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Traumatic brain injuries in New Zealand: National Insurance (Accident Compensation Corporation) claims from 2012 to 2016

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ABSTRACT

Aim: To provide epidemiological data and related costs to the national health insurance scheme for traumatic brain injury (TBI) in New Zealand.
Method: A retrospective analytical review utilising detailed descriptive minor and moderate-to-severe epidemiological TBI data obtained from the Accident Compensation Corporation (ACC) for 2012–2016. Injuries were analysed by three levels of increasing severity: moderate, moderate-to-serious (MSC) and severe claims categories.
Results: Over the January 2012 to December 2016 period there were 97,955 claims for TBI costing ACC $1,450,643,667 [equivalent to £$743,417,120]. Falls accounted for nearly half (41.7%, 8262), and over a quarter (39.9%; $67,626,000 [£34,662,176]) of the moderate claims for TBI. Motor vehicle accidents recorded the highest percentage (36.5%), total costs ($610,978,229 [£313,170,000]) and highest mean cost per-moderate claim per-year ($47,372 ± $2401 [£24,282 ± £1231]) for MSC TBI claims. This was similar for severe claims where motor vehicles accidents accounted for 56% of the total serious claims, 65.1% of the costs with a mean cost per-serious claim of $64,913 ± 4331 [£32,759 ± £2186] per-year.
Conclusion: There were 97,955 TBI injury claims lodged over the duration of the study with 36% (n = 35,304) classified as MSC. The incidence of total TBI in New Zealand was 432 per 100,000 population, and 155 per 100,000 for MSC TBI claims. Despite the growing number of studies reporting on the effects of sports-related TBI, there is a paucity of studies reporting on the longitudinal effects of TBI in falls, assaults and motor vehicle accidents. Further research is warranted into the assessment and management of intimate partner violence and child abuse victims for TBI's.

1. Introduction

With an estimated 10 million people affected annually, traumatic brain injury (TBI) has been reported by the World Health Organisation (WHO) as the one injury that will surpass many diseases as the major cause of death and disability by 2020 [1]. The effects of TBI have been reported to impact the cognitive and neurobehavioural aspects of the individual in the acute phase [2], but there are now concerns that TBI's are also a risk factor for the development of neurodegenerative conditions [3]. The incidence of TBI has been reported to vary between 47 and 558 per 100,000 population in Europe [4] and North America [1,5]. A systematic review [5], by the WHO identified that the annual incidence of mild TBI (mTBI) was in the range of 100 to 300 per 100,000 population. However, as not all mTBI's are treated in hospitals, the actual incidence of mTBI was estimated to be higher at around 600 per 100,000 population [5]. More recently it was reported [6] that the incidence of TBI in New Zealand was 790 per 100,000 population, with mTBI reported to have an incidence of 749 per 100,000 population or 95% of the total TBI's recorded. This study [6] used a mixed urban and rural region (Hamilton and Waikato districts) in New Zealand over the 2010 to 2011 period as the data source.

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In addition to identifying the incidence of TBI, the leading causes of TBI have also been reported to be motor vehicle accidents (MVA) (60–62%), violence (10–24%), falls (8–30%), and other, including work-place and sports related (6–10%) based on global data [1]. Data from New Zealand [6], identified that the leading cause for TBI were falls (38%), followed closely by mechanical force (21%) (defined as an accidental impact with a moving or stationary object resulting in the brain undergoing an acceleration/deceleration movement), [7,8] MVA (20%), assaults (17%) and other (4%), although these percentages varied across different age groups. These causes were similar to another study [9] in a follow up assessment of participants from a previous study [6] reporting on mTBI with falls (32%) being the most common cause recorded. Yet the full extent of the cause of TBI remains unknown as some people may not report, or be aware, that they have received a TBI and, when assessed by healthcare professionals, the subtle signs of TBI may not be obvious [10,11].

Two areas of assaults where there is likely an under-reporting on the number and cause of TBI's are intimate partner violence (IPV), also termed domestic violence (DV), and non-accidental injuries (NAI). When presenting to a healthcare provider for any IPV or NAI and the TBI goes unreported, or undiagnosed, then the TBI remains untreated [12]. As a result, this cohort have an increased vulnerability for further victimisation, explosive and aggressive conduct [13], depression, suicidal and self-harming behaviours [14], and a higher probability of sustaining another TBI [12]. Because IPV and NAI are often a behaviour pattern that occurs over time, rather than as a single event, victims of IPV and NAI are prone to multiple episodes of TBI [15] with some studies reporting victims receiving up to at least 10 TBI's in the preceding 12-month period [12]. There are numerous identified reasons [12,16,17] why victims of IPV and NAI do not report these TBI's. These include, lack of knowledge they have a TBI [12,16], fear of retribution or potential legal ramifications [17], lack of knowledge and training of the healthcare provider, and healthcare provider focusing on the visible injuries only [12]. As a result, the actual incidence and cost of IPV and NAI TBI's remains unknown.

Though the knowledge of the causes and effects of head related trauma are becoming more widespread, there are still gaps in the data reporting on costs of TBI. In a New Zealand based study [18] it was reported that the average cost of new TBI's was US$5922 (inflation adjusted to 2017: US$6924; NZ$10,208; [£5233]) and this varied from US$4636 for mTBI (US$5185; NZ$7644 [£3919]) to US$36,648 (US$40,990; NZ$60,430 [£30,980]) for moderate/severe TBI. As a result, the total costs of TBI's were predicted to increase to US$177,100,000 (US$198,081,412; NZ$292,021,521 [£149,706,426]) in 2020 [18]. While the costs of TBI have been reported, these studies have utilised a variety of methods to obtain the data ranging from hospital billing charges [19,20], national data surveys [19,20], sampling [18], reporting on specific sporting activities [21] or through literature reviews [22,23]. Further, no study to date has undertaken an epidemiological overview of the costs and numbers of TBI enabling a review of the predicted costs previously reported. Therefore, the aim of this study was to provide epidemiological data and related costs to the national health insurance scheme for traumatic brain injury (TBI) in New Zealand over a five-year period (2012–2016).

2. Methods

2.1. Accident Compensation Corporation injury reporting system and data

The only detailed epidemiological data available that records injuries in New Zealand is the Accident Compensation (ACC) database. Although the database recorded the number of injury claims and the costs associated with treatment for injuries that occur, the database does not record the specific details of the injury or the associated hospitalisation time that occurs as a result of the injury. The ACC database records, and reports, two types of acute personal injury claims [24], termed minor or moderate-to-serious claims (MSC). These terms are defined under the Injury Prevention, Rehabilitation and Compensation (IPRC) Act, 2001 and identify ACC as being responsible for meeting the costs of the injury claims lodged [24]. As defined in the IPRC Act, 2001, people qualify for cover of an injury when they present with a personal acute injury as a result of an accident to any of the 30,000 ACC recognised, registered medical practitioner's throughout New Zealand [24].

To make an injury claim, people use a standard ACC45 injury reporting form where information about the injury is collected ensuring levels of consistency for data recording and analyses. The person who has been injured completes information about the activity (unless impaired) along with their personal details (e.g., age, gender, ethnicity, contact details). The registered health professional then completes the ACC45 injury reporting form by providing information regarding initial diagnosis and other relevant medical information (e.g., surgical procedure). The claim is then filed with ACC and the relevant details are entered into a central database. As detailed in the IPRC Act, 2001, ACC covers the compensation for the injury that had occurred (sporting or other) including medical treatment, income replacement, social and vocational rehabilitation and ancillary services (transportation and accommodation) as part of the rehabilitation for the injury [25]. There is no disincentive for making claims by ACC nor are people risk-rated or penalised for the amount of claims they make [25]. Although personal injury coverage is guaranteed by ACC, this is offset by the restriction to sue for personal injury except in rare circumstances for exemplary damages [25].

For a claim to be classified as ‘minor’, ACC only pays the registered medical practitioner (e.g., physiotherapist, General Practitioner) for the medical treatment provided for that claim [24] (see Table 1). This typically involves a few treatments with ACC meeting most of the costs [24]. For a claim to be classified as MSC, the injury typically requires assistance beyond medical treatment alone [24]. As a result, MSC may involve a combination of medical care, rehabilitation costs and income replacement for employment time lost as a result of the injury [24]. For the purpose of the study, the authors focused on MSC claims from 1st January 2012 to 31st December 2016 that resulted in a brain injury (concussion/brain injury, moderate-to-severe brain injury and severe brain injury) being recorded as a result of a fall, assault, motor vehicle accident or sporting activity. The total injury claims are the minor claims combined with the moderate and severe claims for brain injuries.

All costs were inflation adjusted using the Reserve Bank inflation adjustor (https://www.rbnz.govt.nz/monetary-policy/inflation-calculator) to reflect all costs at 2017 rates with a mean inflation of 3.7 ± 1.0% per-year.

All epidemiological studies are dependent on data quality for any analysis to be undertaken [25]. Therefore, the data provided for the analyses was from the ACC database and this is dependent on several factors [26]. This database was utilised as there were no other available databases for collection of specific data such as number of falls, assaults, mother vehicle accidents or how many people participate in the sporting activities recorded and how long these activities occurred for. As a result, the authors are unable to report the data in injury rates. A potential identified limitation related to the use of this database is the way the data are retrieved to protect client confidentiality. Any data less than, or equal to, three injury claims were rounded to represent three claims only. All claims and related costs with the potential to identify an individual were removed from analyses.

Table 1
Definitions utilised in reporting and classification of Accident Compensation Corporation claims for traumatic brain injury in New Zealand by claims and causes.

Classification	Definition
Minor claims	Minor claims are where ACC has made payments to cover medical treatment costs such as those provided by a GP, physiotherapist or dentist in the period but where the client has not received entitlements.
Entitlement claims	Entitlement claims are considered to cover moderate-to-serious injuries requiring entitlement beyond medical treatment only. Examples of these payments include compensation for loss of earnings, allowances for attendant care and childcare, provision of wheelchairs and other equipment, and modifications to home and vehicles.
Moderate-to-serious claims	Moderate-to-serious claims are where the injury typically requires assistance beyond medical treatment alone (i.e. more than a minor claim). MSC may involve a combination of medical care, rehabilitation costs and income replacement for employment time lost as a result of the injury (i.e. they are more severe than minor claims and can include entitlement costs).
Severe claims	Severe claims are those claims that are being managed by Serious Injury Claim Unit. These claims generally include those that will require constant monitoring for a long time
TBI	Concussions have been defined where the read code contains 'Concussion', or the diagnosis is "Concussion/Brain injury", or where an injury has been classified as a 'severe to moderate brain injury' or 'severe brain injury'
Assault	Includes accepted claims only. It uses a mixture of a keyword search of the accident description and the relevant categories of activity prior, read code, contact and cause. Excludes Sexual Assault Claims.
MVA	Includes accepted claims only. It has claims from Motor Vehicle Account.
Fall	Includes accepted claims only. Cause = Slipping, skidding on foot, Tripping or Stumbling, loss of consciousness/sleep, something giving way underfoot, misjudgement of support, loss of balance or personal control
Sport	Includes accepted claims only. Claims where the sport field code is available.

2.2. Ethical consent

Ethical consent was sought from the Health and Disability Ethics Committee but was not required. Informed consent from the injured participants was not obtained as de-identified data were collected from the ACC data base without individual participant identification or follow-up.

2.3. Statistical analyses

To enable identification of the rate per 100,000 people, population data were obtained for the years in the study (http://archive.stats.govt.nz/~/media/Statistics/browse-categories/population/estimates-projections/pop-indicators/pop-indic-tables.xls). All data collected were entered into a Microsoft Excel spreadsheet and analysed with SPSS (IBM Corp, Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp). Data are reported as means and standard deviations (±SD) and 95% confidence intervals (CI) where appropriate [27]. Injury entitlement claims were compared for two selected periods chosen as the start (2012) and the end (2016) of the study period and by the previous year. Comparisons between reporting years were calculated using a one sample chi-squared (χ^2) test. All costs are reported in NZ (NZ$) and Great Britain Pounds (£) unless otherwise stated.

3. Results

Over the January 2012 to December 2016 period there were 97,955 ACC45 claims costing ACC NZ$1,450,643,667 [equivalent to £743,417,120] (see Table 2). The claims and costs increased over the study period from 2012 (claims: 19.4%; costs: 17.4%) to 2016 (claims: 21.4%; costs: 23.5%). Total claims increased by an average of 2.6 ± 4.0% and total costs increased by an average of 10.6 ± 3.7% per reporting year over the duration of the study. As a result, the mean cost per-claim increased from NZ$13,304 [£6818] (2012) to NZ$16,239 [£8322] (2016). On average there were 53.6 total claims lodged for a traumatic brain injury per-day equating to an average of 2.2 TBI claims lodged per-hour. There were 35,242 MSC claims representing 36.0% of the total number claims but 99.0% (NZ$1,435,773,471 [£735,769,492]) of the total costs (see Table 2). Although the number of MSC claims increased over the duration of the study from 6159 (2012) to 8269 (2016; $\chi^2 = 30.9$; $p < 0.0001$) the highest mean cost per-claim occurred in 2013 (NZ$41,134 [£21,079]) while the lowest mean cost per-claim occurred in 2015 (NZ$40,318 [£20,661]). The number of MSC claims increased by an average of

Table 2
Total claims, average claims per-day and per-hour, total costs and mean costs per-claim for traumatic brain injury claims in New Zealand from 2012 to 2016. All costs in New Zealand Dollars (NZD$).

Year	Claims				Costs	
	Total number n = (%)	Incidence per 100,000 population Mean	Average claims		Total costs NZD$ (%)	Mean cost
			Per day n =	Per-hr n =		per-claim
					NZD$	
Total claims						
2012	18,974 (19.4)	430.2	51.8	2.2	$252,429,414 (17.4)	$13,304
2013	18,905 (19.3)[ab]	425.1	51.8	2.2	$262,757,871 (18.1)	$13,899
2014	19,619 (20.0)[ab]	434.7	53.8	2.2	$287,792,206 (19.8)	$14,669
2015	19,474 (19.9)[b]	423.4	53.4	2.2	$306,916,907 (21.2)	$15,760
2016	20,983 (21.4)[ab]	446.8	57.3	2.4	$340,747,268 (23.5)	$16,239
Total	97,955 (100.0)	432.2	53.6	2.2	$1,450,643,666 (100.0)	$14,809
Moderate-to-serious claims						
2012	6159 (6.3)	139.6	16.8	0.7	$248,450,398 (17.1)	$40,339
2013	6293 (6.4)	141.5	17.2	0.7	$258,859,324 (17.8)	$41,134
2014	6952 (7.1)[ab]	154.0	19.0	0.8	$284,506,021 (19.6)	$40,924
2015	7569 (7.7)[ab]	164.6	20.7	0.9	$305,166,188 (21.0)	$40,318
2016	8269 (8.4)[ab]	176.1	22.6	0.9	$338,791,540 (23.4)	$40,971
Total	35,242 (36.0)	155.5	19.3	0.8	$1,435,773,471 (99.0)	$40,740
Minor claims						
2012	12,815 (13.1)	290.5	35.0	1.5	$3,979,016 (0.3)	$310
2013	12,612 (12.9)	283.6	34.6	1.4	$3,898,547 (0.3)	$309
2014	12,667 (12.9)[ab]	280.7	34.7	1.4	$3,286,185 (0.2)	$259
2015	11,905 (12.2)[ab]	258.8	32.6	1.4	$1,750,720 (0.1)	$147
2016	12,714 (13.0)[ab]	270.7	34.7	1.4	$1,955,728 (0.1)	$154
Total	62,713 (64.0)	276.7	34.3	1.4	$14,870,196 (1.0)	$237

SD = standard deviation; Significant difference ($p < 0.05$) compared with (a) = difference from previous year; (b) = Difference from 2012.

7.7 ± 3.7% whereas the costs increased by 11.4 ± 4.2% per reporting year over the duration of the study. Over the duration of the study, there was an average of 22.4 MSC TBI claims per-day equating to an average of 0.9 MSC TBI claims per-hour. More than half (64.0%, 62,713) of the total TBI claims were classified as minor. As a result, there was an average of 36.5 TBI claims per-day equating to an average of 1.5 TBI claims per-hr. The mean cost per minor TBI claim decreased over the study duration from $310 [£159] (2012) to $154 [£79] (2016).

Falls accounted for nearly half (41.7%; 8262) of the moderate claims and over a quarter (39.9%; NZ$67,626,000 [£34,662,176]) of the costs (see Table 3). There were more moderate TBI claims recorded as a result of sport than MVA ($\chi^2 = 177.4$; $p < 0.0001$) and assaults ($\chi^2 = 1970.9$; $p < 0.0001$). On average there were 10.9 ± 2.1 moderate TBI claims lodged every day equating to an average of 0.5 ± 0.1 TBI claims lodged per-hr. Falls recorded the highest moderate TBI cost per-year (NZ$13,525,200 ± NZ$3,693,509 [£6,932,435 ± £1,892,755]) but MVA recorded the highest mean TBI cost per-claim per-year (NZ$11,691 ± NZ$931 [£5911 ± £477]). Motor vehicle accidents recorded the highest number of serious TBI claims (8638, 56.0%) and total costs (NZ$561,239,815 [£287,609,862]; 65.1%) over the duration of the study. This was similar for severe claims where motor vehicles accidents accounted for 56% of the total serious claims, 65.1% of the costs with a mean cost per-serious claim of NZ$64,913 ± $NZ4,331 [£32,759 ± £2186] per-year. There were more serious TBI claims recorded for sport ($\chi^2 = 4.5$; $p = 0.0329$) when compared with assaults, however assaults recorded a higher cost per-year (NZ$10,231,115 ± NZ$1,714,964 [£5,242,981 ± £878,841]) and mean cost per-claim per-year (NZ$23,209 ± NZ$12,327 [£11,894 ± £6317]). There were an average of 9.2 ± 1.5 serious TBI claims lodged every day equating to an average of 0.4 ± 0.1 serious TBI claims lodged per-hr. Motor vehicle accidents recorded the highest percentage (36.5%), total costs (NZ$610,978,229 [£313,170,000]) and highest mean cost per-claim per-year (NZ$47,372 ± NZ$2401 [£24,282 ± £1231]) for MSC TBI claims over the duration of the study. There were more MSC TBI claims recorded as a result of falls than sports ($\chi^2 = 1419.1$; $p < 0.0001$) and assaults ($\chi^2 = 5439.9$; $p < 0.0001$). On average there were 19.3 ± 2.4 MSC claims for a TBI lodged per day equating to 0.8 ± 0.1 claim lodged per-hour.

4. Discussion

This study identified the number of injury entitlement claims lodged, and the associated costs for traumatic brain injuries that were

Table 3
Total, moderate, severe and moderate-to-severe injury entitlement claims; average claims per-year, per-day, per-hour; total injury entitlement costs; average costs per year and mean costs per-claim per-year for traumatic brain injury claims by motor vehicle accidents, fall, sport and assaults in New Zealand from 2012 to 2016. All costs in New Zealand Dollars (NZD$).

	Injury entitlement claims					Injury entitlement costs		
	Total Number	Mean Per-year	Incidence per 100,000 population	Average claims		Total costs (%)	Mean costs per year	Mean cost per-claim
				Per-day	Per-hr			Per-year
	n = (%)	Mean ± SD	Mean (95% CI)	Mean ± SD	Mean ± SD	NZD $	Mean ± SD	Mean ± SD
Moderate claims								
Falls	8,262 (41.7)[bcdef]	1,652.4 ± 378.6	36.3 (29.9-42.7)	4.5 ± 1.0	0.2 ± 0.0	$67,626,000 (39.9)	$13,525,200 ± $3,693,509	$8,123 ± $363
Sport	5,556 (28.0)[acdef]	1,111.2 ± 276.3	24.4 (19.6-29.2)	3.0 ± 0.8	0.1 ± 0.0	$34,421,704 (20.3)	$6,884,341 ± $2,254,721	$6,095 ± $533
MVA	4,238 (21.4)[abdef]	847.6 ± 71.1	18.7 (17.7-19.6)	2.3 ± 0.2	0.1 ± 0.0	$49,708,414 (29.3)	$9,941,683 ± 1,483,440	$11,691 ± $931
Assaults*	1,759 (8.9)[abcef]	351.8 ± 55.8	7.7 (6.8-8.6)	1.0 ± 0.2	0.0 ± 0.0	$17,565,573 (10.4)	$3,513,021 ± $770,509	$9,911 ± 628
Total	19,815 (100.0)[ef]	3,963.0 ± 779.0	87.1 (74.1-100.1)	10.9 ± 2.1	0.5 ± 0.1	$169,321,222 (100.0)	$33,864,244 ± 8,157,412	$8,489 ± $416
Serious claims								
MVA	8,638 (56.0)[bcdf]	1,727.6 ± 61.1	38.1 (37.3-38.9)	4.7 ± 0.2	0.2 ± 0.0	$561,239,815 (65.1)	$112,247,963 ± 10,145,371	$ 64,913 ± $4,331
Falls	3,982 (25.8)[acdef]	796.4 ± 61.6	17.6 (16.7-18.4)	2.2 ± 0.2	0.1 ± 0.0	$200,881,231 (23.3)	$40,176,246 ± $5,079,694	$50,334 ± $3,312
Sport	1,460 (9.5)[abd]	292.0 ± 25.0	6.4 (6.1-6.8)	0.8 ± 0.7	0.0 ± 0.1	$49,334,269 (5.7)	$9,866,854 ± $1,633,119	$33,643 ± $3,020
Assaults*	1,347 (8.7)[abcef]	269.4 ± 42.5	6.0 (5.1-6.8)	0.7 ± 0.1	0.0 ± 0.0	$51,155,573 (5.9)	$10,231,115 ± $1,714,964	$39,209 ± $12,327
Total	16,780 (100.0)[ef]	3,356.0 ± 555.2	68.0 (67.3-68.8)	9.2 ± 1.5	0.4 ± 0.1	$862,610,888 (100.0)	$172,522,888 ± $18,400,403	$52,613 ± $10,247
Moderate-to-severe claims								
MVA	12,876 (36.5)[bcdef]	2,575.2 ± 121.0	56.8 (55.6-58.0)	7.0 ± 0.3	0.3 ± 0.0	$610,948,229 (42.6)	$122,189,646 ± $11,526,412	$47,372 ± $2,401
Falls	12,244 (34.7)[acdef]	2,448.8 ± 433.5	53.9 (46.7-61.0)	6.7 ± 1.2	0.3 ± 0.0	$268,507,231 (18.7)	$53,701,446 ± $8,636,744	$21,980 ± $573
Sport	7,016 (19.9)[abdef]	1,403.2 ± 298.5	30.8 (25.8-35.9)	3.8 ± 0.8	0.2 ± 0.0	$73,619,703 (5.1)	$14,723,941 ± $3,562,616	$10,445 ± $334
Assaults*	3,106 (8.8)[abcef]	621.2 ± 58.3	13.7 (12.8-14.6)	1.7 ± 0.2	0.1 ± 0.0	$68,720,677 (4.8)	$13,744,135 ± $2,484,152	$22,053 ± $2,848
Total	35,242 (100.0)[ef]	7,048.4 ± 884.9	155.2 (141.6-168.7)	19.3 ± 2.4	0.8 ± 0.1	$1,435,773,471 (100)	$287,154,694 ± $36,388,335	$40,737 ± $381

SD = standard deviation; CI = Confidence Interval; MVA = Motor Vehicle Accidents; * = refers to the physical injuries purposefully inflicted onto a person and includes non-accidental and intentional injuries, and domestic violence; Significant difference ($p < 0.05$) compared with (a) = MVA; (b) = Falls; (c) = Sport; (d) = Assaults; (e) = Difference across reporting period; (f) = Difference from 2012.

recorded on the ACC database in New Zealand over the 2012 to 2016 reporting period. As shown there were 97,955 injury claims lodged over the duration of the study but only 36% (n = 35,304) were classified as MSC. It must be noted that the term MSC is an accounting term utilised by ACC and is not a reflection of the severity classification of the injury recorded. The majority of the claims recorded (n = 62,713; 64%) reflect the number of TBI claims that did not require further additional rehabilitation assistance. The numbers reported in this study are not a reflection of how many TBI injuries were occurring [28] but how many injuries were recorded by individuals. The results of this study could be biased as they exclude those individuals that do not lodge an ACC injury entitlement form for a TBI that they dealt with themselves, or were unaware of, and those TBI that were not identified when medically assessed resulting in an under-reporting of the actual number, and costs of these injuries. All the injuries recorded in this study required additional assistance beyond medical treatment alone [24].

Over the past decade there has been a large focus on sports-related concussion [2,29], its longitudinal effects, increasing the awareness of, and in the assessment and management of sports-related concussion. Although the awareness has increased, the finding that sport TBI accounted for one-fifth (20%) of MSC claims and 5.1% of MSC costs highlights that other areas relating to TBI are in need of a similar focus in order to begin to assess and manage these injuries across the general population.

Over the duration of the study there has been an upward trend in the number of TBI claims and, as a result, the associated costs recorded. The finding that the number of sports claims recorded annually by 2.6% may be related to the increased media coverage of sports-related concussions and the associated education surrounding this (see Fig. 1A), and the upward trend towards the end of the reporting period for sports reflects maybe reflective of this. What was unexpected was the initial decrease in fall related TBI then the rise towards the end of the study period. As no gender and age specific data were available for analysis the reason for this remains unclear but further research is warranted to identify the reason for the increase in the number of fall related TBI. Interestingly the number of MVA and assault TBI claims remained similar over the reporting period. Although some of the costs can be accounted for through an annual inflation rate of 1.1% over the reporting period (Reserve Bank of New Zealand inflation adjustor; https://www.rbnz.govt.nz/monetary-policy/inflation-calculator) the finding that the costs increased on average by 10.6% per year (see Fig. 1B) is unclear.

The difficulty in identifying the true extent of TBI is there is no single universally accepted definition [29,30], and these injuries are often not reported [31] or people may not be aware that they actually have a TBI. Traumatic brain injuries have been reported to occur as a result of a direct blow to the head, face, neck or elsewhere in the body that results in an impulsive force transmitted to the head [2]. But other forms of force can also result in a TBI occurring such as shaking of the body, anoxia or hypoxia as a result of strangulation, drowning or pressure applied to the throat or chest [17,30,32]. In a review [17] of screening tools, it was reported that no single tool covered all aspects of the possible mechanisms that may result in a TBI occurring. As a result, the accuracy of TBI diagnosis in an emergency department may be limited. It has been identified [33] that despite patients reporting symptoms

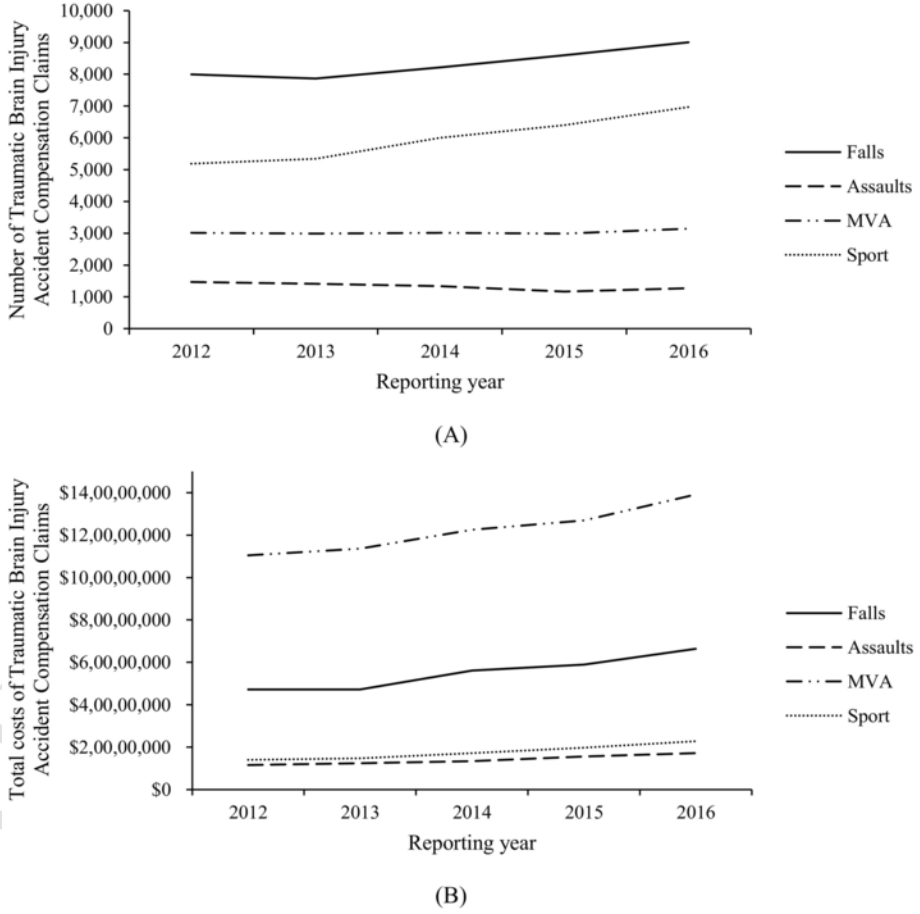

Fig. 1. Total traumatic brain injury Accident Compensation Corporation injury claims (A) and associated costs (B) by reporting year for the four categories of injury cause for 2012 to 2016 in New Zealand. MVA = Motor Vehicle Accidents.

consistent with a mTBI diagnosis, the diagnosis of mTBI were frequently not recorded [33,34]. This may be a reflection of the primary mission of emergency departments to stabilise and treat serious injuries and, combined with time constraints, may result in possible TBI to remain undiagnosed [34]. As a result, the true extent of TBI will be under-reported.

In reporting [18] on the cost of traumatic brain injury in New Zealand, it was identified that the average cost per new TBI was US$5922 (inflation adjusted to 2017: US$6924; NZ$10,208;[£5233]). This value is similar to the moderate TBI costs (NZ$8489 [£4350]) reported in this study, yet well below the mean MSC cost per-claim, per-year of NZ$40,737 [£30,848]. When compared by moderate and serious TBI claims, it has been reported [18] that the total lifetime cost of a mild TBI (mTBI) was US$4636 (2017: US$5185; NZ$7644 [£3919]) per person whereas the moderate/severe TBI total lifetime cost was US$36,648 (2017: US$40,990; NZ$60,430 [£30,980]) which is more than the costs reported in the current study. It was also identified [18] that the total cost for TBI in 2010 was US$146,500,000 (2017: US$163,856,165; NZ$241,646,879 [£123,826,103]) and this was predicted to rise to US$177,100,000 (2017: US$198,081,412; NZ$292,021,521 [£149,706,426]) by 2020. The costs recorded in this study were NZ$252,429,414 [£129,343,032] in 2012, and this is similar to the previous cost reported [18] but this rose to NZ$340,747,268 [£174,596,470] in 2016, and this is higher than the costs previously predicted over a shorter time period. Further epidemiological studies are recommended to continue to monitor and evaluate the number and costs of TBI.

The global incidence rate of TBI has been estimated to be 200 per 100,000 people per year, which is less than half of the rate reported in this study, but this is likely to be an underestimation of the true incidence [35]. In a systematic review and meta-analysis on the international incidence of TBI [36], the pooled annual incidence of TBI was 294.7 per 100,000 population. The incidence proportion of TBI varied with Europe (227.7 per 100,000 population) being lower than North America (331.3 per 100,000 population), Asia (380.4 per 100,000 population) and Australasia (414.6 per 100,000 population) [36] which is similar to the current study. These incidence rates in other countries show that the incidence rate and costs of TBI's in New Zealand are problematic.

The incidence of TBI in New Zealand had been reported [6] to be 790 per 100,000 population based on data obtained through one regional district. It was reported [6] that more than a quarter (28%) of the TBI's recorded were outside of a hospital or the family doctor. This is similar to other studies that have reported that not all TBI's (especially mTBI) are reported to a health practitioner or hospital and, as a result of this, the true incidence remains unknown. Although this study has reported the incidence of TBI in New Zealand to be somewhat less than the previous regional district study [6] (432 per 100,000 population) if an estimated 28% of the total population over the study period did not lodge an ACC injury claim for a TBI, and this percentage were to be added to the database numbers, the resulting incidence may be in the vicinity of 523 to 552 per 100,000 population based on ACC data.

In 2002, when reporting [15] on intimate partner abuse (IPV), it was identified that as many as 92% of IPV victims reported to have received blows to the head and, for 40% of the victims this has resulted in loss of consciousness. In addition, it was also reported [15] that 83% of IPV victims have been hit in the head and shaken, 72% had been strangled and 8% had received blows to the head at least 20 times in the previous year. Additional research has identified that the incidence of TBI in IPV victims ranges from 30 to 75% [32]. These acts of violence often involve choking, blows to the head or being forcibly shaken and these have been reported to place an individual at a high risk for a brain injury [37], but these are often not identified in IPV victims and remain undiagnosed [10]. The effects of repetitive impacts to the head have been reported in sports-related concussion and have identified that in the immature brain, exposure to repetitive impacts to the head can lead to long-term associative learning deficits in adulthood [38]. As well, exposure to repetitive head impacts results in microstructural and functional changes to the brain but the long term sequelae of repetitive impacts has yet to be identified [39]. The assessment of these types of injuries are often not completed as the primary focus on the healthcare provider is on the visible physical injuries while the subtle symptoms of TBI in IPV and child abuse victims are overlooked [10,11]. As a result, the costs and number of TBI recorded in this study for assault are likely to be under-reported. Further research is warranted into the assessment and management of IPV and child abuse victims for TBI.

There are several limitations to this study that should be considered when interpreting the data presented here. The dataset contained only summary data for the TBI claims and costs by minor, moderate and severe classifications and no further analysis could be undertaken in an area such as age, gender, and ethnicity. The data pertaining to assaults, falls and MVA TBI claims and costs did not have a breakdown of the causative mechanism and therefore, limited the analysis that was undertaken. In addition, unless the healthcare provider is aware of the risk of aspects of TBI such as concussion (mTBI) when assessing people with a fall, assault or MVA injury then this aspect may be omitted from the assessment. As a result, the data pertaining to TBI in these categories may be under-reported.

5. Conclusion

This study reports the number of ACC claims lodged, and the associated costs of TBI that occurred in New Zealand over a five-year period. The incidence of TBI for the 2013 to 2017 was 432 per 100,000 population resulting in average of 53.6 total claims lodged for a TBI per-day equating to an average of 2.2 TBI claims lodged per-hour. The majority of claims (64%) were classified as minor, but this accounted for only 1% of the total TBI costs. Although the awareness of TBI has increased, the finding that sport TBI accounted for one-fifth (20%) of MSC claims and 5.1% of MSC costs highlights that other areas relating to TBI are in need of a similar focus in order to begin to assess and manage these injuries across the general population.

Competing interests

The authors declare that there are no competing interests associated with the research contained within this manuscript.

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The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted. According to the definition given by the International Committee of Medical Journal Editors (ICMJE), the authors listed above qualify for authorship based on making one or more of the substantial contributions to the intellectual content of:

(i) Conception and design [DK; PH; NH]; and/or,
(ii) Acquisition of data [NH; DK; PH]; and/or
(iii) Analysis and interpretation of data [DK, PH, NH, CC, TC, AP]; and/or
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