Update on the epidemiology of work-related traumatic brain injury: a systematic review and meta-analysis

Danielle Toccalino ,[1] Angela Colantonio,[2,3] Vincy Chan[1,3]

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[1]Institute of Health Policy, Management and Evaluation, University of Toronto, Toronto, Ontario, Canada
[2]Department of Occupational Science and Occupational Therapy; Temerty Faculty of Medicine, University of Toronto, Toronto, Ontario, Canada
[3]KITE -Toronto Rehabilitation Institute, University Health Network, Toronto, Ontario, Canada

Correspondence to
Danielle Toccalino, Institute of Health Policy, Management and Evaluation, University of Toronto, Toronto, ON M5S 1A1, Canada;
danielle.toccalino@mail.utoronto.ca

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ABSTRACT

Background Traumatic brain injury (TBI) is a public health concern that can occur in a range of contexts. Work-related TBI (wrTBI) is particularly concerning. Despite overall work-related injury claims decreasing, the proportion of claims that are wrTBI have increased, suggesting prevention and support of wrTBI requires ongoing attention.

Objectives This review aimed to provide updated information on the burden and risk factors of wrTBI among the working adult population.

Methods Medline, Embase, PsycINFO, and Cumulative Index to Nursing and Allied Health Literature (CINAHL) were searched using a combination of TBI, work, and epidemiology text words and medical subject headings. Two reviewers independently assessed articles for inclusion. Meta-analyses were conducted to estimate prevalence and mortality of wrTBI and a narrative synthesis was conducted to provide additional context.

Results Pooled proportions meta-analyses estimate that 17.9% of TBIs were work-related and 6.3% of work-related injuries resulted in TBI, with 3.6% of wrTBI resulting in death. Populations of wrTBI were predominantly male (76.2%) and were 40.4 years of age, on average. The most commonly reported industries for wrTBI were education and training, healthcare and social assistance, construction, manufacturing, and transportation. Falls, being struck by an object or person, motor vehicle collisions, and assaults were the most commonly reported mechanisms of wrTBI.

Conclusions A better understanding of the epidemiology of wrTBI can inform prevention and management strategies. This review highlights existing gaps, including a notable lack of sex or gender stratified data, to direct future investigation.

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Key messages

What is already known about this subject?

► Work-related traumatic brain injuries (wrTBI) comprise an increasing proportion of work-related injury claims in Canada and there is an emphasis more globally on work-related injuries in the construction industry.

What are the new findings?

► wrTBI constitutes an estimated 17.9% of traumatic brain injuries and 6.3% of work-related injuries. An inability to return to work following wrTBI was reported for subsets of participants in several studies. This review identified an increase in reporting of wrTBI among service-oriented occupations, including education and healthcare. Sex and gender remain under-reported.

How might this impact on policy or clinical practice in the foreseeable future?

► This work identifies existing gaps that must be addressed to make equitable and effective changes to policy and clinical practice. Comprehensive synthesis of the knowledge in this field and sex and gender-based analyses are needed to inform policy decisions surrounding work-place safety, recommendations for injury prevention, and frameworks for supports post injury.

INTRODUCTION AND RATIONALE

Globally, an estimated 69 million individuals sustain a traumatic brain injury (TBI) each year.[1] Though some individuals recover fully with no lasting effects, an estimated 3.17 million individuals live with TBI sequelae in the United States alone.[2] Even TBIs classified as 'mild' can result in significant, long-term effects including poorer health, unemployment, and increased healthcare costs, causing a significant impact on the individual, their family, and the healthcare system.[3–5] Though TBI can occur in a range of contexts, work-related TBI (wrTBI) is of particular concern. Despite claims for work-related injuries as a whole decreasing, the proportion of TBI among work-related injury claims have increased in Canada,[6] suggesting persistent gaps in the prevention and support of wrTBI as well as a need for increased awareness of this injury. Furthermore, the loss of meaningful work that may follow a TBI can have severe consequences for an individual's identity and sense of self-worth.[7] Significant effort must be undergone, therefore, not only to better understand and prevent wrTBI, but also to understand and accommodate the needs of individuals with TBI in returning to work.

A systematic review was published in 2015 on the epidemiology of wrTBI.[8] This review, conducted on articles published until December 2013, noted a paucity of outcome data on wrTBI and a large enough variation in the data presented that a meta-analysis was not possible. Since that review was conducted, the Canadian Institutes of Health Research (CIHR), Canada's federal funding agency for health research, announced nine new research chairs in Gender, Work, and Health,[9] one of which was specifically dedicated to wrTBI, contributing to the additional work published in this area since the 2015 review. The current systematic review aimed to update our understanding of the burden, risk factors, and outcomes of wrTBI.

METHODS

This systematic review looked at the burden (ie, incidence, prevalence, mortality) and risk factors (ie, sex, age, industry/occupation, mechanism of injury, severity of injury) of wrTBI in the global adult working population, as reported in prospective and retrospective cohort studies, case-control studies, cross-sectional studies, and case series published since January 2014.

As this systematic review is an update of a previous review,[8] the search strategy and eligibility criteria will replicate those of the original study with the exception of the publication dates included in the search (original study: January 1980 to December 2013; current study: January 2014 to February 2020). We also reported outcomes (ie, sequalae, return to work) examined in studies investigating the burden or risk factors associated with wrTBI.

Search strategy

Medline, Embase, PsycINFO, and Cumulative Index to Nursing and Allied Health Literature (CINAHL) were searched for relevant articles using a search strategy including text words and subject headings (eg, medical subject headings (MeSH), Embase subject headings (Emtree)) related to work, TBI, and epidemiology (ie, risk, burden, mortality) (online supplemental file 1). Searches were limited to English-language publications published between January 2014 and February 2020 without restriction on geographical location. Records returned from this search were managed in EndNote and Covidence.[10]

Eligibility criteria: title and abstract screen

Following the removal of duplicates, two reviewers (DT, VC) independently assessed all identified titles and abstracts for eligibility. This screen focused on identifying studies addressing burden or risk of either work-related injuries or TBI. To minimise the possibility of missing relevant articles, studies were included in the full-text screen if they investigated a population or subset of work-related injuries, or if they investigated a population or subset of TBI, and if the full-text article was available through the University of Toronto Library system. This broad approach was taken based on previous experience with reviews on TBI suggesting that both relevant subgroups (in this case, work-related injuries and TBI) are not always included in the abstract though relevant data may be presented in the body of the article.

Commentaries, conference abstracts, reviews, case studies, randomised controlled trials, and reports without described methods were excluded. Studies were additionally excluded if they focused on traumatic injury without mention of head injury or a worker population, if they focused on a non-TBI work-related injury (eg, noise-related hearing loss), if they were conducted in animals or at the cellular level, if they focused on military-related or sports-related TBI, or if they were conducted in non-working paediatric or elderly populations.

To ensure the reviewers interpreted these criteria in a similar manner, a sample of articles was reviewed by both reviewers and compared to assess for agreement. Covidence software was used for screening and to monitor agreement between the two reviewers' assessments.[10] Any differences were resolved through discussion and consensus. If consensus could not be reached, articles were moved to the full-text screen for further review.

Eligibility criteria: full-text screen

All articles included in the full-text screen were reviewed independently by two reviewers (DT, VC). For inclusion in the review, studies needed to provide quantitative information on the burden or risk factors of wrTBI specifically. Exclusion criteria used for the abstract and title screen continued to apply. Additionally, articles were excluded if wrTBI data could not be separated from more general data (eg, TBI not examined separately from neck, spinal cord, facial, or superficial head injuries).

As with the title and abstract screen, a sample of full-text articles were reviewed to calibrate interpretation of the inclusion criteria. Covidence software was used to conduct the screening and monitor agreement between the reviewers' assessments.[10] All differences in screening were resolved through discussion and consensus. The reference lists of articles meeting the criteria for full-text review were manually searched for additional articles relevant to the review.

Data extraction

Study details (ie, location, duration, design, population, sample size, data source, TBI and work case definitions), epidemiological findings (ie, prevalence, mortality, demographic information, industry or occupation, mechanism of injury), and TBI-related outcomes (ie, psychological and physical sequelae, return to work) were extracted from included studies as reported. One reviewer (DT) completed the data extraction, which was then peer reviewed by a second reviewer (VC).

Quality assessment

A 17-item checklist, developed by Chang *et al* for their 2015 review (online supplemental file 2), was used to assess the quality of included studies.[8] It is an amalgamation of tools developed for evaluating primary research[11] and occupational injuries and illnesses.[12] Notably, this tool assesses the robustness of studies' definitions of work, TBI, and TBI severity (case definition). Items were rated from 0 (not reported or defined) to 2 (clearly reported/well defined) or 'N/A' if not applicable. As maximum possible scores varied between studies, both a fraction (total/maximum) and a percentage score were calculated. No studies were excluded based on these scores. One reviewer (DT) completed the quality assessment, which was then peer reviewed by a second reviewer (VC).

Narrative synthesis

A narrative synthesis was conducted to provide context for the meta-analysis and report on aspects of the studies where meta-analysis was not feasible. Specifically, this synthesis looked at case definitions for work and TBI across studies, reported industries, mechanism of injury, and outcomes. Due to a limited number of studies reporting on incidence of wrTBI, this was also explored in the narrative synthesis.

Data synthesis

Pooled estimates of sex (proportion male) and mean age of individuals with wrTBI were calculated to provide context for the wrTBI population represented. Studies needed to report sex and age, respectively, for wrTBI separately from other injuries to be included in analyses. Studies purposely recruiting for equal representation of males and females or with samples of less than 10 were excluded. Only studies reporting age as a mean and standard deviation (SD) could be included in the age estimate.

To provide estimates of prevalence and mortality, we conducted pooled proportions, random-effect model meta-analyses.[13] Specifically, the prevalence of wrTBI among work-related injuries, the prevalence of wrTBI among TBI, and the mortality rate of wrTBI were assessed. To be included in these

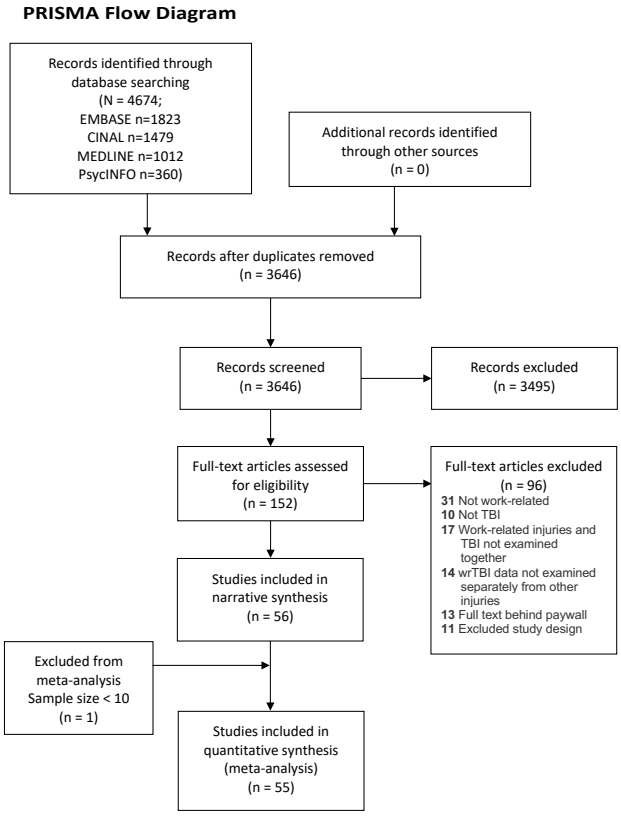

Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram.

analyses, studies needed to include the number or proportion of wrTBI within the relevant population (work-related injuries or TBI, respectively) or report on the number or proportion of fatal injuries within a wrTBI population. All meta-analyses used random-effects models[13] and excluded studies with samples less than 10. Analyses were conducted using R.[14]

RESULTS

Search & screening

Our search strategy returned 4674 records across the four searched databases. After removing duplicates, 3646 titles and abstracts were reviewed, and 152 full-text articles were assessed to identify 56 articles for inclusion (figure 1). No additional articles were identified from reference lists. The reviewers had 97% agreement for the review of titles and abstracts and 84% agreement for the review of full-text articles for inclusion. All discrepancies were resolved in discussion between the two reviewers.

Included studies

Of the included studies, 18 (32%) report on wrTBI (online supplemental table 1), 33 (59%) report on work-related injuries (online supplemental table 2), and 9 (16%) report on TBIs (online supplemental table 3). Two studies explored traumatic injuries more broadly and had both TBI and work-related subsets; [15 16] they are presented in both online supplemental tables 2 and 3. Additionally, one study conducted a comparison between wrTBI and non-wrTBI with detailed wrTBI reporting; [17] it has been included in both online supplemental tables 1 and 3. Finally, one study explored wrTBI specifically, but reported on wrTBI in relation to overall work-related injuries during the study period; [18] it has been included in both online supplemental

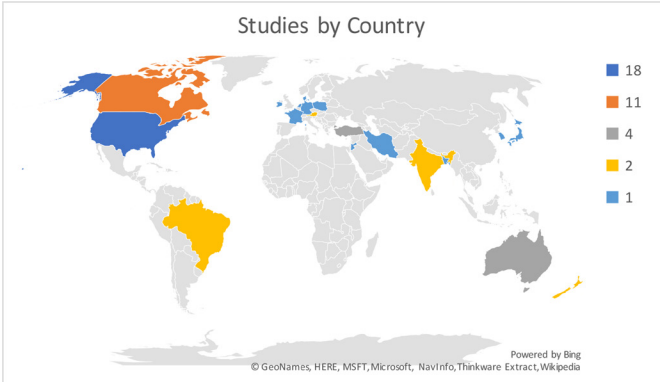

Figure 2 Included studies by country.

tables 1 and 2. Studies represented in multiple tables are denoted with a § with additional information on the relevant sample.

Age and sex are presented for all groups when provided. Industry/occupation and mechanism of injury are reported for the wrTBI group only due to inconsistent reporting among work-related injury and TBI focused studies and an inability to extract wrTBI-specific information in these domains.

Included studies spanned a variety of contexts, with the majority situated in specific employment environments (24%) or healthcare settings (39%). Almost all included studies were cohort studies (34%), cross-sectional studies(23%), or descriptive secondary analyses of surveilance or claims data (21%). The majority originated from the United States (32%) or Canada (20%) (figure 2) and study periods spanned 1980–2018, with durations ranging from months to decades (figure 3). Of the 18 studies reporting on wrTBI, over half were conducted in Canada (55%) with the remainder conducted in the United States (22%), Australia (17%), and Brazil (6%).

Quality assessment

Quality assessment scores for included studies ranged from 43% to 97%. Maximum possible scores ranged from 28 to 34, with total scores ranging from 13 to 33. Many studies failed to report TBI case or severity definitions, resulting in the lowest average scores and highest SD in these categories (case definitions of TBI: 0.82±0.88; TBI severity 0.59±0.85).

The 2015 review only assessed quality of wrTBI articles (53%–94%).[8] When looking at just the wrTBI subset included here, scores ranged from 69% to 94%, suggesting the quality of wrTBI articles may have increased since the 2015 review was completed.

No articles were excluded from the review or analyses due to their score. A summary of scores is presented in online supplemental file 2.

Narrative synthesis

The studies included in this review were highly heterogeneous in study population, data sources, and study design; as such, significant variability was seen in the case definitions, reported industry/occupation, mechanism of injury, and outcomes.

Severity and case fatality

Of the 56 articles included in this review, 11 (20%) included fatal injuries, 5 (9%) of which investigated fatal injuries exclusively. In the five studies with a sample size greater than 10 reporting on fatal injuries as a subset of all wrTBI, the percentage of fatal cases ranged from 1% to 8%.[19–23] Studies reporting on fatal

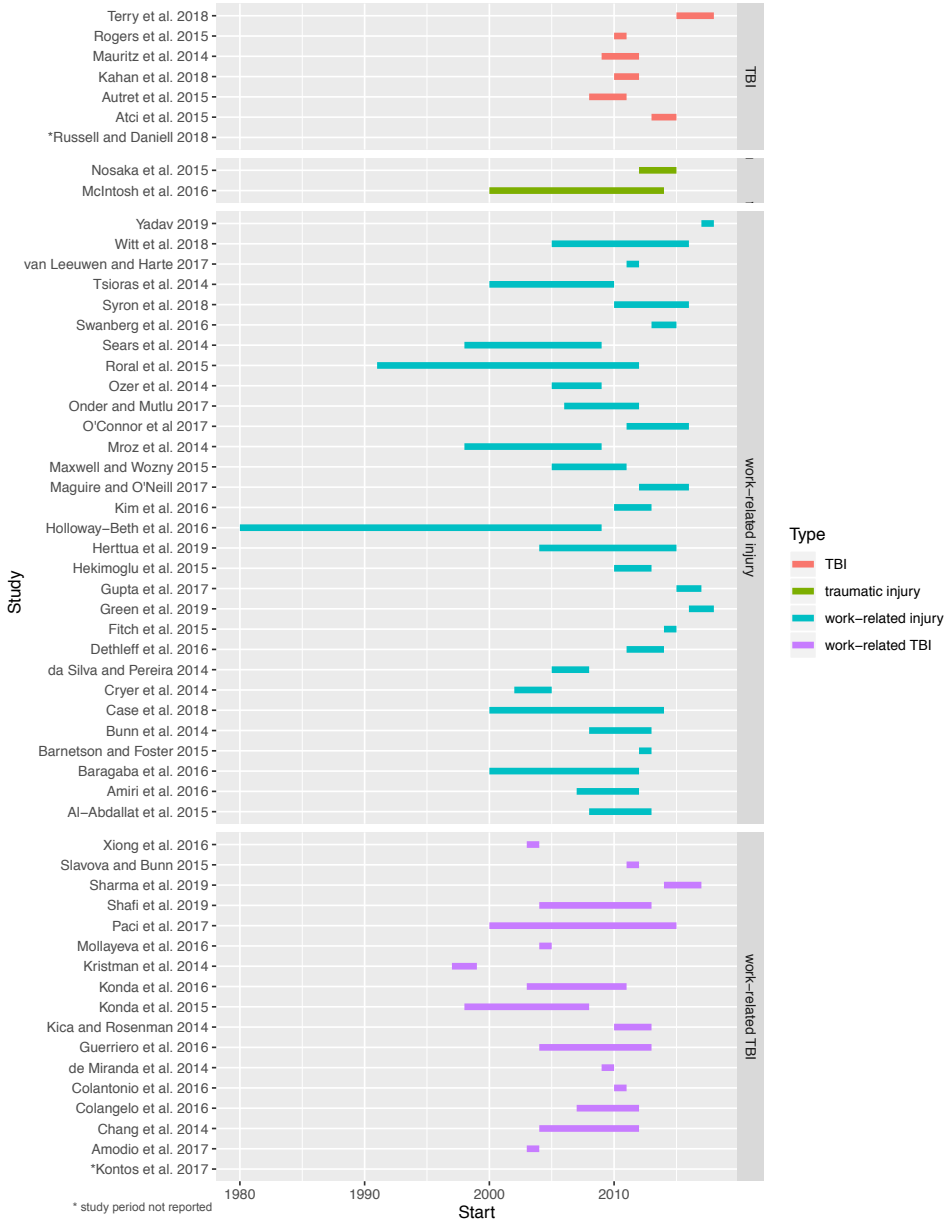

Figure 3 Study periods of included studies

work-related accidents reported wrTBI as the cause of 14-26% of work-related fatalities. [15 24–26 27]

Case definition: TBI and work

Fewer than half of the included studies (n=22, 39%) identified TBI using specific codes or frameworks (eg, International Classification of Diseases, workers' compensation database codes), seven (13%) used a TBI diagnosis, and the remainder (n=27, 48%) did not specify how TBI was identified. The majority of both the wrTBI-specific articles (89%) and TBI-specific articles (78%) used codes or diagnosis to identify TBI.

Similarly, methods of identifying work-related injuries were highly variable, with 24 (44%) studies using worker's compensation data or specific employment settings, 12 (22%) using other defined datasets that included reporting on occupation, 4 (7%) relying on self-report, and the remainder (27%) lacking information on how work-related cases were identified. All wrTBI-specific articles reported case definitions for work; however, eight articles focusing on work-related injuries (26%) failed to specify how work was identified.

Industries/occupations

Among studies looking at work-related injuries (n=33), 15 (46%) looked at specific industries, predominantly in manual labour (ie, mining, construction, farming).[25 26 28–40] Only one of the work-related injury studies reported the industry for workers experiencing wrTBIs (24.7% construction related),[20] and one study that examined TBI reported that all but one of the wrTBIs were farm related.[15]

Among studies looking specifically at wrTBI (n=18) almost all (n=15, 82%) included some information about the industries or occupations of the affected workers, with the most commonly reported industries being construction, education and training, healthcare and social assistance, and transportation. Only one study looked at a specific industry, reporting on fatal wrTBI in construction.[24] Construction was cited as the cause of

8.3%–33.6% of wrTBI in seven studies.[19 21 23 41–44] Interestingly, eight studies reported on wrTBI occurring in both the education and training sector (4.7%–16.0% of wrTBIs reported) and the healthcare and social assistance sector (9.2%–40.9% or wrTBIs reported),[18 19 23 42–46] both of which receive relatively little research attention. Finally, transportation accounted for a range of 2.2%–12.0% of wrTBI across eight studies.[17–19 21 23 41 42 44 47] Further analysis of industries or occupations is complicated by inconsistent grouping across studies and difficulty mapping occupations to industries and vice versa.

Mechanism of injury

Five studies specifically investigated falls as a mechanism of interest among the broader work-related injury (online supplemental table 2) or TBI populations (online supplemental table 3).[16 20 38 48 49] Additionally, one study on work-related injury specifically noted that 63.5% of wrTBI were attributable to falls.[28] The remainder of articles looking at work-related injury or TBI did not report on the mechanism of injury for the wrTBI subset.

Among studies specifically investigating wrTBI (online supplemental table 1), 12 reported mechanism of injury (67%) with the most commonly reported mechanisms being falls, being struck by an object or person, motor vehicle collisions, and assaults. Falls, slips or trips caused 23.7%–58.2% of injuries across 11 studies.[17 19 21 23 24 42 43 45–47 50] Being struck by an object or person accounted for 14.4%–53.1% of all injuries across eight studies.[17 19 21 23 43 45–47] All but one of these studies reported assaults separately, indicating injuries coded as being struck by an object or person were likely accidental. Motor vehicle collisions were reported in eight studies, representing 6.5%–29.8% of wrTBI.[17 19 21 23 43 45 47 50] Finally, eight studies reported assault as being the cause of 1.1% to 14% of wrTBI,[17 19 21 23 43 45 46 50] with one additional study looking specifically at wrTBI due to assault.[18]

Outcomes

Very few studies that reported on the burden of and risk factors for wrTBI also reported on outcomes post-wrTBI (excluding death). Return-to-work outcome information was reported in eight wrTBI studies; six of which reported some portion of their study population (17.1%–87%) did not return to work at various stages of recovery.[17 18 43 50–52] Additionally, two studies reported that time off from work was required post injury.[23 46] One study focused on mental health outcomes, identifying 82.1% of the wrTBI subset as having probable PTSD.[53]

Incidence of wrTBI

Only five studies reported on the incidence of wrTBI among the working population. Two studies estimated the incidence based on full-time worker equivalents (2.6/100 000 and 4.3/10 000).[24 42] The remaining three used 'workers',[23] 'employed civilians',[47] and 'worker contracts'[41] as the denominator (estimated at 19.8, 31.6, and 6.14 per 10 000, respectively).

Reporting on sex/gender

Of the 56 studies included in this review, 22 (39%) reported on the sex or gender of individuals with wrTBI. However, only five of the studies (9%) stratified the reporting of other variables by sex or gender,[23 44 52 54 46] all of which reported significant differences between the two reported groups (male/female or man/woman).

Data synthesis

Pooled estimates of sex and age were calculated to characterise individuals with wrTBI. All studies reporting sex used a male/female binary; therefore, we calculated the pooled proportion of males among individuals with wrTBI. This was done using a random effects model pooled proportions meta-analysis of the 19 studies reporting sex data for wrTBI. One study purposely recruited to have equal representation of men and women and was excluded from this analysis.[45] Based on the available data, 76.2% of wrTBI occurred in males (table 1 and online supplemental figure 1). Though age was reported in 20 studies, only 8 reported a mean and SD; therefore, the pooled means meta-analysis was limited to these studies. Based on this subset, the average age of workers was 40.44 years (table 1 and online supplemental figure 2).

A pooled proportion of wrTBI among work-related injuries was calculated based on data from 32 studies reporting on this subset, resulting in an estimate of 6.3% of work-related injuries being wrTBI (table 1 and online supplemental figure 3) Using the same methodology, wrTBIs were estimated to comprise 17.9% of TBIs based on eight TBI studies (table 1 and online supplemental figure 4). Finally, based on a pooled proportion meta-analysis of five studies including a fatal wrTBI subset, 3.6% of all wrTBIs were estimated to result in death (table 1 and online supplemental figure 5). One study[16] had a sample size of less than 10 and was excluded from all meta-analyses.

DISCUSSION

As with the previous review,[8] the studies included here were highly heterogeneous in the target populations, definitions of TBI, and data sources used. However, several of our findings aligned with those from the initial review. In both reviews, the majority of studies investigated mild injury with studies focusing on severe and fatal cases having a higher proportion of males. Falls, motor vehicle collisions, and being struck by or against an object or person were the top three mechanisms of injury in both reviews; however, this review found higher rates of assault as a cause of injury.

Similar to the previous review, the majority of studies were based in Canada and the USA.[8] However, the current review identified more studies outside of these two countries, with a

Table 1 Results from pooled proportions and pooled mean meta-analyses

Variable of interest	# of Studies	Pooled estimate	95% CIs	tau^2	I^2
Average age of workers with wrTBI	8	40.44 years	39.62 to 41.26	0.83	85.1%
Proportion of wrTBI that occur in males	19	0.762	0.657 to 0.843	1.27	99.7%
Proportion of TBI that are work-related	8	0.179	0.073 to 0.376	2.12	99.6%
Proportion of work-related injuries that are TBI	32	0.063	0.045 to 0.089	1.01	99.9%
Proportion of wrTBI that are fatal	5	0.036	0.016 to 0.077	0.77	93.6%

TBI, traumatic brain injury; wrTBI, work-related TBI.

total of 19 countries represented. The majority of wrTBI specific publications were based in Canada, which is likely due, in part, to initiatives such as CIHR research chairs in Gender, Work and Health.[9]

Only one study reported on the rates of wrTBI among various industries stratified by sex,[23] which supported similar industry-specific trends by sex to those reported in the previous review.[8] Specifically, females had lower rates of injury across industries with the exception of the health and social service sectors.[23] Though sex and gender are acknowledged as distinct but related concepts, neither of which is binary,[55] the majority of studies included did not distinguish between sex and gender and none of the included studies included sexes or genders beyond the binary distinction of males/females or men/women, respectively. Future work should clearly distinguish between sex and gender in their methodologies and conduct sex and gender-based analyses to guide policy and social services. It is important to note, however, that many of the sources of data used in these studies (eg, worker's compensation claims) do not differentiate between sex and gender, nor do they provide reporting beyond the binary of male/female in most cases. To be able to report on sex and gender differences at regional or national levels using surveillance data, data on both sex and gender must be collected at that level.

This review was able to make significant additions to the findings of the 2015 review it intended to update.[8] Specifically, we were able to formally estimate the prevalence of wrTBI among work-related injury (6.3%) and TBI (17.9%) as well as the prevalence of a fatal outcome (3.6%) using meta-analyses, which was not conducted in the previous review. Additionally, we were able to report on outcomes following wrTBI based on studies that examined the burden of and risk factors for wrTBI (ie, studies that met the inclusion/exclusion criteria). While these studies examined return to work, an important outcome, it is recognised that it is far from the only one. Cognitive, physical, and psychological sequelae are well documented post-TBI and may impact an individual's ability to return to work,[3–5 56] yet were largely not explored by the studies in this review. We acknowledge that there is a body of literature examining return-to-work and other outcomes following wrTBI that was not included in this review as it does not examine burden or risk factors of wrTBI. We would encourage future studies investigating wrTBI burden and risk factors to investigate return to work further.

The studies included in this review represent a variety of methodologies, data sources and definitions of work and TBI. Population-level data was used in half of the included studies and two thirds of studies focused on wrTBI. However, in most cases, these data were not leveraged to compare wrTBI with other work-related injuries or non-work-related TBI, making drawing comparisons and broader conclusions about the wrTBI population difficult.

The ways in which studies identified wrTBI were also highly heterogenous. Standardised codes for area of injury were used more often in studies focusing on TBI or wrTBI; however, much of the literature is on work-related injuries. As with sex and gender, comparisons using worker's compensation data, or the equivalent, are limited by the data collected. Claims data are not collected for research purposes, and using it for such comes with limitations both in what data are collected and for whom.[57] Many of the worker's compensation data sources only report on successful claims, thereby excluding injured workers whose claims are unsuccessful or who do not make a claim. Additionally, the data collected are likely to be highly variable between countries or even regions within countries, which can impact the ability to compare between jurisdictions. Our review found this specifically with injury definitions. For example, Australian workers compensation datasets often use the Type of Occurrence Classification System codes that include TBI-specific codes,[23 46] whereas Canadian datasets often use a diagnosis of concussion or brain injury,[18 58] and others use combinations of codes to approximate a TBI.[42] Many studies included here used worker's compensation data collected at a provincial or state level (eg, Victoria, Australia[23]; Ontario, Canada[58]; Michigan, USA.[19] Only three of the articles looking at wrTBI explored datasets at the national level, one using Ministry of Work and Employment datasets in Brasil,[41] and the other two based out of the USA using the National Electronic Injury Surveillance System and the Bureau of Labour Statistics Census, respectively.[24 42] The paucity of studies investigating wrTBI in juxtaposition to other forms of work-related injury highlights an important area for future research.

Falls and being struck by objects accounted for a large proportion of the reported injuries, suggesting opportunities for prevention. Falls can be addressed with proper footwear, protective rigging, and appropriate maintenance of facilities; being accidentally struck by objects or people can be addressed through appropriate procedures and training, which are already documented in the literature.[59 60] As most of the studies included here examined non-fatal injuries, it is possible that these prevention efforts have been implemented to the extent that they prevent fatal injuries but not those that are less severe. Future work on wrTBI would benefit from discussions on the policy and preventative measures in place that might safeguard against fatal or severe TBI. This context will also facilitate more robust comparisons across jurisdictions where protective measures may differ.

Strengths and limitations

The purposefully broad search strategy and two-stage, systematic screening process was a considerable strength of this review, maximising the relevant literature captured. Furthermore, this review is the first, to our knowledge, to perform meta-analyses of the burden and risk of wrTBI and to provide a narrative synthesis of outcomes from studies that examined the burden of and risk factors for wrTBI, the lack of which was a noted limitation in the 2015 review.[8]

The decision to exclude non-English language articles is a major limitation of this study but was made to ensure consistency with the 2015 review.[8] To determine the impact of excluding non-English abstracts, we ran a comparison search without language restrictions. This search showed approximately 1% of abstracts were missed by excluding non-English language articles published between 2014 and 2020; future reviews may wish to expand on both reviews by looking at non-English articles addressing wrTBI. Additionally, any primary research presented in grey literature was not captured in our search strategy. It is possible the high representation of American and Canadian studies in the sample is due to wrTBI reporting in other countries occurring predominantly in grey literature or publications in languages other than English. This should be explored in further reviews.

This review used the inclusion/exclusion criteria described by Chang *et al* in 2015.[8] Based on those criteria, articles focusing on outcomes without mention of wrTBI risk factors or burden were excluded. Therefore, the data presented in this review discussing outcomes following wrTBI are not a comprehensive picture of the literature on outcomes. Indeed, we are aware of several studies not included in this review that focus on wrTBI

outcomes.[61–63] The wrTBI literature would benefit from a review focusing more specifically on outcomes following wrTBI.

The articles included in this review were highly heterogeneous, limiting the possible analyses and necessitating caution with the interpretation of results. Due to the heterogeneity in the method of reporting ages, mean age for study populations need to be calculated or estimated in many cases, which may impact the robustness of analyses.

CONCLUSIONS

This review summarises the literature on wrTBI published since 2013, providing much needed updates to our knowledge in this area. Comprehensive synthesis of the knowledge in this field and sex and gender-based analyses are needed to inform policy decisions surrounding workplace safety, provide recommendations for injury prevention, and to guide frameworks for supports post injury. Though more work must be done, this review is a step towards that goal. To that end, this review elucidates current gaps in our understanding of wrTBI, providing guidance on the research still needed in this field.

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Contributors DT and AC conceptualised the study as an update to a previous review conceptualised by AC and colleagues (Chang et al. 2015). DT updated the search strategy and conducted the search. DT and VC screened titles/abstracts and full-text articles for inclusion. DT extracted data from included articles and conducted quality appraisals of included studies; extracted data and quality appraisals were peer reviewed by VC. DT conducted meta-analyses and drafted the manuscript. VC and AC critically reviewed the manuscript, and all authors read and approved the final manuscript.

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ORCID iD

Danielle Toccalino http://orcid.org/0000-0002-8738-2894

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