Turun yliopisto
University of Turku

PEDIATRIC TRAUMATIC BRAIN INJURY IN FINLAND

Contextual Influences and Threats to Caregiver Capacity

Michael Lowery Wilson

TURUN YLIOPISTON JULKAISUJA – ANNALES UNIVERSITATIS TURKUENSIS
Sarja - ser. D osa - tom. 1385 | Medica - Odontologica | Turku 2018

Turun yliopisto
University of Turku

PEDIATRIC TRAUMATIC BRAIN INJURY IN FINLAND

Contextual Influences and Threats to Caregiver Capacity

Michael Lowery Wilson

TURUN YLIOPISTON JULKAISUJA – ANNALES UNIVERSITATIS TURKUENSIS
Sarja - ser. D osa - tom. 1385 | Medica - Odontologica | Turku 2018

University of Turku

Faculty of Medicine

Adolescent Psychiatry

Doctoral Programme in Clinical Research

Turku University Hospital, Unit of Adolescent Psychiatry

Supervised by

Professor Simo Saarijärvi, MD, PhD
Department of Psychiatry and Adolescent Psychiatry,
University of Turku
Unit of Adolescent Psychiatry,
Turku University Hospital

Adjunct Professor Olli Tenovuo, MD, PhD
Turku University Hospital,
Division of Clinical Neurosciences
Department of Rehabilitation and Brain Trauma

Reviewed by

Professor Willy Serlo, MD, PhD
Oulu University,
Oulu, Finland

Professor David Schwebel, PhD
University of Alabama at Birmingham,
Birmingham, AL, USA

Opponent

Associate Professor Koustuv Dalal, PhD
School of Health Sciences
Örebro University
Örebro, Sweden

The originality of this thesis has been checked in accordance with the University of Turku quality assurance system using the Turnitin OriginalityCheck service.

ISBN 978-951-29-7400-9 (PRINT)
ISBN 978-951-29-7401-6 (PDF)
ISSN 0355-9483 (PRINT)
ISSN 2343-3213 (PDF)
Painosalama Oy – Turku, Finland 2018

Pediatric traumatic brain injury in Finland: Contextual influences and threats to caregiver capacity

Michael L. Wilson

University of Turku, Faculty of Medicine, Adolescent Psychiatry, Doctoral Programme in Clinical Research, Turku University Hospital, Unit of Adolescent Psychiatry

ABSTRACT

A traumatic brain injury (TBI) occurs when a mechanical force to the head distorts brain function. This interruption in function can result in temporary, long term or permanent brain damage or even death. Research on TBI's among children and adolescents remains limited, especially on caregiver-level factors that might modify their susceptibility to this form of trauma. This thesis augments and extends prior research findings which suggest that even less severe TBIs in childhood may increase the risk of behavioral, social and psychiatric sequalae later in life. It examines the geographic patterning and distribution of pediatric TBI and provides additional information on the possible relationship between parent health and risk for TBI involving the children under their care. The latter two papers focus on well defined populations in Finland, with some attention given to global comparison.

Three studies are elaborated and consecutively numbered as interconnected chapters in this thesis. The **first (I) Study** examined previously published peer-reviewed data on pediatric TBI outcomes in the form of a systematic review. Its aim was to systematically review existing empirical evidence concerning neuropsychological, psychosocial and academic outcomes subsequent to mild and moderate TBI during childhood and adolescence. Altogether data on 8 553 participants under 18 years of age who experienced mild or moderate TBIs were included. This represented a total of 55 studies published between January 2008 and April 2013. The overall results of this systematic review indicated that not all children and adolescents who have experienced a moderate or mild TBI recover without sustaining long term problems and that significant disparity existed in the literature regarding this finding.

The second **Study (II)** examined data on 21 457 Finnish children and adolescents who were hospitalized with a TBI between 1998 and 2012. The data were derived from the Finnish National Hospital Discharge Register and several forms of TBI were considered identified by their ICD-10 codes. These data were divided into five age categories which were used as the basis for calculating overall and per group incidence rates. The study found that males were overrepresented in Finnish injury statistics with concussions being the most common form of brain injury among both sexes. The study also revealed that compared with countries having similarly robust data on pediatric TBI such as Australia, USA and Fiji, that Finnish children and adolescents had higher rates of TBI. Substantial differences existed in the adjusted population injury rates by geographic region in Finland which may be attributable to diagnostic practices and the possible role of distance to emergency care centers.

The third **Study (III)** utilizes data on 60 069 Finnish children and their parents derived from the 1987 Finnish Birth Cohort. It examines the role that demographic and parent mental health attributes exercise in modifying underlying susceptibility for TBI among Finnish children and adolescents. High educational attainment and high socio-economic status of parents were found to be factors which were associated with a lowered risk of TBI among Finnish children and adolescents. Among the mental health attributes among parents considered, several were associated with increased rates of TBI among children under their care. For example mood disorders, personality disorders, schizophrenia and behavioral disorders among both mothers and fathers were associated with statistically significantly increased rates of TBI among children.

Key words: traumatic brain injury, psychiatry, parental health, birth cohort, epidemiology

Michael L. Wilson

Turun yliopisto, Lääketieteellinen tiedekunta, Nuorisopsykiatria, Turun kliininen tohtoriohjelma, Turun yliopistollinen keskussairaala, Nuorisopsykiatrian osasto

TIIVISTELMÄ

Tapaturmaisessa aivovammassa mekaaninen voima vaurioittaa aivojen toimintaa. Tämä toiminnan häiriö voi aiheuttaa ohimenevän, pitkäaikaisen tai pysyvän aivojen vaurion ja jopa potilaan kuoleman. Lasten ja nuorten aivovammoihin liittyvä tutkimus on jäänyt melko vähäiseksi, ja erityisen vähän on tutkittu huoltajiin liittyviä tekijöitä, mitkä voivat vaikuttaa lapsen altistumiselle tapaturmaiselle aivovammalle. Tämä väitöskirja laajentaa aiempia tutkimuslöydöksiä, joiden mukaan jopa lievä tapaturmainen aivovamma lapsuudessa voi lisätä riskiä käyttäytymiseen liittyviin, sosiaalisiin ja psykiatrisiin seurausvaikutuksiin myöhemmin elämässä. Se tutkii lasten aivovammojen alueellista jakautumista ja antaa lisätietoa mahdollisista vanhempien terveyden ja heidän hoidossaan olevan lapsen aivovamman välisistä keskinäisistä suhteista. Näitä yhteyksiä tarkastellaan tarkkaan valituissa suomalaisissa otoksissa, pyrkien osin myös maailmanlaajuiseen vertailuun.

Tämä väitöskirja koostuu kolmesta toisiinsa liittyvästä osatutkimuksesta. Ensimmäinen (I) tutkimus on systemaattinen katsaus lasten aivovammojen hoidon tuloksista. Tavoitteena oli selvittää neuropsykologisia, psykososiaalisia ja akateemisia toipumistuloksia lievän ja keskivaikean lapsuudessa tai nuoruudessa tapahtuneen aivovamman jälkeen. Kaikkiaan tutkimukseen sisältyi 8 553 alle 18-vuotiasta tai nuorempaa tutkittavaa, joille oli sattunut lievä tai keskivaikea aivovamma. Katsaukseen valikoitui 55 tutkimusta, jotka oli julkaistu tammikuun 2008 ja huhtikuun 2013 välisenä aikana.

Katsauksen tulosten mukaan kaikki lapset ja nuoret, joilla oli ollut lievä tai keskivaikea aivovamma eivät parantuneet ilman pitkäaikaisia ongelmia mutta kirjallisuudessa oli paljon toisistaan eriäviä tuloksia tämän suhteen.

Toinen tutkimus (II) selvitti 21 457 sairaalahoidossa aivovamman vuoksi vuosien 1998-2012 välisenä aikana olleen suomalaisen lapsen ja nuoren tietoja. Tiedot kerättiin sairaaloiden poistorekisteristä ja kaikki eri aivovammatyypit tunnistettiin ICD-10 diagnoosikoodien perusteella. Aineiston potilaat jaettiin viiteen ikäluokkaan joita käytettiin yleisen ja ikäryhmäkohtaisen ilmaantuvuuden laskemiseen.

Tutkimuksessa havaittiin miespuolisten yliedustus suomalaisessa tapaturma-aineistossa ja aivotärähdys oli yleisin aivovammatyyppi molemmilla sukupuolilla. Tutkimuksessa osoitti myös, että verrattuna maihin missä aivovammojen tilastointi lapsilla on samaa tasoa kuten Australiassa, USAssa ja Fijillä, suomalaisilla lapsilla ja nuorilla oli suurempi aivovammojen ilmaantuvuus. Merkittäviä eroja löytyi ikään suhteutetussa vammojen määrässä Suomen eri alueiden välillä. Tämä voi heijastaa erilaisia diagnoosikäytäntöjä tai mahdollisesti maantieteellisiä etäisyyksiä päivystyspisteisiin.

Kolmannessa tutkimuksessa (III) käsiteltiin tietoja 60 069 vuoden 1987 suomalaisen syntymäkohorttiaineiston lapsesta ja heidän vanhemmistaan. Työssä tutkittiin miten demografiset ja vanhempien mielenterveyteen liittyvät tekijät vaikuttavat suomalaisten lasten ja nuorten riskiin saada aivovamma. Vanhempien korkea koulutustaso ja hyvä sosioekonominen asema assosioituvat alentuneeseen aivovamman riskiin suomalaisilla lapsilla ja nuorilla. Monet vanhemmilla todetut mielenterveysongelmat assosioituvat heidän hoidossaan olevien lasten aivovammojen todennäköisyyteen. Esimerkiksi mielialahäiriöt, persoonallisuushäiriöt, skitsofrenia ja käytöshäiriöt sekä äideillä että isillä olivat tilastollisesti merkitsevästi yhteydessä lisääntyneisiin lasten aivovamman riskiin.

Asiasanat: tapaturmainen aivovamma, psykiatria, vanhempien terveys, syntymäkohortti, epidemiologia

TABLE OF CONTENTS

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following published articles, which are referred to in the text by their Roman numerals.

I. Lloyd, J., Wilson, M. L., Tenovuo, O., Saarijärvi, S. (2015) Outcomes from mild and moderate traumatic brain injuries among children and adolescents: A systematic review of studies from 2008-2013 Mar 19;1–11 Brain Injury

II. Wilson, M. L., Tenovuo, O., Mattila, V., Gisler, M., Celedonia, K., Impinen, A., Saarijärvi, S. (2017) Pediatric TBI in Finland: an examination of hospital discharges (1998-2012). European Journal of Paediatric Neurology DOI: 10.1016/ j.ejpn.2016.10.008

III. Wilson, M. L., Tenovuo, O., Gisler, M., Saarijärvi, S. (2018) Association between parent mental health and pediatric TBI: Epidemiological observations from the 1987 Finnish Birth Cohort. Injury Prevention DOI: 10.1136/injuryprev-2017-042624

ABBREVIATIONS

ER	Emergency room
GCS	Glasgow Coma Scale
ICD	International Classification of Diseases
NHD	National Hospital Discharge Registry
TBI	Traumatic brain injury
THL	Terveyden ja hyvinvoinnin laitos (Finnish National Institute for Health and Welfare)
ANOVA	Analysis of Variance
FBC	Finnish Birth Cohort
MeSH	Medical Subject Headings
EPHPP	Effective Public Health Practice Project
CAT	Computed Axial Tomography
MRI	Magnetic resonance Imaging
SPECT	Single-photon emission computed tomography
PET	Positron Emission Tomography
LOC	Loss of Consciousness
CINAHL	Cumulative Index of Nursing and Allied Health

1. INTRODUCTION

Traumatic brain injuries (TBI) are among the leading causes of mortality among children under age four years and the most common form of acquired cognitive impairment and physical disability among young people worldwide (Cossa & Fabiani, 1999; Ibrahim, Ralston, Smith, & Margulies, 2010). Among those children who do survive a TBI, the immediate family and societal burdens are often considerable. There are substantial institutional costs associated with long term, if not life-long efforts aimed at rehabilitating children affected by TBI. In the United States, the costs related to TBI acute care and rehabilitation have been estimated at USD $85 million per year (Singh, Lu, Chen, Kallakuri, & Cavanaugh, 2006). Frequently also, the parents of brain injured children may require counseling and suffer from a loss of productivity (Masalha & Auslander, 2017). Within the European Union, there are still no well-grounded studies on the costs associated with TBI treatment and rehabilitation (Berg, Tagliaferri, & Servadei, 2005). Unfortunately also few, reliable country-wide estimates concerning the incidence of pediatric TBI or prevalence figures for those living with a TBI, are presently available.

1.1. Traumatic brain injury (TBI) in children and adolescents

1.1.1. Definition of TBI

TBI is widely defined as a closed or penetrating trauma to the head. Within the context of a closed head injury, the brain is injured by way of an external blunt force which results in the acceleration and deceleration of the brain complex within the neurocranium. TBIs which are classed as penetrating injuries are typically the result of a compromised scalp and neurocranium in which the brain tissue has been exposed (Bandak, 1995; Sosin, Sniezek, & Waxweiler, 1995).

In Finland, TBI clinical guidelines further elaborate on case definitions and includes the following addenda: 1) Any period of altered consciousness; 2) Any memory loss prior or subsequent to the the trauma; 3) Any altered mental functioning (which could be for example, confusion or disorientation) in relation to the trauma; or 4) Any intermittent or long term neurological sign or symptom which is indicative of localized brain injury (Suomen Fysiatriyhdistys, 2003).

All forms of brain injury are also defined within the International Classification of Diseases (ICD) which also specifies the location of the injury. The current version of the ICD manual, version 10, also includes skull fractures, contusions, concussions, other forms of intracranial injury such as subarachnoid, subdural and external hematomas as well as diffuse axional injuries.

1.2. Clinical differences in pediatric TBI

Several considerations warrant mention in the case of pediatric TBI. The brain of the pediatric patient differs from that of the adult brain in ways that are clinically relevant. In the event of a brain injury, the pediatric patient has an increased likelihood of posttraumatic seizure, increased levels of apoptosis, biomarkers which are development specific, age-dependent patterns of cerebral metabolism and blood flow, differing sensitivities to common neuroactive medications and altered neuroplasticity when recovering from a TBI. There also exists preclinical evidence for hightened neuronal cellular death in the developing brain which is triggered by anesthetics and anticonvulsants (Giza, Mink, & Madikians, 2007).

The pediatric patient may also be less able to discern and articulate symptoms that they might experience post trauma which makes monitoring of TBI effects challenging. The plasticity and potential resiliency of young brains, have also been implicated in discussions on whether and how children are able to recover from a brain injury.

1.3. Diagnosis of pediatric TBI

Where it concerns identification and TBI diagnosis, the procedure for TBI diagnostics involves a neurological examination followed by brain imaging with a CAT scan, MRI, SPECT or PET. After this a cognitive evaluation by a neuropsychologist with a formal neuropsychological testing procedure may take place. This process then typically ends with additional evaluations by physical, occupational and speech therapists to help clarify specific deficits in the injured individual. This procedure is followed in most countries including Finland.

1.4. TBI severity

Brain injuries are subdivided into three classifications of clinical severity. These are (in order of increasing severity): mild, moderate and severe (Vos et al., 2002). The basis for these classifications is usually found in the Glasgow Coma Scale (GCS) score (Teasdale & Jennett, 1974), loss of consciousness (LOC), and the duration of post-traumatic amnesia (PTA) (Russell & Smith, 1961). The pediatric version of the GCS differs from the adult version in that the adult version requires verbal interaction with the patient. Preverbal children are not yet able to communicate symptoms, so the pediatric GCS uses age appropriate modifications to account for developmental differences (Borgialli et al., 2016). A brain injury is typically classified as severe if the score on the GCS is 8 or less, moderate if the score on the GCS is 9-12, (Teasdale & Jennett, 1974) mild if the score on the GCS is 13-15 (Teasdale & Jennett, 1974). Despite multiple decades of substantial inquiry into TBI, there still remains no universal definition for a mild TBI. However the four criteria which most scientific bodies rely on for defining a mild TBI are: 1) a biomechanical force to the head; 2) a loss of consciousness, and if present, for less than 30 minutes; 3) a GCS score of between 13 and 15 after 30 minutes subsequent to an injury; and 4) amnesia post-trauma, which if present is less than 24 hours in duration.

Table 1: Glasgow Coma Scale score chart (Borgialli et al., 2016; James, 1986)

Eye Opening	Verbal	Motor
		6: Normal spontaneous movement
	5: Smiles, coos, babbles	**5**: Withdraws to touch
4: Opens eyes spontaneously	**4**: Irritable, crying (but consolable)	**4**: Withdraws to pain
3: Opens eyes to speech only	**3**: Inconsolable crying or crying only in response to pain	**3**: Abnormal flexion to pain (Decorticate response)
2: Opens eyes to pain only	**2**: Moans in response to pain	**2**: Abnormal extension to pain (Decerebrate response)
1: Does not open eyes	**1**: No response	**1**: No response

Scores defined
14-15: Mild TBI
9-13: Moderate TBI
3-8: Severe TBI

1.5. Epidemiology of pediatric TBI

Research demonstrates that approximately 28% of all head injuries occur among children and adolescents (Lehr, 1990). The epidemiology of child and adolescent TBI differs in several important ways from that of adults. Children and adolescents have different physiologies, psychosocial behaviors and developmental phases which underlie a significant contribution to their risk for TBI. They are also challenged by their environments in ways in which an adult may not be and their locus of control within these environments is also characterized by substantial variation across the stages of their development. For a majority of their pre-adolescent lives, children are strongly influenced by parental involvement in the social and environmental circumstances which underlie their risk and therefore their risk profiles are necessarily linked to parents, caregivers and the environments in which their interaction takes place.

1.5.1. Bronfenbrenner's ecological systems theory

According to Bronfenbrenner's ecological sytems theory, there are five environmental systems in which an individual interacts. This theory offers a framework through which it is possible also to understand how risk and protective factors may be understood and potentially mitigated given sufficient data.

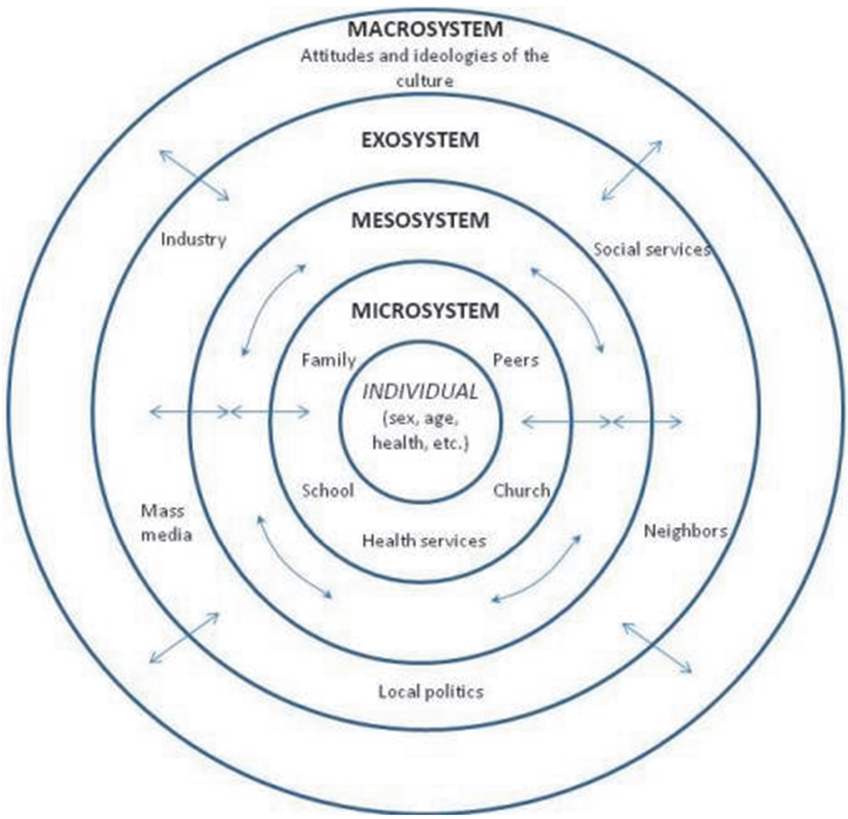

Figure 1: Bronfenbrenner's Ecological Theory of Development (Hchokr, 2012)

At the individual level it is possible to discern from Figure 1 that the individual's sex, age and overall health status are areas which can be examined as risk and protective factors for TBI. Most studies demonstrate that males are are overrepresented in TB occurrence. Age is also related as it corresponds well to the individual's stage of physiological and biological development as well as their cognitive ability at a given age. Health status may also be a key factor. Poor health may mean that an individual might not have the mobility to walk or stand for extended periods of time or may have reduced capacity for recovery in the event of a TBI.

At the level of the microsystem, family, school and peer influences become particularly relevant. The family situation may not be a particularly supportive one or even abusive. Stressed parenting or the presence of alcohol abuse within the family may also represent additional risk. During adolescence, peer influences become particularly relevant and risk taking behaviors associated with wanting to fit in with peer groups becomes more frequent. Access to heath services can mean the difference between long term disability and full recovery in certain situations.

Within the meso and exosystems it can be seen that societal factors are capable of heavily influencing risk and protective factors. For example, mass media which promotes beliefs that rough competitive sports play is appropriate for boys while cooperative interactive play is for girls may be one of the explanations behind why boys are overrepresented in TBI cases (L Wilson et al., 2017). It is also the case that neighbors and other other factors at this level might reinforce such behaviors. The macrosystem is largely concerned with the attitudes and beliefs of the culture in which the individual finds him or herself. It is possible that conflicts between levels have the potential to represent risk factors for injury. Such may be the case when an individual has family and or cultural values that differ strongly from the culture in which they reside and these differences are reinforced at institutional levels. This may result in forms of ostracization, feelings of rejection and a poor sense of belonging. In extreme cases such individuals may be at risk for violence, whether against others or themselves (Martínez García & Martín López, 2015).

1.6. Risk factors for pediatric TBI

The Haddon's Matrix is another useful tool for understanding risk and protective factors before, during and subsequent to an injury event. In **Table 2** pediatric TBI has been considered along with potential risk and protective factors and caregiver circumstances. Caregiver circumstances, along with the physical legal, and socio-economic environment can have an effect at several stages of an event having the potential to result in a TBI.

Table 2. Haddon's Matrix model considering pediatric TBI risk and protective factors and contributing caregiver circumstances

	Host (child)	Agent (caregiver circumstance)	Physical environment	Legal and socio-economic environment
Pre-event ***(Before the TBI occurs)***	Developmental aspects inherent in the child such as walking, climbing, balance Disabilities affecting mobility/ development Under the influence of drugs/substances Level of cognitive development enabling the comprehension and avoidance of risk situations	Caregiver mental health Awareness, comprehension and education related to pediatric risks Under the influence of or abusing drugs/ alcohol Supervision	Unsecured flooring/rugs/stairs Presence of unlocked/ unsecured windows Falling objects Visibility Poor signage	Societal ambiguity between child discipline and abuse Access to safer/ affordable housing/ protective equipment
Event ***(During the TBI-causing event)***	Suitability of harnesses or other protective equipment such as helmets which are properly fitted Speed of travel during event/fall before impact	Reaction to potentially hazardous circumstances Timely caregiver intervention Negligence	Are subsequent injuries possible in the same event (falling down stairs) Presence of material/objects which capture/ slow down or absorb impact	Access to safer housing/protective equipment Are subsequent injuries possible in the same event (violence)
Post event ***(Immediately after exposure to TBI)***	Plasticity of the neurocomplex Quality of protective equipment Child's age	Understanding that a potentially catastrophic event has occurred and can initiate appropriate action Response times in notifying emergency services Removal of unconscious individual from immediate risk zone Non-removal in the event of possible damage to the spinal column	Rural location and or distance to treatment centers Access to site of injury by emergency personnel Quality of available treatment	Access to diagnosis and treatment Accessibility to emergency services (artificial barriers to treatment)

Column 1 of the matrix reflects the three stages of public health prevention where pre-event, event, and post event correspond to primary, secondary and tertiary prevention respectively. Primary prevention is concerned with readiness, that in the event a risk situation presents itself there are factors which can help to avoid a scenario that has the potential to result in some form of injury.

Secondary prevention is concerned mostly with mitigation. At the mitigation stage an event has occurred or is in the process of occurring that has the potential to result in bodily harm. Here factors are depicted which are inherent at the individual, caregiver and environment level that can minimize harm. This can be compared for example to a seatbelt in a motor vehicle or a bicycle helmet. A collision involving the head may occur, but the damage is minimized due to the presence of the helmet. At tertiary prevention the focus is on reducing the risk for further consequences such as long term disability or death. At this level timely access to emergency care and diagnosis is of paramount importance.

For example, at the intersection of host (child) and pre-event, it pertains to factors inherent in the child which might predispose or protect them in the event of situation exposing them to injury. Such factors might include having a prior brain injury which increases the risk of additional brain injuries. Being under the influence of substances impairing vision or executive function such as certain medications or alcohol and disabilities which affect motor skills or might represent fall risks.

As described previously, younger children are particularly vulnerable to falls which result in head injury due to their unique anatomy. At the intersection between agent (caregiver circumstance), pre-event, event, and post-event, it can be seen that caregiver readiness plays an important role in the prevention process. Here education and awareness are important, but also the state of mind of the individual may have an impact on whether they are able to recognize and adequately respond to risk situations in the home or other environment in which care provision takes place. The hypothesis explored in **Study III** for instance, is that caregiver mental health may be an important factor in the prevention, mitigation and harm reduction phases of this matrix.

Harm reduction is an important factor in reducing the potential for long term disability or death resulting from the a head injury. At the intersection between the last row and the last column several factors can be seen which are needed to reduce further harms within the lego-socio-economic environment. Access to diagnosis and treatment are especially important. Given that some settings may lack qualified specialists or the facilities needed, those individuals not having access to these services and facilities are at a disadvantage relative to others where their longer term surviveability and life quality are concerned. Similarly, individuals who might be face artificial barriers to access to such treatment due to their age, sex or ethnic background would face similar concerns.

Some of the major situational factors which increase the likelihood of a child sustaining a TBI include maltreatment and falls from stairs or other uneven surfaces (Pomerantz, Gittelman, Hornung, & Husseinzadeh, 2012; Salehi-Had, Brandt, Rosas, & Rogers, 2006). Small ambulating children are especially vulnerable, with elevated risks being found among poor housing conditions (Klonoff, 1971), during falls from furniture (Pomerantz et al., 2012) and during unsafe play (Sharples, Storey, Aynsley-Green, & Eyre, 1990).

Household and parent-level factors which increase the risk of child TBI include low socioeconomic status of the parents (Engström, Diderichsen, & Laflamme, 2002); age of the mother (Janson, Aleco, Beetar, Bodin, & Shami, 1994) having a mother who suffers from depression (Reichenheim & Harpham, 1989); household crowding (Delgado et al., 2002); low maternal education (Bangdiwala & Anzola-Pérez, 1990); low paternal education (Pernica et al., 2012), parent occupation (Hong, Lee, Ha, & Park, 2010), parental alcohol abuse (Winqvist, Jokelainen, Luukinen, & Hillbom, 2007), and potentially the health of the main caregiver (Wilson, Hasselberg, Kigwangalla, Boursiquot, & Laflamme, 2012). In some settings, a child having many siblings may increase their susceptibility to injury (Ahmed, Rahman, & van Ginneken, 1999; Bang, Ebrahim, & Sharma, 1997; Janson et al., 1994; Rahman, Rahman, Shafinaz, & Linnan, 2005). While most research tends to focus on mothers, recent research suggests that fathers also have an important role to play in home safety (Laflamme, Månsdotter, Lundberg, & Magnusson, 2012).

Other factors inherent in the child which may increase risk at the individual levels include low birth weight (McCormick, 1985) age and sex of the child (Ruiz-Casares, 2009). Evidence also suggests that once a child has been diagnosed with a TBI, they are at increased risk of experiencing a second TBI (Child Health, 2007). Puberty presents additional variations in risk due to the physiological, psychological and behavioral changes which occur during adolescence (Wilson, 2012).

It is also understood that even in high-income country (HIC) settings, injuries are strongly associated with socioeconomic disparities (Laflamme, Hasselberg, & Burrows, 2010). Poverty for example, can be both a risk factor and a result of a serious injury (Delgado et al., 2002; Peden et al., 2008; W Pickett et al., 2005; Valent et al., 2004). Resource deprived families, may have limited access to life saving injury treatment and often live in more hazardous locations (Peden et al., 2008; Satterthwaite, 2003). A serious injury can often result in significant financial burdens for families. These families in turn may then be driven deeper into poverty by long-term medical costs or suffer a loss of income due to the need to care for a child with a long term disability (Mock, Gloyd, Adjei, Acheampong, & Gish, 2003).

Children who are left disfigured or disabled from an injury, may be reluctant or unable to return to school. Without an education, they are more likely to have difficulty finding employment as adults and have less opportunities to significantly change their socioeconomic status. Thus understanding the underlying mechanisms of injury in the home environment is important in minimizing a wide range of negative individual, family and societal consequences (Peden et al., 2008; Ruiz-Casares, 2009; Sengoelge, Hasselberg, & Laflamme, 2011).

1.7. The contribution of substance use and abuse

Alcohol and drug misuse and abuse by parents or caregivers is positively associated with many forms of childhood injury both in situations of abuse and neglect (Bijur, Kurzon, Overpeck, & Scheidt, 1992; Villalba-Cota, Trujillo-Hernández, Vásquez, Coll-Cárdenas, & Torres-Ornelas, 2004; Widom & Hiller-Sturmhöfel, 2001). Alcoholism among mothers represents a two-fold increase in risk for injury for the children under their care when compared with non-alcoholic mothers. Research also shows that when both parents have problematic drinking behaviors the risk for injury is even more pronounced (Bijur et al., 1992). Adolescents themselves may also have problematic drinking behavior which predisposes them to potentially injurious outcomes. Dischinger et al. (2001) found in their longitudinal study of 27 339 American adolescents aged 15 and older, there existed a relative risk (RR) of 1.9 ($p<0.05$) for the risk of death given a previous alcohol-related injury. In an even larger U.S. study of 1.5 million adolescents aged 10 and older, alcohol consumption was related to a 30% increase in the risk for hospitalization or emergency room visit OR=1.3 (1.3-1.4) (Miller, Lestina, & Smith, 2001). Picket et al. (2002) examined data on 49 461 adolescents aged 11-15 in 12 countries and found that drinking was associated with a 70% increased in risk for a medically attended injury. Because the risk profiles between for TBI and other forms of injury are similar, much of the available research on injury as it relates to risk factors is also useful for examining TBI risks. Alcohol use, misuse and abuse is one such area. Impairments from alcohol and substance use are also significant risk factors in the traffic environment. The mechanisms are also very complex and multi-directional. An intoxicated driver of the vehicle in which the child is present, an intoxicated driver of other vehicles sharing the same roadway as well as intoxicated passengers all increase the risk of collisions resulting in death or severe disability of children and adolescents who are passengers or sharing the road environment.

1.8. Mental health and injury risk

Table 3. Selected dependent variables (parent mental health) and hypothesis supporting literature.

ICD-10 Code	Description	Supporting literature
F10-F19	Mental and behavioral disorders due to psychoactive substance use	Dependencies strongly linked to emergency department visits and motor vehicle crashes (Movig et al., 2004; Soderstrom et al., 1997)
F20-F29	Schizophrenia, schizotypal, delusional, and other non-mood psychotic disorders	At greater risk for violence (Nestor, 2002)
F30-F39	Mood [affective] disorders	Gait unsteadiness and fall risks (Hausdorff, Peng, Goldberger, & Stoll, 2004)
F40-F48	Anxiety, dissociative, stress-related, somatoform and other nonpsychotic mental disorders	Dose-response relationships of violence to depression and PTSD were observed (Golding, 1999)
F50-F59	Behavioral syndromes associated with physiological disturbances and physical factors	Sleep deprivation and risk of injury to car occupants (Connor et al., 2002)
F60-F69	Disorders of adult personality and behavior	Self-harm and suicidal behavior among those with personality disorders (Z Brown, Comtois, & Linehan, 2002)
F70-F79	Intellectual disabilities	Increased fall risks (Willgoss, Yohannes, & Mitchell, 2010)
F80-F89	Pervasive and specific developmental disorders	Increased fall risks (Renfro, Bainbridge, & Smith, 2016)
F90-F98	Behavioral and emotional disorders with onset usually occurring in childhood and adolescence	Behavioral and emotional disorders have also been linked with TBI in childhood (Lloyd, Wilson, Tenovuo, & Saarijärvi, 2015)
F99-F99	Unspecified mental disorder	Mental illness is an independent risk factor for unintentional injury and injury recidivism (Wan, Morabito, Khaw, Knudson, & Dicker, 2006)

1.8.1. Dependent variables (parent mental health)

All disordered mental health states identified by the relevant section F ICD-10 codes within the cohort, were considered for inclusion as dependent variables. These variables were selected based on the hypothesis that disordered mental health may affect decision-making, well-being or cause major changes in mood or ability to cope at the individual level, and as such, has the potential to represent a threat to optimal care provision. In **Table 2**, are the selected variables in the form of ICD-10 diagnostic codes, their description and prior research lending support to the hypotheses in question.

1.8.2. Individual level developmental risk factors for TBI during childhood and adolescence

Children and younger adolescents are vulnerable to risks in the home environment. Younger children may lack the experience and learned capacity to adequately respond to dangers in their environment, and their physical characteristics make them especially prone to devastating outcomes. The types of risks that children are exposed to change with age and corresponds to their changing biophysical and psychosocial development. In **Figure 2,** during the phase in which a child begins to walk unaided, can climb stairs and furniture, falls from furniture become more frequent as do falls from stairs. Uneven surfaces and unsecured rugs also become risk factors for falls. Prior to this age children are mostly at risk of falling from their caregiver's arms.

1.8.3. Individual level biophysiological exposures

Ambulating infants are at an increased risk for falls in which a head injury is an outcome. This is due to their greater head size and weight in proportion to the rest of their anatomy (Kemp & Sibert, 1997). The head and upper body are also functionally more developed than the rest of the child's body. Falls from stairs and furniture can be particularly serious. While unsecured floor mats, rugs and wet surfaces are potential sources of falls among small children, falls from less than 1.25m (4ft) are rarely associated with serious head trauma (Hardy & Boynes, 2008, Chapter 9).

Pubertal timing is also important in the understanding of underlying biophysical attributes which may increase a child's susceptibility to TBI. When a child reaches puberty their bodies undergo periods of extremely rapid development. Each organ system grows at a different rate and the relationship between the body systems changes over time as illustrated in **Figure 1** (Hardy & Boynes, 2008). This accelerated growth may result in less than optimal coordination because neurological development occurs more slowly than the rest of the adolescent's anatomy (Michaud, Renaud, & Narring, 2001).

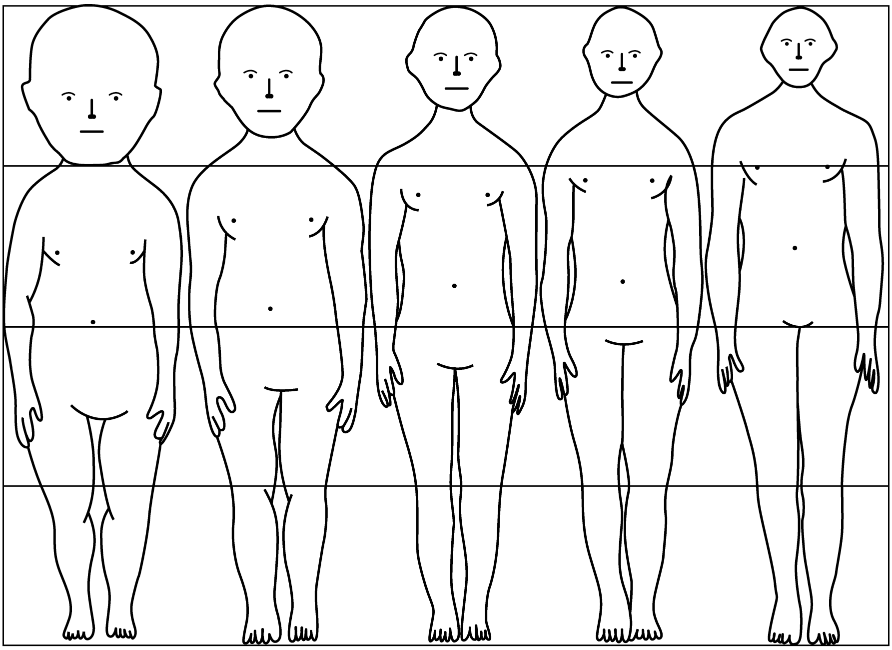

Figure 2. Modified from Paediatric Radiography (Hardy & Boynes, 2008, Chapter 1)

1.8.4. Psychosocial exposures

Very young children may not have the capacity to comprehend and respond to potentially dangerous situations. Their early stage physiologies mean that it is often more difficult for them to coordinate an escape from an event which might result in injury. Increasing gender awareness (Figure 2), may also be accompanied with socially desirable gendered notions of play behavior such as rough and more physical activities for boys. During puberty adolescents may spend less time under the supervision of parents and more time with friends. This phase of development is characterized by increased risk-taking behavior as they navigate increased autonomy in their decision-making. During this phase adolescents may experiment with alcohol or other substances whether to fit in with peers or as a coping mechanism for emotional problems (Steinberg & Silverberg, 1986). Young adolescents are more sensitive and socially very self-conscious. They are egocentric and do not want to perceived as being different from their peers (Hardy & Boynes, 2008).

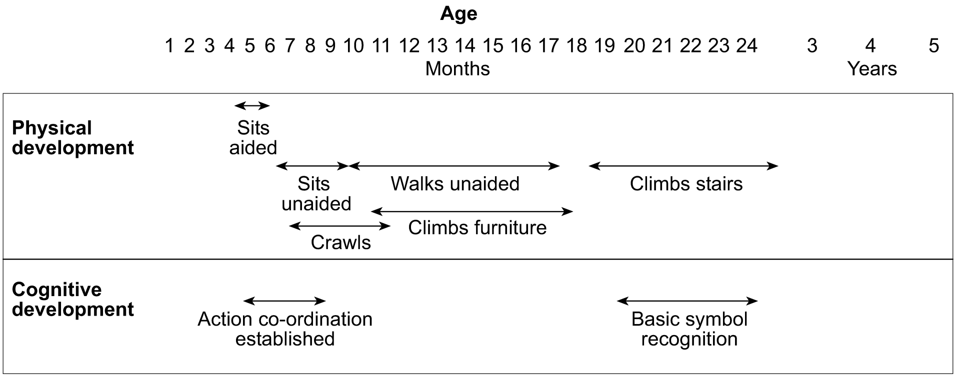

Figure 3. Modified from Pediatric Radiography. (Hardy & Boynes, 2008, Chapter 1)

1.8.5. Environmental exposures

The physical environment exposes children and adolescents to numerous risk factors. This is because the vast majority of built environments are constructed by and for adult use with little thought given to the safety of children in engineering designs and decisions. This is however slowly changing as policies are adopted which take into consideration the use of the built environment by children (Peden et al., 2008).

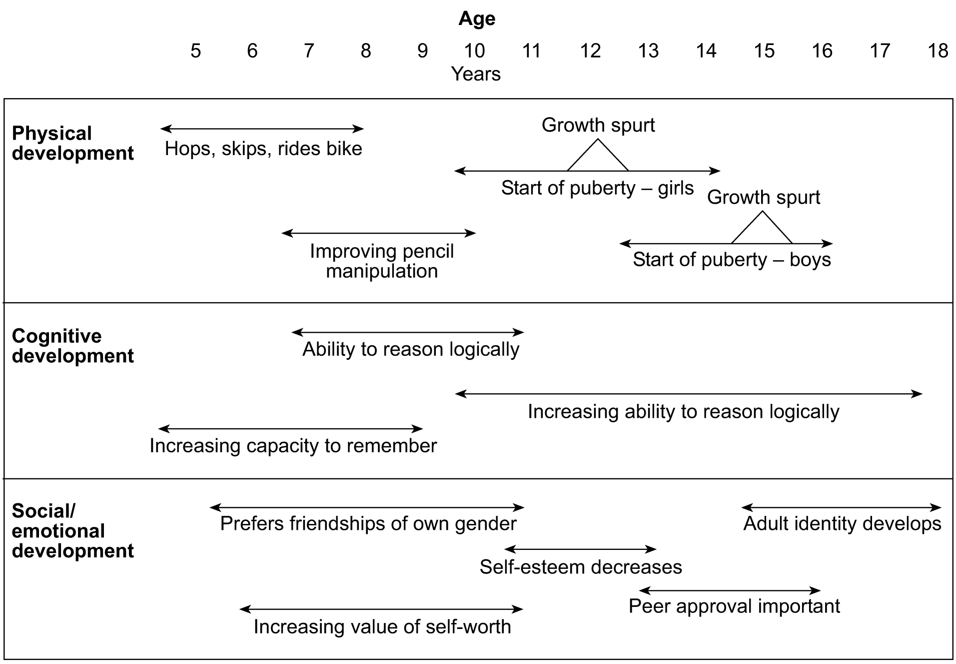

Figure 4. Modified from Pediatric Radiography. (Hardy & Boynes, 2008, Chapter 1)

1.8.6. Intentional injury

Research has demonstrated that close to 7% of children suffer from some form of physical abuse during their childhood (Rajaram, Batty, Rittey, Griffiths, & Connolly, 2011). Several epidemiological studies have suggested an annual incidence of 36 per 100 000 in children under the age of six months and 14-24 per 100 000 in those under 1 year. These rates drop to 0.3-3.8 per 100 000 children per year (Barlow & Minns, 2000; Hobbs, Childs, Wynne, Livingston, & Seal, 2005; Jayawant et al., 1998).

The physical abuse of children is a persistent social problem which is present to some extent in all societies. Physical abuse encompasses the actual or likely physical injury to a child, or the failure to prevent physical injury (or suffering). This definition includes deliberate poisoning, suffocation and Münchhausen's syndrome by proxy. A consistent definition of abuse differs internationally and is determined by what a particular society deems as being socially acceptable. Child disciplining for example becomes abuse when the expectations and social norms of a particular society are breached. This also changes over time as social values change. The vast majority (80%) of child victims of physical abuse are under two years of age (Hardy & Boynes, 2008, Chapter 9). In many instances where TBIs are diagnosed in infants, a common but under-diagnosed, cause is often "shaken baby syndrome" or abusive head trauma as it is termed by the American Academy of Pediatrics. This is particularly the case when subdural hematoma, retinal hemorrhage and hypoxic-ischemic encephalopathy are present in the absence of an impact injury (Strouse, 2018). Additionally, most cases of SBS are infants under the age of two years of age when the head is heavy compared to the rest of the body (Figure 2). Shaking the child can easily result in damage to brain tissues and SBS is fatal in 7-23% of cases (Salokorpi, Sinikumpu, & Serlo, 2015).

There are several known risk factors for the physical abuse of children and they are mostly associated with parental pressures: a premature baby or a child with a serious neonatal illness; a child with a disability; parental failure to bond with the child; a baby which is difficult to console; a young, immature or inexperienced parent; a socially deprived parent or the presence of substance/alcohol abuse and a lack of adequate parenting role models (Hardy & Boynes, 2008, Chapter 9).

1.9. Effects of TBI on child development

Longitudinal research conducted on children in Finland has revealed that transient or permanent physical, adaptive and behavioral disturbances often result from TBIs (Timonen et al., 2002). These deficits may include lapses in the child's ability to interact with their environment, lags in skill acquisition, poor educational progress and even antisocial or aggressive behavior towards others (Anderson, Catroppa, Morse, Haritou, & Rosenfeld, 2001; Andrews, Rose, & Johnson, 1998). Some of these deficits may persist into adulthood where they can disrupt work and family life (Arroyos-Jurado, Paulsen, Merrell, Lindgren, & Max, 2000a). For those individuals who remain incapacitated or fail to recover from a TBI, the prolonged impaired consciousness and mortality are costly in both social and economic terms (Micklewright, King, O'Toole, Henrich, & Floyd, 2012; Thompson et al., 2012). TBIs are often stressful for the families of affected children. Parents report increased lifelong burdens resulting from the rise in care demands often required by a child with a TBI. As a result of this, distresses in family and spousal relationships have also been shown to occur with greater frequency (Stancin, Wade, Walz, Yeates, & Taylor, 2008).

1.9.1. Psychosocial

There is considerable agreement among researchers that childhood TBI is associated with impairments or deficits in working memory, motor skills, academic performance, behavioral problems which may persist into adulthood, issues with self-esteem, poor awareness of social rules, grooming challenges, inappropriate behavior for their age, difficulties in sexuality, maladaptive behavior, aggressive antisocial behavior, higher levels of loneliness, apathy, irritability, disinhibition and reduced overall social functioning (Arroyos-Jurado, Paulsen, Merrell, Lindgren, & Max, 2000b). TBI in childhood has also been associated with later criminal behavior. An often cited Finnish birth cohort study of 12 000 individuals found a four-fold increased risk of adult offending as a result of mental disorders following exposure to TBI in childhood (Timonen et al., 2002).

1.9.2. Cognitive

Children who are injured in early childhood are particularly vulnerable to generalized cognitive deficits. They have hampered performance on tests of intelligence, increased difficulties when examined on linguistic attainment and have less well developed reading skills compared with children injured later in life (Gerrard-Morris et al., 2010). Executive functioning and memory are similarly impaired when head injuries affect the temporal and frontal lobes, Figure 5 (Ewing-Cobbs & Barnes, 2002; Levin, Ewing-Cobbs, & Eisenberg, 1995).

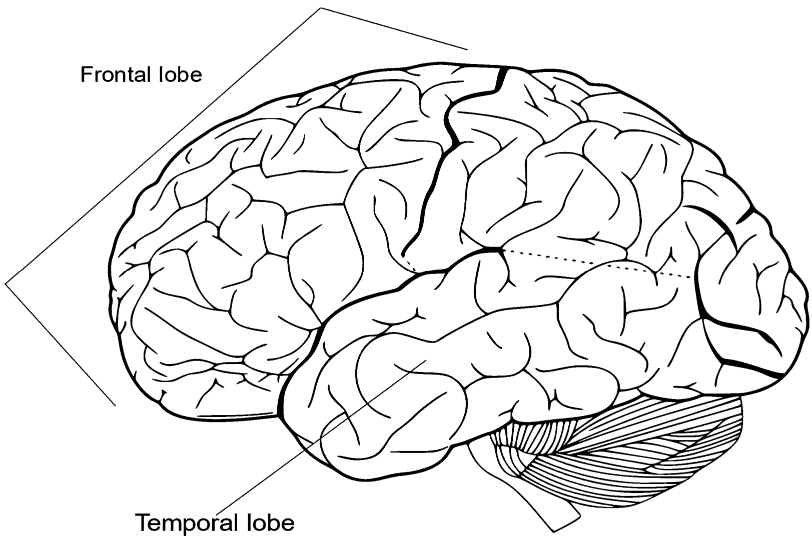

Figure 5. Lobes of the brain with frontal and temporal lobes indicated (redrawn from a public domain image)

1.9.3. Behavioral

Research suggests that even mild traumatic brain injuries may have long term consequences on a child's behavior (Lloyd et al., 2015). Most studies that have examined longer term behavioral consequences of TBI suggest that the timing of the brain injury is an important factor. The long term effect of brain injuries which occurs before the age of 5 years, when the brain undergoes its most critical developmental changes, may be more pronounced. Many skills before the age of 5 years have not yet matured or are still undergoing rapid development (McKinlay, Grace, Horwood, Fergusson, & MacFarlane, 2010). Persistent behavioral problems in children who experience a mild TBI may begin to evidence themselves after 3 years of follow-up. These are typically characterized by hyperactivity disorder, inattention and conduct disorders in children ages 10-13 years who experienced a mild TBI before the age of 10 years (Taylor et al., 2015).

1.10. Purpose of the Study and Theoretical Framework

Various mechanisms in the causal pathway could potentially increase risk for TBIs among children. Among them, the physical ability of parents to actively monitor and supervise vulnerable children may be compromised (B. A. Morrongiello & House, 2004). Sensory impairments may impede timely reaction in situations where averting risk situations makes demands on visual and auditory perception.

Thus, slower or uncoordinated reaction times during potentially harmful situations involving children may not be sufficient to avert harm. Slow or impaired reaction in the assessment of potential risks may exacerbate otherwise avoidable dangers which may be especially the case in the home environment (Barbara A Morrongiello, Ondejko, & Littlejohn, 2004). Given that parental involvement is significant, and indeed necessary during the early years of life, it is therefore possible that additional factors may warrant investigation into the nature of their potential for modifying risk for child TBI.

2. AIM

Brain injuries are a common form of trauma among the pediatric population. To understand the extent of this problem and to evaluate contributing factors the following aims formed the basis of this thesis: 1) To study the relationship between mild and moderate pediatric TBI and long-term outcomes on cognitive development and behavior; 2) To define the incidence of pediatric traumatic brain injury in Finland and to look for differences in various geographical areas; 3) To study the relationship between parent mental health and pediatric TBI in Finland.

3. SUBJECTS AND METHODS

Study I aimed to systematically examine studies which presented empirical data concerning outcomes of mild and moderate TBI for children under the age of 18 years. In order to do this a systematic search and analytic process was devised based upon refinements made to previous systematic reviews by Satz et al. (1997) and Babikian et al. (2009). During the period of research, the Satz et al. (1997) and Babikian et al. (2009) studies were the only studies having reviewed clinical or population-based literature on outcomes from TBI among the pediatric population. The present review examined literature from PubMed, CINAHL Plus and Scopus to obtain research literature which had been published between 1 January 2008 and 22 April 2013. Medical Subject Headings (MeSH) "child" and similar were used and cross-referenced with "head injuries", "brain injuries", "TBI" and "cognition". All peer-reviewed articles matching the subject matter were then downloaded and organized in the EndNote citation management software. Subsequently a search of grey literature was performed via Google Scholar and PubMed Health utilizing the same publication period as the peer-reviewed literature search, **Figure 6**.

The review process began with the peer-reviewed and grey literature in the following order: 1) Title search and review; 2) Abstract search review, and full text search and review independently by two separate reviewers. The percent of disagreement between the two reviewers was calculated using a standardized quality assessment tool from the Effective Public Health Practice Project's (EPHPP) Quality Assessment Tool for Quantitative Studies. Using this tool a consensus system was utilized to determine which articles would be marked for inclusion in the review.

Scores (Strong=1; Moderate=2; Weak=3) were given independently by the two co-reviewers which reflected a study's design, data collection methods, selection bias, possible confounders, blinding, withdrawals and drop-outs, and intervention integrity. The marked studies were then given a calculated global score of "weak, "medium", or "strong" based on the number of "weak" scores they received. Because the quality assessment tool rated randomized controlled trials highly, the majority of the included studies which were included received a relatively weak rating because they encompassed other prospective, longitudinal designs. Due to this and in order to capture otherwise strong studies, even if their global score was rated as "weak", they were not excluded from the initial review process.

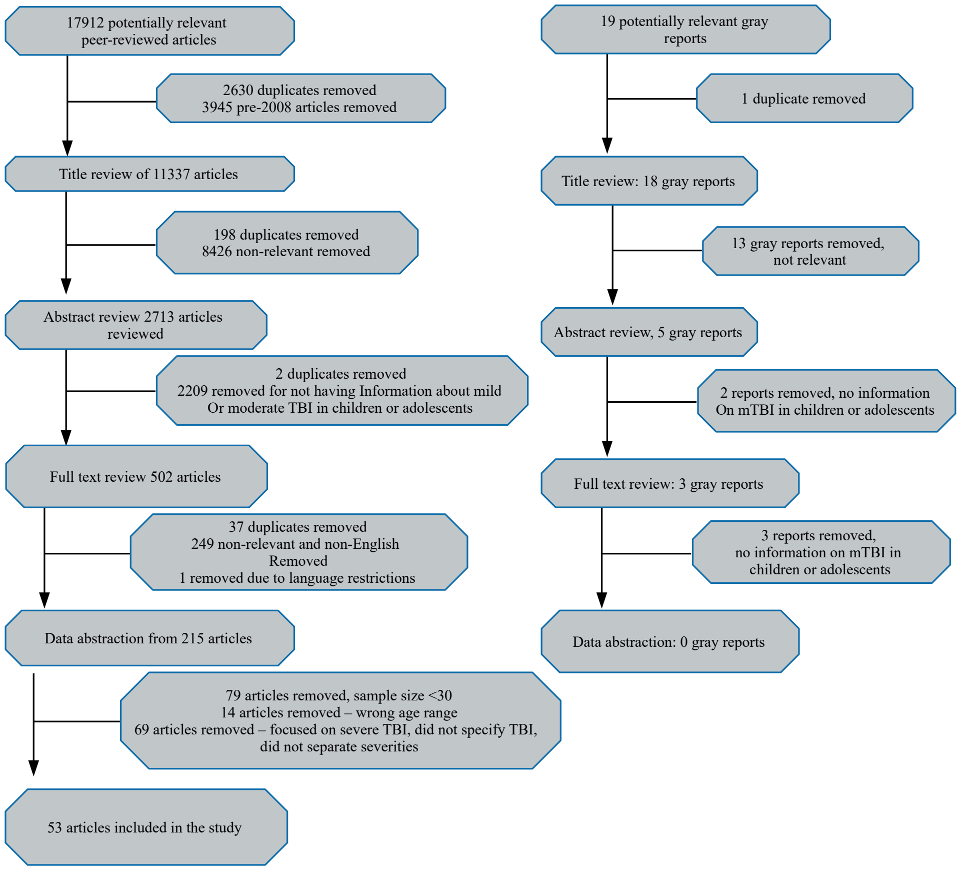

Figure 6. Flowchart of systematic review article selection and review process

In order to allow for a diversity of results, studies of any design were included, even if children with mild or moderate TBI were not the main focus of the study. Case studies, however, owing to their poor generalizability, were not included. Studies that had a sample size of 30 or more participants below the age of 18 years were included. The same categories used for reporting in the original review were used. These were extracted using a standardized data abstraction form and included: adverse outcomes (academic psychosocial adverse outcomes, neuropsychological adverse outcomes), null outcomes (same categories as before), and indeterminate outcomes.

Study II explored whether significant regional differences existed within Finland with regard to the external causes of traumatic brain injury. The analytic strategy for this study first involved identifying all new cases of TBI that were diagnosed during the first 18 years of life in Finland between 1998 and 2012. The data utilized in this study were derived from the Finnish Hospital Discharge Register. Once cases were identified, incidence rates were compiled by region per 100,000 persons for each year under study. The population-based denominators that were used were the two year averages for each age group. Six regions were considered (**Figure 7**): Åland Islands (6), and the provinces of Southern Finland (1), Western Finland (2), Eastern Finland (3), Oulu (4) and Lapland (5). This division was selected mostly for convenience and because they captured some nuance in terms of cultural, historical and geographic differences which exist in Finland. Although the former were not explored in detail in this study. The following ICD-10 codes which covered the TBI diagnoses were considered for inclusion: S06.0 Concussion; S06.1 Traumatic cerebral edema; S06.2 Diffuse brain injury; S06.3 Focal brain injury; S06.4 Epidural hemorrhage; S06.5 Traumatic subdural hemorrhage; S06.7 Intracranial injury with prolonged coma; S06.8 Other intracranial injuries; S06.9 Unspecified intracranial injury.

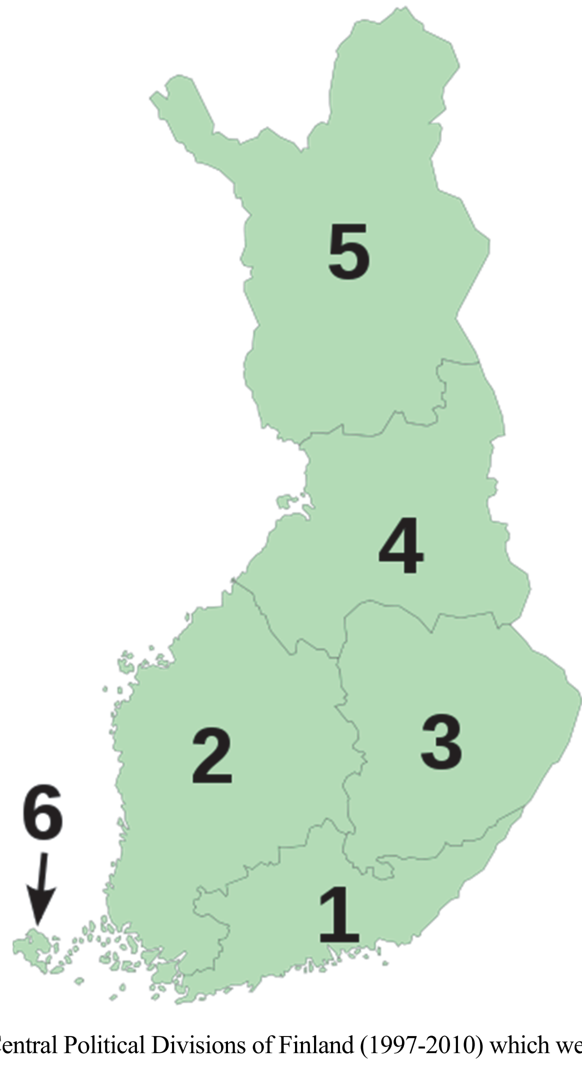

Figure 7: State Central Political Divisions of Finland (1997-2010) which were used for Study II

In **Study III**, data from the 1987 Finnish Birth Cohort were used as the basis of this study. This unique cohort contains information on 60 069 children within Finnish administrative health registers. The data include both live and still-born infants who weighed at least 500g or had a minimal gestational age of 22 weeks and born in Finland in 1987. For this study only complete data on 59 476 children from 1987 to 2012 were included. Additional details concerning the cohort and its contents are described in detail in the literature (Paananen & Gissler, 2011).

This study made use of two classifications of pediatric TBI which were created from the 1987 Finnish Birth Cohort. The first classification of TBI was created to consist of only those children with a TBI diagnosis which was of a severity requiring one or more night stays in a hospital emergency department. This category was named “inpatient TBI” (iTBI).

The second classification of TBI consisted of children who had been diagnosed with a TBI whose severity was low enough to not require overnight hospitalization. This second classification was named “outpatient TBI” (oTBI). The two classifications were used as proxies for mild and moderate TBI respectively. Linked data for the latter category were only available beginning from the year 1998.

Dividing the data into two categories in this manner allowed for the issue of the lack of clinical severity criteria in the data to be somewhat mitigated for comparative purposes. This also allowed for the possible elaboration of demographic and parent mental health differences which might be associated with differences in TBI severity via severity proxy. It is important to emphasize here that these were not two distinct groups of children, they are the same children followed-up in the cohort. The only difference is that the outpatient data do not appear until 1998. Thus for iTBI and oTBI, each category is considered separately in the analyses which were performed cross-sectionally, separately by classification, and compared only against those without a TBI diagnosis (controls).

Fifteen variables were obtained from the cohort. They were categorical variables which detailed diagnoses pertaining to parent health, socioeconomic status, the relationship status between the parents and parent educational attainment. The variables included parent age at the time of the child's birth; this was considered as a continuous variable in the analyses. Socioeconomic status at the household level was based on the entries for parent occupation combined with education. This is based on the standard classification for SES carried out by Statistics Finland (Statistics Finland, 2017). Determination of SES was based on the highest maternal and paternal education achieved at the end of the follow-up period. The database has several measures of SES. These are based on the highest maternal and paternal education (at the end of follow-up). More specifically, SES was based on maternal occupation when the child was 7 years of age, household income during the childhood years, and the need for social assistance during the childhood years. Cohort data included ICD-10 coded inpatient and outpatient parent diagnoses for parents in ICD-10 format. Only inpatient diagnoses for the parents were considered for use in the analyses.

The following parent inpatient diagnoses were considered for inclusion and subsequent analysis:

F10-F19 Mental and behavioral disorders due to psychoactive substance use;

F20-F29 Schizophrenia, schizotypal, delusional, and other non-mood psychotic disorders;

F30-F39 Mood [affective] disorders;

F40-F48 Anxiety, dissociative, stress-related, somatoform and other nonpsychotic mental disorders;

F50-F59 Behavioral syndromes associated with physiological disturbances and physical factors;

F60-F69 Disorders of adult personality and behavior

F70-F79 Intellectual disabilities;

F80-F89 Pervasive and specific developmental disorders;

F90-F98 Behavioral and emotional disorders with onset usually occurring in childhood and adolescence;

F99-F99 Unspecified mental disorder.

3.1. Ethical considerations

All relevant data protection and ethical guidelines were following during the conduct of the research documented within this thesis. As a condition of data acquisition and research participation a non-disclosure agreement was signed. All research described in this proposal made use of previously collected data. **Study I** involved the review and analysis of prior research findings existing in the peer-reviewed literature and thus did not require additional ethical considerations. **Study II** made use of data from the Finnish Hospital Discharge Register and data linkage was performed at Statistics Finland which had all necessary permissions.

Study III made use of existing data from the 1987 Finnish Birth Cohort (FBC), which is a long-term register-based follow-up collected and managed at the Finnish National Institute for Health and Welfare (THL) by Prof. Mika Gissler (Information Department) and coordinated by Dr. Reija Paananen (Department of Children, Youth and Families). The 1987 FBC is based on the following registers: Finnish Medical Birth Register, Finnish Hospital Discharge Register, Cause of Death Register, Register on Prescribed Medicine and Special Refunded Medicine, Statistics Finland Registers/Population Register, Infectious Disease Register, Register on Induced Abortions, Register on Social Assistance, Register on Child Welfare, Finnish Defense Forces Registers and registers from the Finnish Legal Center. Permission to use the 1987 FBC was provided by an ethics committee (Ethical committee §28/2009) and all relevant permissions from all register keeping authorities.

Because the administrative health data were be stripped of identifying characteristics and reported in aggregated form, there were no threats to privacy to the individual cohort participants. No individual cohort participants were contacted during or after the research period. Any data linkage will have had identifying information removed in the linkage process by administrative personnel at THL. Only those with official permissions granted by THL and relevant register keeping bodies have access to the complete data.

4. STATISTICAL METHODS

Study I did not employ the use of meta-analysis. Instead studies were categorized according to TBI outcome, whether mild or not and whether adverse effects were found which could be classified as neuropsychological, psychosocial, academic, or other outcomes. For **study II** the Finnish National Board of Health maintains a nationwide register of hospital discharges. These discharges cover all inpatient registrations within the country. This study utilizes this register to identify all new cases of TBI for those aged 18 years and younger 1998 and 2012. The discharge data were divided into five age groupings: <1, 1-4, 5-9, 10-14 and 15-18 years. Subsequently, the incidence rates for each diagnosis were calculated based on average annual rates per 100,000 persons for each year under study using a Poisson distribution method for the calculation of standardized ratios (Ulm, 1990). The two-year averages for each age group were used for the population denominator. Population information was obtained from Statistics Finland.

Study III first carried out bivariate analyses to determine the level of association of the two dependent categorical TBI classifications with the selected demographic and mental health independent variables. The continuous variable parent age was examined using ANOVA whereas the chi^2 test was used for all other categorical variables. Subsequent to this, multivariable logistic regression was performed using only the variables which were found to be statistically significantly associated in the bivariate analyses to determine the strength and direction of the association while adjusting for possible confounders. The outcomes of the bivariate analyses were reported as either proportions or means along with corresponding p-values. In the case of the multivariate analyses the results were reported as odds ratios and accompanied by 95% confidence intervals. The pre-determined threshold for statistical significance for both the preliminary and confirmatory analyses was <0.05. The statistical software package Stata 12 was used for all analyses (StataCorp LP, 2012).

5. RESULTS

Study I yielded a total of 17 912 peer-reviewed results and 19 gray-literature results in the initial search which were possibly relevant for the study. Upon the removal of duplicate studies and those published prior to 2008, the review was started with a total of 11 337 peer reviewed manuscripts and 18 reports from the gray literature. **See Appendices I, II & III** for a complete listing of results. An exhaustive process subsequently removed additional manuscripts at each subsequent phase of the review and data abstraction **Figure 6**.

In **study II** there were 21 457 diagnosed cases of pediatric TBI in Finland during the period 1998-2012. Because these are data from hospital inpatient records, they represent hospitalizations for TBI. This figure translates into a cumulative incidence rate of 99/100 000 persons per year. Count data by age and the corresponding incidence rates are illustrated om **Table 4**. It can be noticed that male injury rates begin to diverge from the age of three years and are higher consistently thereafter.

In **Table 5** count and incidence rates for male and female TBI are depicted sorted by region for the period under study. The highest cumulative incidence rate for pediatric TBI across both sexes was found in the province of Åland with 254.9/100 000 persons p/y. This was followed by Lapland with a incidence of 132.3/100 000 persons p/y. In all municipalities males were significantly overrepresented in TBI rates with the smallest incidence rate variation between the sexes being in the province of Southern Finland. **Table 6** depicts TBI diagnosis by age, gender and region. In **Table 7** it can be seen that the overwhelming majority of TBIs which had a specified cause were due to falls, with the subsequent categories in order of rank being sport related and TBIs which occurred as a result of intentional behavior.

Table 4: Count and incidence rates per 100 000 by age for male and female pediatric TBI in Finland 1998-2011

	Count data			Incidence rates		
Age	**Males**	**Females**	**Cumulative**	**Males**	**Females**	**Cumulative**
0	623	486	1109	150.1	122.4	136.5
1	526	507	1033	126.3	127.2	126.8
2	510	533	1043	122	133.2	127.5
3	515	403	918	122.5	100.1	111.5
4	500	357	857	118	87.9	103.3
5	505	290	795	118.2	70.8	95
6	433	262	695	100.3	63.3	82.2
7	534	312	846	122.5	74.6	99
8	515	272	787	117	64.4	91.3
9	532	301	842	119.7	72.7	96.7
10	535	287	822	119.5	66.8	93.7
11	551	270	821	122.3	62.5	93
12	515	279	794	113.6	64.1	89.4
13	536	313	849	117.1	71.3	94.7
14	578	356	934	125	80.3	103.1
15	684	427	1111	146.6	95.5	121.6
16	536	287	823	114.2	63.8	89.6
17	477	242	719	101.5	53.8	78.2
18	667	322	989	142	71.6	107.5
19	697	262	959	148.5	58.4	104.5
Total	10576	6599	17175	119	77.5	98.7

Table 5. Count and incidence rates per 100 000 by region for male and female pediatric TBI in Finland 1998-2011

	Count data			Incidence rates		
Region	**Male**	**Female**	**Cumulative**	**Male**	**Female**	**Cumulative**
Southern Finland	3269	2053	5322	92.2	60.0	76.3
Western Finland	4100	2515	6615	131.9	84.8	108.9
Eastern Finland	1175	805	1980	123.7	88.6	106.5
Oulu	1309	762	2071	143.4	87.8	116.3
Lapland	521	320	841	160.5	102.9	132.3
Åland	126	99	225	276.7	231.7	254.9
Cumulative	10576	6599	17175	119	77.5	98.7

Table 6. Diagnosis by region and gender, count data (incidence rates)

Region (Gender)	S060	S061	S062	S063	S064	S065	S066	S067	S068	S069	Cumulative
Southern Finland (Male)	2821 (79.5)	12 (0.3)	203 (5.7)	102 (2.9)	59 (1.7)	88 (2.5)	33 (0.9)	4 (0.1)	6 (0.2)	29 (0.8)	3269 (92.2)
Western Finland (Male)	3609 (116.1)	28 (0.9)	188 (6)	133 (4.3)	57 (1.8)	95 (3.1)	23 (0.7)	5 (0.2)	14 (0.5)	26 (0.8)	4100 (131.9)
Eastern Finlalnd (Male)	1017 (107.1)	8 (0.8)	57 (6)	41 (4.3)	20 (2.1)	28 (2.9)	10 (1.1)	0 (0)	3 (0.3)	13 (1.4)	1175 (123.7)
Oulu (Male)	1152 (126.2)	11 (1.2)	58 (6.4)	51 (5.6)	16 (1.8)	27 (3)	6 (0.7)	2 (0.2)	3 (0.3)	18 (2)	1309 (143.4)
Lappi (Male)	462 (142.3)	3 (0.9)	28 (8.6)	19 (5.9)	7 (2.2)	12 (3.7)	4 (1.2)	0 (0)	0 (0)	3 (0.9)	521 (160.5)
Åland (Male)	118 (259.2)	1 (2.2)	4 (8.8)	0 (0)	3 (6.6)	0 (0)	1 (2.2)	0 (0)	0 (0)	1 (2.2)	126 (276.7)
Southern Finland (Female)	1817 (53.1)	4 (0.1)	108 (3.2)	49 (1.4)	30 (0.9)	29 (0.8)	26 (0.8)	2 (0.1)	3 (0.1)	10 (0.3)	2053 (60)
Western Finland (Female)	2303 (77.7)	10 (0.3)	77 (2.6)	54 (1.8)	20 (0.7)	40 (1.3)	13 (0.4)	3 (0.1)	0 (0)	23 (0.8)	2515 (84.8)
Eastern Finland (Female)	730 (80.3)	3 (0.3)	33 (3.6)	25 (2.8)	5 (0.6)	10 (1.1)	2 (0.2)	0 (0)	1 (0.1)	7 (0.8)	805 (88.6)
Oulu (Female)	699 (80.5)	5 (0.6)	20 (2.3)	17 (2)	9 (1)	12 (1.4)	4 (0.5)	3 (0.3)	1 (0.1)	5 (0.6)	762 (87.8)
Lapland (Female)	281 (90.3)	3 (1)	17 (5.5)	7 (2.3)	3 (1)	7 (2.3)	2 (0.6)	0 (0)	1 (0.3)	3 (1)	320 (102.9)
Åland (Female)	93 (217.6)	0 (0)	3 (7)	1 (2.3)	0 (0)	1 (2.3)	1 (2.3)	0 (0)	1 (2.3)	0 (0)	99 (231.7)
Cumulative	15211 (87.4)	88 (0.5)	800 (4.6)	500 (2.9)	230 (1.3)	356 (2)	127 (0.7)	19 (0.1)	34 (0.2)	138 (0.8)	17175 (98.7)

Table 7: External causes of injury by region and gender, count data and cumulative incidence rates in parenthesis

Sex	ICD-10 code	S. Finland	W. Finland	E. Finland	Oulu	Lapland	Åland	UN	AB/UN	IC	Cumulative
Male	V01-V99	920 (25.9)	1099 (35.3)	297 (31.3)	351 (38.5)	175 (53.9)	23 (50.5)	1	17	2	2881 (32.4)
Male	W00-W19	1867 (52.6)	2313 (74.4)	592 (62.3)	769 (84.3)	260 (80.1)	72 (158.1)	0	45	2	5917 (66.6)
Male	W65-W74	1 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0	0	0	1 (0)
Male	W75-W84	1 (0)	1 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0	0	0	2 (0)
Male	X00-X09	0 (0)	1 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0	0	0	1 (0)
Male	X40-X49	3 (0.1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0	0	0	3 (0)
Male	X60-X84	6 (0.2)	8 (0.3)	2 (0.2)	1 (0.1)	0 (0)	0 (0)	0	0	0	17 (0.2)
Male	X85-Y09	80 (2.3)	74 (2.4)	23 (2.4)	18 (2)	13 (4)	5 (11)	0	1	0	214 (2.4)
Male	Y35-Y36	1 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0	0	0	1 (0)
Male	Y60-Y69	1 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0	0	0	1 (0)
Male	Y70-Y82	4 (0.1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0	0	0	4 (0)
Male	Y83-Y84	1 (0)	2 (0.1)	1 (0.1)	0 (0)	0 (0)	0 (0)	0	0	0	4 (0)
Male	Y85-Y89	4 (0.1)	4 (0.1)	0 (0)	4 (0.4)	0 (0)	0 (0)	0	0	0	12 (0.1)
Male	Unspecified	90 (2.5)	191 (6.1)	116 (12.2)	52 (5.7)	15 (4.6)	23 (50.5)	0	5	2	494 (5.6)
Male	Other causes	394 (11.1)	553 (17.8)	185 (19.5)	142 (15.6)	70 (21.6)	5 (11)	0	10	1	1360 (15.3)
Female	V01-V99	539 (15.7)	577 (19.5)	161 (17.7)	198 (22.8)	99 (31.8)	19 (44.5)	0	18	0	1610 (18.9)
Female	W00-W19	1263 (36.9)	1585 (53.5)	481 (52.9)	471 (54.3)	178 (57.2)	57 (133.4)	1	21	1	4058 (47.6)
Female	W75-W84	2 (0.1)	2 (0.1)	0 (0)	3 (0.3)	0 (0)	0 (0)	0	0	0	7 (0.1)
Female	X40-X49	1 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0	0	0	1 (0)
Female	X60-X84	6 (0.2)	2 (0.1)	0 (0)	1 (0.1)	1 (0.3)	0 (0)	0	0	0	10 (0.1)
Female	X85-Y09	27 (0.8)	21 (0.7)	13 (1.4)	4 (0.5)	10 (3.2)	0 (0)	0	0	0	75 (0.9)
Female	Y70-Y82	3 (0.1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0	0	0	3 (0)
Female	Y83-Y84	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0)	0	0	0	1 (0)
Female	Y85-Y89	2 (0.1)	1 (0)	1 (0.1)	2 (0.2)	0 (0)	0 (0)	0	0	0	6 (0.1)
Female	Unspecified	32 (0.9)	108 (3.6)	73 (8)	24 (2.8)	13 (4.2)	18 (42.1)	0	2	0	270 (3.2)
Female	Other causes	216 (6.3)	265 (8.9)	96 (10.6)	69 (7.9)	26 (8.4)	7 (16.4)	0	5	0	684 (8)
	Cumulative	5322 (76.3)	6615 (108.9)	1980 (106.5)	2071 (116.3)	841 (132.3)	225 (254.9)	2	124	7	17175 (98.7)

UN= Undetermined province, AB/UN= Abroad / Undetermined province, IC= Invalid state code

V01-V99 Injured in transport accident, **W00-W19** Slipping, tripping, stumbling and falls, **W65-W74** Accidental non-transport drowning and submersion, **W75-W84** Other accidental threats to breathing, **X00-X09** Exposure to smoke, fire and flames, **X40-X49** Accidental poisoning by and exposure to noxious substances, **X60-X84** Intentional self-harm, **X85-Y09** Assault, **Y35-Y36** Legal intervention, operations of war, military operations, and terrorism, **Y60-Y69** Misadventures to patients during surgical and medical care, **Y70-Y82** Medical devices associated with adverse incidents in diagnostic and therapeutic use, **Y83-Y84** Surgical and other medical procedures as the cause of abnormal reaction of the patient, or of later complications, without mention of misadventure at the time of the procedure, **Y85-Y89** Sequelae of external causes of morbidity and mortality. ICD-10 codes and descriptions excerpted from (Langley & Chalmers, 1999).

6. DISCUSSION

Study I examined existing literature for global data on the long term outcomes of pediatric TBI. The study was conducted partially due to the sparse nature of evidence which clarifies whether mild head injuries among pediatric populations constitute long term health and behavior consequences.

The findings supplemented and extended previous systematic reviews by (Satz et al. and Babiakan et al.) making use of a validated quality assessment instrument. A two-person independent rating system was used and ascertained the quality of each publication with regard to selection bias, design attributes, blinding, data collection methodologies, withdrawals and drop-outs.

This systematic review, despite its limitations with regard to both the suitability of the assessment tool as well as the heterogeneity of the types of studies under examination, provided useful information concerning pediatric TBI. Of the 45 studies reviewed pertaining to mild TBI outcomes, nearly half of them indicated adverse psychosocial outcomes were apparent following mild TBI diagnoses. Children with a moderate TBI diagnosis were found to perform worse than children with mild TBI in 6 out of 8 reviewed studies.

Unfortunately these and numerous other deficits have occurred without receiving much in the way of extensive etiological examination. This may have partially been due to the fact that pediatric cases which present in clinical settings with severe TBI have very obvious signs immediate and latent deficits in neurological function. Whereas mild and moderate TBIs may require more nuanced investigation. Another consideration where the potential for long term deficits are called into question, is that early age and the severity of the injury are key factors. TBIs that occur during the first five years of life are more likely to have psychiatric and behavioral sequelae that lingers into adolescence and even adulthood.

An important consideration in future studies which might seek to shed additional light into long term trends in pediatric TBI, is the time period which elapses between the first diagnosis of a TBI and and when the patient is subsequently reevaluated by their primary care physician. Early evaluations may potentially capture latent symptoms and offer rehabilitative strategies to assist with countering the effects of potential deficits before they manifest in ways which may be detrimental to the individual long term.

In **Study II**, The observation that Åland had the highest rates of TBI is likely due to their small population which overestimates the TBI given the smaller population of the region. The sparsely populated, predominantly rural regions of Lapland demonstrated higher injury rates in proportion to their population consistent with rural regions elsewhere (Mitchell & Chong, 2010). Variations between rural and urban injury rates may be explained due to differences in environmental exposures. In the case of Southern Finland having the smallest variation between sexes may be partially related to its rate of urbanization which may expose the population in question more equally to increased risks in the traffic environment due to their greater exposure via time in traffic heavy settings. A previous Finnish study which examined a birth cohort from the two northernmost provinces of Finland (Lapland and Oulu) found that the rate of concussions with or without skull fractures for those up to 14 years of age was a cumulative incidence of 18.1/1000 (Rantakallio & von Wendt, 1985). This is higher than rates found in southwestern Sweden with a mean average of 12/100,000 (Emanuelson & v Wendt, 1997). The present study based on more recent data, averaged over time, places the country-wide rate of 99/100,000. This represents a rate which is nearly an order of magnitude higher than the average rate in southern Sweden for a similarly aged population.

Due to the outpatient data only being available later during the period under study (1998 onwards) the cases which appear in the additional data would be older in the 1998-onwards group. However this is not expected to affect the results meaningfully, only that TBI risk increases somewhat during puberty.

Additional observations are the increase in TBI rates from 2006 onwards. One possible explanation might lie in nationwide policy changes related to alcohol taxation which occurred two years prior. Puljula, in a doctoral thesis, observed that subsequent to a decrease in alcohol taxation and loosening of import restrictions in 2004, there was a marked increase in alcohol consumption, alcohol-induced liver diseases and sudden deaths involving alcohol one year after the policy change (Puljula, 2012). In the present study (**Study II**), the researchers noted an increase in pediatric TBI from 2006 onwards with a peak appearing in 2009. Prior to this, rates of pediatric TBI had been on a downward trend between 2001 and 2003. While it is not possible to discern with certainty whether these cases of pediatric TBI occurred in the presence of alcohol, a significant proportion of pediatric TBI cases did occur as a result of transport related incidents. Transport related collisions are often correlated with alcohol use. Alcohol sales are strictly regulated in Finland, with the sale of strong alcohol (>5% alcohol content) only available for purchase within government-controlled outlets. Sales of beverages with an alcohol content of <5% are available for purchase in a wider variety of stores but with some limitations as to the time of day that they may be purchased. Taxation is also used as a means to modify consumption behavior in the population.

7. THE MAIN FINDINGS AND THEIR INTERPRETATION

7.1.1. Parental mental illness as a risk factor for pediatric TBI

Parent mental illness as a factor which potentially modifies TBI risks within a caregiving scenario with potentially harmful outcomes was explored in **Study III**. Prior to the observations made in this study, the existing literature on the subject dealt mainly with distracted parenting (Saluja et al., 2004), substance use and abuse within the caregiving context (Rehan, Antfolk, Johansson, Jern, & Santtila, 2017), mothers with an intellectual disabilities (Wickström, Höglund, Larsson, & Lundgren, 2017), as well as depression and anger as potential risk factors within the context of child abuse (Hien, Cohen, Caldeira, Flom, & Wasserman, 2010; Yamaoka, Fujiwara, & Tamiya, 2016). The present study is addresses research gaps in the role of paternal mental health as well as several other mental illnesses previously not examined in the literature on child injury with only minor attention given specifically to risks for TBI.

Fathers, we noted, who had received a diagnosis of a mental illness as a result of psychoactive substance abuse had children under their care who were more likely to be diagnosed with a of TBI. This observation is generally congruent with existing research which demonstrates that drug abuse involving either parent is strongly associated with the abuse of children under their care. Alcohol in particular is related with not only abuse but also other forms of impairment including those which may result in a higher threshold for being able to reduce injury risks involving the children under their care.

Depression, a common mood disorder, often has a bi-directional association with substance abuse, and is by itself associated with pediatric TBI. This is especially the case for maternal postpartum depression. The study also revealed that behavioral disorders were strongly associated with pediatric TBI. Various types of adult behavioral disorders, if left untreated, may represent risks for not only the person with the disorder but for others in their environment as well.

Other forms of mental illness such as psychotic disorders have also been linked with pediatric TBI with maternal psychosis being linked with severe physical abuse (González, Igoumenou, Kallis, & Coid, 2016; Husted, Ahmed, Chow, Brzustowicz, & Bassett, 2010). Conversely, psychosis among fathers was found to be unrelated with child maltreatment which was also found to be the case in the present study (Fisher et al., 2010). One of the most noted factors in maternal abuse scenarios is that of delayed onset of maternal affection after child birth, which occurs more frequently among mothers with mental illness (Paris, Zweig-Frank, & Guzder, 1994; Robson & Kumar, 1980). Diagnoses encompassing ICD-10 codes F70 through F99 were not found in the cohort data. This is because persons with these diagnoses rarely become parents due to the nature of the diseases in these categories. Persons with profound congenital mental disabilities, are often not able to carrying a fetus to term.

7.1.2. Effect of child sex on risk for TBI

Across the three studies, sex differences in injury rates were largely confirmed by the vast majority of existing literature on the subject. Male and female children have patterns of injury and TBI risk which differ markedly. Males typically have a two-fold higher risk of injury over the course of their lifetimes. There are various hypotheses for this divergence and they center mostly around socio-cultural factors. Such factors include relaxed views on boys being allowed to explore and venture off into higher risk play activities such as rough sports, while girls may be kept away from the same. Mass media also emphasizes competition and raw strength when sending messages intended for boys, whereas messages for girls emphasize cooperative play and consensus (Granié, 2010; Sorenson, 2011).

7.1.3. Socioeconomic factors

Socioeconomic status is widely understood to be a modifier of risk for injury and a baseline health determinant. Low socioeconomic status is associated with less educational attainment, stressed parenting and less than optimal quality housing in many cases. It therefore underpins a potentially large number of factors in the home environment and at the point of interaction between parents and children.

7.2. Strengths and limitations of the study

Among the strengths of this study are the fact that both the cohort and hospital discharge register were derived from complete and intact sources representative of the entire population of Finland. The data are individually linked. The cohort data included information on both parents and their diagnoses which allowed for a level of in-depth study not typically found in population-based epidemiological studies. Finnish population registers are known to be of high quality and are particularly suitable for research studies (Gissler & Haukka, 2009). The completeness of these registers makes it possible to significantly reduce selection bias common in other types of population-based studies. Furthermore, it is an additional strength that the data collection has been carried out independently of the studies featured here. This allows for the minimization of classification errors and other potentially silent forms of investigator bias. In spite of the inherent strengths, there are a number of acknowledged limitations in the studies found here. Firstly are limitations that pertain to the data and limitations extending from the observations made from the data.

As with most studies making use of administrative registers, the immediate circumstances around the injury are not known. Intentionality is also not easily discerned (**Studies II and III**). Additionally the possible influence of hereditary, but undiagnosed factors which might predispose the children to risks are not adequately addressed owing to the limitations inherent in the data

Among the data related limitations are those which relate to severity classification of TBI. Because the register data were not specifically collected with the conduct of research on TBI in mind, there were no clinically relevant definitions of TBI severity which could be used to differentiate between diagnoses. This is the case for pediatric TBI diagnoses as well as the mental health related diagnoses for their parents. These limitations introduce challenges which make the conclusions not necessarily comparable to other studies which include a well defined severity criterion from the point of data collection.

In **Study III** one of the key limitations concerns the nature of the data used for the study. One of the most important goals of epidemiological studies involving injury, is the discernment of the circumstances surrounding the injury event itself. This information then, when available, proves useful in informing interventions designed to mitigate a specific type of injury. As is often the case with administrative data, they do not unfortunately contain injury characteristics such as injury circumstances, place where the injury occurred, whether others were involved in the same event, whether the event was intentional or whether substance use was involved. In nearly all cases administrative data contains only demographic background information about the victim and the diagnosis and the prescribed treatment. Other variables which might be pertinent to the incident typically have to be linked with other registers, such as law enforcement databases or similar. Because of this, we were not able to provide information which might allow for a more in depth profiling of the injured individuals in **Study III**.

With regard to the observations made from the analyzed data, increasing parental age was found to be protective against pediatric TBI in **Study III**. In this case the possible effect of birth order was not accounted for in the analyses as a potential confounder. It is plausible that with each additional child, parents could have potentially gained useful experiences which may in and of themselves represent protective factors against TBI in successive births.

Also concerning **Study III**, while there exists a large literature base on child abuse as a risk factor for pediatric TBI (with parental health often being described tangentially); literature which attempts to describe the pathway towards child TBI being via parent mental illness which is potentially linked to suboptimal care provision, is not widely available. This study emphasizes that that it is not necessarily only physical abuse which may be responsible for child TBI in these cases, but rather also deprivation, suboptimal monitoring of environmental risks in the home or inadequate responses to risk situations. Because of this the study results may not readily be comparable with existing studies.

8. CONCLUSIONS

Based on the present study of existing evidence-based knowledge, even mild and moderate TBI during childhood can have long term consequences on later neuropsychological, psychosocial and behavioral outcomes. It appears also that even academic outcome is affected with 48.3% of patients with mild TBIs having persistent problems post injury with a significant portion of them (32.2%) only completing high school. Even in the event of brain injuries which are considered not significant enough to warrant hospitalization, long term effects are possible which are difficult to predict and warrant attention. The silent and insidious nature of pediatric TBI in particular, at the very least, deserves more attention than it currently receives.

The annual yearly incidence of traumatic brain injury in Finland 77.5/100,000 for females and 119/100,000 for males. The incidence varied by area and gender between 60/100,000 and 276.7/100,000 at risk. The study did not aim at explaining the areal differences, however the most common contributors to pediatric injuries (whether with a TBI diagnosis or not) were transport related or occurred as a result of falls.

Several forms of parent mental illness are linked with pediatric TBI. Mood disorders and illnesses which resulted from psychoactive substance abuse among fathers were highly influential in pediatric TBI risk. Among mothers, schizophrenia and psychotic disorders were more influential in modifying pediatric TBI risk higher. Whether the incidents which resulted in brain injured children occurred as a result of abuse, negligence or inherent difficulties in reaction or being inadequately able to assess a potentially dangerous situation, this study was not able to reveal. However the importance of parent mental health should be considered of some importance when examining the overall risk levels which might be present in a care provision scenario.

The findings of this thesis have demonstrated that in addition to the basic indicators of sociodemographic background, that there are important regional, sex and parental capacity related factors which underlie pediatric TBI risk. The exposure to injury risks is not uniform across the Finnish national landscape and some regions have proportionally higher risk ratios for pediatric TBI. While no testable hypotheses emerged as to why rates differed across Finland, one theory did emerge for why an uptrend in pediatric TBI rates may have occurred within one time frame within the 1998-2012 period. It was also uncovered that among countries with similarly available data, that pediatric TBI rates in Finland are above average. This may also reflect different diagnostic traditions between countries, better reporting, better emergency care coverage, and or different health seeking behavior among the Finnish population as a whole. No clear explanation emerged as to why country variations differed but the question warrants further study using normalized data sets designed with comparability in mind.

8.1.1. Challenges for future studies

Given the seriousness and long term consequences on families and national health services, it is rather unfortunate that all forms of childhood injuries are given a low priority on the policy agenda within Europe (McKee & Oresković, 2002). Despite their preventability, there is still a generalized belief that injuries are events which occur as “accidents” which implies a lack of agency or will to examine causative factors and implement necessary mitigations (Peden et al., 2008). Many contextual and causative factors for TBIs are well known and have been reiterated in research venues for decades. Effective solutions for mitigating risk factors at the societal level, such as engineering safer environments, enforcing existing policies and integrating safety education awareness into daily activities have shown great promise.

The challenge for future research lies in examining not only physical environmental determinants for pediatric TBI but also the context and interrelationships between individuals and their collective capacity to effectively modify the risks within their own environments. Within this also lies the examination of the potential for threats to this capacity, whether they be mental health related or otherwise. This aspect of capacity has largely been lacking in the literature and this research has attempted to address these questions.

Future research should also as a minimum include not only mothers in the determination of health outcomes among children, but also the role of fathers. The participation of fathers in childcare was recently revealed to have a protective effect on child injury rates. In neighboring Sweden, increases in paternal parental leave were shown to be parallelled by a downward trend in child injury rates (Laflamme, Månsdotter, Lundberg, & Magnusson, 2012). While the phenomenon has not been similarly studied in Finland, which has as a similar tradition of fathers participating in shared paternal leave, the evidence should spur a deeper interest in the roles not only that fathers play but also that of extended family members – in other words, to what extent does it “take a village to raise a child”?

ACKNOWLEDGMENTS

This thesis was carried out between 2013 and 2018 within the Department of Adolescent Psychiatry at the University of Turku. Financial support for the conduct of this research came principally from the Finnish Cultural Foundation, the University of Turku Graduate School (UTUGS), the University of Turku Doctoral Programme of Clinical Investigation (CLIDP) and the University of Turku Foundation. I am immensely appreciative of the support and guidance provided by the Graduate School and the Administration of the Faculty of Medicine. I have been very fortunate to have the support, careful guidance and encouragement provided by my two thesis supervisors Professor Simo Saarijärvi and Professor Olli Tenovuo. I remember our meetings as being to the point, extremely constructive and entirely motivating.

One week before handing in the final version of this thesis, I learned about the passing of Professor Simo Saarijärvi, I was deeply saddened by this. The last half decade has been a wonderful journey. His unwavering support, humor and guidance were immensely and will forever be appreciated.

The research carried out in this thesis could not have been conducted without the support of the National Institute for Health and Welfare and Professor Mika Gissler, whose extremely fast email response times were an inspiration for my own efficiency. I am also immensely grateful for all of the early guidance and inspiration by individuals too numerous to name before this process even began. All of the heavyweights in the Karolinska Division of Social Medicine, you were my inspiration for the pursuit of my interest in injury! Professor Leif Svanström, Professor Bjarne Jansson, Dr. Reza Mohammadi and the rest of the team. I am also grateful to Professor Hesham El Sayed and his early mentorship in the conduct of my first large scale epidemiological study.

Dr. Carlos Thomas, ever since Kirby Smith Hall at LSU, I've been on a mission thanks in large part to your encouragement and wisdom. Mr. John James, those late evening chats at Waffle House made me see the world from a different perspective, thank you. Mr. James Wood, I am sure if the school administration knew that you were ok with me “borrowing” chemicals out of chemistry class they would have been quite upset. Thank you for trusting me in those moments of me discovering an interest in science, rest in peace.

To all of my former and present colleagues, our conversations always ended up in profound ideas ripe for exploration.

To my ancestors who have profoundly shaped who I am by what they left behind, it would be a disgrace to not acknowledge you here.

To my parents, I owe an immense gratitude, for not only having the desire to bring me into the world, but for ensuring that I was raised with a curiosity that would carry me places.

To my brother, yes this is a big deal, but the important work has only just begun. Thank you for being in my corner and supporting me. Matt, I will now have time for Slime World again.

To my wife and children. Without your support and encouragement to “just get it done already”, I might still be wondering whether I should include yet another paper. Now its time I turn my focus to you because there are far more important things in life.

To God, for being the Senior Engineer of my journey, and for allowing me to walk into this path with conviction, determination and perseverance.

REFERENCES

Anderson, V., Catroppa, C., Morse, S., Haritou, F., & Rosenfeld, J. (2001). Outcome from mild head injury in young children: a prospective study. *Journal of Clinical and Experimental Neuropsychology*, *23*(6), 705–717. https://doi.org/10.1076/jcen.23.6.705.1015

Andrews, T. K., Rose, F. D., & Johnson, D. A. (1998). Social and behavioural effects of traumatic brain injury in children. *Brain Injury: [BI]*, *12*(2), 133–138.

Arroyos-Jurado, E., Paulsen, J. S., Merrell, K. W., Lindgren, S. D., & Max, J. E. (2000a). Traumatic brain injury in school-age children academic and social outcome. *Journal of School Psychology*, *38*(6), 571–587. https://doi.org/10.1016/S0022-4405(00)00053-4

Arroyos-Jurado, E., Paulsen, J. S., Merrell, K. W., Lindgren, S. D., & Max, J. E. (2000b). Traumatic brain injury in school-age children academic and social outcome. *Journal of School Psychology*, *38*(6), 571–587. https://doi.org/10.1016/S0022-4405(00)00053-4

Babikian, T., & Asarnow, R. (2009). Neurocognitive outcomes and recovery after pediatric TBI: meta-analytic review of the literature. *Neuropsychology*, *23*(3), 283–296. https://doi.org/10.1037/a0015268

Bandak, F. A. (1995). On the mechanics of impact neurotrauma: a review and critical synthesis. *Journal of Neurotrauma*, *12*(4), 635–649. https://doi.org/10.1089/neu.1995.12.635

Bangdiwala, S. I., & Anzola-Pérez, E. (1990). The incidence of injuries in young people: II. Log-linear multivariable models for risk factors in a collaborative study in Brazil, Chile, Cuba and Venezuela. *International Journal of Epidemiology*, *19*(1), 125–132. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/2351507

Barlow, K. M., & Minns, R. A. (2000). Annual incidence of shaken impact syndrome in young children. *Lancet (London, England)*, *356*(9241), 1571–1572. https://doi.org/10.1016/S0140-6736(00)03130-5

Berg, J., Tagliaferri, F., & Servadei, F. (2005). Cost of trauma in Europe. *European Journal of Neurology*, *12 Suppl 1*, 85–90. https://doi.org/10.1111/j.1468-1331.2005.01200.x

Bijur, P. E., Kurzon, M., Overpeck, M. D., & Scheidt, P. C. (1992). Parental alcohol use, problem drinking, and children's injuries. *JAMA*, *267*(23), 3166–3171.

Borgialli, D. A., Mahajan, P., Hoyle, J. D., Powell, E. C., Nadel, F. M., Tunik, M. G., … Pediatric Emergency Care Applied Research Network (PECARN). (2016). Performance of the Pediatric Glasgow Coma Scale Score in the Evaluation of Children With Blunt Head Trauma. *Academic Emergency Medicine: Official Journal of the Society for Academic Emergency Medicine*, *23*(8), 878–884. https://doi.org/10.1111/acem.13014

Child Health. (2007). Child health. Having had one head injury increases the risk for another. *Child Health Alert*, *25*, 4–5.

Connor, J., Norton, R., Ameratunga, S., Robinson, E., Civil, I., Dunn, R., … Jackson, R. (2002). Driver sleepiness and risk of serious injury to car occupants: population based case control study. *BMJ*, *324*(7346), 1125. https://doi.org/10.1136/bmj.324.7346.1125

Cossa, F. M., & Fabiani, M. (1999). Attention in closed head injury: a critical review. *Italian Journal of Neurological Sciences*, *20*(3), 145–153.

Delgado, J., Ramírez-Cardich, M. E., Gilman, R. H., Lavarello, R., Dahodwala, N., Bazán, A., … Lescano, A. (2002). Risk factors for burns in children: crowding, poverty, and poor maternal education. *Injury Prevention*, *8*(1), 38–41. https://doi.org/10.1136/ip.8.1.38

Dischinger, P. C., Mitchell, K. A., Kufera, J. A., Soderstrom, C. A., & Lowenfels, A. B. (2001). A longitudinal study of former trauma center patients: the association between toxicology status and subsequent injury mortality. *The Journal of Trauma*, *51*(5), 877–884; discussion 884-886.

Emanuelson, I., & v Wendt, L. (1997). Epidemiology of traumatic brain injury in children and adolescents in south-western Sweden. *Acta Paediatrica (Oslo, Norway: 1992)*, *86*(7), 730–735.

Engström, K., Diderichsen, F., & Laflamme, L. (2002). Socioeconomic Differences in Injury Risks in Childhood and Adolescence: A Nation-Wide Study of Intentional and Unintentional

Injuries in Sweden. *Injury Prevention*, *8*(2), 137–142. https://doi.org/10.1136/ip.8.2.137

Ewing-Cobbs, L., & Barnes, M. (2002). Linguistic outcomes following traumatic brain injury in children. *Seminars in Pediatric Neurology*, *9*(3), 209–217.

Fisher, H. L., Jones, P. B., Fearon, P., Craig, T. K., Dazzan, P., Morgan, K., … Morgan, C. (2010). The varying impact of type, timing and frequency of exposure to childhood adversity on its association with adult psychotic disorder. *Psychological Medicine*, *40*(12), 1967–1978. https://doi.org/10.1017/S0033291710000231

Gerrard-Morris, A., Taylor, H. G., Yeates, K. O., Walz, N. C., Stancin, T., Minich, N., & Wade, S. L. (2010). Cognitive development after traumatic brain injury in young children. *Journal of the International Neuropsychological Society*, *16*(1), 157–168. https://doi.org/10.1017/S1355617709991135

Gissler, M., & Haukka, J. (2009). Finnish health and social welfare registers in epidemiological research. *Norsk Epidemiologi*, *14*(1), 113–120.

Giza, C. C., Mink, R. B., & Madikians, A. (2007). Pediatric traumatic brain injury: not just little adults. *Current Opinion in Critical Care*, *13*(2), 143–152. https://doi.org/10.1097/MCC.0b013e32808255dc

Golding, J. M. (1999). Intimate Partner Violence as a Risk Factor for Mental Disorders: A Meta-Analysis. *Journal of Family Violence*, *14*(2), 99–132. https://doi.org/10.1023/A:1022079418229

González, R. A., Igoumenou, A., Kallis, C., & Coid, J. W. (2016). Borderline personality disorder and violence in the UK population: categorical and dimensional trait assessment. *BMC Psychiatry*, *16*, 180. https://doi.org/10.1186/s12888-016-0885-7

Granié, M.-A. (2010). Gender stereotype conformity and age as determinants of preschoolers' injury-risk behaviors. *Accident; Analysis and Prevention*, *42*(2), 726–733. https://doi.org/10.1016/j.aap.2009.10.022

Hardy, M., & Boynes, S. (2008). *Paediatric Radiography*. John Wiley & Sons.

Hausdorff, J. M., Peng, C.-K., Goldberger, A. L., & Stoll, A. L. (2004). Gait unsteadiness and fall risk in two affective disorders: a preliminary study. *BMC Psychiatry*, *4*, 39. https://doi.org/10.1186/1471-244X-4-39

Hchokr. (2012). Bronfenbrenner's Ecological Theory of Development (English).jpg. In *Wikipedia*. Retrieved from https://en.wikipedia.org/wiki/File:Bronfenbrenner%27s_Ecological_Theory_of_Development_(English).jpg

Hien, D., Cohen, L. R., Caldeira, N. A., Flom, P., & Wasserman, G. (2010). Depression and anger as risk factors underlying the relationship between maternal substance involvement and child abuse potential. *Child Abuse & Neglect*, *34*(2), 105–113. https://doi.org/10.1016/j.chiabu.2009.05.006

Hobbs, C., Childs, A.-M., Wynne, J., Livingston, J., & Seal, A. (2005). Subdural haematoma and effusion in infancy: an epidemiological study. *Archives of Disease in Childhood*, *90*(9), 952–955. https://doi.org/10.1136/adc.2003.037739

Hong, J., Lee, B., Ha, E. H., & Park, H. (2010). Parental socioeconomic status and unintentional injury deaths in early childhood: consideration of injury mechanisms, age at death, and gender. *Accident, Analysis and Prevention*, *42*(1), 313–319. https://doi.org/10.1016/j.aap.2009.08.010

Husted, J. A., Ahmed, R., Chow, E. W. C., Brzustowicz, L. M., & Bassett, A. S. (2010). Childhood trauma and genetic factors in familial schizophrenia associated with the NOS1AP gene. *Schizophrenia Research*, *121*(1–3), 187. https://doi.org/10.1016/j.schres.2010.05.021

Ibrahim, N. G., Ralston, J., Smith, C., & Margulies, S. S. (2010). Physiological and pathological responses to head rotations in toddler piglets. *Journal of Neurotrauma*, *27*(6), 1021–1035. https://doi.org/10.1089/neu.2009.1212

James, H. E. (1986). Neurologic evaluation and support in the child with an acute brain insult. *Pediatric Annals*, *15*(1), 16–22.

Janson, S., Aleco, M., Beetar, A., Bodin, A., & Shami, S. (1994). Accident risks for suburban preschool Jordanian children. *Journal of Tropical Pediatrics*, *40*(2), 88–93. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/8015037

Jayawant, S., Rawlinson, A., Gibbon, F., Price, J., Schulte, J., Sharples, P., … Kemp, A. M. (1998). Subdural haemorrhages in infants: population based study. *BMJ (Clinical Research Ed.)*, *317*(7172), 1558–1561.

Kemp, A., & Sibert, J. (1997). Childhood Accidents: Epidemiology, Trends, and

Prevention. *Journal of Accident & Emergency Medicine*, *14*(5), 316–320. https://doi.org/10.1136/emj.14.5.316

Klonoff, H. (1971). Head injuries in children: predisposing factors accident conditions, accident proneness and sequelae. *American Journal of Public Health*, *61*(12), 2405–2417.

L Wilson, M., Tenovuo, O., Mattila, V. M., Gisler, M., Celedonia, K. L., Impinen, A., & Saarijärvi, S. (2017). Pediatric TBI in Finland: An examination of hospital discharges (1998-2012). *European Journal of Paediatric Neurology: EJPN: Official Journal of the European Paediatric Neurology Society*, *21*(2), 374–381. https://doi.org/10.1016/j.ejpn.2016.10.008

Laflamme, L., Hasselberg, M., & Burrows, S. (2010). 20 Years of Research on Socioeconomic Inequality and Children's-Unintentional Injuries Understanding the Cause-Specific Evidence at Hand. *International Journal of Pediatrics*, *2010*. https://doi.org/10.1155/2010/819687

Laflamme, L., Månsdotter, A., Lundberg, M., & Magnusson, C. (2012). Dangerous dads? Ecological and longitudinal analyses of paternity leave and risk for child injury. *Journal of Epidemiology and Community Health*, *66*(11), 1001–1004. https://doi.org/10.1136/jech-2011-200181

Langley, J. D., & Chalmers, D. J. (1999). Coding the circumstances of injury: ICD-10 a step forward or backwards? *Injury Prevention: Journal of the International Society for Child and Adolescent Injury Prevention*, *5*(4), 247–253.

Lehr, E. (1990). Psychological management of traumatic brain injuries in children and adolescents. Aspen Publishers.

Levin, H. S., Ewing-Cobbs, L., & Eisenberg, H. M. (1995). Neurobehavioral outcome of pediatric closed head injury. In *Traumatic head injury in children.* (pp. 70–94). New York, NY, US: Oxford University Press.

Lloyd, J., Wilson, M. L., Tenovuo, O., & Saarijärvi, S. (2015). Outcomes from mild and moderate traumatic brain injuries among children and adolescents: A systematic review of studies from 2008-2013. *Brain Injury*, *29*(5), 539–549. https://doi.org/10.3109/02699052.2014.1002003

Martínez García, J. M., & Martín López, M. J. (2015). Group Violence and Migration Experience among Latin American Youths in Justice Enforcement Centers (Madrid, Spain). *The Spanish Journal of Psychology*, *18*, E85. https://doi.org/10.1017/sjp.2015.87

Masalha, W., & Auslander, G. (2017). Coping strategies used by parents of children with traumatic brain injury: A cross-sectional study of Palestinians and Israelis. *Social Work in Health Care*, *56*(10), 964–983. https://doi.org/10.1080/00981389.2017.1353568

McCormick, M. C. (1985). The contribution of low birth weight to infant mortality and childhood morbidity. *The New England Journal of Medicine*, *312*(2), 82–90. https://doi.org/10.1056/NEJM198501103120204

McKee, M., & Oresković, S. (2002). Childhood injury: call for action. *Croatian Medical Journal*, *43*(4), 375–378.

McKinlay, A., Grace, R. C., Horwood, L. J., Fergusson, D. M., & MacFarlane, M. R. (2010). Long-term behavioural outcomes of pre-school mild traumatic brain injury. *Child: Care, Health and Development*, *36*(1), 22–30. https://doi.org/10.1111/j.1365-2214.2009.00947.x

Michaud, P. A., Renaud, A., & Narring, F. (2001). Sports activities related to injuries? A survey among 9-19 year olds in Switzerland. *Injury Prevention: Journal of the International Society for Child and Adolescent Injury Prevention*, *7*(1), 41–45.

Micklewright, J. L., King, T. Z., O'Toole, K., Henrich, C., & Floyd, F. J. (2012). Parental distress, parenting practices, and child adaptive outcomes following traumatic brain injury. *Journal of the International Neuropsychological Society: JINS*, *18*(2), 343–350. https://doi.org/10.1017/S1355617711001792

Miller, T. R., Lestina, D. C., & Smith, G. S. (2001). Injury risk among medically identified alcohol and drug abusers. *Alcoholism, Clinical and Experimental Research*, *25*(1), 54–59.

Mitchell, R. J., & Chong, S. (2010). Comparison of injury-related hospitalised morbidity and mortality in urban and rural areas in Australia. *Rural and Remote Health*, *10*(1), 1326.

Mock, C. N., Gloyd, S., Adjei, S., Acheampong, F., & Gish, O. (2003). Economic consequences of injury and resulting family coping strategies in Ghana. *Accident; Analysis and*

Prevention, *35*(1), 81–90. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12479899

Morrongiello, B. A., & House, K. (2004). Measuring parent attributes and supervision behaviors relevant to child injury risk: examining the usefulness of questionnaire measures. *Injury Prevention*, *10*(2), 114–118. https://doi.org/10.1136/ip.2003.003459

Morrongiello, Barbara A, Ondejko, L., & Littlejohn, A. (2004). Understanding toddlers' in-home injuries: II. Examining parental strategies, and their efficacy, for managing child injury risk. *Journal of Pediatric Psychology*, *29*(6), 433–446. https://doi.org/10.1093/jpepsy/jsh047

Movig, K. L. L., Mathijssen, M. P. M., Nagel, P. H. A., van Egmond, T., de Gier, J. J., Leufkens, H. G. M., & Egberts, A. C. G. (2004). Psychoactive substance use and the risk of motor vehicle accidents. *Accident Analysis & Prevention*, *36*(4), 631–636. https://doi.org/10.1016/S0001-4575(03)00084-8

Nestor, P. G. (2002). Mental Disorder and Violence: Personality Dimensions and Clinical Features. *American Journal of Psychiatry*. https://doi.org/10.1176/appi.ajp.159.12.1973

Paananen, R., & Gissler, M. (2011). Cohort Profile: The 1987 Finnish Birth Cohort. *International Journal of Epidemiology*. https://doi.org/10.1093/ije/dyr035

Paris, J., Zweig-Frank, H., & Guzder, J. (1994). Psychological risk factors for borderline personality disorder in female patients. *Comprehensive Psychiatry*, *35*(4), 301–305.

Peden, M., Oyegbite, K., Ozanne-Smith, J., Hyder, A. A., Branche, C., Rahman, A. F., … Bartolomeos, K. (2008). World report on child injury prevention. Retrieved December 3, 2012, from http://www.who.int/violence_injury_prevention/child/injury/world_report/en/

Pernica, J. M., Leblanc, J. C., Soto-Castellares, G., Donroe, J., Carhuancho-Meza, B. A., Rainham, D. G. C., & Gilman, R. H. (2012). Risk factors predisposing to pedestrian road traffic injury in children living in Lima, Peru: a case-control study. *Archives of Disease in Childhood*, *97*(8), 709–713. https://doi.org/10.1136/archdischild-2011-300997

Pickett, W, Molcho, M., Simpson, K., Janssen, I., Kuntsche, E., Mazur, J., … Boyce, W. F. (2005). Cross National Study of Injury and Social Determinants in Adolescents. *Injury Prevention*, *11*(4), 213–218. https://doi.org/10.1136/ip.2004.007021

Pickett, William, Schmid, H., Boyce, W. F., Simpson, K., Scheidt, P. C., Mazur, J., … Harel, Y. (2002). Multiple risk behavior and injury: an international analysis of young people. *Archives of Pediatrics & Adolescent Medicine*, *156*(8), 786–793.

Pomerantz, W. J., Gittelman, M. A., Hornung, R., & Husseinzadeh, H. (2012). Falls in children birth to 5 years: different mechanisms lead to different injuries. *The Journal of Trauma and Acute Care Surgery*, *73*(4 Suppl 3), S254-257. https://doi.org/10.1097/TA.0b013e31826b017c

Puljula, J. (2012). Alcohol-related traumatic brain injuries before and after the reduction of alcohol prices : observations from Oulu Province and Northern Ostrobothnia. University of Oulu.

Rajaram, S., Batty, R., Rittey, C. D. C., Griffiths, P. D., & Connolly, D. J. A. (2011). Neuroimaging in non-accidental head injury in children: an important element of assessment. *Postgraduate Medical Journal*, *87*(1027), 355–361. https://doi.org/10.1136/pgmj.2010.103150

Rantakallio, P., & von Wendt, L. (1985). Trauma to the nervous system and its sequelae in a one-year birth cohort followed up to the age of 14 years. *Journal of Epidemiology and Community Health*, *39*(4), 353–356.

Rehan, W., Antfolk, J., Johansson, A., Jern, P., & Santtila, P. (2017). Experiences of severe childhood maltreatment, depression, anxiety and alcohol abuse among adults in Finland. *PloS One*, *12*(5), e0177252. https://doi.org/10.1371/journal.pone.0177252

Renfro, M., Bainbridge, D. B., & Smith, M. L. (2016). Validation of Evidence-Based Fall Prevention Programs for Adults with Intellectual and/or Developmental Disorders: A Modified Otago Exercise Program. *Frontiers in Public Health*, *4*. https://doi.org/10.3389/fpubh.2016.00261

Robson, K. M., & Kumar, R. (1980). Delayed onset of maternal affection after childbirth. *The British Journal of Psychiatry: The Journal of Mental Science*, *136*, 347–353.

Ruiz-Casares, M. (2009). Unintentional childhood injuries in sub-Saharan Africa: an overview of risk and protective factors. *Journal of Health Care for the Poor and Underserved*, *20*(4 Suppl), 51–67. https://doi.org/10.1353/hpu.0.0226

Russell, W. R., & Smith, A. (1961). Post-Traumatic Amnesia in Closed Head Injury. *Archives of Neurology*, *5*(1), 4–17. https://doi.org/10.1001/archneur.1961.00450130006002

Salehi-Had, H., Brandt, J. D., Rosas, A. J., & Rogers, K. K. (2006). Findings in older children with abusive head injury: does shaken-child syndrome exist? *Pediatrics*, *117*(5), e1039-1044. https://doi.org/10.1542/peds.2005-0811

Salokorpi, N., Sinikumpu, J., & Serlo, W. (2015). Ravistellun vauvan oireyhtymä–Vaikeasti tunnistettava kaltoinkohtelu. *Potilaan Lääkärilehti. Lääkäriliitto. Saatavilla*, *5*, 2017.

Saluja, G., Brenner, R., Morrongiello, B. A., Haynie, D., Rivera, M., & Cheng, T. L. (2004). The role of supervision in child injury risk: definition, conceptual and measurement issues. *Injury Control and Safety Promotion*, *11*(1), 17–22. https://doi.org/10.1076/icsp.11.1.17.26310

Satterthwaite, D. (2003). The Links Between Poverty and the Environment in Urban Areas of Africa, Asia, and Latin America. *The ANNALS of the American Academy of Political and Social Science*, *590*(1), 73–92. https://doi.org/10.1177/0002716203257095

Satz, P., Zaucha, K., McCleary, C., Light, R., Asarnow, R., & Becker, D. (1997). Mild head injury in children and adolescents: a review of studies (1970-1995). *Psychological Bulletin*, *122*(2), 107–131.

Sengoelge, M., Hasselberg, M., & Laflamme, L. (2011). Child home injury mortality in Europe: a 16-country analysis. *European Journal of Public Health*, *21*(2), 166–170. https://doi.org/10.1093/eurpub/ckq047

Sharples, P. M., Storey, A., Aynsley-Green, A., & Eyre, J. A. (1990). Causes of fatal childhood accidents involving head injury in northern region, 1979-86. *BMJ (Clinical Research Ed.)*, *301*(6762), 1193–1197.

Singh, A., Lu, Y., Chen, C., Kallakuri, S., & Cavanaugh, J. M. (2006). A new model of traumatic axonal injury to determine the effects of strain and displacement rates. *Stapp Car Crash Journal*, *50*, 601–623.

Soderstrom, C. A., Smith, G. S., Dischinger, P. C., McDuff, D. R., Hebel, J. R., Gorelick, D. A., … Read, K. M. (1997). Psychoactive Substance Use Disorders Among Seriously Injured Trauma Center Patients. *JAMA*, *277*(22), 1769–1774. https://doi.org/10.1001/jama.1997.03540460033029

Sorenson, S. B. (2011). Gender disparities in injury mortality: consistent, persistent, and larger than you'd think. *American Journal of Public Health*, *101 Suppl 1*, S353-358. https://doi.org/10.2105/AJPH.2010.300029

Sosin, D. M., Sniezek, J. E., & Waxweiler, R. J. (1995). Trends in death associated with traumatic brain injury, 1979 through 1992. Success and failure. *JAMA*, *273*(22), 1778–1780.

Stancin, T., Wade, S. L., Walz, N. C., Yeates, K. O., & Taylor, H. G. (2008). Traumatic brain injuries in early childhood: initial impact on the family. *Journal of Developmental and Behavioral Pediatrics: JDBP*, *29*(4), 253–261. https://doi.org/10.1097/DBP.0b013e31816b6b0f

StataCorp LP. (2012). Stata: Data Analysis and Statistical Software. Retrieved November 5, 2012, from http://stata.com/

Statistics Finland. (2017). Official Statistics of Finland (OSF): Employment [e-publication]. Retrieved December 26, 2017, from http://www.stat.fi/til/tyokay/kas_en.html

Steinberg, L., & Silverberg, S. B. (1986). The vicissitudes of autonomy in early adolescence. *Child Development*, *57*(4), 841–851. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/3757604

Strouse, P. J. (2018). Shaken baby syndrome is real. *Pediatric Radiology*, *48*(8), 1043–1047. https://doi.org/10.1007/s00247-018-4158-0

Suomen Fysiatriyhdistys. (2003). Aikuisiän aivovammojen käypä suositus (Adult Traumatic Brain Injury Guideline), Suomen Neurologinen Yhdistys, Suomen Vakuutuslääkärien yhdistys ja Suomen Neuropsykologinen yhdistys. *Duodecim*, *7*, 654–681.

Taylor, H. G., Orchinik, L. J., Minich, N., Dietrich, A., Nuss, K., Wright, M., … Yeates, K. O. (2015). Symptoms of Persistent Behavior Problems in Children With Mild Traumatic Brain Injury. *The Journal of Head Trauma Rehabilitation*, *30*(5), 302–310. https://doi.org/10.1097/HTR.0000000000000106

Teasdale, G., & Jennett, B. (1974). Assessment of coma and impaired consciousness: A Practical

Scale. *The Lancet*, *304*(7872), 81–84. https://doi.org/10.1016/S0140-6736(74)91639-0

Thompson, H. J., Weir, S., Rivara, F. P., Wang, J., Sullivan, S. D., Salkever, D., & MacKenzie, E. J. (2012). Utilization and costs of health care after geriatric traumatic brain injury. *Journal of Neurotrauma*, *29*(10), 1864–1871. https://doi.org/10.1089/neu.2011.2284

Timonen, M., Miettunen, J., Hakko, H., Zitting, P., Veijola, J., Wendt, L. von, & Räsänen, P. (2002). The association of preceding traumatic brain injury with mental disorders, alcoholism and criminality: the Northern Finland 1966 Birth Cohort Study. *Psychiatry Research*, *113*(3), 217–226. https://doi.org/10.1016/S0165-1781(02)00269-X

Ulm, K. (1990). A simple method to calculate the confidence interval of a standardized mortality ratio (SMR). *American Journal of Epidemiology*, *131*(2), 373–375.

Valent, F., Little, D., Bertollini, R., Nemer, L. E., Barbone, F., & Tamburlini, G. (2004). Burden of disease attributable to selected environmental factors and injury among children and adolescents in Europe. *The Lancet*, *363*(9426), 2032–2039. https://doi.org/10.1016/S0140-6736(04)16452-0

Villalba-Cota, J., Trujillo-Hernández, B., Vásquez, C., Coll-Cárdenas, R., & Torres-Ornelas, P. (2004). Causes of accidents in children aged 0-14 years and risk factors related to the family environment. *Annals of Tropical Paediatrics*, *24*(1), 53–57. https://doi.org/10.1179/027249304225013259

Vos, P. E., Battistin, L., Birbamer, G., Gerstenbrand, F., Potapov, A., Prevec, T., … Wild, K. von. (2002). EFNS guideline on mild traumatic brain injury: report of an EFNS task force. *European Journal of Neurology*, *9*(3), 207–219. https://doi.org/10.1046/j.1468-1331.2002.00407.x

Wan, J. J., Morabito, D. J., Khaw, L., Knudson, M. M., & Dicker, R. A. (2006). Mental Illness as an Independent Risk Factor for Unintentional Injury and Injury Recidivism. *Journal of Trauma and Acute Care Surgery*, *61*(6), 1299. https://doi.org/10.1097/01.ta.0000240460.35245.1a

Wickström, M., Höglund, B., Larsson, M., & Lundgren, M. (2017). Increased risk for mental illness, injuries, and violence in children born to mothers with intellectual disability: A register study in Sweden during 1999-2012. *Child Abuse & Neglect*, *65*, 124–131. https://doi.org/10.1016/j.chiabu.2017.01.003

Widom, C. S., & Hiller-Sturmhöfel, S. (2001). Alcohol abuse as a risk factor for and consequence of child abuse. *Alcohol Research & Health: The Journal of the National Institute on Alcohol Abuse and Alcoholism*, *25*(1), 52–57.

Willgoss, T. G., Yohannes, A. M., & Mitchell, D. (2010). Review of risk factors and preventative strategies for fall-related injuries in people with intellectual disabilities. *Journal of Clinical Nursing*, *19*(15-16), 2100–2109. https://doi.org/10.1111/j.1365-2702.2009.03174.x

Wilson, M. L. (2012). Child and adolescent injury in Africa - still underappreciated and understudied. *Tanzania Journal of Health Research*, *14*(3). http://dx.doi.org/10.4314/thrb.v14i3.1

Wilson, M. L., Hasselberg, M., Kigwangalla, H. A., Boursiquot, B. L., & Laflamme, L. (2012). The association between family health status and child injury in a sample of African children. *International Journal of Injury Control and Safety Promotion*. https://doi.org/10.1080/17457300.2011.648674

Winqvist, S., Jokelainen, J., Luukinen, H., & Hillbom, M. (2007). Parental alcohol misuse is a powerful predictor for the risk of traumatic brain injury in childhood. *Brain Injury: [BI]*, *21*(10), 1079–1085. https://doi.org/10.1080/02699050701553221

Yamaoka, Y., Fujiwara, T., & Tamiya, N. (2016). Association Between Maternal Postpartum Depression and Unintentional Injury Among 4-Month-Old Infants in Japan. *Maternal and Child Health Journal*, *20*(2), 326–336. https://doi.org/10.1007/s10995-015-1832-9

Z Brown, M., Comtois, K., & Linehan, M. (2002). Reasons for suicide attempts and non suicidal self-injury in women with Borderline Personality Disorder. *Journal of Abnormal Psychology*, *111*, 198–202. https://doi.org/10.1037/0021-843X.111.1.198

APPENDICES

Appendix 1: Results of the quality assessment for the included manuscripts in Study I

Study	Selection Bias	Study Design	Confounders	Blinding	Data Collection Methods	With-drawals and Drop-outs	Global Score
Kirk et al., 2008	Mod	Weak	Weak	Moderate	Strong	Strong	Moderate
Levin et al., 2008	Mod	Weak	n/a	Moderate	Strong	Mod	Moderate
Sesma et al., 2008	Mod	Weak	Strong	Moderate	Strong	Strong	Mod-Strong
Ayr et al., 2009	Weak	Weak	n/a	Moderate	Strong	Mod	Mod-Weak
Hanten et al., 2009	Weak	Weak	Strong	Moderate	Strong	Weak	Mod-Weak
Maillard-Wermelinger et al., 2009	Strong	Moderate	Strong	Moderate	Strong	Strong	Mod-Strong
McKinlay et al., 2009	Moderate	Moderate	Strong	Moderate	Strong	Weak	Mod-Strong
Moran et al., 2009	Weak	Weak	n/a	Moderate	Strong	Weak	Mod-Weak
Nance et al., 2009	Moderate	Weak	n/a	Moderate	Strong	Weak	Mod-Weak
Yeates et al., 2009	Moderate	Moderate	Strong	Moderate	Strong	Strong	Mod-Strong
Aitken et al., 2009	Moderate	Weak	n/a	Moderate	Strong	Strong	Mod-Strong
Anderson et al., 2009	Moderate	Weak	Strong	Moderate	Strong	Strong	Mod-Strong
Barlow et al., 2010	Moderate	Moderate	Strong	Moderate	Strong	Mod	Mod-Strong
Fay et al., 2010	Moderate	Weak	Strong	Moderate	Strong	Strong	Mod-Strong
Gerrard-Morris et al., 2010	Moderate	Weak	Strong	Moderate	Strong	Strong	Mod-Strong
Hajek et al., 2010	Moderate	Weak	Strong	Moderate	Strong	Strong	Mod-Strong
McKinlay et al., 2010	Moderate	Weak	Strong	Moderate	Strong	Strong	Mod-Strong
Taylor et al., 2010	Weak	Weak	Strong	Moderate	Strong	Moderate	Moderate
Rockhill et al., 2010	Moderate	Moderate	Strong	Moderate	Strong	Strong	Mod-Strong
Babikian et al., 2011	Moderate	Weak	Strong	Moderate	Strong	Moderate	Mod-Strong
Hajek et al., 2011	Weak	Weak	Strong	Moderate	Strong	Moderate	Moderate
Max et al., 2011	Moderate	Weak	n/a	Moderate	Strong	Moderate	Moderate
Rivara et al., 2011	Moderate	Moderate	Strong	Moderate	Strong	Strong	Mod-Strong
Woodrome et al., 2011	Weak	Weak	Strong	Moderate	Strong	Strong	Mod-Strong
Thomas et al., 2011	Moderate	Moderate	n/a	Moderate	Strong	Strong	Mod-Strong

Study	Selection Bias	Study Design	Confounders	Blinding	Data Collection Methods	With-drawals and Drop-outs	Global Score
Anderson et al., 2012	Weak	Weak	Strong	Moderate	Strong	Strong	Mod-Strong
Crowe et al., 2012	Moderate	Weak	Strong	Moderate	Strong	Strong	Mod-Strong
Kenardu et al., 2012	Weak	Weak	Strong	Weak	Strong	Strong	Moderate
Max et al., 2012	Moderate	Weak	Weak	Moderate	Strong	Strong	Moderate
Moran et al., 2012	Weak	Weak	Strong	Moderate	Strong	Moderate	Moderate
O'Connor et al., 2012	Moderate	Moderate	Strong	Moderate	Strong	Weak	Mod-Strong
Rivara et al., 2012	Moderate	Weak	Strong	Moderate	Strong	Moderate	Mod-Strong
Rivara et al., 2012	Moderate	Moderate	Strong	Moderate	Strong	Moderate	Mod-Strong
Yeates et al., 2012	Weak	Weak	Strong	Moderate	Strong	Moderate	Moderate
Yeates et al., 2012	Weak	Moderate	Strong	Moderate	Strong	Moderate	Mod-Strong
Babikian et al., 2012	Moderate	Weak	Strong	Moderate	Strong	Moderate	Mod-Strong
Tham et al., 2012	Moderate	Moderate	Strong	Moderate	Strong	Moderate	Mod-Strong
Babcock et al., 2013	Moderate	Weak	n/a	Moderate	Strong	Moderate	Moderate
Olsson et al., 2013	Moderate	Weak	Strong	Moderate	Strong	Strong	Mod-Strong
Ornstein et al., 2013	Moderate	Weak	Strong	Moderate	Strong	Weak	Moderate

Appendix 2: Sample size comparison of included articles in Study I

Number	Author	Title	Year	Sample size
63	C. N. Kirk, G.; Abu-Arafeh, I.	Chronic post-traumatic headache after head injury in children and adolescents	2008	93 children with minor
66	H. S. H. Levin, G.; Roberson, G.; Li, X.; Ewing-Cobbs, L.; Dennis, M.; Chapman, S.; Max, J. E.; Hunter, J.; Schachar, R.; Luerssen, T. G.; Swank, P.	Prediction of cognitive sequelae based on abnormal computed tomography findings in children following mild traumatic brain injury	2008	80 children
76	H. W. S. Sesma, B. S.; Ding, R.; McCarthy, M. L.; Children's Health After Trauma Study, Group	Executive functioning in the first year after pediatric traumatic brain injury	2008	185 mild out of 330 children
84	L. K. Y. Ayr, K. O.; Taylor, H. G.; Browne, M.	Dimensions of postconcussive symptoms in children with mild traumatic brain injuries	2009	186 children
119	G. L. Hanten, X.; Newsome, M. R.; Swank, P.; Chapman, S. B.; Dennis, M.; Barnes, M.; Ewing-Cobbs, L.; Levin, H. S.	Oral reading and expressive language after childhood traumatic brain injury: Trajectory and correlates of change over time	2009	59 mild out of 135 children
129	A. Y. Maillard-Wermelinger, K. O.; Gerry Taylor, H.; Rusin, J.; Bangert, B.; Dietrich, A.; Nuss, K.; Wright, M.	Mild traumatic brain injury and executive functions in school-aged children	2009	186 Children
132	A. G. McKinlay, R.; Horwood, J.; Fergusson, D.; MacFarlane, M.	Adolescent psychiatric symptoms following preschool childhood mild traumatic brain injury: evidence from a birth cohort	2009	(1) inpatient group (n = 19) comprised children admitted to hospital for MTBI before age 5 years; (2) outpatient group (n = 57), children with any incidence of MTBI before age 5 seen by a general practitioner or at an accident and emergency department and sent home;
133	L. M. T. Moran, H. G.; Ganesalingam, K.; Gastier-Foster, J. M.; Frick, J.; Bangert, B.; Dietrich, A.; Nuss, K. E.; Rusin, J.; Wright, M.; Eates, K. O.	Apolipoprotein E4 as a predictor of outcomes in pediatric mild traumatic brain injury	2009	99 children
135	M. L. P.-W. Nance, A.; Collins, M. W.; Wiebe, D. J.	Neurocognitive evaluation of mild traumatic brain injury in the hospitalized pediatric population	2009	116 children
153	K. O. T. Yeates, H. G.; Rusin, J.; Bangert, B.; Dietrich, A.; Nuss, K.; Wright, M.; Nagin, D. S.; Jones, B. L.	Longitudinal trajectories of postconcussive symptoms in children with mild traumatic brain injuries and their relationship to acute clinical status	2009	186 children
163	M. E. M. Aitken, M. L.; Slomine, B. S.; Ding, R.; Durbin, D. R.; Jaffe, K. M.; Paidas, C. N.; Dorsch, A. M.; Christensen, J. R.; Mackenzie, E. J.; Chat Study Group	Family burden after traumatic brain injury in children	2009	91 mild out of 288 children
167	V. B. Anderson, S.; Newitt, H.; Hoile, H.	Educational, vocational, psychosocial, and quality-of-life outcomes for adult survivors of childhood traumatic brain jnjury	2009	60 mild out of 124 young adults
176	K. M. C. Barlow, S.; Stevenson, A.; Sandhu, S. S.; Belanger, F.; Dewey, D.	Epidemiology of postconcussion syndrome in pediatric mild traumatic brain injury	2010	670 children

Number	Author	Title	Year	Sample size
191	T. B. Y. Fay, K. O.; Taylor, H. G.; Bangert, B.; Dietrich, A.; Nuss, K. E.; Rusin, J.; Wright, M.	Cognitive reserve as a moderator of postconcussive symptoms in children with complicated and uncomplicated mild traumatic brain injury	2010	182 children
199	A. T. Gerrard-Morris, H. G.; Yeates, K. O.; Walz, N. C.; Stancin, T.; Minich, N.; Wade, S. L.	Cognitive development after traumatic brain injury in young children	2010	87 children
201	C. A. Y. Hajek, K. O.; Gerry Taylor, H.; Bangert, B.; Dietrich, A.; Nuss, K. E.; Rusin, J.; Wright, M.	Relationships among post-concussive symptoms and symptoms of PTSD in children following mild traumatic brain injury	2010	186 children
215	A. G. McKinlay, R. C.; Horwood, L. J.; Fergusson, D. M.; MacFarlane, M. R.	Long-term behavioural outcomes of pre-school mild traumatic brain injury	2010	76 children
239	H. G. D. Taylor, A.; Nuss, K.; Wright, M.; Rusin, J.; Bangert, B.; Minich, N.; Yeates, K. O.	Post-concussive symptoms in children with mild traumatic brain injury	2010	186 children
252	C. M. F. Rockhill, J. R.; Fan, M. Y.; Hollingworth, W.; Katon, W. J.	Healthcare costs associated with mild traumatic brain injury and psychological distress in children and adolescents	2010	490 children
258	T. S. Babikian, P.; Zaucha, K.; Light, R.; Lewis, R. S.; Asarnow, R. F.	The UCLA longitudinal study of neurocognitive outcomes following mild pediatric traumatic brain injury	2011	124 children
272	C. A. Y. Hajek, K. O.; Taylor, H. G.; Bangert, B.; Dietrich, A.; Nuss, K. E.; Rusin, J.; Wright, M.	Agreement between parents and children on ratings of post-concussive symptoms following mild traumatic brain injury	2011	186 children
291	J. E. K. Max, E.; Wilde, E. A.; Bigler, E. D.; Levin, H. S.; Schachar, R. J.; Saunders, A.; Ewing-Cobbs, L.; Chapman, S. B.; Dennis, M.; Yang, T. T.	Anxiety disorders in children and adolescents in the first six months after traumatic brain injury	2011	86 mild out of 177 children
302	F. P. K. Rivara, T. D.; Wang, J.; Temkin, N.; Dorsch, A.; Vavilala, M. S.; Durbin, D.; Jaffe, K. M.	Disability 3, 12, and 24 months after traumatic brain injury among children and adolescents	2011	616 mild out of 729 patients
320	S. E. Y. Woodrome, K. O.; Taylor, H. G.; Rusin, J.; Bangert, B.; Dietrich, A.; Nuss, K.; Wright, M.	Coping strategies as a predictor of post-concussive symptoms in children with mild traumatic brain injury versus mild orthopedic injury	2011	167 children
323	D. G. C. Thomas, M. W.; Saladino, R. A.; Frank, V.; Raab, J.; Zuckerbraun, N. S.	Identifying neurocognitive deficits in adolescents following concussion	2011	60 patients
338	V. E. Anderson, S.; Dob, R.; Le Brocque, R.; Iselin, G.; Davern, T. J.; McKinlay, L.; Kenardy, J.	Early attention impairment and recovery profiles after childhood traumatic brain injury	2012	130 mild out of205 children
346	L. M. C. Crowe, C.; Babl, F. E.; Rosenfeld, J. V.; Anderson, V.	Timing of traumatic brain injury in childhood and intellectual outcome	2012	57 mild out of181 children
366	J. L. B. Kenardy, R.; Hendrikz, J.; Iselin, G.; Anderson, V.; McKinlay, L.	Impact of posttraumatic stress disorder and injury severity on recovery in children with traumatic brain injury	2012	94 mild out of 205 children
373	J. E. K. Max, E.; Wilde, E. A.; Bigler, E. D.; Schachar, R. J.; Saunders, A. E.; Ewing-Cobbs, L.; Chapman, S. B.; Dennis, M.; Yang, T. T.; Levin, H. S.	Depression in children and adolescents in the first 6 months after traumatic brain injury	2012	63 mild out of 177 children
380	L. M. T. Moran, H. G.; Rusin, J.; Bangert, B.; Dietrich, A.; Nuss, K. E.; Wright, M.; Minich, N.; Yeates, K. O.	Quality of life in pediatric mild traumatic brain injury and its relationship to postconcussive symptoms	2012	186 children

Number	Author	Title	Year	Sample size
382	S. S. Z. O'Connor, D. F.; Wang, J.; Temkin, N.; Koepsell, T. D.; Jaffe, K. M.; Durbin, D.; Vavilala, M. S.; Dorsch, A.; Rivara, F. P.	Association between posttraumatic stress, depression, and functional impairments in adolescents 24 months after traumatic brain injury	2012	158 mild out of 189 children
389	F. P. K. Rivara, T. D.; Wang, J.; Temkin, N.; Dorsch, A.; Vavilala, M. S.; Durbin, D.; Jaffe, K. M.	Incidence of disability among children 12 months after traumatic brain injury	2012	200? Mild out of 436 children
390	F. P. V. Rivara, M. S.; Durbin, D.; Temkin, N.; Wang, J.; O'Connor, S. S.; Koepsell, T. D.; Dorsch, A.; Jaffe, K. M.	Persistence of disability 24 to 36 months after pediatric traumatic brain injury: A cohort study	2012	513 mild out of 1108 children
399	Yeates	Reliable change in postconcussive symptoms and its functional consequences among children with mild traumatic brain injury	2012	186 children
402	Yeates, K.O., Taylor, H. G., Rusin, J., Bangert, B., Dietrich, A., Nuss, K., Wright, M.	Premorbid child and family functioning as predictors of post-concussive symptoms in children with mild traumatic brain injuries	2012	186 children
418	Babikian, T., McArthur, D., Asarnow, R. F.	Predictors of 1-month and 1-year neurocognitive functioning from the UCLA longitudinal mild, uncomplicated, pediatric traumatic brain injury study	2012	76 children
448	S. W. P. Tham, T. M.; Vavilala, M. S.; Wang, J.; Jaffe, K. M.; Koepsell, T. D.; Dorsch, A.; Temkin, N.; Durbin, D.; Rivara, F. P.	The longitudinal course, risk factors, and impact of sleep disturbances in children with traumatic brain injury	2012	616 mild out of 729 children
465	L. B. Babcock, T.; Wade, S. L.; Ho, M.; Mookerjee, S.; Bazarian, J. J.	Predicting postconcussion syndrome after mild traumatic brain injury in children and adolescents who present to the emergency department	2013	406 children and parents
478	K. A. L. Olsson, O. T.; Lebrocque, R. M.; McKinlay, L.; Anderson, V. A.; Kenardy, J. A.	Predictors of child post-concussion symptoms at 6 and 18 months following mild traumatic brain injury	2013	150 children
479	T. J. M. Ornstein, J. E.; Schachar, R.; Dennis, M.; Barnes, M.; Ewing-Cobbs, L.; Levin, H. S.	Response inhibition in children with and without ADHD after traumatic brain injury	2013	57 mild out of 103 children

Appendix 3: Sample size comparison of excluded articles in Study I

Author	Title	Year	Sample size
A. M. C. Chilosi, P.; Pecini, C.; Brizzolara, D.; Biagi, L.; Montanaro, D.; Tosetti, M.; Cioni, G.	Acquired focal brain lesions in childhood: Effects on development and reorganization of language	2008	Case study
D. L. Boutin, M.; Robert, M.; Vanassing, P.; Ellemberg, D.	Neurophysiological assessment prior to and following sports-related concussion during childhood: a case study	2008	Case study
O. G. Brosseau-Lachaine, I.; Forget, R.; Faubert, J.	Mild traumatic brain injury induces prolonged visual	2008	18 children
C. A. Catroppa, V. A.; Morse, S. A.; Haritou, F.; Rosenfeld, J. V.	Outcome and predictors of functional recovery 5 years	2008	11 children with mild
E. A. Hessen, V.; Nestvold, K.	MMPI-2 profiles 23 years after paediatric mild traumatic brain injury	2008	41 adults with mild TBI as children
F. C. Muscara, C.; Anderson, V.	Social problem-solving skills as a mediator between executive function and long-term social outcome following paediatric traumatic brain injury	2008	27 children with mild
F. C. Muscara, C.; Anderson, V.	The impact of injury severity on executive function 7-10 years following pediatric traumatic brain injury	2008	13 children with mild
T. H. Balaban, N.; Colantonio, A.	The effects of traumatic brain injury during adolescence on career plans and outcomes	2009	24 adolescents with mild
K. v. R. Caeyenberghs, D.; van Aken, K.; De Cock, P.; Linden, C. V.; Swinnen, S. P.; Smits-Engelsman, B. C.	Static and dynamic visuomotor task performance in children with acquired brain injury: predictive control deficits under increased temporal pressure	2009	1 child with mild?
K. v. R. Caeyenberghs, D.; Swinnen, S. P.; Smits-Engelsman, B. C.	Deficits in executed and imagined aiming performance in brain-injured children	2009	1 child with mild?
C. M. Catale, P.; Closset, A.; Meulemans, T.	Attentional and executive functioning following mild traumatic brain injury in children using the Test for Attentional Performance (TAP) battery	2009	15 children with TBI
T. B. Hilger, M.	Late sequelae of minor head injury in children - Is routine follow-up necessary?	2009	46 children with TBI
J. D. Limond, L.; McMillan, T. M.	Quality of life in children with acquired brain injury: Parent perspectives 1-5 years after injury	2009	31 children with mild
S. R. M. McCauley, M. A.; Pedroza, C.; Chapman, S. B.; Levin, H. S.	Incentive Effects on Event-Based Prospective Memory Performance in Children and Adolescents With Traumatic Brain Injury	2009	15 children with mild
F. C. Muscara, C.; Eren, S.; Anderson, V.	The impact of injury severity on long-term social outcome following paediatric traumatic brain injury	2009	27 children with mild
T. J. L. Ornstein, H. S.; Chen, S.; Hanten, G.; Ewing-Cobbs, L.; Dennis, M.; Barnes, M.; Max, J. E.; Logan, G. D.; Schachar, R.	Performance monitoring in children following traumatic brain injury	2009	31 children with mild-mod

Author	Title	Year	Sample size
R. M. Wells, P.; Phillips, M.	Predicting social and functional outcomes for individuals sustaining paediatric traumatic brain injury	2009	17 children with mild
O. E. L. Demir, S. C.; Goldin-Meadow, S.	Narrative skill in children with early unilateral brain injury: a possible limit to functional plasticity	2010	8 children had small and medium lesions
J. J. B. Dooley, M.; Anderson, V. A.	The measurement of sociomoral reasoning in adolescents with traumatic brain injury: A pilot investigation	2010	47 children had uncomplicated mild
J. Kerr	An investigation into the cognitive and neuropsychological sequelae of minor head injury in children - a prospective pilot study	2010	abstract- only included 15 children
N. S. F. Sroufe, D. S.; West, B. T.; Singal, B. M.; Warschausky, S. A.; Maio, R. F.	Postconcussive symptoms and neurocognitive function after mild traumatic brain injury in children	2010	28 children with mild
T. C. W. Wu, E. A.; Bigler, E. D.; Li, X.; Merkley, T. L.; Yallampalli, R.; McCauley, S. R.; Schnelle, K. P.; Vasquez, A. C.; Chu, Z.; Hanten, G.; Hunter, J. V.; Levin, H. S.	Longitudinal Changes in the Corpus Callosum following Pediatric Traumatic Brain Injury	2010	3 children with complicated mild
M. H. D. Beauchamp, M.; Maller, J. J.; Catroppa, C.; Godfrey, C.; Rosenfeld, J. V.; Kean, M. J.; Anderson, V. A.	Hippocampus, amygdala and global brain changes 10 years after childhood traumatic brain injury	2011	11 children with mild
F. M. M. Lewis, B. E.	Language function in a child following mild traumatic brain injury: Evidence from pre- and post-injury language testing	2011	case study with mild
L. J. Porto, A.; Margerkurth, J.; Althaus, J.; Zanella, F.; Hattingen, E.; Kieslich, M.	Morphometry and diffusion MR imaging years after childhood traumatic brain injury	2011	2 children with mild
S. J. C. Tlustos, C. Y. P.; Walz, N. C.; Holland, S. K.; Bernard, L.; Wade, S. L.	Neural correlates of interference control in adolescents with traumatic brain injury: Functional magnetic resonance imaging study of the counting stroop task	2011	8 children had complicated mild
J. Y. Tonks, P.; Frampton, I.; Williams, W. H.; Harris, D.; Slater, A.	Resilience and the mediating effects of executive dysfunction after childhood brain injury: A comparison between children aged 915 years with brain injury and non-injured controls	2011	2 children with mild
D. T. C. Woods, C.; Barnett, P.; Anderson, V. A.	Parental disciplinary practices following acquired brain injury in children	2011	21 children with mild
V. G. Anderson, C.; Rosenfeld, J. V.; Catroppa, C.	Predictors of cognitive function and recovery 10 years after traumatic brain injury in young children	2012	7 children with mild
C. G. Catroppa, C.; Rosenfeld, J. V.; Hearps, S. S. J. C.; Anderson, V. A.	Functional recovery ten years after pediatric traumatic brain injury: Outcomes and predictors	2012	7 children with mild
C. Y. P. T. Chiu, S. J.; Walz, N. C.; Holland, S. K.; Eliassen, J. C.; Bernard, L.; Wade, S. L.	Neural correlates of risky decision making in adolescents with and without traumatic brain injury using the balloon analog risk task	2012	8 children with mild
L. P. Ewing-Cobbs, M. R.; Swank, P.; Kramer, L.; Mendez, D.; Treble, A.; Payne, C.; Bachevalier, J.	Social communication in young children with traumatic brain injury: relations with corpus callosum morphometry	2012	10 children with mild

Author	Title	Year	Sample size
L. G. Green, C.; Soo, C.; Anderson, V.; Catroppa, C.	Agreement between parentadolescent ratings on psychosocial outcome and qualityoflife following childhood traumatic brain injury	2012	2 children with mild
J. E. W. Max, E. A.; Bigler, E. D.; Thompson, W. K.; MacLeod, M.; Vasquez, A. C.; Merkley, T. L.; Hunter, J. V.; Chu, Z. D.; Yallampalli, R.; Hotz, G.; Chapman, S. B.; Yang, T. T.; Levin, H. S.	Neuroimaging correlates of novel psychiatric disorders after pediatric traumatic brain injury	2012	10 children with complicated mild
C. K. Moran, C.; Powell, E.	Spoken persuasive discourse abilities of adolescents with acquired brain injury	2012	3 adolescents with mild?
C. Jourdan, Brugel, D., Hubeaux, K., Toure, H., Laurent-Vannier, A., Chevignard, M.	Weight gain after childhood traumatic brain injury: a matter of concern	2012	14 children with mild-mod
L. M. C. Crowe, C.; Babl, F. E.; Anderson, V.	Executive function outcomes of children with traumatic brain injury sustained before three years	2013	19 with mild
Jonsson, C., Andersson, E.E.	Mild traumatic brain injury: A description of how children and youths between 16 and 18 years of age perform leisure activities after 1 year	2012	35 children with mild

Appendix 4: Methodological Characteristics of Studies of TBI in Children and Adolescents (2008-2013)

Study	Design	Source of Participants	Preinjury Factors	Nonhead injury control group(s)	Follow-up(s)	Type of Assessment	Reported outcome
Kirk et al, 2008	prospective observational study	Stirling Royal Infirmary	Children with an open HI or requiring admission to the neurosurgical department were excluded from the study.	none	telephone call 8 weeks after, 4-monthly intervals for up to 3 years	telephone call with structured questionnaire about headaches	**Adverse** **Neurological:** 7 children had headaches post injury. All except 4 had resolved within 3-27 months. 2 had headaches previous to the injury that had continued and or transformed after head injury.
Levin et al, 2008	prospective longitudinal design	trauma centers at Dallas, Houston, San Diego, and Toronto	Inclusion criteria in our study consisted of a lowest GCS score of 13–15 on examination in the emergency center, a history of an altered or a loss of consciousness not exceeding 30 minutes, closed head trauma as a mechanism, CT scanning data obtained within 24 hours after injury, and an age of 5–15 years. Exclusion criteria included evidence or a history of child abuse; preexisting neurological disorder, autism, or schizophrenia; arrival at the emergency center 24 hours after injury; and a penetrating brain injury.	none	2 weeks, 3, 6, and 12 mo	General Working Memory; CVLT-C; Stop-Signal Reaction Time Task; SCWIT; WISC-III; Grooved Pegboard Test; Woodcock-Johnson III	
Sesma et al, 2008	longitudinal study	Participating hospitals included Johns Hopkins Hospital (Baltimore, MD), Children's Hospital of Philadelphia (Philadelphia, PA), Harborview Medical Center (Seattle, WA), and Arkansas Children's Hospital (Little Rock, AR).	*Inclusion Criteria:* Study participants were children between the ages of 5 and 15 years who sustained a TBI or an orthopedic fracture with an Abbreviated Injury Scale (AIS) severity score of _2 and were hospitalized for at least 1 night at 1 of 4 level I pediatric trauma center hospitals.30 Participating hospitals included Johns Hopkins Hospital (Baltimore, MD), Children's Hospital of Philadelphia (Philadelphia, PA), Harborview Medical Center (Seattle, WA), and Arkansas Children's Hospital (Little Rock, AR). Exclusion Criteria: Potential participants were excluded if the child or his or her parents did not speak English or in cases of suspected child abuse. Children also were excluded if they had a preexisting medical condition that markedly affected their premorbid physical (eg, amputation), psychological (eg, bipolar disorder), or cognitive (eg, mental retardation) functioning. However, children with premorbid learning disabilities or behavioral problems were included to increase the generalizability of the findings and evaluate the role of preinjury risk factors on postinjury executive functioning.	103 orthopedic fracture control group	baseline, 3 mo and 1 year	AIS; BRIEF; GEC	**Adverse** **Cognitive:** 3 months post injury, caregivers reported significantly greater executive dysfunction than controls (0.3 SD). Even greater difference at 12 months post injury. proportion with significant executive dysfunction doubled among the children with a mild TBI by 3 months after injury.

Study	Design	Source of Participants	Preinjury Factors	Nonhead injury control group(s)	Follow-up(s)	Type of Assessment	Reported outcome
Ayr et al, 2009	prospective, longitudinal design	Children were recruited from the Emergency Departments at Nationwide Children's Hospital in Columbus, Ohio and Rainbow Babies and Children's Hospital in Cleveland, Ohio.	Children were excluded if their injury resulted in a loss of consciousness lasting more than 30 min or if they had any Glasgow Coma Scale score less than 13. They were also excluded if they demonstrated any delayed neurological deterioration or had any medical contraindication to magnetic resonance imaging. Children were not excluded if they required hospitalization or demonstrated intracranial lesions or skull fractures on acute computerized tomography. Children also were excluded if they met any of the following general criteria: neurosurgical or surgical intervention; any associated injury with an Abbreviated Injury Scale (AIS; American Association for Automotive Medicine, 1990) score greater than 3; any associated injury that interfered with neuropsychological testing (e.g., fracture of preferred upper extremity); hypoxia, hypotension, or shock during or following the injury; ethanol or drug ingestion involved with the injury; documented history of previous head injury requiring medical treatment; premorbid neurological disorder or mental retardation; any injury determined to be a result of child abuse or assault; or a history of severe psychiatric disorder requiring hospitalization.	none	initial assessment no later than 3 weeks post injury, 1, 3, and 12 mo post injury	HBI	**indeterminate**
Hanten et al, 2009	retrospective cross-sectional study	identified and recruited from a medical records search or from participation in previous studies of childhood TBI	none	none	n/s	GORT-3; CELF-3	**Null** **Educational:** Oral Reading: mild group had better comprehension scores than either mod or severe TBI group. Mild TBI patients had the best performance, but when the index was higher than 50, moderate TBI patients had the best performance. Expressive Language: Mild had the greatest scores and severe had the lowest. Age at injury had the predicted strong effect.

Study	Design	Source of Participants	Preinjury Factors	Nonhead injury control group(s)	Follow-up(s)	Type of Assessment	Reported outcome
Maillard-Wermelinger et al, 2009	concurrent cohort, prospective, longitudinal study	Emergency Departments at Nationwide Children's Hospital in Columbus, Ohio and Rainbow Babies and Children's Hospital in Cleveland, Ohio.	Exclusion criteria for the mild TBI group included a LOC lasting more than 30 minutes, any GCS score of less than 13, any delayed neurological deterioration, or any medical contraindication to MRI. Children were not required to have undergone a CT scan to be eligible to participate. Children who had an acute CT scan were not excluded from the study if they demonstrated intracranial lesions or skull fractures, as long as they did not require surgical intervention. Children were eligible for the OI group if they sustained upper or lower extremity fracture associated with an Abbreviated Injury Scale (AIS; American Association for Automotive Medicine, 1990) score of 3 or less. They were excluded if they displayed any evidence of head trauma or symptoms of concussion. Exclusionary criteria for both groups were as follows: neurosurgical or surgical intervention following injury; any associated injury with an AIS score greater than 3; any associated injury that interfered with neuropsychological testing (e.g., fracture of preferred upper extremity); hypoxia, hypotension, or shock during or following the injury; ethanol or drug ingestion involved with the injury; previous head injury requiring medical treatment; premorbid neurological disorder or mental retardation; any injury determined to be a result of child abuse or assault; or a history of severe psychiatric disorder requiring inpatient hospitalization.	99 OI controls	baseline no later than 3 week post injury, 3 and 12 mo post injury	WASI; Spatial Working Memory and Stockings of Cambridge; BRIEF	**Null** **Educational:** The current findings do not indicate significant executive dysfunction, either cognitively or behaviorally, during the first year following mild TBI in school-aged children. The OI group made more errors on the Spatial Working Memory subtest than the mild TBI group, $F(1,246) = 6.68$, $p < .05$, $\eta 2 = .03$. Both groups showed significant improvements in performance over time, as reflected in a significant main effect of assessment occasion, $F(2,245) = 11.51$, $p < .001$, $\eta 2 = .09$.
McKinlay et al, 2009	longitudinal birth cohort	CHDS	Nonspecific head injury by itself was insufficient for inclusion in the MTBI groups. Children were excluded from any group if there was evidence of a moderate or severe head injury.	839 control group	birth, 4 mo, and annual intervals to the age of 16 years	DSM-III-R Classification of ADHD, CD/ODD, anxiety disorder, mood disorder, and alcohol or illicit substance abuse/dependence using a combination of mother and self-report scales. Self-Report Early Delinquency scale	**Adverse** **Psychological:** Inpatient MTBI status clearly increased the likelihood of ADHD, CD/ODD, alcohol or illicit substance abuse/dependence, and mood. The higher OR for the inpatient group compared with other children for CD/ODD and alcohol or illicit substance abuse/dependence remained significant when adjusted for covariates, with ORs for ADHD just failing to reach significance ($P < .053$). **Null** **Psychological:** outpatient mTBI patients didn't differ from Control group with reference to DSM-III-R disorders

Study	Design	Source of Participants	Preinjury Factors	Nonhead injury control group(s)	Follow-up(s)	Type of Assessment	Reported outcome
Moran et al, 2009	prospective, longitudinal design	Emergency Departments at Nationwide Children's Hospital in Columbus, Ohio, and Rainbow Babies and Children's Hospital in Cleveland, Ohio.	Children were not eligible if they demonstrated a LOC lasting more than 30 min, any GCS score of less than 13, any delayed neurological deterioration (i.e., a decline in GCS below 13 following admission or any emergent neurosurgical intervention), or any medical contraindication to magnetic resonance imaging (MRI). Other exclusion criteria included any associated injury with an Abbreviated Injury Severity (AIS) (American Association for Automotive Medicine, 1990) score greater than 3; any surgical interventions; previous head injury requiring medical treatment; history of severe psychiatric illness resulting in hospitalization; premorbid neurological disorders or mental retardation; hypoxia, hypertension, or shock during or following the injury; injury resulting from child abuse or assault; or injuries that would interfere with neuropsychological testing (e.g., fracture of preferred upper extremity).	none	2 weeks, 3 months, and 12 months post injury	APOE genotyping; PCR; CVLT-C; VMI; CANTAB: WASI; WRAT-3; PCS; HBI	Null Participants with an e4 allele exhibited consistently better performance on the VMI across time than children without the allele, F(1,95)¼6.2, p<0.02, Z2¼0.06. the allele may serve a protective function during neurodevelopment. However, our findings of a positive effect are limited to only one cognitive outcome measure, and hence may not be robust.
Nance et al, 2009	prospective longitudinal design	level 1 Urban Pediatric Trauma Center	Patients with penetrating injuries, those treated and released from the emergency room, Spanish speaking only, and patients with associated injuries that limited their ability to take the computer-based test (eg, upper extremity injury) were excluded	none	2-3 weeks f-u	ImPACT	**Adverse** **Cognition:** Neurocognitive deficits in the cohort with follow-up testing were also common. The mean percentiles were below 50% (the normative value) for all subtests for the population as a whole. 93.7% of tested subjects scored below the 25th percentile on at least one subtest including 27.0% that scored below the 25th percentile for all subtests administered. The mean symptom score recorded for the population was 26.9 (range, 1–98; normal, 0–8). An abnormal symptom score (score 8) was noted in 87.3% of subjects at the time of inpatient testing.

Study	Design	Source of Participants	Preinjury Factors	Nonhead injury control group(s)	Follow-up(s)	Type of Assessment	Reported outcome
Yeates et al, 2009	longitudinal, cohort study	emergency departments at Nationwide Children's Hospital and Rainbow Babies & Children's Hospital.	Exclusion criteria for the mild TBI group included any GCS score below 13, delayed neurologic deterioration, or any medical contraindication to MRI. Children were not excluded if they were hospitalized or demonstrated intracranial lesions or skull fractures on acute computed tomography. Thus, the mild TBI group included injuries often described as complicated (eg, those with intracranial abnormalities) but excluded injuries that would typically be defined as moderate in severity. Both groups were subject to multiple exclusion criteria: neurosurgical or surgical intervention; any associated injury with an AIS score of 3; any associated injury that interfered with neuropsychological testing; hypoxia, hypotension, or shock; ethanol or drug ingestion involved with the injury; previous head injury requiring medical treatment; premorbid neurologic disorder or mental retardation; any injury resulting from child abuse or assault; or premorbid severe psychiatric disorder requiring hospitalization. Children were not excluded for premorbid learning difficulties or attention problems.	99 OI controls	3 weeks, 1, 3, and 12 months	Postconcussive Symptom Interview	**Adverse** **Psychological:** children with mild TBI were more likely to belong to the high acute/resolved PCS group and the high acute/persistent PCS group than children with OI. The mild TBI and OI groups did not differ significantly in membership in the moderate persistent PCS group. Both mild TBI severity groups were more likely than the OI group to belong to the high acute/resolved or high acute/persistent PCS groups (33% of high severity group, 18% of low severity group, 6% of OI group).
Aitken et al, 2009	n/s	4 pediatric trauma centers	Children were excluded if they or their parents were non–English-speaking; they had a preexisting medical condition that seriously impacted preinjury function; or they were a suspected child abuse case.	none	3 week, 3 and 12 month post injury	EIS of Child Health Questionnaire; PedsQL; AIS	**Adverse** **Cognition:** 24% of caregivers for children with mild TBI said the TBI interferes with the childs routine/concentration and 54% still had a general worry about thir condition 3 months after the injury
Anderson et al, 2009	retrospective cross-sectional	neurosurgical ward at the Royal Children's Hospital, Melbourne, Australia	Inclusion criteria were (i) aged between 0 and 16 at the time of TBI; (ii) a diagnosis of TBI; (iii) medical records sufficient to determine injury severity; (iv) aged 18 to 30 years at the time of assessment; (v) no preinjury history of neurological, developmental, or psychiatric disorder, based on parent interview and/or medical record audit; (vi) accidental injury; and (vii) English speaking.	none	n/s	SPRS; 30-item participant questionnaire;	**Null** **Cognition:** 82.5% had no psychosocial problems followed by adjustment problems (12.5%) in 2 years post-TBI. Same as over the last 5 years. QoL: 65.0 total score. Less than moderate but more than severe. **Adverse** **Educational:** 48.3% had study problems post injury and 20.0% had problems in the last 5 years. More than mod but less than serve. The majority completed high school only. **Employment:** 28.3% currently unemployed. More than mod but less than severe.

Study	Design	Source of Participants	Preinjury Factors	Nonhead injury control group(s)	Follow-up(s)	Type of Assessment	Reported outcome
Barlow et al, 2010	prospective, consecutive controlled-cohort study	tertiary referral emergency department	Children with simple scalp lacerations, facial injuries/fractures, or superficial injuries who did not display neurobehavioral change were excluded. mTBI children who had any ECI were also excluded.	197 ECI controls	7-10 days post injury	PCSI; RPQ; GFS; FAD; BSI	**Adverse** **Cognition:** the probability of a child in the mTBI group remaining symptomatic was significantly higher than for a child in the ECI group. In the first month after injury, 58.5% of children with mTBI were symptomatic. If a child with mTBI was symptomatic at 100 days, for example, the child would have a 40% likelihood of remaining symptomatic compared with a 15% likelihood for a child with ECI. The most common symptoms that had increased from before injury to 1 month after injury were "fatigue" (79%), "more emotional" (60%), "irritability" (58%), and head- aches (58%). 9% of all children with mTBI (n=60) had PCS 3 months after injury. asymptomatic mTBI group was younger than the symptomatic mTBI group (P <.05). Children older than 6 years were also more likely to remain symptomatic than younger children. Fifteen children with mTBI (2.3%) remained symptomatic for longer than 12 months.
Fay et al, 2010	prospective, longitudinal study	Emergency Departments of Nationwide Children's Hospital in Columbus, Ohio and Rainbow Babies and Children's Hospital in Cleveland, Ohio	Children were excluded from the mild TBI group if they displayed delayed neurological deterioration, but not if they required hospitalization or demonstrated intracranial lesions or skull fractures on acute computerized tomography. Additional exclusion criteria for children in both groups included: (a) any injury that required surgical or neurosurgical intervention; (b) any associated injury with an AIS score greater than 3; (c) any injury that interfered with neuropsychological testing (e.g., fracture of preferred upper extremity); (d) hypoxia, hypotension, or shock associated with the injury; (e) ethanol or drug ingestion involved with the injury; (f) documented history of previous head trauma requiring medical treatment; (g) premorbid neurological disorder or mental retardation; (h) any injury resulting from child abuse or assault; (i) history of severe psychiatric disorder requiring hospitalization; or (j) any medical contraindication to MRI. Children were not excluded for premorbid learning difficulties or attention problems	99 OI control	3 weeks, 1, 3, and 12, months post injury	WASI; WRAT-3; CVLT-C; VMI; CANTAB; PCS-I; HBI; DSM-IV	**Adverse** **Cognition:** The complicated mild TBI group demonstrated higher total scores on the PCS-I than the OI group at 3 months post injury. In addition, children with lower cognitive ability had higher total scores at 3 months. The uncomplicated mild TBI group showed a more rapid rate of decline in the total score at 3 months post injury compared to the OI group. mild TBI are more likely to result in PCS, relative to OI, among children of lower cognitive ability than among children of higher cognitive ability. children with low cognitive ability and a complicated mild TBI endorsed the most symptoms at baseline relative to all other groups, but then showed a rapid linear decrease in symptoms to 3 months post injury. Parent ratings of cognitive symptoms on the HBI demonstrated a more pronounced pattern of increased vulnerability to mild TBI among children with low cognitive ability. More specifically, children with low cognitive ability and complicated mild TBI showed significant increases in cognitive symptoms to 3 months post injury, and the largest group differences relative to children with OI were apparent for children of low cognitive ability with complicated mild TBI. **Null** **Cognitive:** In contrast, children with complicated mild TBI but high cognitive ability endorsed relatively few symptoms across time.

Study	Design	Source of Participants	Preinjury Factors	Nonhead injury control group(s)	Follow-up(s)	Type of Assessment	Reported outcome
Gerrard-Morris et al, 2010	n/s	Three tertiary care children's hospitals and a general hospital, all with Level 1 trauma centers.	Children were excluded from the study if English was not the primary language spoken in the home or if they had histories of child abuse, autism, mental retardation, or a neurological disorder.	117 OI controls	baseline, 6, 12, and 18 months post-injury	HOME; DAS GCA; CASL; NEPSY; WJ-III; SS	**Null** **Cognitive:** effect sizes were small for complicated mild vs OI controls (.38 for Recall of digits and .46 for Sentence Repetition). Everything else was only significant for mod or severe TBI
Hajek et al, 2010	longitudinal study	Emergency Departments at Nationwide Children's Hospital (Columbus, OH) and Rainbow Babies and Children's Hospital (Cleveland, OH).	General exclusion criteria for both groups included: injury-related surgery; hypoxia or shock following the injury; previous head injury requiring hospitalization; pre-morbid neurological disorders; severe psychiatric disorder requiring hospitalization; associated injuries with an Abbreviated Injury Scale [26] greater than 3; injuries that would hinder neuropsychological assessment; and injuries related to child abuse or drug/alcohol use. A history of previous traumatic events was not an exclusion criterion	99 OI controls	3 weeks, 1, 3, and 12 months post injury	HBI; PCS-I; PTSD for the PCL-C/PR	**Adverse** **Cognitive:** cognitive PCS- children in the mild TBI group demonstrating higher symptom levels than children in the OI group at all 3 assessments. the mild TBI group was slightly but significantly elevated for hyperarousal (PTSD) compared to the OI group at 12 months. The mild TBI group continued to demonstrate higher total scores on the PCS-I after controlling for baseline symptoms of PTSD. The mild TBI group also showed higher scores on the HBI cognitive sub-scale at all three occasions after controlling for baseline symptoms of PTSD, but the difference decreased rapidly over time. **Null** **Cognitive**: both groups showed a similar decreasing trend over time, but the decline was faster in the mild TBI group. children with mild TBI displayed higher levels of somatic PCS at baseline, but group differences were not apparent by 12 months. the proportion of children meeting symptom criteria for PTSD was significantly higher in the OI group than in the mild TBI group at 12 months post-injury, but not prior to that.
McKinlay et al, 2010	prospective longitudinal study	CHDS	Children were excluded from any group if there was evidence of a moderate or severe head injury (no child met this criterion). Children who had no history of brain injury, or only non-specific injury to the head and no medical diagnosis of concussion, were assigned to a general reference group (*n* = 826–864).	852 controls	n/s	ADHD and ODD/CD	**Adverse** **Psychosocial:** more severe instances of MTBI in preschool childhood are likely to produce long-term, adverse behavioural developmental outcomes. Increased symptoms of ADHD and ODD/CD were evident in the inpatient MTBI group when compared with the outpatient MTBI and reference groups. **Null** **Psychosocial:** children in the outpatient group were comparable with the reference group on these psychosocial measures. early age at injury and severity as two important issues when examining outcomes associated with MTBI. combination of age and severity poses the greatest risk

Study	Design	Source of Participants	Preinjury Factors	Nonhead injury control group(s)	Follow-up(s)	Type of Assessment	Reported outcome
Taylor et al, 2010	n/s	two children's hospitals in Ohio, Nationwide Children's Hospital in Columbus and Rainbow Babies and Children's Hospital in Cleveland	Children with mTBI were excluded if they had a LOC >30 minutes, a GCS score of less than 13, delayed neurological deterioration, or any medical contraindication to magnetic resonance imaging (MRI). Potential participants were not excluded if they required hospitalization or demonstrated intracranial lesions or skull fractures on acute computerized tomography (CT) scans. Criteria for exclusion from both groups included neurosurgical or surgical intervention; an injury that would interfere with neuropsychological testing (e.g., fracture of preferred upper extremity); hypoxia, hypotension, or shock during or following the injury; ethanol or drug ingestion involved with the injury; documented history of previous head injury requiring medical treatment; premorbid neurological disorder or mental retardation; injury determined to be the result of child abuse or assault; or a history of severe psychiatric disorder requiring hospitalization.	99 OI controls	3 weeks, 1, 3, and 12 months post injury	HBI; PCS;	**Adverse** **Cognitive:** ratings of somatic PCS were higher in the mTBI group than in the OI group at baseline and 1 month, but not at 3 months or 12 months. **Null** **Cognitive:** Decreases in ratings over follow-up were significant for the mTBI group only. Self-ratings of somatic PCS decreased significantly for the mTBI group from baseline to 1 month and from 1 month to 3 months, but did not vary significantly over follow-up for the OI group.
Rockhill et al, 2010	prospective cohort study	Group Health providers	mild TBI	1470 matched controls	3 year FU	Costs were determined using the HMOs automated cost accounting system. These included outpatient services for general medical or mental healthcare, inpatient medical and mental health services, emergency visits, pharmacy costs, laboratory and radiology costs and other healthcare services paid for by GHC.	**Adverse** Psychological**:** mild TBI exposure and psychological distress were associated with higher total healthcare costs in the 3-year period following a mild TBI in children under 15 years. The mean cost of all 489 TBI-exposed patients is around 75% greater than the mean for the 1470 TBI-unexposed controls. The mean cost for the 403 patients with psychological distress in the 3 years of the study was 2.8-times the mean for the 1556 subjects without psychological distress ($5037 vs $1816). Increased cost in TBI-exposed subjects was most likely to occur in the first 6–12 months after the TBI reference date.

Study	Design	Source of Participants	Preinjury Factors	Nonhead injury control group(s)	Follow-up(s)	Type of Assessment	Reported outcome
Babikian et al, 2011	longitudinal study	14 emergency rooms in Los Angeles, Riverside, and Orange Counties	Inclusion criteria for the head injury group consisted of the following: (1) concussion resulting in an Abbreviated Injury Scale (AIS) score of 1 or 2; (2) no injuries above AIS level 2 at any anatomic location; (3) injury from unintentional external causes; (4) no litigation related to injury; (5) no serious injury or death of others involved in the index accident; (6) treated at 1 of 14 emergency rooms located in one of three counties within the greater Los Angeles area; (7) aged 8–17 years at the time of injury; (8) no significant preexisting central nervous system damage or serious chronic diseases (e.g., cancer, congenital malformation); (9) availability of parent/guardian consent; and (10) child residing with parent/guardian.	94 other injury; 106 non injury	1, 6, 12 months post injury	Prospective Memory Test; Pitcure Memory Test; Word List Memory est; Symbol Digit Modalities; color Trails-Part B; Pin Test; Span of Apprehension Test; Stroop Test; DSCPT; Peabody Picture Vocabulary Test	**Adverse** **Cognitive:** Both the TBI and the other injury groups scored more poorly than the non-injured control group on the Prospective Memory and the List Learning tests, while only the TBI group performed more poorly than the non-injured control group on the Picture Memory test. Effect sizes suggested that the group differences for the Picture Memory and List Learning tasks were relatively small, but the effect size for the difference between the TBI and non-injured control group on the Prospective Memory test approached a moderate level (Hedge's g5.434). Both the TBI and the other injury groups performed more poorly than the non-injured control group on the Symbol Digit Modalities and Color Trails tests. Of note, effect sizes associated with these group differences were relatively small. Both the TBI and other injury groups performed more poorly than the non-injured control group on the PPVT-R. Almost a third of both the TBI (29%) and the other injury (32%) groups scored 1.5 standard deviations or more below the mean of the non-injured control group at 12 months post injury on at least 3 of the 10 measures (statistically significant). **Null** **Cognitive**: The TBI group performed slightly better than the other injury group on the Span Test, with a relatively small associated effect size.
Hajek et al, 2011	prospective, longitudinal study	Nationwide Children's Hospital in Columbus, Ohio and Rainbow Babies and Children's Hospital in Cleveland, Ohio	Children were excluded from the mild TBI group if they experienced a loss of consciousness over 30 minutes, hypoxia or shock in association with the injury, or received any GCS score below 13. Children were not excluded if they were hospitalized or demonstrated intracranial lesions or skull fractures on acute computerized tomography. Thus, the mild TBI group included injuries often described as "complicated" (e.g., those with intracranial abnormalities) but excluded injuries that would typically be defined as moderate in severity. Exclusion criteria for both groups included injury-related surgery; any previous head injury requiring hospitalization; premorbid neurological disorders or severe psychiatric disorders requiring hospitalization; any other injuries with an AIS greater than 3; injuries that would hinder neuropsychological assessment; and injuries related to child abuse or drug or alcohol use. Children were not excluded for premorbid learning difficulties or attention problems.	99 OI controls	3 weeks, 1, 3, and 12 months	HBI; PCS-I	**Adverse** **Psychological:** Mild TBI: headaches (M=.72), tired a lot (0.62), trouble remembering things (0.43); 1 month: headaches (M=.44), tired a lot (0.40), cranky or irritably (0.39); 3 month: headaches (M=.42), tired a lot (0.40), cranky or irritably (0.39). OI: tired a lot (.47), feel nervous or scared (.46), cranky or irritably (.43); 1 month: feel nervous or scared (.32), trouble sleeping (.32), cranky or irritably (.31); 3 month: cranky or irritably (.39), tired a lot (.39), trouble remembering things (.32)

Study	Design	Source of Participants	Preinjury Factors	Nonhead injury control group(s)	Follow-up(s)	Type of Assessment	Reported outcome
Lepach et al, 2011							
Max et al, 2011	prospective, longitudinal study	Three academic medical centers in Texas; Rady Children's Hospital in San Diego, CA; and The Hospital for Sick Children in Toronto, Canada.	Exclusion criteria included preexisting autistic disorder or schizophrenia, mental deficiency, and injury due to child abuse or penetrating-missile injury. In San Diego, CA, only, children were excluded if they had preexisting attention-deficit/hyperactivity disorder.	none	6 month post injury	SADS-PL; NPRS; VABS; FADGFS; FHRDC; FFI; MRI; GCS	**Adverse** **Psychological:** Of those with mild TBI, 8/70 (11%) developed a definite anxiety disorder, and 14/70 (20%) developed a definite/subclinical anxiety disorder. There were no significant associations with other psychiatric disorders (personality change due to TBI, pre-injury anxiety disorder).
Rivara et al, 2011	prospective cohort study	hospitals in King County, Washington	n/s	197 arm injury patients	baseline, 3, 12, and 24 months	PedsQL	**Adverse** **Psychological:** Children in the mild III group had lower scores at 3 months than those in the other 2 mild TBI groups. **Null** **Cognitive:** Children in the mild III TBI group also had lower communication skills at 3 months, but these differences diminished and were not significant by 12 months after injury. The small differences in self-care among those in the mild TBI I group were not significant after considering the changes in the controls with arm injury. Among children in the mild TBI I group, quality-of-life scores were lower at all follow-up times and were statistically, but not clinically, significant at the 12- and 24-month follow-up times. By 12 months, those in the mild III TBI group had scores that were not significantly different from those at baseline. The changes from baseline in the PedsQL scores in the other mild TBI groups were small and not significant after adjusting for the changes in the controls with arm injury.
Woodrome et al, 2011	prospective, longitudinal study	emergency departments at Nationwide Children's Hospital in Columbus, Ohio, and Rainbow Babies and Children's Hospital in Cleveland, Ohio	Children were not excluded if they demonstrated intracranial lesions or skull fractures on acute computerized tomography or if they were hospitalized; however, they were excluded if they displayed any neurological deterioration (i.e., any GCS score below 13) or had any medical contraindication to magnetic resonance imaging. Exclusion criteria for both groups included any surgical intervention; any associated injury resulting in an AIS score greater than 3; any associated injury likely to interfere with neuropsychological testing (e.g., fracture of preferred upper extremity); hypoxia, hypotension, or shock during or following the injury; alcohol or drug ingestion associated with the injury; a documented history of previous TBI requiring medical treatment; a premorbid neurological disorder or mental retardation; a history of severe psychiatric disorder requiring hospitalization; or a determination that the injury was the result of child abuse or assault.	84 OI controls	2 weeks, 1, 3, 12 months post injury	CSI; HBI; PCS-I	**Adverse** **Cognitive**: self-reports of problem focused disengagement were associated with more symptoms in the mild TBI group; contrary to expectations, however, problem-focused disengagement predicted fewer self reported symptoms in the OI group. Thus, a preference for problem-focused disengagement may be detrimental for children with mild TBI, but beneficial for children with OI.

Study	Design	Source of Participants	Preinjury Factors	Nonhead injury control group(s)	Follow-up(s)	Type of Assessment	Reported outcome
Thomas et al, 2011	prospective, cohort study	ED of the Children's Hospital of Pittsburgh	Patients were excluded for the following reasons: not awake enough or otherwise unwilling to complete the GOAT, prior mental defect or disease (e.g. mental retardation, developmental delay, ADHD, or learning disability), or known intracranial injury (e.g. intracranial bleeding, cerebral contusion). We also excluded subjects with conditions that would interfere with the ability to complete computer-based neurocognitive assessment: vision impairment (including known color-blindness), restricted use of dominant hand, or inability to sit upright for testing.	none	3 days and 2 weeks post injury	concussion graded using AAN and Cantu guidelines; ImPACT	**Adverse** **Psychological:** at the 3 month FU, 85% of patients reported at least one PCS in our main categories; physical, cognitive, emotional, and sleep disturbance. **Null** **Educational:** median # of school days missed was 2. **Psychosocial:** return to normal activity was reported by 58/60 subjects during the 3 month phone FU period. Median time was 13.5 days.
Anderson et al, 2012	prospective, longitudinal study	The Mater Children's Hospital in Brisbane and the Royal Children's Hospitals in Brisbane and Melbourne.	Inclusion criteria were the following: (1) 6 to 14 years at time of TBI; (2) admission to hospital for TBI; and (3) a documented period of altered consciousness. Exclusion criteria included the following: (1) parent's level of English unsatisfactory for completion of questionnaires; (2) previous documented neurological or developmental disorder (including attention deficit hyperactivity disorder); and (3) TBI as a result of nonaccidental injury.	none	n/s	VABS; CBCL; BRIEF-GEC; FSIQ; DF; CNT; SS; Score!; DB; SSDT; ScoreDT	**Null** **Cognitive:** Those who had experienced a severe TBI demonstrating significantly poorer Full Scale Intelligence Quotient (M = 91.78, SD = 10.39), compared with children with mild (M = 104.97, SD = 11.96) or moderate (M = 100.44, SD = 13.41) injuries. Mild children scored better than severe and mod for attentional capacity, selective attention, and processing speed. No group differences were detected for sustained attention or divided attention. for most measures of both simple and complex attention, performance improves over time following TBI in children.
Crowe et al, 2012	prospective, longitudinal study	Emergency Department or admission to the Intensive Care Unit of the Royal Children's Hospital, Melbourne, Australia	Inclusion criteria were: (i) age at injury 0–13 years, (ii) documented evidence of TBI including a period of altered consciousness, and (iii) ability to complete cognitive assessment. The following exclusion criteria were applied: English as a second language, prior TBI, and pre-existing neurological or developmental disorder.	none	24-45 month post injury	FFQ; WPPSI-R/WPPSI-III; WISC-R/WISC-III;	**Null** **Cognitive:** children with mild TBI had IQ scores in the average range. There was a significant group difference for VIQ, PIQ, PSI, and FSIQ measures, with post hoc testing indicating that the severe group performed below the mild (p<.001, d¼.85–1.13) for each of these domains. Findings suggest that recovery is influenced by age at injury as well as stage of brain and cognitive maturation.
Kenardu et al, 2012	prospective, longitudinal study	Royal Children's Hospital, Melbourne, Victoria, and the Royal Children's Hospital and Mater Children's Hospital in Brisbane, Queensland	Inclusion criteria were child TBI with a documented period of altered consciousness (e.g., coma, posttraumatic amnesia, disorientation); consent from parents; and, for children 10 years and older, assent to participate. Potential recruits were excluded from consideration if the child's and=or parent's command of English was insufficient for completion of interviews and questionnaires; the child had a prior neurological or developmental disorder; the period of PTA was longer than 28 days; or the child had a history of child abuse or their injury was nonaccidental.	none	2, 3, 6, 12, and 18 months	SES; CBCL; VABS; BRIEF; GEC; GCS; CAPS-CA; CHQ-PF50; CHQ-PsS	**Null** **Psychosocial:** The effect of TBI on physical function was immediate, and at 2 months it was significantly less for those with severe TBI compared with the mild group (M difference¼13.10, 95% CI¼4.15–22.05, p¼.002). However, the moderate and mild groups were not significantly different. One month later at 3 months, the mild group had started to recover, the moderate group was unchanged, but the severe group had worsened. children with mild head injuries performed at the level of the general population.

Study	Design	Source of Participants	Preinjury Factors	Nonhead injury control group(s)	Follow-up(s)	Type of Assessment	Reported outcome
Max et al, 2012	prospective, longitudinal study	5 medical centers (3 in Texas, 1 in San Diego, and 1 in Toronto).	Exclusion criteria included pre-existing schizophrenia or autistic disorder, mental retardation, and injury due to child abuse or penetrating missile injury. In San Diego only, children with pre-existing attention-deficit/hyperactivity disorder were excluded.	none	baseline, 6 months post injury	DSM-IV-TR diagnoses; K-SADS-PL; NPRS; VABS; FAD; FFI; MRI; GCS	**Adverse** **Cognitive:** Age at injury was significantly related to depression vs no depression. i.e. there was a 5-fold increase in the rate of depression for children with age of injury >12 years compared with age of injury <9 years. Similarly, the rate of non-anxious depression in children with age of injury ≥ 12 years was 14% compared with 0% with age of injury < 9 years. **Null** **Cognitive:** Participants in the 6-month psychiatric assessment had MRI lesions visualized in 34/63. (54%) of mild TBI cases. Less than both mod and severe. In the mild group, there were 7 non-anxious children and 8 anxious children (non-significant difference).
Moran et al, 2012	prospective, longitudinal study	Emergency Departments of two Midwestern children's hospitals	Criteria for exclusion from the mild TBI group included an observed LOC lasting more than 30 min, any GCS score of less than 13, any delayed neurological deterioration (i.e., a decline in GCS score to below 13 following admission or any emergent neurosurgical intervention), or any medical contraindication to MRI. Children were not excluded from the study if they demonstrated intracranial lesions or skull fractures, as long as they did not require neurosurgical intervention. General exclusion criteria applying to both groups included any surgical interventions; any associated injury with an AIS score greater than 3; hypoxia, hypertension, or shock during or following the injury; injury resulting from child abuse or assault; injuries that would interfere with neuropsychological testing (e.g., fracture of preferred upper extremity); previous head injury requiring medical treatment; history of severe psychiatric illness resulting in hospitalization; or premorbid neurological disorders or intellectual disability.	99 OI controls	2 weeks, 3 and 12 months post injury	HBI; CHQ-PF50 (HRQOL)	**Adverse** **Psychosocial:** the mild TBI group had lower physical HRQOL at 12 months postinjury as compared to the OI group, after controlling for premorbid HRQOL. **Null** **Psychological**: There was no difference in psychological HRQOL between mild TBI and OI controls

Study	Design	Source of Participants	Preinjury Factors	Nonhead injury control group(s)	Follow-up(s)	Type of Assessment	Reported outcome
O'Connor et al, 2012	prospective cohort study	Participants for the CHAI study were recruited from nine hospitals in the Pacific Northwest and one in the mid-Atlantic. The hospitals sampled in the Pacific Northwest comprised one Level 1 trauma center, four Level 3 or 4 trauma centers, and four nontrauma center hospitals randomly chosen from hospitals in the county	Children under the age of 18 at the time of injury who were discharged alive from the hospital or emergency department following a TBI or arm injury between March 1, 2007 and September 30, 2008 were eligible to participate in the study.	39 isolated arm injury controls	baseline, 3, 12, and 24 months	PHQ-9; UCLA PTSD Reaction Index for DSM-IV; PedsQL; FAD	**Adverse** **Psychological:** significant differences in PTSD symptoms in the Mild I TBI group compared to the arm injury group across the 3-, 12-, and 24-month assessment points ($z = 3.09$, $p = .02$; Figure 1). At 3, 12, and 24 months, 2%, 3%, and 0% of the arm-injured group, 6%, 4%, and 5% of the Mild I group were identified as probable depression caseness. **Null** **Psychological:** The Mild II and Moderate/Severe TBI groups did not differ significantly compared to the arm-injury group. No cases of major depressive episode were observed in the Mild II group at any of the follow-up assessments. There were no observed significant differences between TBI groups and the arm-injury group for depressive symptoms across 3, 12, and 24 months, though the Mild I TBI group did not demonstrate the greatest difference across time ($z = 2.36$, $p = .08$; Figure 2).
Rivara et al, 2012	n/s	18 hospitals in King County with emergency departments	n/s	153 arm injury controls	baseline, 3 and 12 month post injury	PedsQL; ABAS-II; CASP; PSC-17	**Adverse** **Psychological:** Among those with mild TBIs, 14.3% were receiving new services 12 months after their injury. By comparison, 8.3% of children with arm injuries were receiving new services. population burden of disability was mostly due to mild TBIs because of their much higher incidence. The population incidence rate of children receiving new services at 12 months was nearly 9-fold higher among those with mild TBIs than among those with moderate or severe TBIs. incidence rate of disability after a mild TBI increased with age from 27.2 per 100 000 child-years among children aged 2 to 4 years to 66.2 among those aged 15 to 17 years at the time of their injury; the reason was that the percentage of mild TBI cases that were followed by a new disability increased with age from 8.2% to 22.0% in these groups. This pattern was not seen among those with moderate or severe injuries.

Study	Design	Source of Participants	Preinjury Factors	Nonhead injury control group(s)	Follow-up(s)	Type of Assessment	Reported outcome
Rivara et al, 2012	prospective, cohort study	one of 10 hospitals in King County, Washington, or Philadelphia, Pennsylvania	n/s	174 arm injury controls	baseline, 3, 12, 24, and 36 month post injury	PedsQL; ABAS-II; CASP; FAD	**Adverse** **Cognitive:** Compared to those with an arm injury, children in the Mild TBI groups II and III had modestly but significantly lower scores for self-care at 36 months than at baseline. There was no significant change in function on the two ABAS subscales, or in participation in activities on the CASP, between 24 and 36 months for any of the TBI subgroups. While children in the Mild TBI I and III groups had lower scores than at baseline, these differences, as well as those for the Mild TBI II group, disappeared after accounting for the change among the arm injury controls. Scores worsened between 24 and 36 months for three groups, the Mild III, moderate and severe TBI patients, although the difference was statistically significant only for those with moderate TBI.
Yeates et al, 2012	prospective, longitudinal cohort	Emergency departments at Nationwide Children's Hospital in Columbus, Ohio, and Rainbow Babies and Children's Hospital in Cleveland, Ohio.	Children were not excluded for intracranial lesions or skull fractures or if they were hospitalized; however, they were excluded for any Glasgow Coma Scale score less than 13 or any medical contraindication to MRI. Exclusion criteria for both groups included any surgical intervention; any associated injury resulting in an Abbreviated Injury Scale score greater than 3 or that interfered with neuropsychological testing; hypoxia, hypotension, or shock following the injury; alcohol or drug ingestion associated with the injury; history of previous TBI requiring medical treatment; premorbid neurological disorder or mental retardation; history of severe psychiatric disorder; or assault or child abuse as the cause of injury.	99 OI controls	2 weeks, 3 and 12 months post injury	HBI; CHQ(HRQOL); educational programming information; CBCL	**Adverse** **Cognitive:** Children with mild TBI and LOC were more likely than children with OI to display reliable increases in cognitive symptoms. Children with mild TBI, both those with and without LOC, showed significant declines over time in the like. children with mild TBI with and without MRI abnormalities also showed significant declines in the likelihood of reliable change in somatic symptoms. Both mild TBI groups were more likely to display reliable increases at the initial assessment than the OI group. Among children with mild TBI, reliable increases in both cognitive and somatic somatic symptoms at the initial assessment predicted significantly worse physical HRQOL at both 3 and 12 months than for children who did not display any reliable symptom increases

Study	Design	Source of Participants	Preinjury Factors	Nonhead injury control group(s)	Follow-up(s)	Type of Assessment	Reported outcome
Yeates et al, 2012	prospective, longitudinal cohort study	Emergency Departments of Nationwide Children's Hospital in Columbus, Ohio, USA, and Rainbow Babies and Children's Hospital in Cleveland, Ohio, USA,	Children were excluded from the mild TBI group if they displayed delayed neurological deterioration, but not if they required hospitalization or demonstrated intracranial lesions or skull fractures on acute computerized tomography. Additional exclusion criteria for children in both groups included: (a) any injury that required surgical or neurosurgical intervention; (b) any associated injury with an AIS score greater than 3; (c) any injury that interfered with neuropsychological testing (e.g., fracture of preferred upper extremity); (d) hypoxia, hypotension, or shock associated with the injury; (e) ethanol or drug ingestion involved with the injury; (f) documented history of previous head trauma requiring medical treatment; (g) premorbid neurological disorder or mental retardation; (h) any injury resulting from child abuse or assault; (i) history of severe psychiatric disorder requiring hospitalization; or (j) any medical contraindication to magnetic resonance imaging (MRI). Children were not excluded for premorbid learning difficulties or attention problems. The mild TBI and OI groups did not differ on retrospective parent ratings of premorbid school performance or attention problems.	99 OI controls	3 weeks, 1, 3, and 12 months post injury	CBCL; FAD-GF; LISRES-A; PCS-I; HBI	**Adverse** **Cognitive:** Children with mild TBI and LOC displayed significantly more symptoms than those in the OI group according to parent ratings on the PCS-I. Children with mild TBI but no LOC also displayed more symptoms than the OI group, but the difference was not significant after Bonferroni correction, $t(285) = 2.36$, $p = .019$. The mild TBI group with LOC displayed significantly more cognitive symptoms than the OI group across time, but the contrast between the mild TBI group without LOC and the OI group was not significant
Babikian et al 2012	prospective, longitudinal study	14 different emergency rooms in the greater Los Angeles area.	Inclusion criteria for the head injury group consisted of: (a) presentation to a participating emergency room for an injury involving and resulting in an AIS score of 1 or 2; (b) no injuries above AIS level 2 at any anatomic location; (c) injury from unintentional external causes; (d) no litigation related to injury; (e) no serious injury or death of others involved in the index accident; (f) treated at 1 of 14 emergency rooms located in one of three counties within the greater Los Angeles area; (g) aged 8–17 years at the time of injury; (h) no significant pre-existing central nervous system damage or serious chronic diseases (e.g., cancer, congenital malformation); (i) parent/guardian consent; and (j) child residing with parent/guardian.	79 other injury controls	1 and 12 month post injury	Prospective memory test; picture memory test; word list memory test; symbol digit modalities; color trials-part B; pin test; span of apprehension test; stroop test; DSCPT; peabody picture vocab test	**Adverse** **Psychological:** mild injury group, 97% of the parents at the 1-month evaluation reported at least one concussive symptom that was present acutely (e.g., headache, vertigo), although the presence or the severity of the concussive symptoms was not predictive of neurocognitive impairments. The mTBI group had a higher number of lifetime head injuries (ranging from 1 to 12 with a mean of 2) than the OI group (ranging from 0 to 3with amean of 0.5), **Null Psychological:** 57% of the mTBI group and 50% of the Other Injury group were classified as not impaired at either time point while 20% of the mTBI and 24% of the Other Injury group was classified as impaired at both time points.

Study	Design	Source of Participants	Preinjury Factors	Nonhead injury control group(s)	Follow-up(s)	Type of Assessment	Reported outcome
Tham et al, 2012	prospective, cohort study	emergency department or during admission to a study hospital. study hospitals were comprised of one Level 1 trauma hospital, four Level 3 or 4 trauma centers, and four non-trauma center hospitals randomly selected from all hospitals in King County, Washington. An additional pediatric Level 1 trauma hospital from Pennsylvania	children were part of the CHAI study	197 OI controls	3, 12, and 24 months post injury	baseline data; PedsQL; PSC-17; ABAS-II; CASP	**Adverse** **Psychological:** Children with TBI experienced significantly higher pain frequency up to 12 months post-injury compared to children in the OI group. Baseline (pre-injury) sleep disturbances were reported to be higher in the mild TBI I/II group compared to the other TBI and OI groups. membership in the mild I/II TBI group was associated with more frequent sleep disturbances (b= -6.3, 95% CI - 9.2, - 3.4). **Null** **Psychological:** At 24 months, children with TBI (with the exception of children with mild TBI III) continued to experience a higher severity of sleep disturbances compared to pre-injury levels.
Babcock et al, 2013	Retrospective analysis of a prospective observational study.	pediatric and adult EDs of the University of Rochester Medical Center	none	none	3 month FU	RPQ	**Adverse** **Educational:** those patients missed an average of more than 1 week of school as a result of their injury and the associated sequelae **Psychosocial:** 29.3% of children and adolescents with mTBI who presented to the ED developed PCS. Headache was the most common symptom.
Olsson et al, 2013	prospective study	Two tertiary hospitals in Brisbane, Australia and one tertiary hospital in Melbourne, Australia.	Children were included in the larger study if (a) they sustained an accidental TBI, (b) parents and children had adequate English to complete the assessments, (c) children were not under the care of the Department of Family Services and (d) children's duration of post-traumatic amnesia was less than 21 days.		n/s	TSCC-A; CHQ-PF28; WASI; WISC-IV; CMS; CNT; TEA-Ch; CBCL; IES-R; GHQ	**Adverse** **Cognition**: Children with complicated mTBI had poorer pre-injury physical HRQoL and lower verbal IQ scores than children with mTBI (no imaging) and uncomplicated mTBI. pre-injury PCS and pre-injury parent distress, particularly increased hyperarousal symptoms, predicted increased child PCS at 6 months post-injury. Higher levels of pre-injury parent anxiety predicted increased PCS at 6 months post-injury among children with complicated mTBI. However, and in contrast to the hypothesis, higher levels of pre-injury parent anxiety were associated with lower levels of child PCS at 6 months post-injury among children with mTBI (no imaging) and pre-injury parent anxiety was unrelated to child PCS at 6 months post-injury among children with uncomplicated mTBI

Study	Design	Source of Participants	Preinjury Factors	Nonhead injury control group(s)	Follow-up(s)	Type of Assessment	Reported outcome
Ornstein et al, 2013	retrospective study	one of several large, urban pediatric hospitals in Toronto, Dallas, or Houston	excluded if they showed evidence of a neurological disorder, chronic or serious medical condition, a history or evidence of psychosis, or a clinically significant anxiety disorder. TBI excluded if they presented with a pre-injury diagnosis of ADHD, learning disability, or speech and language delay.	79 TD controls; 92 ADHD children	6 month FU	OCHS-R: S-ADHD; SSP	**Null** **Cognition:** sign diff among the three groups for SSRT. On avg the ADHD children had the poorest inhibitory control, followed by the TBI group. No sign diff in goRT among the three groups. Based on mean scores, inhibitory control performance in the TBI children with S-ADHD appears to be similar to that of the children with ADHD, while that of children with TBI without S-ADHD is more like that of controls.

Annales Universitatis Turkuensis

Turun yliopisto
University of Turku

ISBN 978-951-29-7400-9 (PRINT)
ISBN 978-951-29-7401-6 (PDF)
ISSN 0355-9483 (PRINT) | ISSN 2343-3213 (PDF)

Painosalama Oy, Turku, Finland 2018