (2017). Provider perceptions of the assessment and rehabilitation of sexual functioning after Traumatic Brain Injury. *Brain Injury*, *31*(12), 1605-1611.

Bellesi, G., Barker, E. D., Brown, L., & Valmaggia, L. (2019). Pediatric traumatic brain injury and antisocial behavior: are they linked? A systematic review. *Brain Injury*, *33*(10), 1272-1292.

Bowlby, J. (2005). *A secure base: Clinical applications of attachment theory* (Vol. 393). Taylor & Francis.

Coetzer, R., & Bichard, H. (2020). The challenges and opportunities of delivering clinical neuropsychology services during the Covid-19 crisis of 2020. *Cuadernos de Neuropsicología/Panamerican Journal of Neuropsychology*, *14*(1).

Dams-O'Connor, K., Gibbons, L. E., Bowen, J. D., McCurry, S. M., Larson, E. B., & Crane, P. K. (2013). Risk for late-life re-injury, dementia and death among individuals with traumatic brain injury: a population-based study. *J Neurol Neurosurg Psychiatry*, *84*(2), 177-182.

Della Sala, S., & Cubelli, R. (2020). Entangled in an ethical maze. *The Psychologist*, *29*. Retrieved from https://thepsychologist.bps.org.uk/volume-29/december-2016/entangled-ethical-maze.

Downing, M., & Ponsford, J. (2018). Sexuality in individuals with traumatic brain injury and their partners. *Neuropsychological Rehabilitation*, *28*(6), 1028-1037.

Farrer, T. J., Frost, R. B., & Hedges, D. W. (2012). Prevalence of traumatic brain injury in intimate partner violence offenders compared to the general population: A meta-analysis. *Trauma, Violence, & Abuse*, *13*(2), 77-82.

Godwin, E. E., Kreutzer, J. S., Arango-Lasprilla, J. C., & Lehan, T. J. (2011). Marriage after brain injury: Review, analysis, and research recommendations. *The Journal of Head Trauma Rehabilitation*, *26*(1), 43-55.

Haag, H., Jones, D., Joseph, T., & Colantonio, A. (2019). Battered and Brain Injured: Traumatic Brain Injury Among Women Survivors of Intimate Partner Violence—A Scoping Review. *Trauma, Violence, & Abuse*, 1524838019850623.

Harris, G. T., Rice, M. E., & Lalumière, M. (2001). Criminal violence: The roles of psychopathy, neurodevelopmental insults, and antisocial parenting. *Criminal justice and behavior*, *28*(4), 402-426.

Hughes, N., Williams, H., Chitsabesan, P., Davids, R., & Mounce, L. (2012). Nobody made the connection: The prevalence of neuro-disability in young people who offend. *Office of the Children's Commissioner*. Retrieved from https://www.childrenscommissioner.gov.uk/publication/nobody-made-the-connection/

Jackson, H., Philp, E., Nuttall, R. L., & Diller, L. (2002). Traumatic brain injury: A hidden consequence for battered women. *Professional Psychology: Research and Practice*, *33*(1), 39.

Kabat, H., & Anderson, J. P. (1943). Acute arrest of cerebral circulation in man: Lieutenant Ralph Rossen. *Archives of Neurology & Psychiatry*, *50*(5), 510-528.

Klok, F. A., Kruip, M. J. H. A., Van der Meer, N. J. M., Arbous, M. S., Gommers, D. A. M. P. J., Kant, K. M., ... & Endeman, H. (2020). Incidence of thrombotic complications in critically ill ICU patients with COVID-19. *Thrombosis Research*.

McKee, A. C., Cantu, R. C., Nowinski, C. J., Hedley-Whyte, E. T., Gavett, B. E., Budson, A. E., ... & Stern, R. A. (2009). Chronic traumatic encephalopathy in athletes: progressive tauopathy after repetitive head injury. *Journal of Neuropathology & Experimental Neurology*, *68*(7), 709-735.

Mollica, R. F., Henderson, D. C., & Tor, S. (2002). Psychiatric effects of traumatic brain injury events in Cambodian survivors of mass violence. *The British Journal of Psychiatry*, *181*(4), 339-347.

Moreno, A., Gan, C., Zasler, N., & McKerral, M. (2015). Experiences, attitudes, and needs related to sexuality and service delivery in individuals with traumatic brain injury. *NeuroRehabilitation, 37*(1), 99-116.

Oddy, J., & Gosling, M. (2009). "Rearranged marriages: marital relationships after head injury." *Brain Injury, 13*(10), 785-796.

Pierquet, L. (1997). *Neuropsychological consequences of the domestic battering of women*. Doctoral thesis submitted to the Wisconsin School of Professional Psychology. Retrieved via Inter-Library Loan from UMI, Ann Arbor, Michigan.

Saunders, L. L., Selassie, A. W., Hill, E. G., Nicholas, J. S., Horner, M. D., Corrigan, J. D., & Lackland, D. T. (2009). A population-based study of repetitive traumatic brain injury among persons with traumatic brain injury. *Brain injury*, *23*(11), 866-872.

St Ivany, A., & Schminkey, D. (2016). Intimate partner violence and traumatic brain injury. *Family & Community Health, 39*(2), 129-137.

Strack, G. B., McClane, G. E., & Hawley, D. (2001). A review of 300 attempted strangulation cases Part I: Criminal legal issues. *The Journal of Emergency Medicine, 21*(3), 303-309.

UK Legislation (2009). *Prison Rules 1999*. Retrieved from http://www.legislation.gov.uk/uksi/1999/728/contents/made

Valera, E. M., & Berenbaum, H. (2003). Brain injury in battered women. *Journal of Consulting and Clinical Psychology*, *71*(4), 797.

Valera, E., & Kucyi, A. (2017). Brain injury in women experiencing intimate partner-violence: neural mechanistic evidence of an “invisible” trauma. *Brain Imaging and Behavior*, *11*(6), 1664-1677.

Williams, H. (2012). Repairing shattered lives. *Transition to Adult Alliance, Barrow Cadbury Trust*.

Wu, Y., Xu, X., Chen, Z., Duan, J., Hashimoto, K., Yang, L., ... & Yang, C. (2020). Nervous system involvement after infection with COVID-19 and other coronaviruses. *Brain, Behavior, and Immunity*.

Appendix

Ongoing political/legal impact of Systematic Review

DAVIES, James (MP) <james.davies.mp@parliament.uk>

Wed 20/05/2020 23:46

Dear Helen,

Thank you so much for taking the time to write about non-fatal strangulation and the impact it has.

I've not been selected to sit on the Public Bill Committee for this Bill but later stages will be open to votes on the floor of the House (i.e. for all MPs). However, not all amendments are selected by the Speaker for debate and it is rare for many to get through unless the government is already convinced of their merits.

Therefore, I think the best course of action is if I write to Priti Patel to raise your points. I will do so and let you know of her response.

Kind regards,

James

Dr James Davies MP

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lizsavilleroberts@gmail.com

Wed 20/05/2020 07:54

Dear Helen

Thank you very much for sending this information to my colleague, Hywel Williams. I hope to be a member serving on the Domestic Abuse bill committee next month, and will be supporting Harriet Harman's amendment to remove the 'rough sex' defence.

Kind regards

Liz

> On 18 May 2020, at 21:41, WILLIAMS, Hywel <hywel.williams.mp@parliament.uk> wrote:
>
> Meddwl efallai gallai hyn fod o ddiddordeb I ti, Hywel

Fiona Mackenzie <fiona@wecantconsenttothis.com>
Thu 21/05/2020 16:48

Helen - thank you so much for sharing your research with us. It's been so useful already in confirming many of the questions we had been asking on the impacts of strangulation. Our campaign has found too many cases where strangulation of a partner is treated with appalling lightness by the criminal justice system - and now heard from far, far too many women who have been strangled or asphyxiated in sex. And although we knew from the women that these assaults were traumatic and injurious, we needed clear research evidence to bolster their stories.

We will be referring to and using your research in our evidence submission to the Domestic Abuse Bill Committee where we hope to ensure that the law in England and Wales reflects the seriousness of these assaults. Your research will also be part of more detailed briefings we will share with the Ministry of Justice and the MoJ Ministers - to ensure that they are able to propose wideranging measures across all areas of the CJS so that the law *works*. But beyond that - we will use this in public education and our continued push to ensure that strangulation - *uniquely intimate terrorism*- is rightly understood as a seriously harmful act.

And I absolutely agree with your paper's assessment of the further research that is required in this area - but please don't underestimate the importance of your own.

Fiona
We Can't Consent To This Campaign Lead

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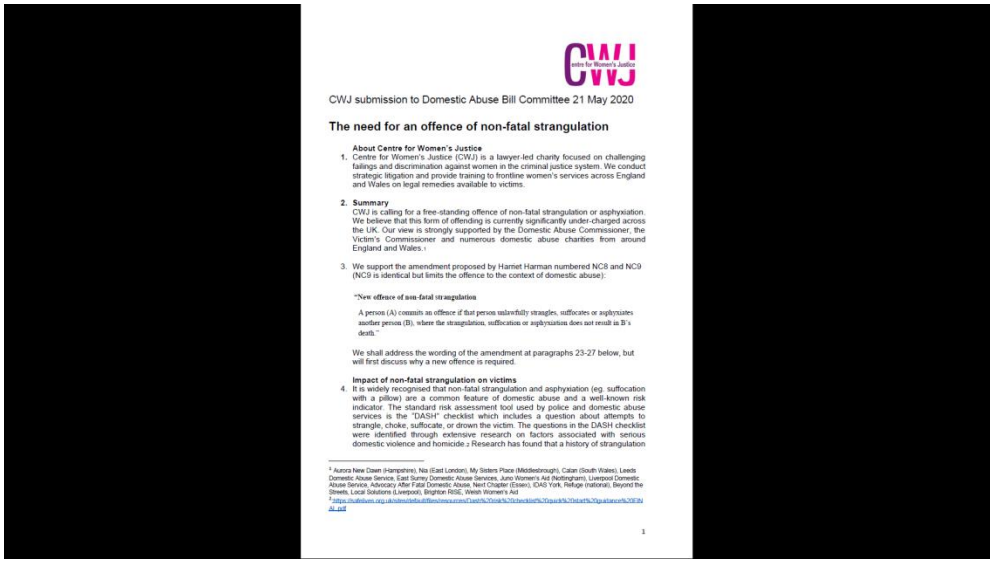
Review cited eight times in this submission to the Domestic Abuse Bill Committee from the Centre for Women's Justice



CWJ submission to Domestic Abuse Bill Committee 21 May 2020

The need for an offence of non-fatal strangulation

About Centre for Women's Justice

1. Centre for Women's Justice (CWJ) is a lawyer-led charity focused on challenging failings and discrimination against women in the criminal justice system. We conduct strategic litigation and provide training to frontline women's services across England and Wales on legal remedies available to victims.

2. **Summary**
CWJ is calling for a free-standing offence of non-fatal strangulation or asphyxiation. We believe that this form of offending is currently significantly under-charged across the UK. Our view is strongly supported by the Domestic Abuse Commissioner, the Victim's Commissioner and numerous domestic abuse charities from around England and Wales.[1]

3. We support the amendment proposed by Harriet Harman numbered NC8 and NC9 (NC9 is identical but limits the offence to the context of domestic abuse):

"New offence of non-fatal strangulation

A person (A) commits an offence if that person unlawfully strangles, suffocates or asphyxiates another person (B), where the strangulation, suffocation or asphyxiation does not result in B's death."

We shall address the wording of the amendment at paragraphs 23-27 below, but will first discuss why a new offence is required.

Impact of non-fatal strangulation on victims

4. It is widely recognised that non-fatal strangulation and asphyxiation (eg. suffocation with a pillow) are a common feature of domestic abuse and a well-known risk indicator. The standard risk assessment tool used by police and domestic abuse services is the "DASH" checklist which includes a question about attempts to strangle, choke, suffocate, or drown the victim. The questions in the DASH checklist were identified through extensive research on factors associated with serious domestic violence and homicide.[2] Research has found that a history of strangulation

[1] Aurora New Dawn (Hampshire), Nia (East London), My Sisters Place (Middlesbrough), Calan (South Wales), Leeds Domestic Abuse Service, East Surrey Domestic Abuse Services, Juno Women's Aid (Nottingham), Liverpool Domestic Abuse Service, Advocacy After Fatal Domestic Abuse, Next Chapter (Essex), IDAS York, Refuge (national), Beyond the Streets, Local Solutions (Liverpool), Brighton RISE, Welsh Women's Aid

[2] https://safelives.org.uk/sites/default/files/resources/Using%20the%20checklist%20quick%20start%20guidance%20EN_0_.pdf

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Submission to Domestic Abuse Bill Committee May 26th 2020

The need for an offence of non-fatal strangulation, and to outlaw the use of the 'rough sex' defence

1. **Summary**

   I am writing in support of amendments NC4-NC11 to the new Domestic Abuse Bill. These amendments refer to the use of the 'rough sex' defence in the case of fatal strangulation, and the characterisation of non-fatal strangulation as a specific offence.

2. **Background**

   I am a Trainee Clinical Psychologist working at the North Wales Brain Injury Service, and an employee of Betsi Cadwaladr University Health Board (BCUHB) within NHS Wales. This is my final year of clinical training, concluding September 2020. I have recently submitted my doctoral thesis, which was on the intersection of brain injury and violence. Part of this was a systematic review of the evidence for the neuropsychological (neurological, cognitive, psychological, and behavioural) outcomes of non-fatal strangulation in domestic and sexual violence[1]. The paper has been submitted for peer review and publication in the journal *Neuropsychological Rehabilitation*. This link (https://psyarxiv.com/c6zbv/) will take you through to a pre-print published on the Open Science website. Since being published eight days ago the paper has already been downloaded and read in full 71 times, indicating a significant level of public and scientific interest at this early stage already.

3. **Impact of non-fatal strangulation on victims**

   I would humbly urge you to read the full paper, but to summarise:

[1] Bichard, H., Byrne, C., Saville, C. W. N., & Coetzer, R. (2020, May 15). The neuropsychological outcomes of non-fatal strangulation in domestic and sexual violence: A systematic review. https://doi.org/10.31234/osf.io/c6zbv

- 27 international, peer-reviewed studies were identified, largely based on medical case reports, or analysis of police and forensic records
- Neck structures are fragile: blocking the jugular vein can take less pressure than opening a can of Coke
- In terms of pathology, strangulation was shown to lead to arterial dissection, compromise of blood flow to and from the brain, cerebral swelling, delayed stroke, and miscarriage
- In fact, it is thought strangulation might be the second most common cause of stroke in women under 40
- Strangulation potentially carries all the consequences of other hypoxic-ischaemic injuries such as cardiac arrest (which it can itself provoke), but has its own additional burden
- Neurological consequences include: loss of consciousness (indicating at least mild brain injury), paralysis, movement disorders, altered sensation, speech disorders, incontinence, and seizures
- Cognitive consequences include: memory loss, impaired executive function (decision-making, judgement)
- Psychological consequences include: existential fear, PTSD and other trauma reactions, dissociation, suicidality, depression, anxiety, personality change
- Behavioural consequences include: increased compliant and submissive behaviour, aggression

From this it should be clear that non-fatal strangulation carries with it the very real potential to cause significant and life-changing injury to brain and mind.

4. Strangulation and 'consent'

I also want to make a specific point about consent. Consent always needs to be informed, and it needs to be able to be withdrawn at any point. Neither of these can possibly pertain in the so-called 'rough sex' defence. People do not currently understand the very severe risks of this behaviour, to inform their decision making when considering consenting: how can they, if the law minimises it so? This equates to having to make an informed decision without having access to the science and knowledge to inform said decision to consent (or not). Furthermore, if consent is provided, the person would not be aware that their consent cannot be withdrawn, because the very organ that is needed to provide consent – the brain – is compromised by the activity to which it applies, i.e. strangulation. Consciousness can be lost in as little as four seconds. In a bizarre and inhumane experiment in the 1940s in which prisoners and

psychiatric patients were strangled to observe its physical, biological effects, the lead examiner first tried the equipment on himself[2]. There was an emergency release button. He found himself unable to press it, even when he wanted to. He was unsure whether this was due to forgetting he could (amnesia) or messages from the brain not getting to his hand (dyspraxia). He almost died. Both these impairments were the result of the cognitive compromise being wrought due to altered brain (and mind) functioning by strangulation.

5. **Conclusion**

I would be extremely grateful if you would consider supporting the amendments. I ask this in both my clinical role, and as a mother of three daughters. This is a gendered crime, and a deadly one. After being strangled, a woman's chance of subsequently being murdered rises eightfold[3]. It is, indeed, the edge of homicide. Finally, though an employee of BCUHB, I am writing in my personal capacity and as a clinician-scientist. My views do not necessarily reflect those of my employing organisation, although it is worth stating they fully supported my contributing to a BBC Disclosure documentary on strangulation, which is currently paused due to Covid-19

Please do not hesitate to contact me with any questions.

Helen Bichard
Trainee Clinical Psychologist

[2] Kabat, H., & Anderson, J. P. (1943). Acute arrest of cerebral circulation in man: Lieutenant Ralph Rossen. *Archives of Neurology & Psychiatry*, *50*(5), 510-528.

[3] Glass, N., Laughon, K., Campbell, J., Block, C. R., Hanson, G., Sharps, P.W., & Taliaferro, T. (2008). Non-fatal strangulation is an important risk factor for homicide of women. *The Journal of Emergency Medicine*, *35*(3), 329-335.

Word Count

	Excluding references, tables, appendices etc	Inclusive
Thesis summary	295	295
Systematic review	6,900	11,971
Empirical study	7,698	11,447
Reflective commentary	4,919	7,129
Title pages, acknowledgements, abbreviations, contents, word count	-	559
Total	*19,812*	*31,401*