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Brain Impairment ASSBI

Experience of mTBI-like symptoms in a sample without brain injury in Aotearoa/New Zealand

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ABSTRACT

Background. Post-mild traumatic brain injury (mTBI) symptoms are not specific to mTBI and are experienced in populations without brain injury. Understanding how people without brain injury experience mTBI-like symptoms and factors influencing symptom reporting is important to determine how symptom experience differs following an mTBI. **Methods.** To understand how people without a history of brain injury experience mTBI-like symptoms, we conducted a cross-sectional survey comprising sociodemographic characteristics, the Brain Injury Screening Tool symptom scale, general health rating, Illness Attitude Scale, Positive and Negative Affect Scale and Perceived Stress Scale. The mean total symptom score and proportion of people experiencing moderate or severe symptoms (≥4) were reported. Associations between sociodemographic variables, stress, negative affect, illness attitudes, health status and symptoms were examined using regression models. **Results.** One-hundred and seventy-three people completed the survey with a mean age of 40 years (s.d. = 15.8; $n = 82$, 47.4% male). The mean total symptom score was 34.5(± 26.6). Commonly experienced symptoms were tiredness ($n = 73$, 42.2%), poor sleep ($n = 64$, 37.0%) and headaches ($n = 56$, 32.4%). Regression analysis revealed that on average higher levels of worry about illness and negative affect were associated with higher symptoms ($\beta = 0.5$, $P = 0.027$ and $\beta = 0.9$, $P = 0.020$ respectively) but there were no significant associations with other variables. **Conclusions.** Cognitive and vestibular-ocular symptoms occur much less frequently than physical symptoms in the general population and may be more specific to mTBI. However, there is a need to consider vestibular-ocular symptoms alongside illness attitudes due to greater concerns about these symptoms by patients.

Keywords: illness attitudes, injury, mood, mild traumatic brain injury, negative affect, post-concussion symptoms, stress, symptom experience.

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Introduction

Mild traumatic brain injury (mTBI) is the most common form of TBI (Dewan *et al.* 2018) and can have a significant impact on a person's quality of life (Theadom *et al.* 2016). The burden extends to society through increased lifetime medical costs and productivity losses (Maas *et al.* 2017; Theadom *et al.* 2017, 2018). Symptoms commonly reported following mTBI include headaches, fatigue, nausea and feelings of frustration, which may last days, weeks, months or years (Theadom *et al.* 2018). The need for symptom evaluation features consistently in mTBI guideline recommendations as part of a multimodal assessment and for monitoring recovery (Silverberg *et al.* 2020). A number of tools have been developed to evaluate post-injury symptoms (Alla *et al.* 2009), such as the Rivermead Post-Concussion Symptoms Questionnaire (RPQ) (King *et al.* 1995), Sport Concussion Assessment Tool 5th Edition (SCAT-5) (Echemendia *et al.* 2017) and Brain Injury Screening Tool (BIST) (Theadom *et al.* 2021; Shaikh *et al.* 2022).

However, post-mTBI symptoms have poor diagnostic utility because of their low specificity (Mulhern and McMillan 2006; Silverberg *et al.* 2020). A number of studies have shown that mTBI-like symptoms are commonly experienced in people without a history of brain injury (Iverson and Lange 2003; Wang *et al.* 2006; Garden *et al.* 2010;

Zakzanis and Yeung 2011; Suzanne *et al.* 2018; Voormolen *et al.* 2019). For example, in the New Zealand (NZ) population, back pain, fatigue and headaches are commonly experienced (Petrie *et al.* 2014). Indeed, Iverson and Lange (2003) report that in a community sample without a history of brain injury, up to 15.5% of participants experienced moderate–severe mTBI-like symptoms.

A number of factors have been found to influence symptom reporting, including psychological traits (e.g. coping, illness perceptions (Hou *et al.* 2012) and low mood (Suhr and Gunstad 2002; Iverson and Lange 2003; Garden *et al.* 2010). It is thought that dysregulation of the body that involves stress, inflammation and emotional attention may also give rise to increased symptom experience in the absence of injury (Viktoriya 2019). Consequently, because symptoms can be experienced as a normal part of life and due to comorbid health conditions, it is important for practitioners to understand patterns of mTBI-like symptoms that may or may not be associated with mTBI pathology. Indeed, people who have an mTBI may sometimes misattribute symptoms to an mTBI that may be due to other causes (Mittenberg *et al.* 1992).

Evidence suggests that the female sex is associated with worse symptom experience following mTBI; however, the evidence is drawn predominantly from sports-related injury studies (Koerte *et al.* 2020). In general population samples, the relationship between sex and symptom experience is unclear, with some studies reporting a relationship between sex and symptom experience (Kjeldsberg *et al.* 2013; Bardel *et al.* 2019) and others not (Chan 2001; Suhr and Gunstad 2002; Garden *et al.* 2010).

Premorbid mental health problems (e.g. depression, anxiety) are a risk factor for prolonged recovery following mTBI (Iverson *et al.* 2020) and are also associated with greater symptom experience in the general population (Suhr and Gunstad 2002; Iverson and Lange 2003; Zakzanis and Yeung 2011; Voormolen *et al.* 2019; Shaikh *et al.* 2022). There is also preliminary evidence that higher levels of stress may be linked to higher levels of physical symptom reporting, but this study was not specific to mTBI-like symptoms (Goldman *et al.* 1996). Perceptions of increased injury severity and emotional impact have also been found to be highly correlated with higher symptoms on the RPQ (Snell *et al.* 2011). Consequently, there is a need to understand how broader illness attitudes, such as engaging in healthy lifestyle behaviours (e.g. smoking and eating) and fear of developing a serious illness, influence symptom reporting in the general population.

An mTBI-like symptom experience may also be influenced by social determinants of health. For example, age can influence symptom type (e.g. somatic vs psychological) and severity of symptoms experienced over time (Kjeldsberg *et al.* 2013; Petrie *et al.* 2014; Bardel *et al.* 2019; Voormolen *et al.* 2019). Health disparities, such as income, education and vulnerability, can also influence health state (Wagstaff 2002; Johnson and Diaz 2023). Cultural interpretations of different symptoms may also influence reporting (Goodyear-Smith and Ashton 2019).

In 2018, the BIST (Theadom *et al.* 2021) was developed to support healthcare decision-making following a symptom assessment. Strengths of the BIST include a user-agnostic design (it can be used by any health professional), culturally responsive for the NZ Indigenous populations and use of simple language. The BIST has demonstrated sound internal consistency, factor structure, concurrent validity and test-retest reliability (Theadom *et al.* 2021; Shaikh *et al.* 2022). Following clinical testing, the BIST was revised in 2022 (BIST 2.0). There are currently no normative data available for the revised tool to enable comparison. Additionally, factors unrelated to mTBI that could affect symptom reporting on this measure, such as stress, and illness attitudes in addition to known symptom-related factors such as low mood and sex, need to be explored.

The aims of the current study are to (1) report the experience of mTBI-like symptoms using BIST 2.0 and (2) determine if factors such as negative affect, stress, sex, age and illness attitudes influence symptom reporting in adults without a history of brain injury. We hypothesised that higher levels of negative affect, stress, poorer health and negative illness attitudes, and older age would be associated with increased symptom reporting. Additionally, we hypothesised that symptom reporting would be significantly higher in females than males.

Methods

Design

A cross-sectional online survey of adults without a history of brain injury was designed. Institutional ethical approval was sought from the Auckland University of Technology Ethics Committee (Ref: 22/148). We reported the current study following guidance from the Strengthening the Reporting of Observational Studies in Epidemiology Statement for cross-sectional studies (Supplementary File S1).

Sampling and recruitment

A convenience sample of participants was recruited through dynata™ (https://www.dynata.com/) between 3 and 9 August 2022. An online recruitment strategy was used, consisting of a blend of proprietary survey panels and other recruitment approaches, such as 'intercepts', whereby traffic is redirected from a product or service to the study survey to minimise response bias. This approach enabled purposive sampling based on age, ethnicity and gender to reflect the age, sex and ethnicity profiles of people with mTBI in NZ (Feigin *et al.* 2013).

People who responded to survey invitations sent by dynata were redirected to an online survey created using the Qualtrics (Provo, UT, USA) survey platform. The survey took approximately 15 min to complete. Upon accessing the survey, respondents were presented with an information sheet about the study. Initial questions checked the eligibility of participants. Respondents were included in the study if they were aged ≥18 years, read and understood English, and were currently living in NZ. Individuals were excluded if they had ever experienced a TBI of any severity or had an unstable, severe or life-threatening condition (e.g. pancreatic cancer). mTBI was defined to participants as being an impact to the head or body causing loss of consciousness (being knocked out), feeling dazed or confused afterwards, not remembering what happened or seeing stars, including injuries such as concussion. To obtain a history of TBI, participants were then asked 'Have you had a concussion or mild traumatic brain injury in the past 5 years?' Individuals who did not consent or meet the inclusion criteria were branched out of the survey and thanked for their interest. Individuals who met the inclusion criteria and completed the survey received reward points by dynata. Informed consent was assumed if they chose to complete the survey questions, and as a result, the data were anonymous. Recruitment ceased after response quotas were achieved.

Survey instruments

Participants were asked to complete general demographic questions, including their age, sex, highest level of education and employment status. Participants were also asked to rate their general health from 0 (worst imaginable health state) to 100 (best imaginable health state).

Symptom experience

mTBI-related symptoms were assessed using the BIST 2.0 symptom scale (Theadom *et al.* 2021). The symptom scale involves rating the severity of 16 symptoms, such as 'headache (my head hurts)' and 'my neck hurts' on a scale of 0 (not at all) to 10 (severe). The 16 symptom ratings are then summed to produce a total score (range 0–160). The symptom scale has excellent internal consistency for the total symptom score ($\alpha = 0.94$) and its three subscales (physical ($\alpha = 0.90$), cognitive ($\alpha = 0.92$) and vestibular-ocular ($\alpha = 0.80$)). Test-retest reliability is moderate to good with intraclass correlation coefficients ranging between 0.51 and 0.83 (Shaikh *et al.* 2022). High concurrent validity has been established against the RPQ ($r = 0.91$) and SCAT-5 ($r = 0.90$) symptom scales (Theadom *et al.* 2021). A cut-off score of ≥66 has been proposed for clinical use to indicate a level of symptoms indicative of the need for treatment following a mTBI.

Mood

The Positive and Negative Affect Scale – Short Form (PANAS-SF (Watson *et al.* 1988)) comprises 20 items describing positive and negative feelings (e.g. 'interested', 'enthusiastic', 'distressed' and 'upset'). Each item is rated on a scale of 1 (very slightly) to 5 (extreme) over the past week. The scale is based on a two-dimensional model of mood, which aligns with its two subscales (each with 10 items that are summed): (1) the positive affect scale (range 10–50), with higher scores representing higher positive affect and (2) the negative affect scale (range 10–50), with lower scores representing lower negative affect. The PANAS-SF has good test-retest reliability (Watson *et al.* 1988) and excellent internal reliability for the positive ($\alpha = 0.89$) and negative affect scales ($\alpha = 0.85$). Discriminant and convergent validity of the scales have been established with measures of depression and anxiety (Watson *et al.* 1988; Crawford and Henry 2004).

Stress

The Perceived Stress Scale (PSS-10 (Cohen *et al.* 1983; Cohen 1988)) consists of 10 items scored between 0 (never) and 4 (very often) and is used to measure psychological stress in general. For example, 'In the last month, how often have you been upset because of something that happened unexpectedly?'. The PSS-10 has been used in both healthy and clinical populations to measure how different situations affect people's perceived levels of stress in the past month. A total score is calculated by summing the individual item ratings, with higher scores representing higher levels of perceived stress (range 0–40). The original 14-item version (Cohen *et al.* 1983), later refined into a 10-item version used in the current study, had test-retest reliability coefficients of 0.85 after 2 days and 0.55 after 6 weeks in a college sample. The PSS possesses excellent internal consistency ($\alpha = 0.89$), and its construct validity has been established against various other tools (Roberti *et al.* 2006; Lee 2012).

Illness attitudes

The Illness Attitude Scale (IAS (Kellner 1987)) was designed to assess people's fears, attitudes and beliefs associated with hypochondriacal concerns and abnormal illness behaviour. It is considered a gold standard for dimensional evaluation of hypochondriacal symptoms (Sirri *et al.* 2008). The measure consists of 27 items, such as 'Do you worry about your health?' and 'Are you worried that you may get a serious illness in the future?', which are scored between 0 (no) and 4 (most of the time). A total score is calculated by summing the individual item score, with higher scores representing more worry about their health (range 0–108). The original IAS comprises nine subscales representing different areas of worry (e.g. worry about illness, concerns about pain and disease phobia); however, fewer factor solutions (e.g. 2–5) have been found to produce more favourable internal consistency (Ferguson and Daniel 1995; Sirri *et al.* 2008). The

use of the IAS is supported by evidence for its test-retest reliability and internal, concurrent and discriminative validity (Sirri *et al.* 2008; Hedman *et al.* 2015).

Data analysis

Outliers were identified and removed from analysis using the outlier labelling rule defined by Hoaglin and Iglewicz (1987). Additionally, the time taken to complete the questionnaire was recorded, with responses of <2 min duration deemed to be 'unreliable' and removed before analysis. Descriptive statistics were used to summarise the sample characteristics and BIST 2.0 symptom scores by their mean and median (minimum, maximum) values. We also calculated the proportion of the sample reporting moderate symptoms defined as ≥ 4 on each of the 16 BIST symptoms.

Multivariable linear regression was used to identify associations between BIST 2.0 total symptom score (outcome variable) and the independent variables age, sex, ethnicity, education status, employment status, general health rating (GHR), illness attitudes, affect and stress. Three additional regressions were performed with each symptom cluster as the outcome variable to explore which symptom clusters were driving associations between significant associations between independent and total symptom scores. Associations with P values ≤ 0.05 were considered of interest. A Bonferroni correction was used to adjust the alpha for additional regressions with the symptom clusters as the outcome variable. We tested the following assumptions of our regression model: (1) normality of the dependent variable by visually inspecting a Q–Q plot, (2) homoskedasticity using the Breusch–Pagan test ($P < 0.05$ was considered problematic), (3) multicollinearity using the variance inflation factor (VIF; VIFs >5 were considered problematic (Meuleman *et al.* 2014). Inspection of these items revealed heteroscedasticity, which was addressed by calculating robust standard errors for all hypothesis tests. All analyses were conducted using IBM SPSS Statistics (v.29).

Results

Of the 290 people who clicked on the survey link, 117 (40.3%) were excluded due to not meeting the inclusion criteria (e.g. history of TBI) or not completing the questionnaire (2.8%) as outlined in Fig. 1. Of the 10 that started the survey but did not finish, five stopped after answering the inclusion/exclusion criteria questions, three stopped after answering the demographic questions, one stopped part-way through the IAS and one stopped after completing the BIST 2.0. One outlier was removed, as their total symptom score exceeded the upper limit calculated as the 99.6th percentile of the sample. Data were available for 173 participants with a mean age of 40 years (s.d. = 15.8; median (IQR) = 34(22)).

The sample characteristics are summarised in Table 1. Participants ranged in age between 18 and 84 years. Just over half of the participants identified as European, and just over a third identified as Māori and/or Pasifika (NZ's indigenous populations). Living with a physical or mental health condition was reported by 72 (41.6%) of participants. Forty-eight out of 72 (66.7%) participants specified their health condition; the most common conditions were high blood pressure ($n = 22$), diabetes ($n = 12$), anxiety and/or depression ($n = 7$), and musculoskeletal disorders (e.g. arthritis; $n = 11$).

Participants' responses to the GHR, IAS, PANAS-SF, PSS and BIST symptom scales were skewed towards more positive health/attitudes as shown in Table 1. Table 2 shows the mean total symptom score and the proportion of participants experiencing each symptom at the moderate level of above (≥ 4), which ranged from 11.0 (nausea) to 42.2% (tiredness).

Results of the regression analysis

Results of the regression model (Table 3) show that illness attitudes and negative affect were significantly associated with BIST total symptom score but that sociodemographic variables, such as sex and age, were not. Specifically, a 1-point increase in illness attitudes (more worry) was

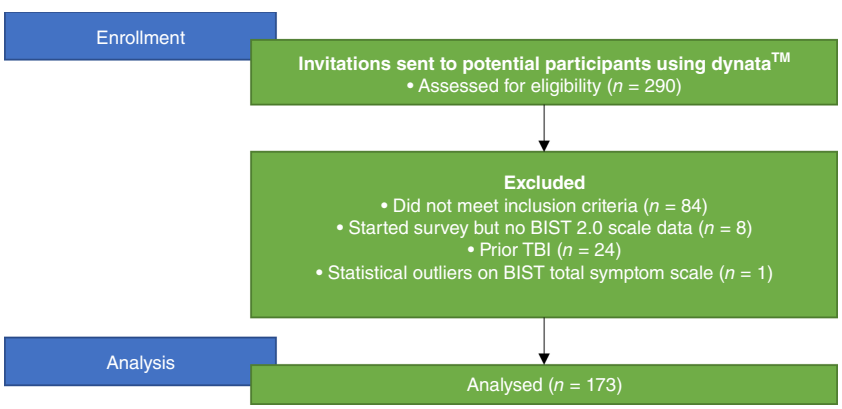

Fig. 1. Study flow diagram.

Table 1. Demographic characteristics of the survey participants ($N = 173$).

Demographic characteristic	N (%)
Sex, male	82 (47.4)
Experiencing a physical or mental health condition, yes	72 (41.6)
Ethnicity	
NZ European	101 (58.4)
Not NZ European	72 (41.6)
Māori	48 (27.7)
Pacific peoples	20 (11.6)
Other	4 (2.3)
Education	
College, professional education or higher	113 (65.3)
Secondary education or lower	60 (34.7)
Current employment	
Employed	136 (78.6)
Unemployed	37 (21.4)
Age (mean years ± s.d.)	40.1 (±15.8)
GHR (0–100)[A]	72.5 (±17.2)
IAS, mean ± s.d. (0–108)[B,J]	34.5 (±14.9)
PANAS-SF positive affect (10–50)[C,K]	28.1 (±7.6)
PANAS-SF negative affect (10–50)[D,K]	18.4 (±7.4)
PSS total score (0–40)[E,K]	17.5 (±6.8)
BIST physical score (0–40)[F]	9.5 (±7.7)
BIST vestibular-ocular score (0–40)[G]	6.5 (±6.5)
BIST cognitive score (0–40)[H]	8.0 (±8.1)
BIST total symptom score (0–160)[I]	34.5 (±26.6)

[A]GHR, general health rating scale (range 0–100, higher rating represents better health).
[B]IAS, Illness Attitude Scale total score (range 0–108, higher scores representing more worry).
[C]PANAS-SF, positive affect scale (range 10–50, higher scores representing high levels of positive affect).
[D]PANAS-SF, negative affect scale (range 10–50, lower scores representing lower levels of negative affect).
[E]PSS, Perceived Stress Scale total score (range 0–40, high scores representing more stress).
[F]BIST, Brain Injury Screening Tool physical cluster score (range 0–40, higher scores representing greater symptom intensity).
[G]BIST, Brain Injury Screening Tool vestibular-ocular cluster score (range 0–40, higher scores representing greater symptom intensity).
[H]BIST, Brain Injury Screening Tool cognitive cluster score (range 0–40, higher scores representing greater symptom intensity).
[I]BIST, Brain Injury Screening Tool total symptom score (range 0–160, higher scores representing greater symptom intensity).
[J]missing $n = 2$.
[K]missing $n = 1$.

Table 2. Proportion of sample reporting moderate (≥4 points) BIST symptoms by physical, vestibular-ocular and cognitive symptom clusters, and other symptoms ($N = 173$).

Symptom	N (%)
Total symptom score mean ± s.d., median (minimum, maximum)	34.5 ± 26.6, 30 (0, 130)
Physical symptom cluster	
Headache (my head hurts)	56 (32.4)
My neck hurts	46 (26.6)
I don't like bright lights	41 (23.7)
I don't like loud noises	47 (27.2)
Vestibular-ocular symptom cluster	
I feel dizzy or like I could be sick	29 (16.8)
If I close my eyes, I feel like I am at sea	19 (11.0)
I have trouble with my eyesight (vision)	55 (31.8)
I feel clumsy (bumping into things or dropping things more than usual)	32 (18.5)
Cognitive symptom cluster	
It takes me longer to think	35 (20.2)
I forget things	43 (24.9)
I get confused easily	28 (16.2)
I have trouble concentrating	40 (23.1)
Other	
I get angry or irritated easily	51 (29.5)
I just don't feel right	37 (21.4)
I feel tired during the day	73 (42.2)
I need to sleep a lot more or find it hard to sleep at night	64 (37.0)

associated with, on average, 0.5 more symptoms ($P < 0.001$), and a 1-point increase in negative affect was associated with, on average, 0.9 more symptoms ($P = 0.004$). Regressing each symptom cluster as the outcome variable revealed that a 1-point increase in illness attitudes was associated with, on average, 0.2 more symptoms ($P < 0.001$) in the vestibular-ocular symptom cluster. No other symptom clusters remained of interest (Supplementary File S1). This suggests that the vestibular-ocular symptom cluster may be driving the association between total symptom score and illness attitudes.

Discussion

This study aimed to determine the experience of mTBI-related symptoms on the BIST among a sample of adults without a history of brain injury and the factors influencing

Table 3. Regression analysis of total BIST symptom score on age, sex, ethnicity, education status, employment status, GHR, illness attitudes, affect and stress.

Predictor	*B*	Robust s.e.	*P*	95% Confidence Interval	
				LL	UL
(Constant)	18.516	17.116	0.281	−15.289	52.320
Age	−0.086	0.130	0.510	−0.344	0.172
Male	−4.022	3.662	0.274	−11.253	3.210
European	−2.457	3.886	0.528	−10.133	5.219
Physical or MH condition	2.735	4.518	0.546	−6.187	11.658
Employed	0.292	5.213	0.955	−10.004	10.588
College or higher education	3.256	3.364	0.335	−3.389	9.901
GHR	−0.257	0.144	0.076	−0.540	0.027
IAS total score	0.492	0.220	0.027[A]	0.058	0.926
PANAS-SF positive affect score	−0.239	0.281	0.396	−0.793	0.315
PANAS-SF negative affect score	0.854	0.362	0.020[A]	0.139	1.570
PSS total score	0.496	0.371	0.183	−0.237	1.229

Notes: total $N = 173$. $R^2 = 0.436$ (R^2 adjusted = 0.397), $F(170) = 11.170$, $P < 0.001$. *B* = unstandardised beta. s.e., standard error. LL and UL indicate the lower and upper limits of the 95% confidence interval, respectively. GHR, general health rating; MH, mental health; IAS, Illness Attitude Scale; PANAS-SF, Positive and Negative Affect Scale – Short Form; PSS, Perceived Stress Scale.
[A]Indicates $P \leq 0.05$.

symptom reporting in this population. At least 1 in 10 participants reported experiencing each of the symptoms at a moderate level or above. The study also revealed that negative mood and illness attitudes have a significant effect on symptom reporting using the BIST but that stress, general health, age and gender did not. These findings are consistent with prior research, suggesting that post-mTBI symptoms are not specific to mTBI but are experienced at a less severe level.

Our results align with previous studies reporting the experience of post-mTBI-like symptoms in the general population (Iverson and Lange 2003; Cassidy *et al.* 2014; Petrie *et al.* 2014; Zeldovich *et al.* 2022). For example, the top three reported moderate symptoms in Table 2 align with a survey of the NZ general population, which found that fatigue and headaches were two of the most commonly experienced symptoms (Petrie *et al.* 2014). Similarly, Garden and Sullivan (2010) reported that headaches (28.1%), poor sleep (27.1%) and fatigue (24%) were the most commonly experienced moderate–severe symptoms in a sample of Australian adults with no history of brain injury or neurological disorders. Interestingly, a study of the general population in Europe (Zeldovich *et al.* 2022) reported a higher prevalence of moderately experienced symptoms on the RPQ (defined as ≥2/5 severity score) compared to the current study: fatigue (49.9% vs 42.2%), sleep (42.4% vs 37.0%), irritability (39.4% vs 29.5%) and headaches (38.6% vs 32.4%). The higher symptom burden reported by Zeldovich *et al.* (2022) may be due to our study excluding individuals with a history of brain injury, differences between symptoms included in the BIST 2.0 and RPQ measurement tools, or cross-cultural differences, which may be important in generating population-specific data. For example, Zakzanis and Yeung (2011) suggested that linguistic and cultural background may moderate individual symptom endorsement.

The current study also adds to the evidence base by revealing that there was no link between sex and age and symptom reporting. Previous findings have been heterogenous, with some studies reporting no relationship between sex (Chan 2001; Suhr and Gunstad 2002; Garden *et al.* 2010) or age (Garden *et al.* 2010) and others revealing that female sex and older age are linked to increased symptom reporting (Kjeldsberg *et al.* 2013; Bardel *et al.* 2019). Reasons for this finding may be because the symptom items included in the BIST 2.0 are less influenced by sex and age than other tools. It may also be that mTBI symptoms following mTBI persist beyond the 5-year exclusion TBI history criterion adopted in this study. Alternatively, the differences between the findings may reflect the complex interplay between symptom reporting and population characteristics.

It was hypothesised that general health, higher stress, negative affect and negative illness attitudes would be linked to higher levels of symptom reporting. However, general health and stress were not found to impact symptom reporting in this sample. These results on mood generally

align with an earlier study using the original version of the BIST, which was found in a bivariate analysis to be linked with depression and anxiety (Shaikh *et al.* 2022). Differences in findings between the two studies on stress are likely due to the use of different measures of stress. The finding that illness attitudes influence symptom reporting in this sample highlights the need to consider other non-TBI-related factors (Suzanne *et al.* 2018), such as illness attitudes and negative affect, alongside symptoms. Further research is needed to see if the links between these non-injury-related factors are also evident in an mTBI population. If similar trends are identified, this would indicate the need to consider clinical symptom reporting in the context of these other variables. After performing regressions on each symptom cluster, only the vestibular-ocular symptom cluster and illness attitudes were significantly related. This suggests that the vestibular-ocular symptom cluster and illness attitudes may be driving the relationship between total symptom score and IAS. We postulate that this may be because the nature of the symptoms within this cluster (e.g. 'I feel dizzy' or like 'I could be sick', 'I have trouble with my eyesight') are weighted as more problematic by participants with higher levels of worry. It would be prudent to conduct a replication study to verify these findings.

Although the recruitment strategy included multiple approaches to minimise potential sampling bias (e.g. online panels and 'intercepts'), the symptom scale was only completed online. This assessment modality, alongside the use of a recruitment service, may have introduced bias into the sample, such as bias towards the inclusion of people with higher levels of education. Although the use of a recruitment service facilitated recruitment to ensure the ethnic profile of this non-injured sample was similar to the ethnic profile of people sustaining mTBI (as identified in a national incidence study (Feigin *et al.* 2013)), the sample was older in age (mean age 40.1 vs 27.5 years) and underrepresented males (63% vs 47%). Other factors associated with prolonged mTBI, such as psychiatric illness and learning difficulties, were also not collected in the current study, which limits our ability to compare our findings against these risk factors for prolonged recovery (Mayer *et al.* 2017). Our findings may also be influenced by non-response bias; we do not know if the characteristics of the individuals who participated in the study differ from those who did not participate in the survey. The sample size was also modest, which may have undermined our ability to detect between-group differences. Respondents may have also misreported if they had a history of brain injury (e.g. due to recall bias), which means that we cannot rule out that our sample does not include individuals with a history of TBI. These factors may have led to an over- or under-estimation of the point estimates reported. A large proportion of people also reported a current health condition (41.6%) in our sample that is higher than the estimated multimorbidity (27.9% (Stanley *et al.* 2018)), prevalence of mental distress (depression (diagnosed), mood disorder 19.5%) or chronic physical conditions in NZ (e.g. the prevalence of chronic pain is 22.6% (Ministry of Health 2022).

Overall, the findings of this study highlight the importance of an assessment of symptoms to be conducted within the context of personal medical history, physiological tests and exploration of evidence of other factors that may be contributing to symptom experience (e.g. cervical neck pain). The data from this study assist in determining the clinical significance of symptom burden by providing normative reference values on the BIST 2.0 for a non-brain-injured population. This is particularly beneficial in the general population context where it is not possible to conduct baseline symptom assessments – unlike the context of professional sport participation.

Conclusion

mTBI-related symptoms are commonly experienced among adults without a history of brain injury. The reporting of post-mTBI symptoms among adults measured using the BIST symptom scale was influenced by worry about illness and negative affect. These psychosocial factors may be important to consider when exploring the symptom experience of the mTBI population.

Supplementary material

Supplementary material is available online.

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Data availability. The data that support this study are available in the article and accompanying online supplementary material.

Conflicts of interest. Dr Chua and Professor Theadom have no conflicts of interest to declare.

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Ethics standard. The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

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Brain Impairment

Supplementary Material

Experience of mTBI-like symptoms in a sample without brain injury in Aotearoa/New Zealand

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-8
Bias	9	Describe any efforts to address potential sources of bias	5-6
Study size	10	Explain how the study size was arrived at	-
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8-9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8-9
		(*b*) Describe any methods used to examine subgroups and interactions	-
		(*c*) Explain how missing data were addressed	-
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	-
		(*e*) Describe any sensitivity analyses	-
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Fig.1, p.9
		(b) Give reasons for non-participation at each stage	Fig.1
		(c) Consider use of a flow diagram	Fig.1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Table 1
Outcome data	15*	Report numbers of outcome events or summary measures	Table 1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear	Table 3

		which confounders were adjusted for and why they were included	
		(*b*) Report category boundaries when continuous variables were categorized	-
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	-
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9
Discussion			
Key results	18	Summarise key results with reference to study objectives	14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14-17
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	1

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Regression tables for symptom cluster scores as the dependent variable

Table 1
Results of the linear regression model with cognitive symptom cluster score as the dependent variable (N=173)

Characteristic	Unstandardised Beta coefficients (95%CI)	p-value
Age (years)	-0.1 (-0.11 to 0.07)	0.621
Male *(base: Female)*	-1.1 (-3.43 to 1.37)	0.397
European *(base: Not European)*	-0.2 (-2.59 to 2.31)	0.912
Physical or mental health condition *(base: No condition)*	0.8 (-2.12 to 3.72)	0.590
Employed *(base: Unemployed)*	-1.5 (-4.95 to 2.04)	0.411
College or higher education *(base: Secondary or lower education)*	2 (-0.29 to 4.14)	0.088
General health rating	-0.1 (-0.15 to 0.04)	0.232
Illness attitude scale total score	0.2 (-0.02 to 0.25)	0.089
PANAS positive affect score	-0.1 (-0.27 to 0.09)	0.289
PANAS negative affect score	0.3 (0.03 to 0.52)	0.032
PSS total score	0.1 (-0.18 to 0.38)	0.467
(Constant)	4.2 (-7.16 to 15.38)	0.472

R^2= 0.313 (R^2 adjusted= 0.266), $F(170) = 6.589$, $p<.001$. PANAS: Positive And Negative Affect Scale. PSS: Perceived Stress Scale. Breusch-Pagan X^2 (1, N = 170) = 38.95, $p < .001$. Bonferroni-corrected alpha of 0.05 = 0.0167.

Table 2
Results of the linear regression model with vestibular-ocular symptom cluster as the dependent variable (N=173)

Characteristic	Unstandardised Beta coefficients (95%CI)	p-value
Age (years)	0.1 (-0.06 to 0.08)	0.792
Male *(base: Female)*	-0.8 (-2.53 to 1.05)	0.413
European *(base: Not European)*	-1.6 (-3.49 to 0.39)	0.115
Physical or mental health condition *(base: No condition)*	1.8 (-0.25 to 3.8)	0.084
Employed *(base: Unemployed)*	0.9 (-1.77 to 3.49)	0.519
College or higher education *(base: Secondary or lower education)*	0.2 (-1.66 to 1.9)	0.894
General health rating	-0.1 (-0.15 to -0.02)	0.021
Illness attitude scale total score	0.2 (0.1 to 0.3)	**<0.001**
PANAS positive affect score	-0.1 (-0.15 to 0.14)	0.963
PANAS negative affect score	0.2 (-0.02 to 0.38)	0.064
PSS total score	-0.1 (-0.23 to 0.17)	0.76
(Constant)	0.5 (-8.77 to 9.64)	0.926

R^2= 0.399 (R^2 adjusted= 0.356), $F(170) = 9.557$, $p<.001$. PANAS: Positive And Negative Affect Scale. PSS: Perceived Stress Scale. Breusch-Pagan X^2 (1, N = 170) = 52.62, $p < .001$. Bonferroni-corrected alpha of 0.05 = 0.0167.

Table 3
Results of the linear regression model with physical symptom cluster as the dependent variable (N=173)

Characteristic	Unstandardised Beta coefficients (95%CI)	p-value
Age (years)	-0.1 (-0.12 to 0.06)	0.517
Male *(base: Female)*	-1.7 (-4.04 to 0.76)	0.178
European *(base: Not European)*	-0.6 (-3.1 to 1.98)	0.663
Physical or mental health condition *(base: No condition)*	1.5 (-1.52 to 4.38)	0.339
Employed *(base: Unemployed)*	1.5 (-1.67 to 4.64)	0.354
College or higher education *(base: Secondary or lower education)*	0.3 (-2.07 to 2.53)	0.844
General health rating	-0.1 (-0.17 to 0.02)	0.111
Illness attitude scale total score	0.2 (-0.05 to 0.26)	0.161
PANAS positive affect score	-0.1 (-0.21 to 0.15)	0.737
PANAS negative affect score	0.2 (-0.08 to 0.41)	0.188
PSS total score	0.1 (-0.21 to 0.38)	0.553
(Constant)	6.1 (-5.15 to 17.29)	0.287

R^2= 0.257 (R^2 adjusted= 0.205), $F(170) = 4.993$, $p<.001$. PANAS: Positive And Negative Affect Scale. PSS: Perceived Stress Scale. Breusch-Pagan X^2 (1, N = 170) = 16.92, $p < .001$. Bonferroni-corrected alpha of 0.05 = 0.0167.