Received: 25 April 2024 | Revised: 18 July 2024 | Accepted: 3 August 2024

DOI: 10.1002/hec.4897

RESEARCH ARTICLE

Health Economics WILEY

The effect of a minor health shock on labor market outcomes: The case of concussions

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Abstract

The literature on health shocks finds that minor injuries have only short-term labor market impacts. However, mild traumatic brain injuries (mTBIs, commonly referred to as concussions) may be different as the medical literature highlights that they can have longer-term health and cognitive effects. Moreover, TBIs are one of the most common causes of disability globally, with the vast majority being mild. Thus, it is important to understand the impact of mTBIs on labor market outcomes. We use administrative data on all medically-diagnosed mild traumatic brain injuries (mTBIs) in New Zealand linked to monthly tax records to examine the labor market effects of a mTBI. We use a comparison group of those who suffer a mTBI at a later date to overcome potential endogeneity issues, and employ a doubly-robust difference-in-differences method. We find that suffering a mTBI has negative labor market effects. Rather than dissipating over time, these negative effects grow, representing a decrease in employment of 20 percentage points and earning losses of about a third after 48 months. Our results highlight the need for timely diagnosis and treatment to mitigate the effect of mTBIs to reduce economic and social costs.

KEYWORDS
health shock, labor market outcomes, mild traumatic brain injury

JEL CLASSIFICATION
I10, I14, J01, J31

1 | INTRODUCTION

There is a growing economics literature on the impact of health shocks on labor market outcomes. Previous studies have shown negative effects of such shocks on both employment and income (e.g., García-Gómez et al., 2013; García-Gómez & López Nicolás, 2006; Lenhart, 2019). However, there is limited evidence on the effects of mild traumatic brain injuries (mTBIs, commonly referred to as concussions) on subsequent labor market outcomes, despite the increasing awareness of the potential health and cognitive consequences of TBIs and the high incidence of such injuries. Moreover, while there are studies on mTBI in the health literature, very few examine the longer-term effects of mTBI on labor market outcomes, and virtually none account for potential endogeneity and attempt to establish causal links.

While there is increasing awareness of the impact of repeated concussions among contact sport athletes, the risk of mTBIs is much more widespread. Worldwide, TBI is one of the most common causes of disability and death in adults and the leading cause of disability in children and young adults (Hyder et al., 2007; Langlois et al., 2006). TBIs also carry significant costs—in terms of healthcare spending alone, the total estimated healthcare spending attributable to non-fatal TBI in the US was more than $40 billion in 2016, with the costs relating to mTBI being greater than more severe cases of TBI due to the higher incidence of mTBIs (Miller et al., 2021).

While apparently minor in nature, mTBIs may have persistent symptoms and long-term effects (Dean & Sterr, 2013). The exact mechanisms involved are complex and are not yet fully understood, but existing evidence highlights the importance of the interplay of physiological and psychological processes (van der Horn et al., 2020). In the early stages, the physiological issues (e.g., cell injury and inflammation) and the acute stress response leads to neural network dysfunction. Patients often report symptoms such as fatigue, headaches, poor concentration and unstable moods. As time passes, psychological processes become more influential, and factors such as coping styles, personality, emotional regulation and the extent of other life demands come into play. Long-lasting symptoms can emerge, potentially leading to negative impacts on social integration, educational and labor market outcomes, and even to increases in antisocial behavior (Theadom et al., 2023; Wehman et al., 2017; Williams et al., 2015). Moreover, while public awareness of the consequences of repeated mTBIs is growing, just one mTBI can have negative effects, further highlighting the potential implications for the general population (Theadom et al., 2023).

Given the persistent health and cognitive outcomes for mTBI cases, it is likely that labor market effects will differ from other forms of minor health shocks. Existing evidence suggests that minor health issues do not have long-term effects on employment and income (Pelkowski & Berger, 2004), and that effects on labor market outcomes generally increase as the severity of the health shock increases (Crichton et al., 2011). Given this evidence, we could expect mTBI to have limited effects on future employment or earnings. However, mTBIs are, by their nature, potentially different from other minor injuries and may have longer-lasting effects.

Therefore, this paper examines (1) if mTBI has an effect on future employment and earnings; (2) if any effect is limited to the short term or if it remains significant after a longer time period; and (3) how the effects of mTBIs differ by age, gender, ethnicity or occupational skill level. In addition, we examine the extent to which the accident compensation system offsets earning losses.

To this end, we use a staggered difference-in-differences framework (Callaway & Sant'Anna, 2021) that allows us to study the monthly effects of the health shock on earnings and employment, while taking into account the fact that not all individuals experience the shock at the same time. Because individuals who experienced a mTBI might have specific unobservable characteristics that affect both their risk of TBI and their labor outcomes, we follow Fadlon and Nielsen (2019) and construct counterfactuals for individuals suffering from a mTBI using individuals who experience one in the future. This is facilitated by New Zealand's (NZ's) linked administrative data, which includes Accident Compensation Corporation (ACC) injury data linked to Inland Revenue (IR) income data. These data allow us to estimate the monthly treatment effects on both earnings and employment up to 48 months after the shock.

These data provide advantages over existing studies. First, ACC data covers all medically-diagnosed mTBIs whereas other studies typically use hospital data, which is more limited in terms of identifying TBIs, particularly mild ones (Graff et al., 2019). Indeed, only about a fifth of individuals in our sample were treated at a hospital, with the majority being treated by a primary care physician. Moreover, IR income data are available on a monthly rather than an annual basis, allowing for the short- and medium-term effects of mTBIs to be better observed.

In addition to these data advantages, this paper offers methodological and policy contributions. First, there are few existing studies that examine the medium-term effects of mTBI on labor market outcomes (Graff et al., 2019; Theadom et al., 2017). In addition, there appears to be only one existing paper which analyses this issue using quasi-experimental methods to account for the potential endogeneity of suffering a TBI and labor market outcomes. Specifically, Fallesen and Campos (2020) use those who suffer TBIs at a later date as a comparison group, as our analysis also does. Relative to that paper, we make a number of further contributions. First, as mentioned, we use all medically-diagnosed mTBIs, which has advantages over the Fallesen and Campos (2020)'s use of Danish hospital and emergency room data to identify those who suffer a TBI. In addition, we use monthly rather than annual earnings. As our results will highlight, the use of monthly data provides a much more nuanced story about the effect of TBIs on employment and earnings, which also reinforces clinical observations. Moreover, Fallesen and Campos (2020) applies a two-way staggered DiD method, which may not be adequate to identify an average treatment effect when effects are heterogeneous (de Chaisemartin & D'Haultfœuille, 2020; Goodman-Bacon, 2021). Thus, we apply Callaway and Sant'Anna (2021)'s doubly-robust staggered difference-in-differences approach. To date, just a handful of studies have applied this approach, and to the best of our knowledge, our paper is the first to apply it to examine the impacts of a health shock.

We also make a contribution from a policy perspective. Given the high prevalence of mTBI and the fact that mTBI can, unlike most other minor physical injuries, have long-lasting effects, we add to the understanding of the potential costs to individuals in terms of their future earnings, and to society in terms of lost productivity and the potential increased burden on health and social welfare systems.

2 | LITERATURE REVIEW

This study relates to the economics literature on health shocks and subsequent labor market outcomes, as well as the health literature on the consequences of TBIs.

In terms of the economics literature on health shocks, numerous studies explore the links between health and labor market outcomes. There is previous evidence of a negative effect of job loss and unemployment on health (Eliason & Storrie, 2009; Sullivan & von Wachter, 2009). There is also a strong positive relationship between income and health, known as the "income gradient of health" (Case et al., 2002). However, these results may suffer from endogeneity and reverse causality issues. Therefore, more recent studies explored the reverse relationship, that is, the effect of health on labor market outcomes.

Empirical studies investigating these effects examine various health shocks such as road accidents (Dano, 2005; Halla & Zweimüller, 2013) or sudden hospitalizations (García-Gómez et al., 2013; Lindeboom et al., 2016), as well as self-assessed health indicators (Contoyannis & Rice, 2001; Lenhart, 2019; Riphahn, 1999) and disability (Lechner & Vazquez-Alvarez, 2011). In general, these studies find negative effects of adverse health shocks on both employment and earnings (García-Gómez et al., 2013; Halla & Zweimüller, 2013). Studies have also found that whether the negative labor market effects persist over time depends on the severity of the injury. For example, Crichton et al. (2011) shows that more severe health shocks have stronger effects on labor market outcomes, and Pelkowski and Berger (2004) finds that temporary illnesses do not have any significant long-term effects on employment and income.

To our knowledge, there is no existing research in the economics literature specifically examining TBIs and subsequent labor market outcomes. However, there is health research on this topic. Using Danish hospital data, Graff et al. (2019) finds a strong negative effect on employment 5 years after the shock and Fallesen and Campos (2020) finds large income penalties. Using NZ data on 245 adults from the Brain Injury Incidence and Outcomes NZ in the Community longitudinal study, Theadom et al. (2017) shows that more than 15% of the studied individuals had exited the labor force four years after experiencing a mTBI, and those who remained in employment suffered work limitations and productivity losses.

An issue in this literature is the ability to attribute the outcomes to the TBI given that there may be a correlation between unobservable individual characteristics, such as risk preferences, and both the likelihood of suffering a TBI and labor market outcomes. As far as we are aware, there is only one existing study which addresses this issue using quasi-experimental methods. Fallesen and Campos (2020) uses a comparison group of those who suffer a mTBI at a future time point. It finds that suffering a mTBI reduces average annual earnings by 4.2%, mostly due to lower employment rates. As discussed, we use a similar methodology, but are able to include all medically-diagnosed mTBIs, including those treated by primary healthcare providers and use monthly, rather than annual, employment and earnings data, allowing for a clearer differentiation between short-run and more persistent effects. Moreover, we use the method of Callaway and Sant'Anna (2021) to address the potential issue of bias in the application of standard two-way fixed effects (TWFE) regressions to staggered difference-in-differences analysis.

3 | EMPIRICAL STRATEGY

For causal estimates of the effects of mTBI on labor market outcomes, we need counterfactual outcomes of what would have happened to these individuals if they had not suffered from a mTBI. A simple comparison with those who have not suffered a mTBI would not enable any observed effect to be attributed to the mTBI. For instance, the (unobserved) characteristics of those who suffer from a mTBI are likely to be different from those who did not suffer from one (e.g., more likely to engage in risk-taking behavior), and these characteristics are also likely to be correlated with labor market outcomes. To address this concern, we use a quasi-experimental design and construct counterfactuals using individuals who experienced the same mTBI shock but in the future (as per Fadlon & Nielsen, 2019). In addition, we need to account for the fact that the individuals in our sample are not all treated at the same time and that treatment effects may vary over time. Therefore, results from a standard TWFE regression may be biased (Callaway & Sant'Anna, 2021; de Chaisemartin & D'Haultfœuille, 2020; Sun & Abraham, 2021).[1] To address this issue, we employ the doubly-robust difference-in-differences estimator proposed by Callaway and Sant'Anna (2021).

3.1 | Model

We estimate the following staggered difference-in-differences (DiD) model:

$$Y_i^{g,t} = \alpha_1^{g,t} + \alpha_2^{g,t}.G_{i,g} + \alpha_3^{g,t}.1\{T=t\} + \beta^{g,t}.\left(G_{i,g} \times 1\{T=t\}\right) + \gamma.X_i + \epsilon_i^{g,t} \tag{1}$$

where g denotes the groups, each group corresponding to all individuals starting to be treated at time G. $Y_i^{g,t}$ denotes the labor earnings of individual i in group g at time t, α_2 and α_3 are respectively group and time fixed effects, and X_i denotes the individual (time-invariant) controls. To differentiate between the intensive and extensive margins, we also estimate the effects of mTBI on employment, using the same specification as in Equation (1), but with $Y_i^{g,t}$ the employment observed for individual i in group g at time t. Under limited anticipation and homogeneous treatment effects assumptions, the average treatment effects $ATT^{g,t}$ are given by $\beta^{g,t}$. However, they are not obtained through the standard $ATT^{g,t} = \mathbb{E}\left[Y_t(g) - Y_t(0) | G_g = 1\right]$, but are instead re-weighted using propensity scores. Following Callaway and Sant'Anna (2021), the average treatment effect of group g at time t can be written:

$$ATT(g;t;\delta) = \left[\left(\frac{G_g}{\mathbb{E}\left[G_g\right]} - \frac{\frac{p_{g,t+\delta}(X)(1-D_{t+\delta})\left(1-G_g\right)}{1-p_{g,t+\delta}(X)}}{\mathbb{E}\left[\frac{p_{g,t+\delta}(X)(1-D_{t+\delta})\left(1-G_g\right)}{1-p_{g,t+\delta}(X)}\right]}\right)\left(Y_t - Y_{g-\delta-1} - m_{g,t,\delta}^{ny}(X)\right)\right] \tag{2}$$

where $m_{g,t,\delta}^{ny}(X) = \mathbb{E}\left[Y_t - Y_{g-\delta-1} | X, D_{t+g}, G_g = 0\right]$ is the population outcome regression for the "not-yet treated" group at time $t+g$. Here, δ is the known duration of the anticipation period, and $p_{g,t+\delta}(X)$ is the probability of being first treated at time g conditional on covariates X and on either belonging to group g, so that $G_g = 1$, or belonging to the "not-yet treated" group at time $t+\delta$, so that $(1 - D_{t+\delta})\left(1 - G_g\right) = 1$.

Since we are interested in the monthly average effects of the mTBI and their dynamics, rather than the group-time ATT, we want to recover at each date the average effect of being treated for the group(s) that have been treated for exactly e time periods. This effect is given by:

$$\theta(e) = \sum_{g=1}^{\tau} 1\{g+e \leq \tau\} ATT(g, g+e) P(G=g | G+e \leq \tau) \tag{3}$$

where τ is the date of treatment of the last group.

We also compute the overall average treatment effects, which are analogous to the ATT in a standard two-period difference-in-differences model, and can be written:

$$\theta_\Delta = \frac{1}{\Delta+1} \sum_{e=0}^{\Delta} \theta(e) \tag{4}$$

where Δ is the duration of the post-period. We compute these estimates for different values of Δ from 12 to 48 months. With $\Delta = 12$, we obtain the average treatment effect of the mTBI on labor market outcomes in the first year following the shock; with $\Delta = 24$, the average treatment effect of the mTBI in the first 2 years following the shock, etc.

3.2 | Identification

This model is identified under five assumptions: (1) irreversibility of treatment, (2) limited anticipation, (3) random sampling, (4) parallel trends and (5) overlap (Callaway & Sant'Anna, 2021). Conditions (1) and (2) are verified since TBIs, by definition, cannot be unexperienced, and a priori cannot be anticipated. The random sampling assumption (3) is likely to be verified given the nature of our data since we observe all medically-diagnosed mTBIs during the period (see Section 4 for more details). The monthly ATT results (Figure 1) confirm the validity of the parallel trends assumption (4). The overlap assumption (5) states that a positive share of the sample starts being treated at each time period g, and that, for each t and g, there is at least a small probability of not being treated, ensuring common support between the treated group and their counterfactuals. Since we use not-yet treated individuals as the control group and given the suddenness of TBIs, the timing of treatment for this population can be considered as good as random, ensuring the overlap assumption is met.

4 | DATA AND POPULATION OF INTEREST

The Integrated Data Infrastructure (IDI) is a large research database managed by Stats NZ. It holds population-wide linked micro-data from various government agencies and Stats NZ surveys.[2]

We use multiple IDI data sources. We use ACC data to identify individuals who experienced a mTBI between January 2012 and June 2022. For each of these individuals, we retrieve their monthly wages and salaries for January 2010–December 2019 from IR tax data. Individual characteristics, such as age, gender and ethnicity come from Stats NZ's personal details table, which collates this information from across different IDI data sources.

NZ's ACC system is unique internationally and has some advantages over hospital data that has been used in previous studies. ACC is a compulsory, universal, no-fault compensation system that encompasses all accidents that occur in NZ. Compensation covers medical treatment costs and, for those in employment, income compensation of up to 80% of their pre-injury earnings for as long as the injury impacts their ability to work. Treatment claims are lodged by medical providers rather than the injured individual, mitigating underreporting issues, and meaning coverage extends beyond hospital treatment to, for example, primary health services. While unreported mTBIs are likely to still be an issue, the inclusion of mTBIs treated by primary health services means that ACC data will capture more mTBIs than hospital data.

Our sample comprises individuals who experienced a mTBI between January 2012 and June 2022, identified using ICD-9 diagnosis code of 850, ICD-10 of S06.0 and/or ACC READ code of S6 (which is an ACC-specific code used by medical practitioners). Ideally, we would restrict attention to concussions with no or only a short period of lost consciousness. While the ICD-9, ICD-10 and ACC READ codes include sub-categories of concussions that would allow this restriction, medical practitioners generally do not code the diagnosis beyond the higher-level "concussion" classification. However, consistent with previous research (Feigin et al., 2013), ACC notes that the vast majority (95%) of TBIs are mild (Accident Compensation Corporation, 2017). Our data also indicates that the majority of mTBIs are initially treated by a primary care physician (79%) or other non-specialist medical practitioner, such as a nurse (83%), which further suggests that the majority are mild in nature.

We restrict our sample to individuals aged at least 25 years old at the beginning of the pre-treatment period (i.e., 24 months before they experience the mTBI), and younger than 65 at the time of the mTBI. We exclude from our analysis individuals who had experienced a prior TBI of any severity from 1994 onwards (when ACC records begin). We also exclude individuals who experience multiple TBI during the study's period. This restriction means that any observed labor market effects can be more clearly attributed to the initial health shock, rather than the cumulative effect of the initial mTBI and any subsequent mTBIs suffered during the study period, particularly as health literature suggests that suffering a mTBI puts an individual at greater risk of suffering subsequent mTBI (Gils et al., 2020). We are therefore examining the effect of just one medically-diagnosed mTBI. Further, we exclude individuals who die before 2020 and those who lived overseas during the period (identified via Customs border movement data).

We include controls for gender, age at the time of the mTBI, ethnicity and fixed effects for region of residence at the time of the shock. To avoid any reverse effect, we only include time-invariant demographics and pre-treatment covariates (Wooldridge, 2005).

We create a balanced panel of labor market outcomes for individuals in our population of interest. We measure employment and earnings outcome variables using IR monthly tax records. Monthly earnings are expressed in NZ

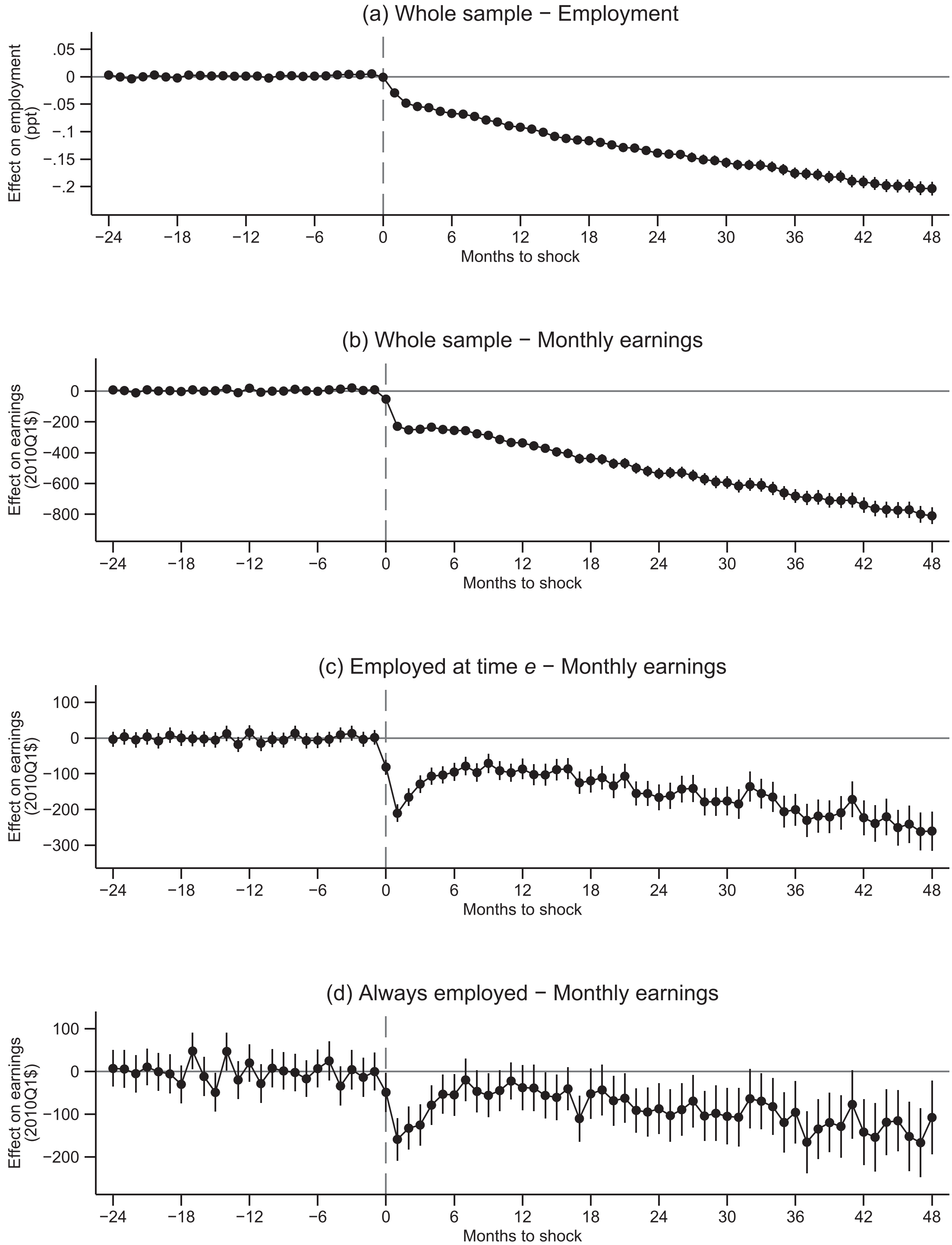

FIGURE 1 Monthly effects of mild traumatic brain injuries on earnings and employment. These figures display the average monthly effects calculated using Equation (3) along with the 95% confidence intervals. Effects in (a) and (b) are calculated for all individuals in the sample. Effects in (c) are calculated conditional on being employed at time *e*. Effects in (d) are calculated on the subsample of individuals employed in all of the 120 periods of our data. Standard errors are clustered at the individual level. *Source*: Authors' calculations using IDI.

dollars (NZ$), deflated to 2010Q1 prices using the CPI. One limitation of the data is that we cannot observe hours of employment. Therefore, we cannot assess how much of any change in the intensive margin is due to reduced hours versus reduced earnings per hour.

Overall, there are 35,301 individuals in the population of interest. Almost half (49.2%) are female and the average age is 43.5 years. In terms of ethnicity, 62.7% are European, 17.0% Māori, 5.3% Pacific peoples, 10.8% Asian, 2.3% Middle

Eastern, Latin American or African, and 2.0% identify with other ethnicities. In terms of regional distribution, 28.3% live in Auckland, 13.7% live in Canterbury, 10.0% in Waikato, 9.6% in Wellington, 7.0% in the Bay of Plenty and the remaining 31.4% are spread across 11 smaller regions. About a third were employed in high-skilled occupations (Australian and NZ Standard Classification of Occupations (ANZSCO) skill levels 1 or 2) and two-thirds were employed in low-to-middle skilled occupations (ANZSCO skill levels 3, 4 or 5).

5 | RESULTS

Figure 1 displays the average monthly effects calculated using Equation (3). We find a negative and significant effect of the health shock on both employment and earnings starting immediately after the mTBI (Figure 1a,b). Employment falls by three percentage points and earnings by NZ$230 in the first month after the shock, which is about 9% of pre-treatment average earnings. The wage penalty remains reasonably stable during the first six months following the shock, before increasing strongly and continuously to reach NZ$330 per month after one year and more than NZ$800 after four years (close to a third of pre-treatment average earnings) (Figure 1b).

Therefore, although these injuries are considered minor, mTBIs have strong and persistent effects on earnings. This contradicts Pelkowski and Berger (2004), which found that temporary illnesses generally have limited impact on labor market outcomes. However, it is in line with the medical literature about TBIs, which evidences longer-term (and sometimes hidden) health and cognitive effects, as well as employment effects (Dean & Sterr, 2013; Ribbers, 2007; Theadom et al., 2017).

The results for earnings conditional on employment show that the negative effect on earnings is mostly due to a decrease in employment. This is illustrated by the muted effects on earnings in Figure 1c (conditional on being employed at time e) and Figure 1d (conditional on being always employed) relative to the impact on earnings evident for the full sample in Figure 1b. This finding is consistent with previous evidence about brain conditions, such as strokes (Tanaka, 2021). The effect of mTBI on employment is smaller than the effect of strokes, with a decrease in employment of around 30% after 4 years while Tanaka (2021) reports a 55% decrease, but remains much higher than for other diseases, such as cancer (Heinesen et al., 2018). This might be related to cognitive difficulties resulting from brain trauma, that do not arise following other health shocks (Theadom et al., 2017). Figure 1c (Figure 1d) also shows that for those employed at time *e* (in each time period), earnings initially drop after the injury, then recover somewhat, before gradually falling again. Thus, wages of people who experienced a mTBI but remain more attached to the labor market, start stagnating in the longer term.

While there are few studies examining the longer-term effects of mTBI on labor market outcomes, our results accord with the limited research in this area. Health research has found that while many of those who suffer mTBIs return to their previous work duties within a short timeframe, they often struggle to meet the demands of their employment in the longer term and may go on to exit employment, reduce their work intensity, and/or change their working style to manage persistent symptoms. While this reduced productivity upon returning to work may be manageable in the short term, over time, individuals may be less able to manage their persistent symptoms and their employers are likely to become less accommodating. Indeed, individuals may return to work before they are fully recovered but they, and their employers, may have the expectation that they will gradually recover and return to their pre-injury levels of productivity. As it becomes evident that they are unable to undertake their pre-injury tasks with a similar level of efficiency, they may then begin to either exit employment, reduce their hours, or take on less demanding roles. This further highlights how mTBI may be different from other forms of minor injuries in terms of having longer-lasting effects.

An important caveat of our analysis is that we examine medically-diagnosed mTBIs. As mentioned, this is an improvement on existing research that only examines hospital-treated mTBI. However, we cannot examine undiagnosed and untreated mTBIs. The expected labor market impacts if the analysis included undiagnosed mTBIs are not clear. The impacts may be smaller on average if undiagnosed mTBIs tend to be less severe. However, the impacts could be larger if diagnosed mTBIs receive more appropriate medical guidance and treatment relative to undiagnosed mTBIs and thus have relatively better labor market outcomes in the longer term.

Also note that the persistent earnings losses also reflect that the estimate is relative to the comparison group of those who suffer TBI at a later date. The earnings of the comparison group continue to grow, thus contributing to the relative earning losses of the treatment group over time. Thus, even in cases where the earnings of individuals stagnate, rather than decrease in absolute terms, they will still be falling behind the comparison group whose earnings continue to grow.

5.1 | Heterogeneity analysis

We estimate the heterogeneous effects on earnings and employment across gender, age, occupational skill level at the time of the shock,[3] and whether the individual suffered from a mTBI only or mTBI and other injuries (such as a limb fracture, for example). Since information on occupation is only collected at the time of the injury, we cannot assess whether changes in earnings over time are related to changes in occupation. Results (θ_Δ) obtained through Equation (4) are reported in Table 1 for these different subgroups.

The penalty is slightly higher for men than women (Panel 1 of Table 1). This may partly reflect that women have lower average wages than men (NZ$2130 a month on average vs. NZ$2790 a month for men). The average monthly penalty during the first year after the shock thus corresponds to a relative loss of 9% for women and 11% for men. However, while employment is similar for both genders the year before the shock (67.6% for women, 67.9% for men), men suffer from slightly higher employment penalties both in the short and longer terms. This could be because women tend to have less consistent labor market attachment than men due to, for example, spending more time out of the labor force to raise children, thus leading to smaller differences between the treatment and comparison groups.

The heterogeneity effect by age is strong (Panel 2 of Table 1). Wage penalties are higher for younger workers (under 40) than for older ones (aged 40+). In the first year following the shock, the average monthly income loss is around NZ $300 for younger workers, compared with NZ$230 for older ones. This absolute magnitude difference is more stark in percentage terms given older workers have higher average pre-shock earnings than younger workers. This difference grows over time, with an income loss of around NZ$650 in the fourth year after the mTBI for younger workers and NZ $420 for older workers. Our results contradict those of Charles (2003), which finds stronger negative effects of health shocks on the earnings of older workers. Our results show an even higher gap between age groups for employment, with the employment effect among younger workers also increasing more strongly over time.

Similar to the case of gender, the differences between younger and older workers might be explained by differences in the labor market trajectories of the comparison group. Earnings of younger workers tend to grow more strongly than those of older workers, who are more likely to have already entered their prime earning years. Thus, younger workers who experience a mTBI may lose an increasing amount of ground against the comparison group of other younger workers whose earnings are rising at a quicker pace.

In terms of occupational skill level, mTBIs are more detrimental for workers in high-skilled jobs than for those in low-to-middle-skilled ones (Panel 3 of Table 1) in both absolute terms and relative to average pre-shock earnings. Over time, the relative penalties also increase more for high-skilled workers (around 36% vs. 29% after 48 months). Our results differ from the economics of health shocks literature which finds that those with lower income prior to the shock suffer larger detrimental effects (Crichton et al., 2011; Dano, 2005; García-Gómez et al., 2013; Riphahn, 1999). Similar results are found by Heinesen and Kolodziejczyk (2013) for cancers, with individuals with lower education being more at risk of exiting employment. However, closer to our results, these authors also highlight a larger increase of the effect in the long term for more educated workers. Besides, Heinesen et al. (2018) show that the labor market effects of health shocks are highly dependent on the skill content of the jobs. In particular, they show that cancers have more negative effects in jobs requiring physical or manual skills. In our case, however, this could explain why we observe stronger effects of mTBI in high-skilled occupations. Indeed, higher skilled occupations are often more reliant on cognitive functions, which are the most affected by TBIs (Dean & Sterr, 2013). Indeed, our results align with those of Theadom et al. (2017), which finds that productivity losses following a mTBI are greater for mental and interpersonal tasks than for physical tasks.

It might be expected that those who received hospital treatment for their mTBI would have more severe injuries on average than those who were treated in a non-hospital setting and, therefore, more negative labor market outcomes. However, there is little difference in the employment results for hospital-treated and non-hospital-treated individuals (Panel 4 of Table 1). The hospital-treated do have larger earnings losses, although the magnitude of the differences are not large.

These smaller-than-expected differences may be because the difference in injury severity between hospital- and non-hospital-treated injuries is not great. For example, perhaps whether or not a mTBI is treated in a hospital is more to do with timing of the injury (e.g., it occurred after hours or on the weekend when most primary care practices are closed) rather than injury severity. However, it could also be that the characteristics of those who are treated in a hospital are different. Hospital treatment for accidents is free in NZ, while primary healthcare treatment typically requires a patient co-payment. Moreover, some individuals do not have a primary care physician and may, therefore, be more likely to go to a hospital emergency department. Since differences in primary healthcare access tend to be related to socioeconomic

TABLE 1 Heterogeneous effects of mTBI on earnings and employment.

	(1) Women ($N = 17,385$)		**(2) Men** ($N = 17,916$)	
Gender	**(a) Monthly earnings**	**(b) Employment**	**(a) Monthly earnings**	**(b) Employment**
Pre-effect	3.47***	0.00***	5.73***	0.00***
	(0.70)	(0.00)	(0.84)	(0.00)
ATT				
$\Delta = 12$	−192.47***	−0.05***	−313.65***	−0.07***
	(11.43)	(0.00)	(14.03)	(0.00)
$\Delta = 24$	−278.79***	−0.08***	−408.56***	−0.09***
	(13.60)	(0.00)	(16.36)	(0.00)
$\Delta = 36$	−356.29***	−0.11***	−493.84***	−0.12***
	(15.90)	(0.00)	(18.62)	(0.00)
$\Delta = 48$	−424.41***	−0.13***	−579.63***	−0.13***
	(18.12)	(0.01)	(20.96)	(0.00)
	(3) Under 40 ($N = 14,952$)		**(4) 40+** ($N = 20,349$)	
Age	**(a) Monthly earnings**	**(b) Employment**	**(a) Monthly earnings**	**(b) Employment**
Pre-effect	9.65***	0.00***	1.11	0.00***
	(0.93)	(0.00)	(0.68)	(0.00)
ATT				
$\Delta = 12$	−299.52***	−0.08***	−226.11***	−0.05***
	(15.30)	(0.00)	(11.26)	(0.00)
$\Delta = 24$	−437.26***	−0.12***	−287.00***	−0.07***
	(18.26)	(0.00)	(13.10)	(0.00)
$\Delta = 36$	−548.33***	−0.15***	−350.21***	−0.08***
	(21.07)	(0.00)	(15.07)	(0.00)
$\Delta = 48$	−646.44***	−0.18***	−415.74***	−0.10***
	(23.88)	(0.01)	(17.12)	(0.00)
	(5) Low- to mid-skilled ($N = 23,505$)		**(6) High-skilled** ($N = 11,796$)	
Skill level	**(a) Monthly earnings**	**(b) Employment**	**(a) Monthly earnings**	**(b) Employment**
Pre-effect	3.90***	0.00***	6.65***	0.00***
	(0.63)	(0.00)	(1.07)	(0.00)
ATT				
$\Delta = 12$	−217.62***	−0.06***	−328.78***	−0.07***
	(10.60)	(0.00)	(17.36)	(0.00)
$\Delta = 24$	−274.18***	−0.08***	−486.88***	−0.11***
	(12.43)	(0.00)	(20.50)	(0.00)
$\Delta = 36$	−325.85***	−0.10***	−626.25***	−0.14***
	(14.15)	(0.00)	(24.03)	(0.01)
$\Delta = 48$	−380.95***	−0.11***	−748.34***	−0.16***
	(15.98)	(0.00)	(27.41)	(0.01)

(Continues)

TABLE 1 (Continued)

	(7) Hospital-treated ($N = 7,890$)		**(8) Non-hospital treated** ($N = 27,411$)	
Hospital	**(a) Monthly earnings**	**(b) Employment**	**(a) Monthly earnings**	**(b) Employment**
Pre-effect	6.62***	0.00***	4.12***	0.00***
	(1.15)	(0.00)	(0.63)	(0.00)
ATT				
Δ = 12	−291.13***	−0.07***	−245.40***	−0.06***
	(20.10)	(0.00)	(10.22)	(0.00)
Δ = 24	−365.73***	−0.09***	−340.10***	−0.09***
	(23.26)	(0.01)	(12.06)	(0.00)
Δ = 36	−437.03***	−0.11***	−423.25***	−0.11***
	(26.53)	(0.01)	(13.91)	(0.00)
Δ = 48	−512.16***	−0.13***	−500.01***	−0.11***
	(29.81)	(0.01)	(15.78)	(0.00)

	(9) mTBI only ($N = 14,567$)		**(10) mTBI plus other injuries** ($N = 20,734$)	
Multiple injuries	**(a) Monthly earnings**	**(b) Employment**	**(a) Monthly earnings**	**(b) Employment**
Pre-effect	5.44***	0.00***	4.02***	0.00***
	(0.84)	(0.00)	(0.73)	(0.00)
ATT				
Δ = 12	−194.31***	−0.05***	−301.48***	−0.07***
	(13.55)	(0.00)	(12.28)	(0.00)
Δ = 24	−315.13***	−0.08***	−370.78***	−0.09***
	(16.23)	(0.00)	(14.27)	(0.00)
Δ = 36	−404.73***	−0.11***	−446.42***	−0.11***
	(18.68)	(0.00)	(16.43)	(0.00)
Δ = 48	−484.00***	−0.13***	−522.53***	−0.13***
	(20.96)	(0.00)	(18.74)	(0.00)

Note: Staggered difference-in-differences estimates are obtained using Equation (1). The effects reported in this table are calculated using Equation (4). Standard errors are clustered at the individual level.

Abbreviation: mTBI, mild traumatic brain injuries.

***indicates significance at the 1% level; **at the 5% level; *at the 10% level.

Source: Authors' calculations using IDI.

status, it is perhaps unsurprising that those who receive hospital treatment are less likely to be in high-skilled occupations (25% vs. 36% for those receiving non-hospital treatment) and have lower average earnings (NZ$2014 monthly earnings in the year before the mTBI, vs. NZ$2220 for those receiving non-hospital treatment). Another possible explanation is that those who are initially treated in a hospital setting have more severe mTBIs, but are provided with more specialized treatment and better follow-up care and guidance, thus leading to similar outcomes as those treated in non-hospital settings.

The results for those who suffered a mTBI only versus those who suffered a mTBI as well as other injuries as a result of the accident show that those who suffer a mTBI plus other injuries have higher earnings losses and falls in employment initially than the mTBI-only group, but these gaps decrease over time. For example, monthly earnings losses are on average 55% higher for the group with mTBI and other injuries compared with the mTBI-only group in the first 12 months, but over 48 months, this difference is just 8%. If examined on a monthly basis (not shown), there are no statistically significant differences in earnings (employment) between the mTBI-only and multiple injury group after 9 (10) months. This convergence of effects between the two groups suggests that the initial shock is larger for those with multiple injuries, but over time, individuals recover from their other injuries (such as fractured limbs, for example), and the remaining longer-lasting effects are largely due to the mTBI. This result is consistent with the health shocks literature that temporary, minor injuries do not have a lasting impact on labor market outcomes, and further highlights that mTBIs are different and tend to have a lasting impact.

5.2 | Effects of mTBIs on accident compensation payments

In addition to the effects of mTBIs on labor market outcomes, we also examine to what extent the ACC system can mitigate the observed earning losses. To this end, we estimate the effects of mTBIs on accident compensation payments using the same methodology (θ_Δ of Equation (4)). Table 2 shows the accident compensation payment results, alongside the monthly earnings results for reference.

As expected, accident compensation payments are positive after experiencing a mTBI, with the average monthly treatment effect over the first 12 months after the mTBI being around NZ$100. However, this amounts to only about 40% of earning losses. As the earning losses grow over time, the accident compensation payments shrink, reaching just 11% of average earning pre-injury losses by the fourth year. These results raise questions about whether the current income replacement scheme recognizes and provides adequate assistance for the potential long-term consequences of mTBIs.

We observe similar patterns in accident compensation payments for all the demographic subgroups (Table 3). The main differences concern the amount received due to the fact that the ACC system calculates the compensation payments based on previous earnings. Therefore, ACC payments are slightly higher for men, those in high-skilled occupations and older workers. However, in terms of ACC payments as a proportion of earning losses, there are some differences particularly for younger versus older workers. ACC payments account for just over a quarter of earning losses for those under 40 years old in the first 12 months after the mTBI, falling to 7% over a 48 month period, compared with just over half and 15% respective for those 40 and over. This difference could be because ACC payments are based on pre-injury earnings, and for younger workers, the earnings of the comparison group continue to go up as their careers progress and they enter their prime earning years, while ACC payments are only adjusted to increase in

TABLE 2 Effects of mTBI on accident compensation payments.

	(1) Monthly ACC payments	(2) Monthly earnings	(3) -ACC/Earning losses
Pre-effect	−0.42***	4.63***	0.09
	(0.12)	(0.55)	
ATT			
$\Delta = 12$	101.92***	−255.58***	0.40
	(3.79)	(9.11)	
$\Delta = 24$	77.80***	−346.55***	0.22
	(3.62)	(10.72)	
$\Delta = 36$	63.75***	−428.09***	0.15
	(3.64)	(12.33)	
$\Delta = 48$	54.98***	−505.74***	0.11
	(3.84)	(13.97)	
N Individuals	35,301	35,301	35,301

Note: Staggered difference-in-differences estimates are obtained using Equation (1). The effects reported in this table are calculated using Equation (4). Effects are calculated for all individuals in the sample. Standard errors are clustered at the individual level.

Abbreviation: mTBI, mild traumatic brain injuries.

***indicates significance at the 1% level; **at the 5% level; *at the 10% level.

Source: Authors' calculations using IDI.

TABLE 3 Heterogeneous effects of mTBI on ACC payments.

	(1) Women $(N=17,386)$		(2) Men $(N=17,915)$	
Gender	**(a) Monthly ACC payments**	**(b) ACC/earning losses**	**(a) Monthly ACC payments**	**(b) ACC/earning losses**
Pre-effect	−0.21	0.06	−0.61***	0.11
	(0.13)		(0.19)	
ATT				
$\Delta = 12$	78.75***	0.41	123.81***	0.39
	(4.56)		(5.97)	
$\Delta = 24$	57.98***	0.21	96.43***	0.24
	(4.34)		(5.72)	
$\Delta = 36$	46.19***	0.13	80.09***	0.16
	(4.39)		(5.72)	
$\Delta = 48$	40.13***	0.09	68.78***	0.12
	(4.81)		(5.90)	
	(3) Under 40 $(N = 14,950)$		**(4) 40+** $(N = 20,351)$	
Age	**(a) Monthly ACC payments**	**(b) ACC/earning losses**	**(a) Monthly ACC payments**	**(b) ACC/earning losses**
Pre-effect	−0.36**	0.04	−0.46***	0.42
	(0.16)		(0.16)	
ATT				
$\Delta = 12$	80.68***	0.27	116.06***	0.51
	(4.89)		(5.41)	
$\Delta = 24$	59.49***	0.14	89.91***	0.31
	(4.63)		(5.19)	
$\Delta = 36$	49.91***	0.09	72.67***	0.21
	(4.70)		(5.19)	
$\Delta = 48$	44.24***	0.07	61.76***	0.15
	(5.06)		(5.43)	
	(5) Low- to mid-skilled $(N = 23,505)$		**(6) High-skilled** $(N = 11,796)$	
Skill level	**(a) Monthly ACC payments**	**(b) ACC/earning losses**	**(a) Monthly ACC payments**	**(b) ACC/earning losses**
Pre-effect	−0.43***	0.11	−0.38**	0.06
	(0.15)		(0.18)	
ATT				
$\Delta = 12$	89.63***	0.41	127.16***	0.39
	(4.39)		(7.26)	
$\Delta = 24$	69.58***	0.25	94.76***	0.19
	(4.21)		(6.93)	
$\Delta = 36$	56.92***	0.17	77.86***	0.12
	(4.22)		(7.01)	
$\Delta = 48$	49.42***	0.13	66.41***	0.09
	(4.40)		(7.55)	

TABLE 3 (Continued)

Hospital	(7) Hospital-treated ($N = 7,890$) (a) Monthly ACC payments	(b) ACC/earning losses	(8) Non-hospital treated ($N = 27,411$) (a) Monthly ACC payments	(b) ACC/earning losses
Pre-effect	−0.84***	0.13	−0.31***	0.08
	(0.26)		(0.13)	
ATT				
$\Delta = 12$	146.71***	0.50	89.09***	0.36
	(8.88)		(4.16)	
$\Delta = 24$	110.54***	0.30	68.33***	0.20
	(8.10)		(4.05)	
$\Delta = 36$	88.92***	0.20	56.43***	0.13
	(7.84)		(4.12)	
$\Delta = 48$	76.23***	0.15	48.68***	0.10
	(7.84)		(4.41)	
Multiple injuries	**(9) mTBI only ($N = 14,567$) (a) Monthly ACC payments**	**(b) ACC/earning losses**	**(10) mTBI plus other injuries ($N = 20,734$) (a) Monthly ACC payments**	**(b) ACC/earning losses**
Pre-effect	−0.18	0.03	−0.61***	0.15
	(0.17)		(0.16)	
ATT				
$\Delta = 12$	42.29***	0.22	146.92***	0.49
	(4.56)		(5.65)	
$\Delta = 24$	34.31***	0.11	111.01***	0.30
	(4.61)		(5.32)	
$\Delta = 36$	29.52***	0.07	90.39***	0.20
	(4.86)		(5.24)	
$\Delta = 48$	25.27***	0.05	78.32***	0.15
	(5.30)		(5.43)	

Note: Staggered difference-in-differences estimates are obtained using Equation (1). The effects reported in this table are calculated using Equation (4). Standard errors are clustered at the individual level.

Abbreviations: ACC, accident compensation corporation; mTBI, mild traumatic brain injuries.

***indicates significance at the 1% level; **at the 5% level; *at the 10% level.

Source: Authors' calculations using IDI.

line with the Labor Cost Index. An alternative explanation could be that younger mTBI sufferers are more strongly encouraged to return to work by ACC given their potential lifetime earnings compensation liability is higher, or because they are perceived to be more able to recover from their injury and return to work. Interestingly, those who suffer from multiple injuries (i.e., the mTBI plus other injuries) have higher ACC payments which compensate for almost half of earning losses in the first 12 months (vs. 22% for the group who suffered from mTBI only), falling to 15% over a 48 month period (vs. 5% for the mTBI-only group). While speculative, this may reflect that other injuries are more visible and the way they impact on people's ability to undertake their jobs more obvious, leading to a higher compensation rate. In contrast, those who suffer only a mTBI have an injury which is not visible and, therefore, receive less compensation relative to the earning losses they suffer as a result of the mTBI.

6 | CONCLUSION

This study investigates the effects of mTBIs on future labor market outcomes. It is important to understand the effects of mTBIs as they are a common injury with a high incidence rate. Despite the growing body of economic research on health shocks, this is the first study to examine TBIs specifically. Past economics literature highlights that minor health shocks have only a short-term effect on labor market outcomes. However, the health literature suggests mTBI could have more lasting effects despite their seemingly minor nature due to the possibility of ongoing cognitive impairment. This paper therefore fills a clear gap in the literature by examining the causal effect of suffering a mTBI on subsequent employment and earnings.

We use population-wide administrative data on all medically-diagnosed mTBIs linked to employment and earnings data from tax records. To account for possible endogeneity, we construct comparison groups of those who suffer from a mTBI but at a future date and apply a doubly-robust staggered difference-in-differences estimator. We examine the effect of suffering just one mTBI by excluding those who had previously been diagnosed with a TBI or who suffered a subsequent TBI (of any severity).

We find that individuals who experience a mTBI suffer adverse effects on employment and large earning losses. Most of the effect is at the extensive margin (i.e., an employment effect), although the intensive margin is also important in explaining earning losses. Indeed, for individuals who manage to stay employed after a mTBI, we observe an initial drop in earnings, followed by a recovery, before earnings gradually decrease again in the medium term. This is in line with the medical literature on mTBIs, which finds that many individuals return to work after an initial recovery period and may manage adequately for a time. However, the expectation that they will continue to gradually improve until they reach their pre-injury level of productivity may not eventuate, resulting in them performing at a lower level for a prolonged period of time. These persistent symptoms then leads to them leaving their roles and/or failing to progress in their careers as they would have otherwise done so, resulting in poor longer-term labor market outcomes.

There are also differences in the magnitude of the adverse effects across groups. The largest difference is between younger and older workers, with younger workers experiencing greater adverse effects on employment and earnings. Additional smaller differences are evident by gender and occupational level. The negative labor market effects are larger for men than women, and for those in high-skilled occupations relative to those in low-to-middle skilled occupations.

Overall, our results show that, despite being classified as minor injuries, suffering a mTBIs can have important and persistent detrimental effects on individuals' labor market outcomes. Our findings highlight the need for timely diagnosis and treatment to mitigate the effects of mTBIs and reduce the burden on the individual, in terms of not only health costs, but also economic and social costs experienced in the labor market. Early intervention would reduce the likelihood of these negative effects, particularly longer-term effects, from occurring.

ACKNOWLEDGEMENT

Open access publishing facilitated by Auckland University of Technology, as part of the Wiley - Auckland University of Technology agreement via the Council of Australian University Librarians.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study were accessed via Stats NZ. Restrictions apply to the availability of these data, which are available to approved researchers only under conditions that give effect to the Data and Statistics Act 2022. These results are not official statistics. They have been created for research purposes from the Integrated Data Infrastructure (IDI) which is carefully managed by Stats NZ. For more information about the IDI please visit https://www.stats.govt.nz/integrated-data/. The results are based in part on tax data supplied by Inland Revenue to Stats NZ under the Tax Administration Act 1994 for statistical purposes. Any discussion of data limitations or weaknesses is in the context of using the IDI for statistical purposes, and is not related to the data's ability to support Inland Revenue's core operational requirements.

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ENDNOTES

[1] For our analysis, TWFE estimations provide substantively the same results as the presented Callaway and Sant'Anna (2021) approach, although with small but consistent pre-treatment effects in the months immediately before the shock.

[2] See https://www.stats.govt.nz/integrated-data/integrated-data-infrastructure/ for more detailed information about the IDI.

[3] We use the Australian and NZ Standard Classification of Occupations (ANZSCO) classification to define our two skill groups. High skilled corresponds to ANZSCO skill levels 1 and 2, low to middle skilled corresponds to ANZSCO skill levels 3, 4 and 5.

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How to cite this article: Fouquet, F., Meehan, L., Pacheco, G., & Theadom, A. (2024). The effect of a minor health shock on labor market outcomes: The case of concussions. *Health Economics*, 1–16. https://doi.org/10.1002/hec.4897