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Prevalence of traumatic brain injury in a male adult prison population and links with offence type

Short title: Prevalence of TBI in prison

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ABSTRACT

Background: Prevalence of traumatic brain injury (TBI) in prison populations has been found to vary considerably. This study aimed to determine prevalence of TBI in a prison population in New Zealand and to identify whether age, ethnicity, offence type, security classification and sentence length were linked to TBI prevalence.

Methods: All offenders admitted to a new Corrections Facility over a 6-month period (May-November 2015) were screened for history of TBI. Data was merged with demographic information, details of the offence type, sentence length and security classification from the prison database. Binary logistic regression was used to identify the contribution of predictors on TBI history.

Results: Of the 1061 eligible male prisoners, N=1054 (99.3%) completed a TBI history screen. N=672 (63.7%) had sustained at least one TBI in their lifetime, with N=343 (32.5%) experiencing multiple injuries. One in five participants experienced their first TBI injury before the age of 15 years. A regression model was able to correctly classify 66.9% of cases and revealed that being of Māori ethnicity or being imprisoned for violent, sexual or burglary offences were independently predictive of TBI ($\chi^2 = 9.86$, $p= 0.28$).

Conclusions: The high prevalence of TBI within male prisoners and a high proportion of injuries sustained in childhood suggests the need for routine screening for TBI to identify prisoners at risk of persistent difficulties. Interventions to support those experiencing persistent difficulties post-TBI are needed to optimise functioning and prevent re-offending.

INTRODUCTION

Traumatic brain injury (TBI) is defined as an injury to the brain resulting from an external physical force.[1] In the general population it is projected that 13.0% of the general population have experienced at least one TBI in their lifetime.[2] Prevalence is slightly higher (14.3%) in NZ males aged 35-39 years.[2] Following a TBI people can experience long-term cognitive and emotional difficulties that affect every day functioning, decision making, social relationships and employment.[3-6] Additionally, there is evidence of a relationship between TBI and increased dysregulated behaviours such as impulsivity and aggression, mood disturbances and substance abuse and psychiatric conditions and[7] a link between a history of TBI and engagement in anti-social or criminal behaviour has been proposed. [8 9]

Adults who experienced a TBI in their childhood have been found to have a 1.7 fold increased risk of incarceration when compared to non-injured siblings.[8] Evidence also suggests that a history of TBI is linked to poorer behaviour within the prison. For example, inmates experiencing at least one TBI in their lifetime were less able to follow rules and experienced more in-prison violent infractions than those prisoners who had not experienced a TBI.[10] Additionally, a history of TBI has been linked with re-offending following release into the community.[6] Elbogen et al,[11] revealed that the relationship between history of TBI and criminal activity is likely to be complex. For example, demographic factors such as the age of the person when the injury was sustained and pre-injury behaviour are highly likely to influence the relationship between TBI and criminal behaviour.[11] It may also be the case

that the TBI may be linked to some offences (such as violence towards others) but not others (such a fraud), however, these links remain unclear.

A recent meta-analysis revealed that the prevalence of traumatic brain injuries in prison populations is far higher than in the general population.[12] The review provides evidence that many studies exploring prevalence in prison populations have been limited by selected or random samples reducing representativeness of the findings. Only four studies routinely screened all male offenders admitted over a specified time period.[6 13-15] Based on these four studies, prevalence of TBI in prison populations was found to vary considerably between 31% in France and 82% in Australia and the United States, with one study revealing a prevalence of 61% for repeated (two or more) TBIs.[16] However, all of the aforementioned studies used different TBI screening tools which means there are challenges in drawing comparisons because of the varying definitions of TBI and screening protocols.

In New Zealand (NZ), only one study of TBI prevalence in prisoners has been conducted. It revealed that in 1998, NZ had the highest prevalence of TBI in offenders internationally, with 86% of male prisoners reporting experiencing at least one TBI in their lifetime. However, the study was based in a provincial prison, did not include high security prisoners and only recruited a selective sample of 118 prisoners (about one third of the potential sample pool) therefore reducing representativeness of the sample. The study also used terminology that was not well defined, such as ‘light’ TBI, making it difficult to translate the findings. In this study it was reported that there were significant ethnic disparities between Māori (the indigenous population of NZ) and Europeans, however, based on the lack of a representative sample it is unclear if this increased prevalence was due to the sampling methods used or reflects an actual increased lifetime risk of TBI.[17] Consequently, there is a need for a population-based prevalence study of TBI history in NZ prisoners.

Security classifications of prisoners are assessed dynamically and reflect the internal and external risks to safety and security. Based on evidence that prisoners with a history of TBI have more prison infractions[10] the relationships between security classification and sentence length therefore need to be determined to identify those most at risk of a positive TBI history. Consequently, this study aimed to understand the prevalence and characteristics of TBI in a NZ prison population and to identify whether age, ethnicity, offence type, security classification and sentence length are linked to prevalence of TBI in this population.

METHODS

This study received ethical approval from the Northern B Health and Disability Ethics Committee (17/NTB/22), Auckland University of Technology Ethics Committee (15/41) and the internal ethics committee of the corrections facility.

Participants: All adult (>18 years) male offenders admitted to the Auckland South Corrections Facility in NZ over a six month period (18th May to 18th November 2015) were eligible for inclusion in the study. Offenders may have been newly sentenced or moved from another prison during this time.

Measures: The TBI screening questions were extracted from a NZ general population incidence study of TBI to enable comparison.[18] These questions were developed to operationalise the World Health Organisation definition of brain injury[1] where the person was asked "have you ever been involved in an accident, where you hit your head and were left feeling dazed, confused or lost consciousness?" The total number of events was recorded,

including details of what happened, age at the time the injury was sustained, whether they lost consciousness and for how long, and any symptoms experienced after the injury (for which more than one could be indicated).

As many mild TBIs often go unreported[16] and many TBIs are missed in medical records, particularly in cases of polytrauma,[19] self-reported prevalence was utilised in preference to medical records. Self-reported TBI in offenders has been found to have high concordance against medical records of TBI, supporting the use of such as an approach to determine prevalence.[20] The severity of the injury was categorised based on period of loss of consciousness[21] with mild TBI (unconscious for less than 30 minutes), moderate (unconscious for more than 30 minutes but less than 24 hours) or severe (unconscious for more than 24 hours). TBI screens were conducted between 2 to 21 days post-admission, in a private interview space within the prison.

Procedure: In conjunction with the opening of the new prison facility in NZ, the TBI screening tool was integrated into the routine electronic health screen conducted with all new inmates. As part of the consent procedure for the health screen, participants gave permission for anonymised information to be used for research purposes. It was made explicit that their confidentiality would be maintained and information may be used for research purposes and to support the development of services. Male prisoners were also informed that their results would have no influence on their care within the prison. All data was de-identified and study procedures had the oversight of the Ethics Committee(s). The lead investigator did not personally administer any TBI screens. If English was not the prisoner's primary language they were supported to complete the TBI screen through members of the healthcare team who could converse in the participant's primary language or via a telephone interpreting service.

Data from the TBI screens collected between May to November 2015 was used for this analysis. Demographic information on age and self-reported ethnicity were extracted from the prison databases. Any identifying information was removed to protect prisoner identity. Offence related information was accessed from the Integrated Offender Management System which is a nationwide Department of Corrections application. This provided details of the prisoner's unique identifier, the offence, sentence length and the most up to date security classification. In the case of multiple offences, the most serious offence was recorded for the purpose of this study. The database had protected access and information was only entered by two members of the healthcare team to ensure consistency. Random data entry checks were conducted to ensure integrity. Offence category and sentence classification were based on standardised definitions employed by the Department of Corrections.

Statistical analysis: Data was entered into IBM SPSS Version 24.0. Descriptive analysis was undertaken to determine the number of prisoners who experienced at least one TBI in their lifetime and the proportion experiencing multiple injuries. Differences between those who had experienced at least one TBI and those who had not were explored using t-tests or Chi square tests. The links between the number of injuries sustained within the person's lifetime and age, ethnicity, sentence length, offence type and security classification level were analysed using binary logistic regression. Statistical significance was set at the $p<0.05$ level.

RESULTS

Of the 1061 men who were admitted to the prison within the study timeframe, 1054 (99.3%) consented to receiving healthcare and as such participated in a TBI screen. Seven men

declined. A further eight men consented to the TBI screen but during the course of the assessment became agitated and verbally aggressive, and a full TBI history was not completed. Of the 672 male prisoners completing the health screen, 63.8% reported experiencing at least one TBI in their lifetime. Similar to the NZ general population, the vast majority of TBIs were classified as being mild in severity. Differences between those experiencing a TBI in their lifetime and those who did not are outlined in Table 1. Statistically significant differences were observed for ethnicity and offence type.

INSERT TABLE 1 HERE

Binary logistic regression was applied to identify whether current age, ethnicity, offence category, security classification or sentence length was predictive of TBI history. The model showed overall good fit to the data with $\chi^2 = 9.86$, p= 0.28 and was able to correctly classify 66.9% of cases. As shown in table 2, being of Māori ethnicity, being imprisoned for violent, sexual or burglary offences were independently predictive of TBI history. Whilst age, security classification and sentence length contributed to the regression model they were not independently predictive of TBI history.

INSERT TABLE 2 HERE

Of those experiencing a TBI in their lifetime, more than half (N = 343, 51.0%) had experienced multiple injuries. Details of TBI history are outlined in Table 3. Of the male prisoners who sustained a TBI, 22% had experienced their first TBI injury before the age of

15 years, with one in five of these caused by an assault. The mean time between age of first injury and age at the time of the TBI screen was 14.35 years (SD 13.04). The most common mechanism of injury (as shown in Table 3) related to assault. Assaults included being punched or kicked to the head, or hit with metal or wooden objects with the intention to cause harm. Injuries identified as 'being hit by an object' were non-intentional injuries such as receiving a knee to the head during a rugby game. The majority of injuries involving being hit by an object were sustained during a sports activity (19.2%). Motor vehicle accidents were most commonly attributed to accidents with unrestrained drivers (head versus windscreen or steering wheel) with alcohol being a common factor. Falls were defined as a person tripping over and falling to the ground or falling off something such as a ladder or bike.

INSERT TABLE 3 HERE

DISCUSSION

This study aimed to determine the prevalence of TBI in a NZ male prison and to identify whether age, ethnicity, offence type, security classification and sentence length were linked to prevalence of TBI. Prevalence was found to more than four times higher (63.7%) than males of an equivalent age in the NZ general population (14.3%). Men identifying as being of Māori ethnicity or who were imprisoned for a burglary, violent or sexual offence were more likely to have sustained a TBI in their lifetime. Male prisoners identifying as being of 'other' ethnicity (including Asian, Indian, South American, African and not specified) had a lower prevalence of TBI. Whilst prison sentence length and security classification contributed to the overall

explanation of variance in the regression model, they were not independent predictors of TBI history. The findings reveal the importance of routine TBI screening in prison facilities.

The prevalence of TBI in this sample was within the middle range of the (31%-82%) prevalence reported internationally within prison populations. The rates of recurrent injury in the current sample were however, much lower than previously reported (51% compared to 61%).[16] One of the challenges in determining prevalence of TBI is that male prisoners can find it difficult to accurately recall injuries, particularly those that were relatively mild or sustained early on in life. Indeed, public awareness of mild injuries has previously been found to be low.[22] This study utilised questions to identify TBI to enable direct comparison of results to the NZ general population. Other screening tools such as the Brain Injury Screening Index[16] or Traumatic brain injury Questionnaire[23] were developed specifically for use with offenders but are subject to similar recall biases. Given the limited awareness or potential underreporting of prior TBIs, prevalence of TBI is likely to be an underestimate of the true scope of the burden. A systematic review[12] on screening for TBI in prison populations reported that there were many challenges in accurately screening for TBI and that comparisons between studies were difficult to make due to the wide diversity of screening tools used. Establishing a consensus on a TBI screening tool and definition of TBI will facilitate comparisons across international literature and between different populations, if applicable also as a tool for the general population.

The higher prevalence of TBI in Māori reflects an increased risk of TBI in Māori in comparison to New Zealand Europeans [19] As ethnic minority groups have been found to be at increased risk of TBI internationally,[24] those identifying as being of an ethnic minority group may also be at increased risk within the international prison population. In contrast to other findings that falls are the main cause of TBI in the general population,[19] assaults were identified as the main cause of TBI in this study. One in five of those experiencing a TBI reported that their first TBI occurred before the age of 15 years. This supports evidence of a

link between early childhood trauma and risk of engagement in criminal activity in later life. Longitudinal studies are needed to determine if there are causal links between early injury and engagement in antisocial behaviour later on in life to inform youth crime prevention initiatives.

The increased prevalence of TBI in men detained for burglary, sexual or violent offences, may suggest a link between the emotional and behaviour regulation as well as decision making that can occur following a brain injury.[7] Indeed the findings support a previous study identifying that between 5-35% of sexual offenders were found to have some neurological damage.[25] Although as suggested by current research literature, the relationships are likely to be more complex and could also be influenced by other factors such as mental health and substance abuse.[26 27] The links between TBI history and offence type identified in this study highlight the need for further exploration between these links.

Whilst this study has highlighted those most at risk of having sustained a TBI in the prison population, the sample may not be representative of a more stable prison population, as the study included prisoners who were transferred to a new prison in South Auckland. The prisoners were adjusting to different systems and processes and as such some of the male prisoners may not have had confidence or trust in the system to disclose TBI information. Despite reassurances, some of the men had verbally stated that they felt they would get in trouble if they had experienced a TBI, especially if there were any prison related injuries. Trust has been identified as a longstanding issue for prisoners, both from a prison/staff and prisoner to prisoner perspective,[28] however, this was managed through the development of relationships and reassurance of confidentiality, processes and how the information would be used. It should also be noted that the sample population were sentenced male prisoners (over the age of 18 years) predominantly from the Auckland region. Given the identified higher prevalence of TBI within the prison population and potential link to engagement in criminal

behaviour and re-offending, it would be important to extend this work through screening young offenders, female prisoners and the inclusion of the remand prison population to determine if similar trends emerge.

A further limitation of this study is that it was not able to determine the proportion of male prisoners who may still be experiencing persistent difficulties following TBI. Given deficits have been found to persist for many years, even after mild TBI,[29] assessments to determine prevalence of common deficits post TBI including post-concussion symptoms, level of cognitive functioning, sleep difficulties and social skills would be useful to identify the difficulties experienced within the prison population. Understanding potential areas where interventions could be targeted may assist in optimising quality of life and reduce re-offending.

As only restricted information was available from the prison service for study participants, limited data on pre-imprisonment psychiatric history, substance use, prior incarceration or neuropsychological profiles was available. However, these factors have been found to be predictive of persistent problems following TBI in both the general population and in prison.[30] It would be important for future studies to explore these additional factors and the role they may play on the effects of TBI on a person's level of functioning and offending.

Based on the feasibility of TBI screening process demonstrated in this study, the TBI screens now form a formal on-going part of the standard health screening procedure in this corrections facility alongside a measure of current post-concussion symptoms to inform the management and care of prisoners who may be experiencing persistent deficits following TBI. Knowledge of TBI history and current symptoms could be used to help identify potential difficulties male prisoners may be experiencing in prison, such as taking longer to process or remember information, fatigue or noise sensitivity. The management of prisoners

within the corrections facility could be developed to include specific staff training around TBI and the establishment of TBI specific units with the aim of supporting the management of persistent TBI impairments.

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REFERENCES

1. Carroll LJ, Cassidy JD, Holm L, Kraus J, Coronado VG, on behalf of the WHO Collaboratng Centre Task Force on Mild Traumatic Brain Injury. Methodological issues and research recommendations for mild traumatic brain injury: the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. J Rehabil Med 2004(43 Suppl):113-125.
2. Te Ao B, Tobias M, Ameratunga S, McPherson K, Theadom A, Dowell A, Starkey N, Jones K, Barker-Collo S, Brown P, Feigin V on behalf of the BIONIC Research Group. Burden of traumatic brain injury in New Zealand: Incidence, prevalence and disability adjusted life years. Neuroepidemiol 2015;**44**(4):255-261.
3. Scholten AC, Haagsma JA, Andriesson TM, Vos PE, Steyerberg EW, van Beeck EF, Polinder S. Health related quality of life after mild, moderate and severe traumatic brain injury: patterns and predictors of suboptimal functioning during the first year post injury. Injury 2015;**46**(4):616-624.
4. Theadom A, Parag V, Dowell T, McPherson K, Starkey N, Barker-Collo S, Jones K, Ameratunga S, Feigin VL on behalf of the BIONIC Research Group. Persistent problems 1 year after mild traumatic brain injury: a longitudinal population study in New Zealand. BJGP 2016;**66**(642):e16-23 doi: 10.3399/bjgp16X683161.

5. Brown AW, Moessner AM, Mandrekar J, Diehl NN, Leibson CL, Malec JF. A survey of very-long-term outcomes after traumatic brain injury among members of a population-based incident cohort. J Neurotrauma 2011;**28**(2):167-76 doi: 10.1089/neu.2010.1400.
6. Piccolino AL, Solberg KB. The Impact of Traumatic Brain Injury on Prison Health Services and Offender Management. J Correct Health Care 2014;**20**(3):203-212.
7. O'Rourke C, Linden MA, Lohan M, Bates-Gaston J.. Traumatic brain injury and co-occurring problems in prison populations: A systematic review. Brain Inj 2016;**30**(7):839-854
8. Schofield PW, Malacova E, Preen DB, D'Este C, Tate R, Reekie J, Wand H, Butler T.. Does Traumatic Brain Injury Lead to Criminality? A Whole-Population Retrospective Cohort Study Using Linked Data. PLOSone 2015; 10(7):e0132558.
9. Kennedy E, Heron J, Munafo M. Substance use, criminal behaviour and psychiatric symptoms following childhood traumatic brain injury: findings from the ALSPAC cohort. Eur Child and Adolesc Psychiatry 2017; Mar 17. doi: 10.1007/s00787-017-0975-1.
10. Shiroma EJ, Pickelsimer EE, Ferguson PC, Gebregziabher M, Lattimore PK, Nicholas JS, Dukes T, Hunt KJ. Association of medically attended traumatic brain injury and in-prison behavioural infractions: a statewide longitudinal study. J Correc Health Care 2012;**16**(4):273-286.
11. Elbogen EB, Wolfe JR, Cueva M, Sullivan C, Johnson J. Longitudinal Predictors of Criminal Arrest After Traumatic Brain Injury: Results From the Traumatic Brain Injury Model System National Database. J Head Trauma Rehabil 2015;**30**(5):E3-13.
12. Allely CS. Prevalence and assessment of traumatic brain injury in prison inmates: a systematic PRISMA review, . Brain Injury 2016;**30**(10):1161-1180.
13. Perkes I, Schofield PW, Butler T, Hollis SJ. Traumatic brain injury rates and sequelae: a comparison of prisoners with a matched community sample in Australia. Brain Inj 2011;**25**(2):131-141
14. Ray B, Sapp D, Kincaid A. Traumatic brain injury among Indiana state prisoners. J Forensic Sci 2014;**59**(5):1248-1253.
15. Durand E, Watier L, Fix M, Weiss JJ, Chevignard M, Pradat-Dieh P. Prevalence of traumatic brain injury and epilepsy among prisoners in France: Results of the Fleury TBI study. Brain Inj 2016;1(1):e00535 doi: 10.1002/brb3.
16. Pitman I, Haddlesey C, Ramos SD, Oddy M, Fortescue D.. The association between neuropsychological performance and self-reported traumatic brain injury in a sample of adult male prisoners in the UK. Neuropsychol Rehabil 2015;**25**(5):763-779 doi: 10.1080/09602011.2014.973887.
17. Barnfield TV, Leathem JM. Incidence and outcomes of traumatic brain injury and substance abuse in a New Zealand prison population. Brain Inj 1998;**12**(6):455-466.
18. Theadom A, Barker-Collo S, Feigin V, Starkey NJ, Jones K, Ameratunga S, Barber PA on behalf of the BIONIC Research Group. The spectrum captured: a methodological approach to studying incidence and outcomes of traumatic brain injury on a population level. Neuroepidemiology 2012(38(1):18-29.
19. Feigin VF, Theadom A, Barker-Collo SL, Starkey NJ, McPherson K, Kahan M, Dowell A, Brown P, Parag V, Kydd R, Jones K, Jones A, Ameratunga S, on behalf of the BIONIC Research Group. Incidence of traumatic brain injury in New Zealand: a population-based study. Lancet Neurol 2013;**12**(1):53-64.
20. Schofield P, Butler T, Hollis S, D'Este C. Are prisoners reliable survey respondents? A validation of self-reported traumatic brain injury (TBI) against hospital medical records. Brain Inj 2011;**25**(1):74-82.
21. Corrigan JD, Selassie AW, Orman JA. The epidemiology of traumatic brain injury. J Head Trauma Rehabil 2010;**25**(2):72-80 doi: 10.1097/HTR.0b013e3181ccc8b4.
22. Cusimano MD, Zhang S, Topolovec-Vranic J, Hutchinson MG, Jing R. Factors affecting the concussion knowledge of athletes, parents, coaches, and medical professionals. SAGE Open Medicine 2017;**8**(5) doi: 10.1177/2050312117694794.

23. Diamond K. Screening for traumatic brain injury in an offender sample: a first look at the reliability and validity of the Traumatic Brain Injury Questionnaire. J Head Trauma Rehabil 2007;**22**(6):330-338.
24. Burnett DM, Kolakowsky-Hayner SA, Slater D, Stringer A, Bushnik T, Zafonte R, Cifu DX. Ethnographic analysis of traumatic brain injury patients in the national Model Systems database. Arch Phys Med Rehabil 2003;**84**(2):263-267 doi: 10.1053/apmr.2003.50091.
25. Simpson G, Blaszczynski A, Hodgkinson A. Sex offending as a psychosocial sequela of traumatic brain injury. J Head Trauma Rehabil 1999;**14**(6):567-580.
26. Farrer TJ, Frost RB, Hedges DW. Prevalence of traumatic brain injury in juvenile offenders: a meta-analysis. Child Neuropsychol 2013;**19**(3):225-234 doi: 10.1080/09297049.2011.647901.
27. Corrigan JD, Bogner J, Holloman C. Lifetime history of traumatic brain injury among persons with substance use disorders. Brain Injury 2012;**26**(2):139-150.
28. Liebling A, Arnold H. Social relaitionhsips between prisoners in a amximum security prison: violence, faith and the declining nature of trust. J Crim Justice 2013;**40**:413-424.
29. Hume P, Theadom A, Lewis GN, Quarrie KL, Brown SR, Hill R, Marshall SW. A Comparison of Cognitive Function in Former Rugby Union Players Compared with Former Non-Contact-Sport Players and the Impact of Concussion History. Sports Med 2016;47(6):1209-1220. doi: 10.1007/s40279-016-0608-8.
30. Lingsma HF, Roozenbeek B, Steyerberg EW, Murray GD, Maas AI. Early prognosis in traumatic brain injury: from prophecies to predictions. Lancet Neurology 2010;**9**(5):543-554 doi: 10.1016/S1474-4422(10)70065-.

Table 1. Demographic and offence characteristics of adult males according to traumatic brain injury

	Total n = 1054	No TBI n = 382	TBI n = 672	Test of Difference
Age in years				
Mean age (SD)	36.74 (12.32)	36.34 (12.01)	37.44 (12.84)	t = 1.39, p = 0.16
Ethnicity				
Māori	431 (40.9%)	125 (32.7%)	306 (45.5%)	
European	233 (22.1%)	80 (20.9%)	153 (22.8%)	x^2=48.44
Pasifika	258 (24.5%)	95 (24.9%)	163 (24.3%)	*p*=<0.00001
Other	132 (12.5%)	82 (21.5%)	50 (7.4%)	
Offence Category				
Violence	289 (27.4%)	102 (26.7%)	187 (27.8%)	
Drugs	220 (20.9%)	110 (28.8%)	110 (16.4%)	
Sexual	242 (23.0%)	75 (19.6%)	167 (24.9%)	χ^2=25.27
Burglary	238 (22.6%)	71 (18.6%)	167 (24.9%)	*p*=<0.0001
Other	65 (6.2%)	24 (6.3%)	41 (6.1%)	
Security Classification				
Minimum	194 (18.4%)	77 (20.2%)	117 (17.4%)	
Low	180 (17.1%)	66 (17.3%)	114 (17.0%)	χ^2=2.64
Medium	293 (27.8%)	110 (28.8%)	183 (27.2%)	*p*=0.45
High	387 (36.7%)	129 (33.8%)	258 (38.4%)	
Prison Sentence				
< 5 years	521 (49.4%)	168 (44.0%)	353 (52.5%)	
5-10 years	299 (28.4%)	119 (31.1%)	180 (26.8%)	χ^2=7.46
10-15 years	101 (9.6%)	43 (11.3%)	58 (8.6%)	*p*=0.59
> 15 years	133 (12.6%)	52 (13.6%)	81 (12.1%)	

Table 2. Independent predictors of logistic regression model of TBI history

	Reference category	B	SE	Wald	Sig	*Exp (B)*	95% C.I. Lower	Upper
Constant		0.56	0.53	1.11	0.29	1.75		
Age (years)		-0.01	0.01	1.25	0.26	0.99	0.98	1.01
Ethnicity	Māori	0.85	0.38	4.92	**0.03**	2.34	1.10	4.94
Offence type	Violent, burglary or sexual offence	-0.37	0.16	5.38	**0.02**	0.69	0.50	0.94
Security classification	High	0.19	0.19	0.98	0.32	1.21	0.83	1.77
Prison sentence	1-5 years	0.15	0.28	0.28	0.60	1.16	0.67	2.02

Table 3. Details of TBIs sustained

	Male prisoners who experienced a TBI N = 672
Number of TBIs experienced in lifetime	
1	329 (48.1%)
2	164 (24.4%)
3	95 (14.1%)
4+	84 (12.5%)
Age at time of first TBI in years	
0-14	148 (22.0%)
15-34	432 (64.3%)
35-64	77 (11.5%)
64 +	2 (0.3%)
Unknown	13 (1.9%)
Loss of consciousness	
Yes	403 (60.0%)
No	264 (39.3%)
Unknown	5 (1.2%)
Mechanism of first injury	
Assault	269 (40.0%)
Hit by object	101 (15.0%)
Motor vehicle accident	179 (26.6%)
Fall	89 (13.2%)
Other or unknown	34 (5.1%)
Severity of first injury sustained	
Mild	491 (73.1%)
Moderate	74 (11.0%)
Severe	32 (4.8%)
Unclear	75 (11.2%)
Severity of last TBI sustained	

Mild	517 (76.9%)
Moderate	70 (10.4%)
Severe	30 (4.5%)
Unclear	55 (8.2%)
Acute symptoms experienced after first injury (more than one could be reported)	
Seizures	22 (3.3)
Vomiting/Nausea	67 (10.0)
Headache	395 (58.8%)
Loss of balance	313 (46.6%)
Visual disturbances	228 (33.9%)
Memory difficulties	150 (22.3%)

References

1. Carroll LJ, Cassidy JD, Holm L, Kraus J, Coronado VG, on behalf of the WHO Collaboratng Centre Task Force on Mild Traumatic Brain Injury. Methodological issues and research recommendations for mild traumatic brain injury: the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. J Rehabil Med 2004(43 Suppl):113-125.
2. Te Ao B, Tobias M, Ameratunga S, McPherson K, Theadom A, Dowell A, Starkey N, Jones K, Barker-Collo S, Brown P, Feigin V on behalf of the BIONIC Research Group. Burden of traumatic brain injury in New Zealand: Incidence, prevalence and disability adjusted life years. Neuroepidemiol 2015;**44**(4):255-261.
3. Scholten AC, Haagsma JA, Andriesson TM, Vos PE, Steyerberg EW, van Beeck EF, Polinder S. Health related quality of life after mild, moderate and severe traumatic brain injury: patterns and predictors of suboptimal functioning during the first year post injury. Injury 2015;**46**(4):616-624.
4. Theadom A, Parag V, Dowell T, McPherson K, Starkey N, Barker-Collo S, Jones K, Ameratunga S, Feigin VL on behalf of the BIONIC Research Group. Persistent problems 1 year after mild traumatic brain injury: a longitudinal population study in New Zealand. BJGP 2016;**66**(642):e16-23 doi: 10.3399/bjgp16X683161.
5. Brown AW, Moessner AM, Mandrekar J, Diehl NN, Leibson CL, Malec JF. A survey of very-long-term outcomes after traumatic brain injury among members of a population-based incident cohort. J Neurotrauma 2011;**28**(2):167-76 doi: 10.1089/neu.2010.1400.
6. Piccolino AL, Solberg KB. The Impact of Traumatic Brain Injury on Prison Health Services and Offender Management. J Correct Health Care 2014;**20**(3):203-212.
7. O'Rourke C, Linden MA, Lohan M, Bates-Gaston J.. Traumatic brain injury and co-occurring problems in prison populations: A systematic review. Brain Inj 2016;**30**(7):839-854
8. Schofield PW, Malacova E, Preen DB, D'Este C, Tate R, Reekie J, Wand H, Butler T.. Does Traumatic Brain Injury Lead to Criminality? A Whole-Population Retrospective Cohort Study Using Linked Data. PLOSone 2015; 10(7):e0132558.
9. Kennedy E, Heron J, Munafo M. Substance use, criminal behaviour and psychiatric symptoms following childhood traumatic brain injury: findings from the ALSPAC cohort. Eur Child and Adolesc Psychiatry 2017; Mar 17. doi: 10.1007/s00787-017-0975-1.
10. Shiroma EJ, Pickelsimer EE, Ferguson PC, Gebregziabher M, Lattimore PK, Nicholas JS, Dukes T, Hunt KJ. Association of medically attended traumatic brain injury and in-prison behavioural infractions: a statewide longitudinal study. J Correc Health Care 2012;**16**(4):273-286.
11. Elbogen EB, Wolfe JR, Cueva M, Sullivan C, Johnson J. Longitudinal Predictors of Criminal Arrest After Traumatic Brain Injury: Results From the Traumatic Brain Injury Model System National Database. J Head Trauma Rehabil 2015;**30**(5):E3-13.
12. Allely CS. Prevalence and assessment of traumatic brain injury in prison inmates: a systematic PRISMA review, . Brain Injury 2016;**30**(10):1161-1180.
13. Perkes I, Schofield PW, Butler T, Hollis SJ. Traumatic brain injury rates and sequelae: a comparison of prisoners with a matched community sample in Australia. Brain Inj 2011;**25**(2):131-141
14. Ray B, Sapp D, Kincaid A. Traumatic brain injury among Indiana state prisoners. J Forensic Sci 2014;**59**(5):1248-1253.
15. Durand E, Watier L, Fix M, Weiss JJ, Chevignard M, Pradat-Dieh P. Prevalence of traumatic brain injury and epilepsy among prisoners in France: Results of the Fleury TBI study. Brain Inj 2016;1(1):e00535 doi: 10.1002/brb3.
16. Pitman I, Haddlesey C, Ramos SD, Oddy M, Fortescue D.. The association between neuropsychological performance and self-reported traumatic brain injury in a sample of adult male prisoners in the UK. Neuropsychol Rehabil 2015;**25**(5):763-779 doi: 10.1080/09602011.2014.973887.

17. Barnfield TV, Leathem JM. Incidence and outcomes of traumatic brain injury and substance abuse in a New Zealand prison population. Brain Inj 1998;**12**(6):455-466.
18. Theadom A, Barker-Collo S, Feigin V, Starkey NJ, Jones K, Ameratunga S, Barber PA on behalf of the BIONIC Research Group. The spectrum captured: a methodological approach to studying incidence and outcomes of traumatic brain injury on a population level. Neuroepidemiology 2012(38(1):18-29.
19. Feigin VF, Theadom A, Barker-Collo SL, Starkey NJ, McPherson K, Kahan M, Dowell A, Brown P, Parag V, Kydd R, Jones K, Jones A, Ameratunga S, on behalf of the BIONIC Research Group. Incidence of traumatic brain injury in New Zealand: a population-based study. Lancet Neurol 2013;**12**(1):53-64.
20. Schofield P, Butler T, Hollis S, D'Este C. Are prisoners reliable survey respondents? A validation of self-reported traumatic brain injury (TBI) against hospital medical records. Brain Inj 2011;**25**(1):74-82.
21. Corrigan JD, Selassie AW, Orman JA. The epidemiology of traumatic brain injury. J Head Trauma Rehabil 2010;**25**(2):72-80 doi: 10.1097/HTR.0b013e3181ccc8b4.
22. Cusimano MD, Zhang S, Topolovec-Vranic J, Hutchinson MG, Jing R. Factors affecting the concussion knowledge of athletes, parents, coaches, and medical professionals. SAGE Open Medicine 2017;**8**(5) doi: 10.1177/2050312117694794.
23. Diamond K. Screening for traumatic brain injury in an offender sample: a first look at the reliability and validity of the Traumatic Brain Injury Questionnaire. J Head Trauma Rehabil 2007;**22**(6):330-338.
24. Burnett DM, Kolakowsky-Hayner SA, Slater D, Stringer A, Bushnik T, Zafonte R, Cifu DX. Ethnographic analysis of traumatic brain injury patients in the national Model Systems database. Arch Phys Med Rehabil 2003;**84**(2):263-267 doi: 10.1053/apmr.2003.50091.
25. Simpson G, Blaszczynski A, Hodgkinson A. Sex offending as a psychosocial sequela of traumatic brain injury. J Head Trauma Rehabil 1999;**14**(6):567-580.
26. Farrer TJ, Frost RB, Hedges DW. Prevalence of traumatic brain injury in juvenile offenders: a meta-analysis. Child Neuropsychol 2013;**19**(3):225-234 doi: 10.1080/09297049.2011.647901.
27. Corrigan JD, Bogner J, Holloman C. Lifetime history of traumatic brain injury among persons with substance use disorders. Brain Injury 2012;**26**(2):139-150.
28. Liebling A, Arnold H. Social relaitionhsips between prisoners in a amximum security prison: violence, faith and the declining nature of trust. J Crim Justice 2013;**40**:413-424.
29. Hume P, Theadom A, Lewis GN, Quarrie KL, Brown SR, Hill R, Marshall SW. A Comparison of Cognitive Function in Former Rugby Union Players Compared with Former Non-Contact-Sport Players and the Impact of Concussion History. Sports Med 2016;47(6):1209-1220. doi: 10.1007/s40279-016-0608-8.
30. Lingsma HF, Roozenbeek B, Steyerberg EW, Murray GD, Maas AI. Early prognosis in traumatic brain injury: from prophecies to predictions. Lancet Neurology 2010;**9**(5):543-554 doi: 10.1016/S1474-4422(10)70065-.