

The association between post-injury chronic physical health conditions, health status, and survival time in people with serious orthopaedic injuries

Trauma

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Abstract

Background: A better understanding of how chronic physical health conditions affect long-term outcomes following injury is essential for quantifying the burden of serious orthopaedic injuries. We aimed to describe the association between the presence of post-injury chronic physical health conditions and (i) the change in health status from before injury to six different follow-up time points after injury; and (ii) survival time.

Methods: A cohort study was conducted using linked data from the REcovery after Serious Trauma: Outcomes, Resource Use, and Patient Experiences study, the Victorian Registry of Births, Deaths and Marriages (BDM) (2009–2017), the Victorian admitted episodes dataset (2009–2017) and the Victorian emergency minimum dataset (2009–2017). Adults (≥ 18 years old) with serious orthopaedic injuries who survived to discharge from their trauma admission were included. Multivariable linear regression analysis was conducted to evaluate the association between post-injury chronic physical health conditions and the mean change in health status (EuroQol-Visual Analogue Scale) from before injury to six follow-up time points post-injury. Survival analysis was conducted to estimate the probability of survival for people with and without chronic physical health conditions following injury.

Results: Out of 894 participants, 177 (19.8%) had at least one chronic physical health condition recorded up to five years post-injury. People with post-injury conditions reported a greater mean decline in health status than people without post-injury conditions (difference, (95% CI): -6.9 (-9.7 , -4.2), $p = 0.01$). Over the study period, almost six times as many people with chronic physical health conditions post-injury died as people without these conditions (AHR (95% CI): 5.7 (2.9, 11.3), $p < 0.01$).

Conclusions: Chronic physical conditions after serious orthopaedic injuries were associated with a lower survival probability and a deteriorating health status. Orthopaedic injury survivors may benefit from early detection and treatment of chronic conditions.

Keywords

Trauma, orthopaedic, chronic conditions, chronic diseases, long-term outcomes, mortality

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Introduction

Serious orthopaedic injury is one of the leading causes of mortality and morbidity.^{1,2} People with serious orthopaedic injuries have a high prevalence of chronic physical health conditions including cancer, cardiovascular disease (CVD), type 2 diabetes (DM), and hypertension.³ Chronic conditions may hinder the recovery process,^{4,5} and may increase mortality risk following injury.⁶

Previous studies have demonstrated that chronic conditions are associated with poorer long-term outcomes following injury.^{7,8} These studies, however, have only looked at pre-existing chronic conditions, rather than conditions that develop after injury.^{9,10} Furthermore, few have focussed solely on serious orthopaedic injury.^{11,12} As such, there is a lack of information specific to this population.

Understanding the link between new-onset chronic conditions and long-term health outcomes post-injury will have implications for both clinical practice and future research. Therefore, in people with serious orthopaedic injuries, we aimed to describe: (i) the association between the presence of post-injury chronic physical health conditions and the change in health status from before injury to six follow-up time points (six months, one, two, three, four, and five years) after injury; and (ii) the association between the presence of post-injury chronic physical health conditions and survival time.

Methods

Study design

We conducted a cohort study using linked data from the REcovery after Serious Trauma Outcomes, Resource Use and Patient Experiences (RESTORE) study, the Victorian Registry of Births, Deaths and Marriages (BDM) (2009–2017), the Victorian Admitted Episodes Dataset (VAED) (2009–2017) and the Victorian Emergency Minimum Dataset (VEMD) (2009–2017).

Data sources

The RESTORE study was a population-based longitudinal cohort study using quantitative and qualitative methods to capture outcomes and experiences of seriously injured people from the Victorian State Trauma Registry (VSTR) up to five years post-injury.¹³ Victorian State Trauma Registry is a population-based registry that collects information about major trauma patients from all trauma-receiving hospitals in the Australian state of Victoria (population 6.4 million) to monitor and evaluate trauma care.^{14,15} Patients are included in the VSTR if they meet any one of the following criteria: death after injury; an Injury Severity Score >12; admission to an intensive care unit for >24 h and requiring mechanical ventilation for at least part of their stay; or requiring urgent/

emergency surgery.^{15,16} People with a date of injury between July 2011 and June 2012 were included in the RESTORE study. The RESTORE dataset included participants' demographics, injury events, diagnosis, treatment, in-hospital outcomes, and patient-reported outcome data from the six-month, one-, two-, three-, four- and five-year follow-up surveys.

The VAED contains de-identified data on hospital admissions for admitted patients in all Victorian public and private hospitals, including rehabilitation centres, extended care facilities and day procedure centres.¹⁷ The VEMD contains de-identified demographic, administrative and clinical details from emergency presentations at all Victorian public hospitals with designated emergency departments (EDs).¹⁸ The Victorian Registry of BDM records births, deaths, marriages and adoptions of all people in Victoria.

Data linkage process

The RESTORE dataset was first linked to data from the Victorian BDM to establish if any patient had died following injury. Dates of death were extracted from the Victorian BDM if not available in the RESTORE study dataset. This combined dataset was provided to the Centre for Victorian Data Linkage (CVDL) at the Department of Health for linkage with data from the VAED and VEMD.¹⁹ Hospital admissions and ED presentations were linked for each RESTORE participant for the two years prior to, and up to five years after their VSTR admission (Figure 1). Data were linked using probabilistic methods based on identifiers such as first name, surname, birth date and sex, using 'fuzzy matching' on the name to achieve a higher linkage rate than exact matching.²⁰ The linkage rate was 97.8%. Ethical approval for the linkage was provided by the Victorian Department of Health and Human Services Human Research Ethics Committee (DHHS HREC) and participating health service ethics committees.

Study participants

Adults (≥ 18 years old) with serious orthopaedic injuries from RESTORE who survived to discharge from their trauma admission were included in this study. Serious orthopaedic injury was defined as a traumatic injury that resulted in at least one fracture and met the VSTR inclusion criteria.^{21,22} People with neurotrauma (spinal cord injury or severe traumatic brain injury (AIS score of ≥ 3 in the spine or head region)) or burns were excluded.

Exposure

Chronic physical health conditions are defined as any condition expected to result in the long-term or ongoing deterioration of an individual's physical health.²³ Post-injury conditions were defined as those identified within the VAED or VEMD datasets up to five years after injury that had not been identified in the

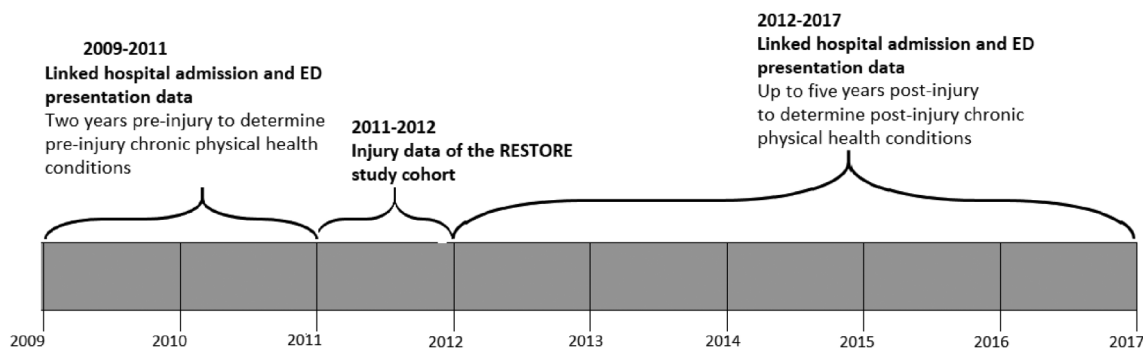


Figure 1. Timeline of the data and time periods required for the analysis of chronic physical health conditions following serious orthopaedic injury.

two years prior to injury (within the VAED or VEMD), nor at the time of injury (within the VSTR). Indicator variables for conditions of interest were mapped from the International Classification of Diseases, 10th Edition, Australian Modification (ICD-10-AM) diagnosis codes and relevant procedure codes from the Australian Classification of Health Interventions (ACHI)-Tenth Edition. Conditions included in the study were arthritis and arthropathies, cancer (all types), cardiovascular disease, chronic kidney disease, chronic pulmonary disease, type 2 diabetes, hypertension, obesity, Alzheimer's disease and vascular dementia. Cardiovascular disease (CVD) includes atherosclerosis, chronic heart failure, ischaemic heart disease, myocardial infarction, peripheral vascular disease or stroke. The methodology for identifying chronic physical health conditions was developed based on research by Tonelli et al.²⁴ The VAED ICD-10-AM prefix classifies conditions as a principal diagnosis, complication or comorbid diagnosis, while VEMD ICD-10-AM codes indicate primary diagnoses only. This study included principal diagnoses from the VAED and primary diagnoses from the VEMD. The presence of post-injury chronic physical health conditions (yes/no) was determined at six follow-up time points (six months, one, two, three, four and five years) post-injury.

Procedures

Participants' demographic information (age, sex, level of education, and socioeconomic characteristics), pre-injury health and disability status, injury event details (cause, place, and intent of injury), Injury Severity Score (ISS)²⁵ and compensation status were obtained from the linked dataset. The ISS was categorised into tertiles for analysis (ISS < 17, ISS = 17–24, ISS > 24). Self-reported pre-injury disability (yes/no) was derived from a five-category global disability rating scale.²⁶ Indicators for pre-injury mental health conditions, alcohol and drug-related conditions and smoking status were mapped from ICD-10-AM diagnosis codes from pre-injury hospital admissions/ED presentations and trauma admissions. Residential postcodes were

mapped to the Accessibility/Remoteness Index of Australia (ARIA),²⁷ and the Index of Relative Socio-economic Advantage and Disadvantage (IRSAD), which ranks areas in Australia according to relative socio-economic advantage and disadvantage.²⁸ Deciles of the IRSAD were collapsed into quintiles. Transport and work-related injuries in Victoria are covered by no-fault compensation schemes regulated by the Transport Accident Commission and the Victorian Workcover Authority respectively.^{29,30}

Outcomes

The change between pre- and post-injury health status at six months, one, two, three, four and five years was measured respectively. Pre- and post-injury health status was measured using the EuroQol-Visual Analogue Scale (EQ-VAS).³¹ To complete the pre-injury EQ-VAS, study participants were asked the following question: 'How would you say your health was prior to your injury on a scale of 0–100, with 0 being the worst imaginable health state and 100 being the best imaginable health state?' To complete the post-injury EQ-VAS, participants were asked the same question, relating to that point in time. Both pre- and post-injury EQ-VAS scores were collected by trained telephone interviewers within the VSTR at six months, one, two, three, four and five years post-injury. The change in health status (EQ-VAS) from pre- to post-injury was calculated by subtracting the pre-injury EQ-VAS from post-injury EQ-VAS for each follow-up period, with a negative value indicating a decline in health status. To address the second aim, we determined survival time by subtracting the date of injury from the date of death, summarised in years.

Data analysis

Descriptive statistics were used to summarise participants' baseline characteristics. Frequencies and percentages were used to characterise categorical variables. For continuous variables, the mean and standard deviation (SD) were

calculated for normally distributed data and median and interquartile range (IQR) for skewed data.

To describe the mean change in health status by post-injury chronic condition status at each time point, we fitted a linear regression model with an interaction between time and outcome. We used a clustered sandwich estimator for the standard errors to account for the repeated EQ-VAS scores reported by each participant.³² The estimates were then standardised to the sample mean and proportion for the following potential confounders: age, sex, pre-existing health conditions (identified in the two years prior to injury or at the time of injury), pre-injury EQ-VAS score, EQ-VAS score at previous time points (for example, 6months and one year for two-year outcome), pre-injury disability, pre-injury smoking status, pre-injury drug and alcohol-related conditions and mental health conditions.³³ These variables were selected because they have previously been identified as being associated with the health status of people with serious orthopaedic injuries.^{34,35}

To estimate the association between post-injury chronic conditions (yes/no) at each follow-up time point (e.g. up to two years post-injury) and the mean change in health status at that time point, we fitted a multivariable linear regression model.³⁶ The estimate of the association was adjusted for the potential confounders listed prior. By inspecting variance inflation factors (VIFs), we identified no collinearity between post-injury chronic physical health conditions and other variables (mean VIF = 2). The homogeneity of variance was graphically tested. Because the pre-injury EQ-VAS values were missing in 9.95% of the study participants, we conducted a sensitivity analysis to investigate if the qualitative interpretations of our study findings changed as a result of the missing pre-injury EQ-VAS data. By comparing the association between chronic physical health conditions and post-injury EQ-VAS to the association between chronic physical health conditions and changes in pre- to post-injury EQ-VAS, we determined if the results were influenced by missing data or the pre-injury adjustment.

Survival analysis was conducted to estimate the survival probability of people with and without post-injury chronic conditions. The exposure (chronic physical health conditions) was treated as time-varying because the percentage of people with post-injury chronic physical health conditions changed from the 'no chronic physical health condition' group to the 'yes' group over the five-year period.³⁷ Participants were followed from the date of injury up to five years post-injury, and were considered censored if still alive at five years. The association between post-injury chronic physical health conditions and survival following serious orthopaedic injury was described with a proportional hazards ratio, estimated using a multivariable Cox proportional hazards model, adjusted for baseline factors: age, sex, pre-injury physical health conditions, pre-injury mental health conditions, smoking, drug and alcohol-related conditions and IRSAD.^{37,38} These variables were selected because they

have previously been identified as being associated with mortality among people with serious orthopaedic injuries.^{34,35} The Cox proportional hazards assumption was assessed by inspecting the log-minus-log plots (log-log survival time against the log analysis time).^{39,40}

Results

Overview of study participants

There were 2941 people with major trauma included in the RESTORE project, of whom 894 met the inclusion criteria (Figure 2). Most (70.7%) participants were male, and the median (IQR) age and ISS were 53 (36–66) years and 30 (25–43), respectively (Table 1).

Post-injury chronic physical health conditions in people with serious orthopaedic injury

Figure 3 shows the percentage of people with and without post-injury chronic physical health conditions. There were 177 people (19.8%) with at least one post-injury chronic physical health condition up to five years after injury. The proportion of people with serious orthopaedic injuries admitted to hospital/presented to ED with each type of condition up to five years post-injury is presented in Supplemental Material 1.

Changes in pre- to post-injury health status

Figure 4 shows the mean change in health status from pre-injury to various time points post-injury up to five years post-injury. The mean (SD) change in health status of people with no post-injury chronic conditions ranged from -14.9 (22.2) at one year post-injury to -17.3 (22.6) at three years post-injury, representing a decline from pre-injury health status at all time points post-injury. The mean (SD) change in health status of people with post-injury chronic conditions ranged from -18.1 (19.1) at two years post-injury to -23.8 (23.3) at five years post-injury, representing a decline from pre-injury health status at all time points post-injury. People with no post-injury conditions reported less health decline at every time point than people with post-injury conditions. There was a significant difference in health status between people with and without post-injury chronic conditions at five years post-injury.

The association between chronic physical health conditions and changes in health status from pre to post-injury

The adjusted association between post-injury chronic physical health conditions (yes/no) and changes in health status is shown in Figure 5. There was no association between post-injury chronic physical health conditions and health status at

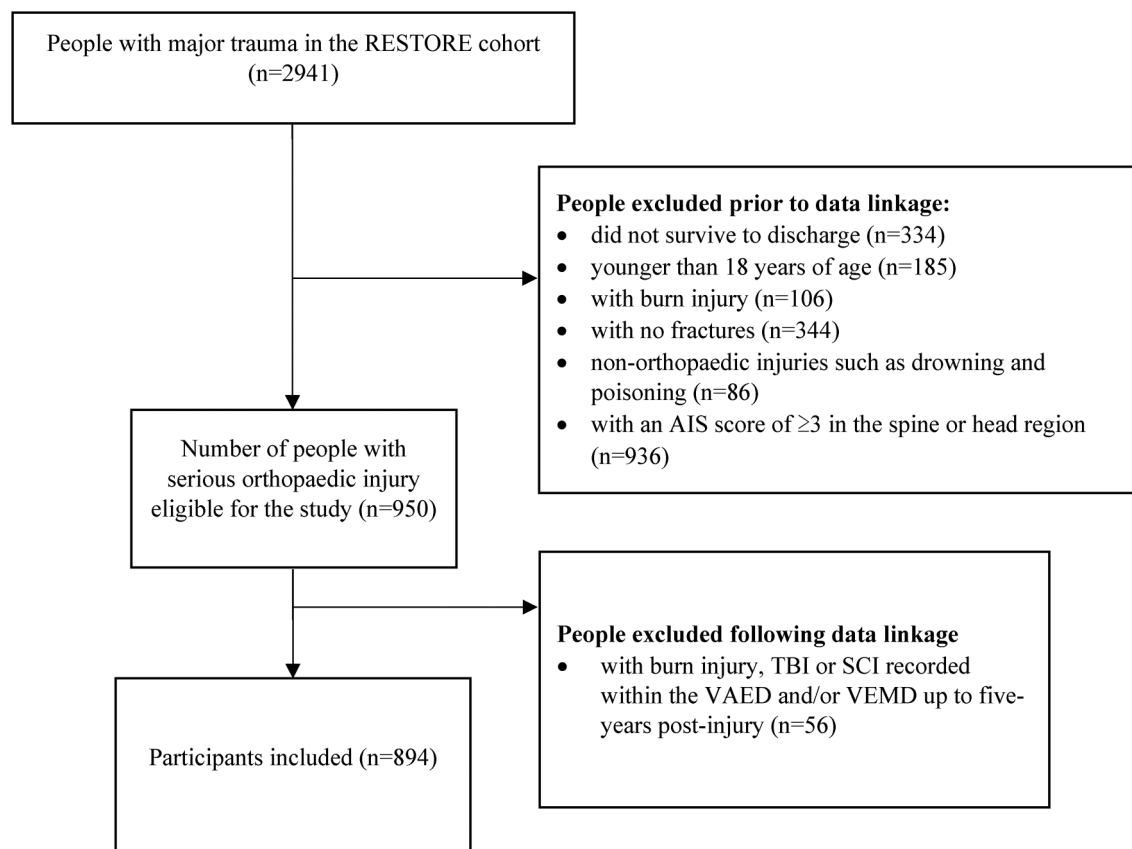


Figure 2. Flow diagram depicting selection of study participants.

AIS: abbreviated injury severity; RESTORE: recovery after serious Trauma - Outcomes, Resource use and patient Experiences study; TBI: traumatic brain injury; SCI: spinal cord injury; VAED: the Victorian Admitted Episodes Dataset (VAED); VEMD: the Victorian Emergency Minimum Dataset.

any time point up to four years after injury. At five years post-injury, the presence of a post-injury chronic physical health condition was significantly associated with a decline in health status. People with post-injury chronic physical health conditions reported a mean decline in health status, 6.9 units greater on the EQ-VAS scale than people without post-injury chronic physical health conditions, after adjusting for confounders (such as age, sex, and socioeconomic status) (difference, (95% CI): -6.9 (-9.7 , -4.2), $p=0.01$). [Supplemental Material 2](#) provides the adjusted mean difference between post-injury chronic physical health conditions (yes/no) and changes in pre-to post-injury health status). The sensitivity analysis using the alternative outcome resulted in values that were consistent with the main analysis ([Supplemental Material 3](#)).

The association between post-injury chronic physical health conditions and mortality following serious orthopaedic injury

The median (IQR) follow-up period for mortality was 2.6 (1.5–3.5) years. The cumulative mortality up to five years post-injury was 12.4% (95% CI: 10.4%, 14.7%). About 16.9% of people

with post-injury chronic physical health conditions, and 11.3% of people without post-injury chronic physical health conditions, had died by five years. The unadjusted Cox proportional hazards regression showed that at any time point during the study period, more than four times as many people with post-injury chronic physical health conditions had died than people without post-injury chronic physical health conditions (AHR (95% CI): 4.2 (2.6, 6.7), $p<0.01$). After adjusting for age, sex, pre-injury physical health conditions, pre-injury mental health conditions, smoking, drug and alcohol-related conditions and IRSAD, the Cox proportional hazards regression showed that at any time point during the study period, almost six times as many people with post-injury chronic physical health conditions had died than people without post-injury chronic physical health conditions (AHR (95% CI): 5.7 (2.9, 11.3), $p<0.01$).

Discussion

The aim of this study was to describe the association between post-injury chronic physical health conditions and long-term outcomes (health status and mortality)

Table 1. Baseline characteristics of study participants (N = 894).

Baseline characteristics	Number (%)	Baseline characteristics	Number (%)
Sex		Pre-injury work status ^d	
Male/female	632 (70.7)/262 (29.3)	Not working	282 (34.6)
Age group (years)		Working	533 (65.4)
18–24	109 (12.2)	Pre-injury disability ^e	
25–34	131 (14.7)	No	757 (84.9)
35–44	132 (14.8)	Yes	135 (15.1)
45–54	145 (16.2)	CCI (weight)	
55–64	164 (18.3)	0	663 (74.2)
65–74	104 (11.6)	I	174 (19.5)
75 +	109 (12.2)	> I	57 (6.4)
Marital status at injury		Compensable status ^f	
Married/partnered	393 (49.2)	Not compensable	353 (39.7)
Never married	292 (36.6)	Compensable	537 (60.3)
Divorced/separated	64 (8.0)	Cause of injury	
Widowed	49 (6.1)	Motor vehicle collision	304 (34.0)
Highest level of education ^a		Motor cycle collision	147 (16.4)
University degree	156 (20.4)	Pedal cyclist collision	69 (7.7)
Advanced diploma, diploma, and certificate	240 (31.3)	Low fall (from standing height or < 1 m)	91 (10.2)
Completed high school	92 (12.0)	Pedestrian collision	61 (6.8)
Did not complete high school	278 (36.3)	High fall	132 (14.8)
Pre-injury alcohol and drug-related conditions		Struck by or collision with a person or object	41 (4.6)
No/yes	803 (89.8)/91 (10.2)	Other	49 (5.5)
Pre-injury smoking		Place of injury	
No/yes	753 (84.2)/141 (15.8)	Home	156 (17.5)
Pre-injury MH conditions		Road/street/highway	533 (59.8)
No/yes	723 (80.9)/171 (19.1)	Other	205 (22.8)
Pre-injury chronic physical health conditions		Pre-injury EQ-VAS median (IQR) ^g	90 (80–100)
No/yes	710 (79.4)/184 (20.6)	Injury Severity Score (ISS)	
ARIA ^b		< 26	365 (40.8)
Major cities	631 (72.5)	26–38	286 (32.0)
Inner regional Australia	195 (22.4)	> 38	243 (27.2)
Outside regional Australia	44 (5.1)		

(continued)

Table 1. Continued.

Baseline characteristics	Number (%)	Baseline characteristics	Number (%)
IRSAD ^c			
1 (most disadvantaged)	275 (31.5)		
2	177 (20.3)		
3	103 (11.8)		
4	227 (26.0)		
5 (least disadvantaged)	90 (10.3)		

MH: mental health; CCI: Charlson comorbidity index; ARIA: accessibility/remoteness index of Australia; IRSAD: index of relative socio-economic advantage and disadvantage; EQ-VAS: EuroQoL-Visual Analogue Scale; IQR: interquartile range.

^aData missing for 128 cases.

^bData missing for 24 cases.

^cData missing for 22 cases.

^dData missing for 79 cases.

^eData missing for two cases.

^fData missing for four cases.

^gData missing for 89 cases.

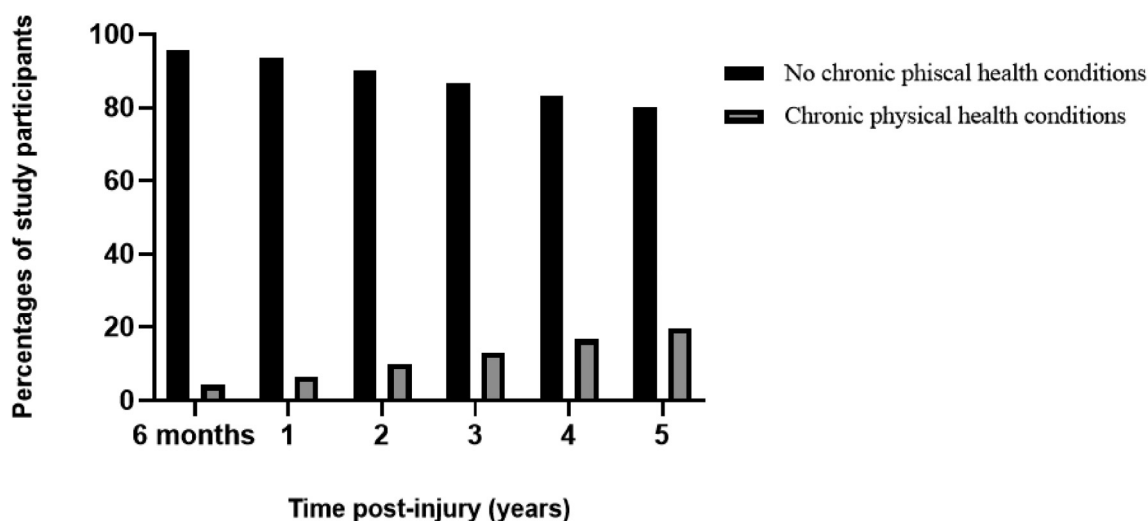


Figure 3. The cumulative distribution of post-injury chronic physical health conditions in people with serious orthopaedic injury up to five years post-injury.

following serious orthopaedic injury. We found that people with post-injury chronic physical health conditions had a poorer long-term health status five years following injury than people without post-injury chronic conditions. A significant association between post-injury chronic conditions and decreased survival probability up to five years post-injury was also observed.

Research indicated that pre-existing conditions are associated with poor long-term health outcomes.^{7,41} However, until now there was a lack of research on the association between post-injury chronic physical health conditions and long-term outcomes in people with serious orthopaedic

injury. There are several possible explanations for the greater health decline observed in people with post-injury chronic conditions.^{42,43} People with post-injury chronic conditions may have diminished physical and mental resilience to the repercussions of the injury, curtailing their capacity to recover.⁴³ Negative behaviour changes caused by injury may also lead to the onset of chronic conditions that are linked to a lower health status after an injury.⁴⁴ Conditions that may have been present at the time of injury or at the pre-diagnosis level but just not identified, whereby some effects of the condition were present to a minor degree of severity but not yet fully expressed, may

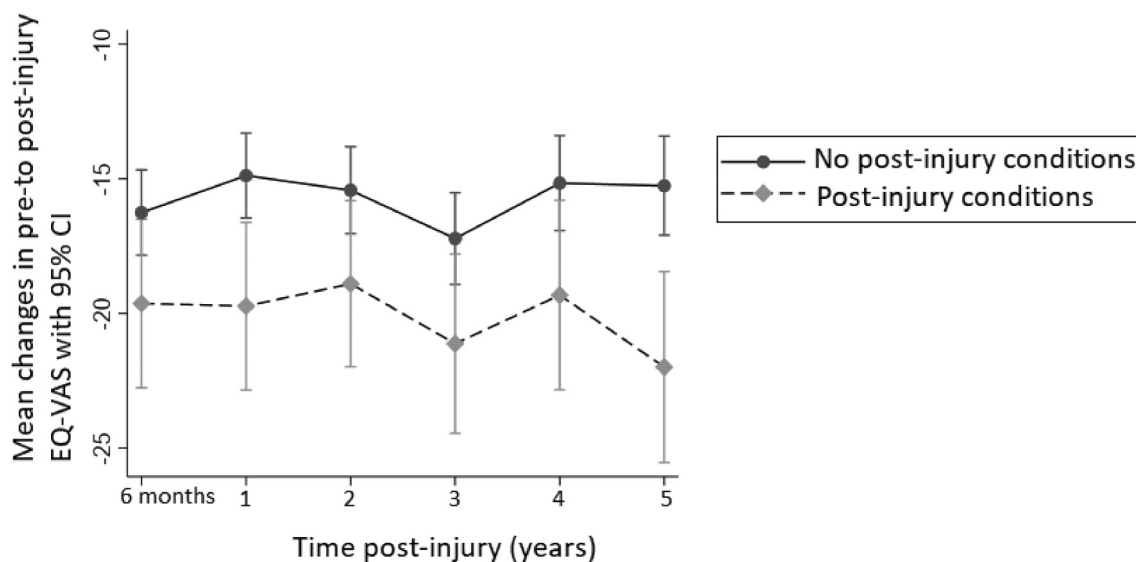


Figure 4. Mean changes in EuroQol-Visual Analogue Scale (EQ-VAS) (health status) from pre-injury to various time points post-injury, up to five years post-injury.

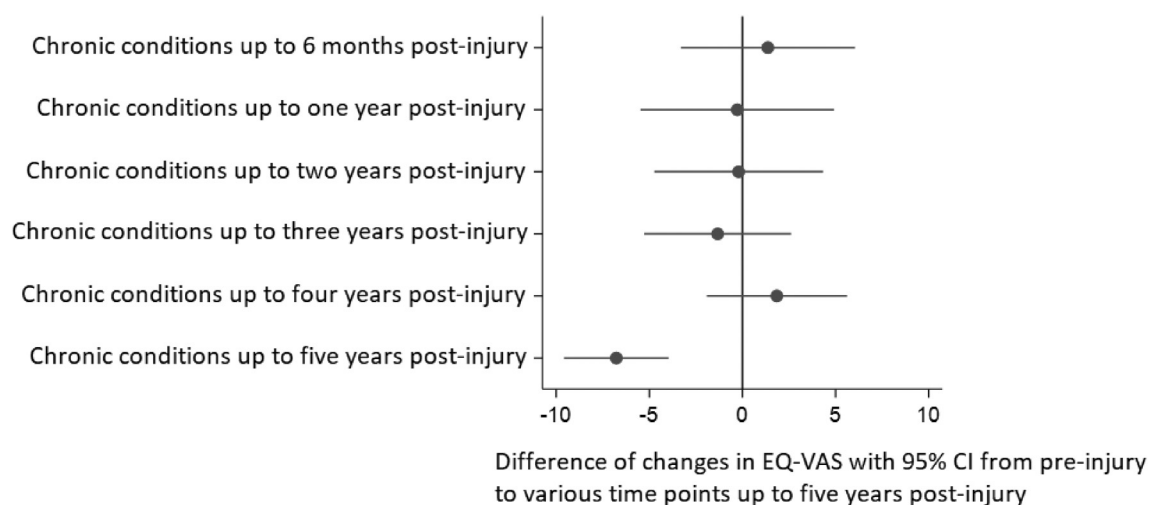


Figure 5. Adjusted association between post-injury chronic physical health conditions (yes/no) and changes in EuroQol-Visual Analogue Scale (EQ-VAS) (health status) from pre-injury to various time points up to five years post-injury: a negative score implies a decrease in post-injury health status.

also lead to poorer long-term outcomes and recovery following injury. This finding was observed only five years after injury, indicating that chronic physical health conditions develop gradually and need a longer period of time to manifest and have an effect on trauma survivors following injury. As such, long-term follow-up care following a significant orthopaedic injury may be necessary to prevent chronic physical health conditions and to reduce long-term effects.

Another explanation for the link between chronic health conditions and health status following serious orthopaedic injury is that chronic physical health conditions can both contribute to, and be a result of, poor long-term physical

and mental health status.⁴⁵ For example, people with serious orthopaedic injuries may experience a variety of negative outcomes, including pain, increasing functional impairment, activity limitation, participation restriction and mental illness such as depression, which may be detrimental to their reported health status. Subsequently, not undertaking sufficient physical activity to incur health benefits, such as maintaining appropriate body weight and a healthy musculoskeletal system, could then facilitate the development of chronic conditions.^{46,47}

Our study showed that people with post-injury chronic physical health conditions had a higher mortality rate than

people with no post-injury chronic physical health conditions during the follow-up period. Until now, the impact of new post-injury chronic conditions on mortality in people with serious orthopaedic injury was unclear, as previous studies focused only on pre-existing conditions.^{48,49} For example, a study on the timing and causes of mortality after injury, found that mortality was associated with pre-existing cancer and CVD.⁵⁰ Given the evidence of an association between post-injury chronic physical health conditions and mortality after serious orthopaedic injury, it may be necessary to identify people with these conditions and implement treatment strategies to prevent mortality following injury.

The findings of this study have significant implications for understanding how chronic physical health conditions may affect the recovery process of people with serious orthopaedic injuries. Given the prevalence of post-injury chronic conditions and their association with poor long-term outcomes and mortality following injury, people with serious orthopaedic injuries may need to be monitored more frequently and over a greater length of time than people without chronic physical health conditions. Early and regular screening for chronic physical health conditions following serious orthopaedic injury may also be needed to help reduce the risk of mortality and poor long-term health status.

Our findings also have important implications for future research. For example, researchers are recommended to consider post-injury chronic physical health conditions when determining risk for long-term outcomes and mortality. Further research such as prospective studies in which chronic conditions and health status are assessed at a baseline time point and re-assessed over time (up to 10 years) post-injury could help in improving our understanding of the impact of chronic conditions on health status and survival. Further research on which types of chronic physical health conditions have the most influence on long-term outcomes following injury may also be needed to develop targeted interventions to improve outcomes and post-injury recovery.

The primary strength of this study was the long-term (five-year) follow-up of outcomes, enabled by linking the RESTORE dataset with administrative data. Additionally, by using self-reported pre-injury health status data to calculate pre-to-post-injury health status changes, we avoided underestimating the impact of injury upon post-injury health outcomes.

Certain limitations should also be considered. It was not clear from this study whether serious orthopaedic injuries are associated with chronic conditions, long-term health outcomes, or both following injury. However, studies showed that the relationship between chronic health conditions and health status following a serious orthopaedic injury is complex.^{3,5,51} Serious orthopaedic injuries, such as fractures, can have significant consequences, including persistent pain, functional impairment, limitations in

activity, and restrictions on participation. A combination of these complications and chronic health conditions may result in an overall decrease in health status.^{52,53} This vulnerability arises from the interplay between serious orthopaedic injury and post-injury chronic health conditions. Additionally, the psychological stress associated with serious orthopaedic injuries can affect an individual's mental and emotional well-being, which, when combined with the effects of chronic physical health conditions, can further compromise health status.^{2,8} This bidirectional nature of the association between chronic health conditions and long-term health outcomes can vary among individuals. This creates a cyclic pattern that underscores the importance of adopting a comprehensive and personalized approach to healthcare. Because we used hospital admission/ED presentations to determine the presence of health conditions, we could not ensure a complete capture of all chronic health conditions (e.g. those diagnosed and treated in the community, or undiagnosed). As a result, the prevalence of chronic physical health conditions is likely to have been underestimated. Using Medicare Benefits Schedule (MBS) and/or Pharmaceutical Benefits Schedule (PBS) data in future Australian studies might reduce this limitation. We limited our analysis to conditions with a principal/primary diagnosis in order to focus on new post-injury conditions. This could also have lowered the prevalence of chronic conditions following serious orthopaedic injury. Furthermore, reported health status may differ systematically between people with chronic conditions that are missed and people with chronic conditions that are captured in hospital admissions/ED presentations. People with chronic physical health conditions managed in the community or people who have better self-management skills for their chronic condition may score higher on the EQ-VAS than those with chronic conditions admitted to the hospital or presenting to the emergency department. Another potential limitation of our study was the potential for 'survivor bias'. People with serious orthopaedic injuries who died before completing follow-up may have differed from people who survived until completed follow-up. For people who died before the follow-up was complete, post-injury health status was not simply missing, but rather, undefined. People with no chronic conditions who died before completing follow-up may have been healthier overall than people without chronic physical health conditions. The other limitation of this study was that about 10% of pre-injury EQ-VAS data were missing. However, we conducted a sensitivity analysis without using pre-injury EQ-VAS and found no qualitative alteration in the overall interpretation of the outcome. Furthermore, because we only looked at elements that could be extracted from the linked dataset, important confounding factors like physical inactivity, sedentary behaviour, post-traumatic stress disorder and dietary habits were not included in our model because they were not included in any datasets.

Conclusion

Post-injury chronic physical health conditions were associated with a lower long-term health status and a higher mortality rate. Chronic conditions may affect recovery after injury, and this needs to be considered in future research. Assessing risk-adjusted long-term outcomes in orthopaedic injury populations requires adjustment for post-injury chronic physical health conditions. Early screening, prevention, detection, and management of chronic physical health conditions could improve long-term outcomes following injury. People with chronic physical health conditions need to receive more frequent long-term health monitoring than people without chronic physical health conditions following injury.

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Ethical approval

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Informed Consent

Not applicable

Trial Registration

Not applicable

Contributorship

AG conceptualized the manuscript. AG was responsible for cleaning and analyzing the data, AG wrote the draft manuscript, and all

others contributed by providing feedback, interpreting results, and refining the manuscript. All authors reviewed and edited the manuscript. All authors have read and approved the final version of the manuscript.

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Supplemental material

Supplemental material for this article is available online.

References

1. Urquhart DM, Edwards ER, Graves SE, et al. Characterisation of orthopaedic trauma admitted to adult level 1 trauma centres. *Injury* 2006 Feb 1; 37: 120–127.
2. Urquhart DM, Williamson OD, Gabbe BJ, et al. Outcomes of patients with orthopaedic trauma admitted to level 1 trauma centres. *ANZ J Surg* 2006; 76: 600–606.
3. Gelaw AY, Gabbe BJ, Braaf SC, et al. Chronic physical health conditions and associated factors among people with serious orthopaedic injuries: a systematic review. *Trauma* 2020; 23: 1460408620968341.
4. Brackbill RM, Cone JE, Farfel MR, et al. Chronic physical health consequences of being injured during the terrorist attacks on World Trade Center on September 11, 2001. *Am J Epidemiol* 2014; 179: 1076–1085.
5. Gelaw AY, Gabbe BJ and Ekegren CL. Chronic physical health conditions up to five years after serious orthopaedic injury. *Injury* 2022 Apr; 53: 1459–1468.
6. Negrete-Corona J, Alvarado-Soriano JC and Reyes-Santiago LA. Hip fracture as risk factor for mortality in patients over 65 years of age. Case-control study. *Acta Ortop Mex* 2014 Dec; 28: 352–362.
7. Fernando DT, Berecki-Gisolf J, Newstead S, et al. Effect of comorbidity on injury outcomes: a review of existing indices. *Ann Epidemiol* 2019 Aug; 36: 5–14.
8. Pozzato I, Craig A, Gopinath B, et al. Outcomes after traffic injury: mental health comorbidity and relationship with pain interference. *BMC Psychiatry* 2020 Apr 28; 20: 89.
9. Gabbe BJ, Harrison JE, Lyons RA, et al. Comparison of measures of comorbidity for predicting disability 12-months post-injury. *BMC Health Services Res* 2013; 13: 30.
10. Cameron CM, Kliewer EV, Purdie DM, et al. Long-term mortality following injury in working-age adults: a systematic review. *Int J Inj Contr Saf Promot* 2007 Mar; 14: 11–18.
11. Bell JJ, Pulle RC, Lee HB, et al. Diagnosis of overweight or obese malnutrition spells DOOM for hip fracture patients: a prospective audit. *Clin Nutr* 2021 Apr 1; 40: 1905–1910.
12. Yoon SH, Kim BR, Lee SY, et al. Influence of comorbidities on functional outcomes in patients with surgically treated fragility hip fractures: a retrospective cohort study. *BMC Geriatrics* 2021 Apr 28; 21: 83.
13. Gabbe BJ, Braaf S, Fitzgerald M, et al. RESTORE: recovery after serious trauma—outcomes, resource use and patient experiences study protocol. *Inj Prev (1353-8047)* 2015 Oct; 21: 348–354.

14. Cameron PA, Finch CF, Gabbe BJ, et al. Developing Australia's first statewide trauma registry: what are the lessons? *ANZ J Surg* 2004 Jun 1; 74: 424–428.
15. Cameron PA, Gabbe BJ, Cooper DJ, et al. A statewide system of trauma care in Victoria: effect on patient survival. *Med J Australia* 2008; 189: 546–550.
16. Gabbe BJ, Sutherland AM, Hart MJ, et al. Population-based capture of long-term functional and quality of life outcomes after major trauma: the experiences of the Victorian State Trauma Registry. *J Trauma Acute Care Surg* 2010; 69: 532–536.
17. Department of Health & Human Services. *Victorian Admitted Episodes Dataset manual 2019-2020 [Internet]*. Victoria, Australia: Department of Health & Human Services; [cited 2020 Apr 15]. Available from: <https://www2.health.vic.gov.au:443/about/publications/policiesandguidelines/Victorian-Admitted-Episodes-Dataset-manual-2019-2020..2012>.
18. Marson R, Taylor DM, Ashby K, et al. Victorian emergency minimum dataset: factors that impact upon the data quality. *Emerg Med Australas* 2005 Apr; 17: 104–112.
19. Department of Health & Human Services. *The Centre for Victorian Data Linkage [Internet]*. Victoria, Australia: Department of Health & Human Services, cited 2020 Aug 20. Available from: <https://www2.health.vic.gov.au:443/about/reporting-planning-data/the-centre-for-victorian-data-linkage>.
20. Dusetzina SB, Tyree S, Meyer AM, et al. *An Overview of Record Linkage Methods [Internet]*. *Linking Data for Health Services Research: A Framework and Instructional Guide [Internet]*. US: Agency for Healthcare Research and Quality (US), 2014 [cited 2020 Jul 1]. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK253312/>.
21. Victorian State Trauma System. Victorian Trauma System-Definition of Major Trauma | Trauma Victoria [Internet]. [cited 2021 Feb 19]. Available from: <https://trauma.reach.vic.gov.au/guidelines/victorian-trauma-system/definition-of-major-trauma>.
22. Victorian Department of Health and Human Services. *Definition of major trauma [Internet]*. Victoria, Australia: Department of Health & Human Services, cited 2021 Aug 25. Available from: <https://www2.health.vic.gov.au:443/hospitals-and-health-services/patient-care/acute-care/state-trauma-system/major-trauma-classification>.
23. Bernell S and Howard SW. Use your words carefully: what is a chronic disease? *Front Public Health [Internet]* 2016; 4: 1. <https://www.frontiersin.org/articles/10.3389/fpubh.2016.00159/full>.
24. Tonelli M, Wiebe N, Fortin M, et al. Methods for identifying 30 chronic conditions: application to administrative data. *BMC Med Inf Decis Making* 2015 Apr 17; 15: 31.
25. Copes WS, Champion HR, Sacco WJ, et al. The injury severity score revisited. *J Trauma [Internet]* 1988; 28: 69–77. <https://doi.org/10.1097/00005373-198801000-00010>
26. Williamson OD, Gabbe BJ, Sutherland AM, et al. Group on behalf of the VOTORP. Does recall of preinjury disability change over time? *Inj Prev* 2013 Aug 1; 19: 238–243.
27. Department of Health and Aged Care. *Measuring remoteness: accessibility/remoteness index of Australia (ARIA)/... prepared by Information and Research Branch, Department of Health and Aged Care, and the National Key Centre for Social Applications of Geographical Information Systems (GISCA) at the University of Adelaide*. Rev. ed. Australia: Dept. of Health and Aged Care, 2001. (Occasional papers (Australia. Dept. of Health and Aged Care). New series ; no. 14).
28. Australian Bureau of Statistics. *Main Features - IRSAD [Internet]*. Australia: c=AU; o=Commonwealth of Australia; ou=Australian Bureau of Statistics, 2018. Available from: <https://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/2033.0.55.001~2016~Main%20Features~IRSAD~20>.
29. TAC. TAC. TAC; [cited 2021 Jun 26]. Who can make a TAC claim? Available from: <https://www.tac.vic.gov.au/what-to-do-after-an-accident/who-can-claim-with-the-tac>.
30. WorkSafe Victoria. WorkSafe Victoria - Home - WorkSafe [Internet]. [cited 2021 Jul 16]. Available from: <https://www.worksafe.vic.gov.au>.
31. EuroQol G. Euroqol—a new facility for the measurement of health-related quality of life. *Health Policy (Amsterdam, Netherlands)* 1990; 16: 99.
32. Cameron AC and Miller DL. Robust inference with clustered data [Internet]. Working Paper; 2010 [cited 2021 Sep 4]. Report No.: 10–7. Available from: <https://www.econstor.eu/handle/10419/58373>.
33. VanderWeele TJ, Jackson JW and Li S. Causal inference and longitudinal data: a case study of religion and mental health. *Soc Psychiatry Psychiatr Epidemiol* 2016 Nov 1; 51: 1457–1466.
34. Cameron CM, Purdie DM, Kliewer EV, et al. Long-term mortality following trauma: 10-year follow-up in a population-based sample of injured adults. *J Trauma Acute Care Surg* 2005; 59: 639–646.
35. Forsén L, Sogaard AJ, Meyer HE, et al. Survival after hip fracture: short- and long-term excess mortality according to age and gender. *Osteoporos Int* 1999; 10: 73–78.
36. Harrell FE Jr. *Regression modeling strategies: with applications to linear models, logistic and ordinal regression, and survival analysis*. USA: Springer, 2015.
37. Kleinbaum DG and Klein M. Extension of the Cox proportional hazards model for time-dependent variables. In: Kleinbaum DG and Klein M (eds) *Survival analysis: a self-learning text [internet]*. New York, NY: Springer, 2012, pp.241–288. https://doi.org/10.1007/978-1-4419-6646-9_6.
38. Harrell FE. Cox proportional hazards regression model. In: Harrell Jr Frank E (ed) *Regression modeling strategies: with applications to linear models, logistic and ordinal regression, and survival analysis [internet]*. Cham: Springer International Publishing, 2015, pp.475–519. https://doi.org/10.1007/978-3-319-19425-7_20
39. Rulli E, Ghilotti F, Biagioli E, et al. Assessment of proportional hazard assumption in aggregate data: a systematic review on statistical methodology in clinical trials using time-to-event endpoint. *Br J Cancer* 2018 Dec; 119: 1456–1463.
40. Garrett J. Graphical assessment of the Cox model proportional assumption. *Stata Tech Bull [Internet]* 1997; 6. Available from: <https://ideas.repec.org/a/tsj/stbull/y1997v6i35gr23.html>.
41. Davie G, Samaranyaka A and Derrett S. The role of pre-existing comorbidity on the rate of recovery following injury: a longitudinal cohort study. *PLoS ONE* 2018; 13: e0193019.

42. Ensrud KE, Ewing SK, Taylor BC, et al. Comparison of 2 frailty indexes for prediction of falls, disability, fractures, and death in older women. *Arch Int Med* 2008 Feb 25; 168: 382–389.
43. Heathcote K, Wulschleger M and Sun J. The effectiveness of multi-dimensional resilience rehabilitation programs after traumatic physical injuries: a systematic review and meta-analysis. *Disabil Rehabil* 2019 Dec; 41: 2865–2880.
44. Lyons RA, Finch CF, McClure R, et al. The injury list of all deficits (LOAD) framework – conceptualising the full range of deficits and adverse outcomes following injury and violence. *Int J Inj Control Saf Promot* 2010 Sep 1; 17: 145–159.
45. Juenger J, Schellberg D, Kraemer S, et al. Health related quality of life in patients with congestive heart failure: comparison with other chronic diseases and relation to functional variables. *Heart* 2002; 87: 235–241.
46. Banierink H, Reininga IHF, Heineman E, et al. Long-term physical functioning and quality of life after pelvic ring injuries. *Arch Orthop Trauma Surg* 2019; 139: 1225–1233.
47. Turner J and Kelly B. Emotional dimensions of chronic disease. *West J Med* 2000 Feb; 172: 124–128.
48. Chang W, Lv H, Feng C, et al. Preventable risk factors of mortality after hip fracture surgery: systematic review and meta-analysis. *Int J Surg* 2018 Apr; 52: 320–328.
49. Chatterton BD, Moores TS, Ahmad S, et al. Cause of death and factors associated with early in-hospital mortality after hip fracture. *Bone Joint J* 2015 Feb; 97-B: 246–251.
50. Sobrino J and Shafi S. Timing and causes of death after injuries. *Proc (Bayl Univ Med Cent)* 2013 Apr; 26: 120–123.
51. Gelaw AY, Gabbe BJ, Simpson PM, et al. Pre-injury health status of major trauma patients with orthopaedic injuries. *Injury* 2020 Feb; 51: 243–251.
52. Gelaw AY, Gabbe BJ and Ekegren CL. Chronic physical health conditions after injury: a comparison of prevalence and risk in people with orthopedic major trauma and other types of injury. *Arch Phys Med Rehabil* 2022 Sep; 103: 1738–1748.
53. Ekegren CL, Beck B, Climie RE, et al. Physical activity and sedentary behavior subsequent to serious orthopedic injury: a systematic review. *Arch Phys Med Rehabil* 2018 Jan 1; 99: 164–177.e6.