

Recovery trajectories for long-term health-related quality of life following a road traffic crash
injury: Results from the UQ SuPPORT study

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Abstract

Background:

Diminished physical and mental health-related quality of life (HRQoL) is a common consequence of road traffic crash (RTC) injury. This study aimed to (a) determine the probable recovery trajectories in physical and mental HRQoL; (b) examine the impact of posttraumatic stress disorder (PTSD) on HRQoL scores within these trajectory groups; and (c) examine the influence of predictor covariates on trajectory group membership.

Methods:

336 (63% female, $M_{\text{age}} = 44.72$; $SD = 14.77$) injured RTC survivors completed the SF-36v2 at approximately 6, 12, and 24 months after sustaining a RTC injury. Participants also completed telephone interviews to assess prior history of psychological disorder and current PTSD at each wave.

Results:

Three trajectories were identified for SF-36v2 Physical Component Score (PCS): "gradual recovery" (27.3%); "low but improving" (54.7%); and "severe and chronic" (17.9%). Four trajectories were defined for SF36v2 Mental Component Score (MCS): "unaffected" (19.1%); "severe but improving" (24.1%); "severe and declining" (17.3%); and "low but improving" (39.5%). A PTSD diagnosis significantly reduced SF36v2 component scores only in trajectories associated with poorer outcome. Age was predictive of trajectory group membership for PCS, whereas injury severity was predictive of trajectory group membership for MCS.

Limitations:

Use of a compensation seeking sample affects generalizability to the general RTC population.

Conclusions:

This study identified a concerning subgroup of individuals who have chronic and/or declining physical and mental HRQoL that can be impacted by a diagnosis of PTSD. The development of interventions with a special focus on associated psychological injury is needed to improve the HRQoL of at-risk individuals following RTC injury.

Keywords: quality of life; road traffic crash; posttraumatic stress disorder

Each year, over 50 million people worldwide sustain a non-fatal injury in a road traffic crash (RTC) (World Health Organization, 2013). Even in first world countries, non-fatal RTC injuries are high: The United States records more than 2.3 million people affected annually (Economic Commission for Europe, 1995). These non-fatal RTCs represent substantial personal, social, and economic public health burdens (Connelly & Supangan, 2006; Gopinath et al., 2015). The majority of research on the consequences of RTC-related injuries has focussed on participants with severe injuries. However, it is increasingly being recognised that even minor injuries, which comprise the majority of injuries sustained in RTCs, can have ongoing consequences for those involved in an RTC (Mayou & Bryant, 2001). These chronic consequences can include functional difficulties, delayed return to work, and reduced health-related quality of life (HRqoL), which may vary depending on a range of premorbid, injury-related, and post-injury factors (Cassidy et al., 2000; Fitzharris, Bowman, & Ludlow, 2010; Fort et al., 2011; Kenardy, Heron-Delaney, Warren, & Brown, 2015a, 2015b; Mayou & Bryant, 2001; McLean et al., 2014; Read et al., 2004).

A commonly cited consequence of RTC-related injury is diminished HRQoL (Alghnam, Palta, Remington, Mullahy, & Durkin, 2014). The measurement of HRQoL following injury is important to assess the full burden of RTC-related disability, rather than the measurement of physical health status alone (Moergeli, Wittmann, & Schnyder, 2012).

Previously, we have found persistently below average HRQoL, as measured by the SF-36, over a 24-month period in a sample of individuals with predominantly minor physical injuries (Kenardy et al., 2015b). Our study suggested that HRQoL can be affected long after injury onset, even when those injuries are considered minor. Understanding the patterns of response following RTC-related minor injury would be of even more benefit, as they may identify distinct groups that would benefit from early targeted interventions following RTC-related injury.

Psychological distress follows physical injury for a significant minority of people, regardless of injury severity (Mayou & Bryant, 2002). A systematic review of predictors of posttraumatic stress disorder (PTSD) found that injury severity had no utility in predicting PTSD in adult RTC survivors (Heron-Delaney et al. 2013), which suggests that the risk of developing PTSD post-RTC is not reduced for those with minor injuries (Heron-Delaney, Kenardy, Charlton, & Matsuoka, 2013). A range of psychological disorders can develop following an RTC-related injury, including depression, anxiety, and PTSD. PTSD is characterized by a constellation of re-experiencing, avoidance, and hyperarousal symptoms that follow a potentially traumatic event (note, this study followed the DSM-IV-TR diagnostic criteria of PTSD, which are slightly modified in the DSM-5) (American Psychiatric Association, 1994, 2013). Given the requirement of a potentially traumatic event in its diagnosis, relative to other disorders, PTSD can be most easily be attributed to the RTC, and not to historical sequelae. Unfortunately, the research on the prevalence of PTSD after RTC-related injury is inconsistent due to differences in studies' sample size, assessment timing, and study site, but it is estimated to be in the range of 6-45% (Heron-Delaney et al., 2013). However, the upper limit in the range of this estimate exceeds the prevalence typical for PTSD developing after trauma exposure. Following an RTC, research shows that individuals diagnosed with PTSD have poorer recovery (in terms of physical and mental HRQoL) than individuals without PTSD (Kenardy et al., 2015b). Further, PTSD appears to predict poorer QoL following an RTC (Hours et al., 2014). As such, an examination of the influence of PTSD on HRQoL trajectories following RTC-related injury is warranted.

Previous research in RTC and general injury populations suggest a multiplicity of preinjury, injury-related, and post-injury factors contribute to an individual's HRQoL outcomes following injury. For example, preinjury history of psychological disorders has been found to influence post-injury outcomes, including HRQoL (Hours et al., 2014; Khati et

al., 2013). It has also been found that females report poorer QoL outcomes than males following major trauma (Holbrook & Hoyt, 2004), traumatic brain injury (Scholten et al., 2015), and RTC-related injury (Hours et al., 2014; Khati et al., 2013; Littleton et al., 2011). However, findings on other demographic outcomes and injury severity are mixed. Even though age is routinely included as a covariate in population-based research in QoL (e.g., Alghnam et al., 2014), the research does not always find a significant association between age and HRQoL. For instance, Moergeli et al. (2012) found no such relation in adults following accidental injury, whereas other studies have found that older age was associated with lower HRQoL following road traffic injury (Hours et al., 2014; Littleton et al., 2011; Nhac-Vu et al., 2014). The strength of the relationship between injury severity and HRQoL is also mixed. Some studies have found a significant association between more severe injuries and poorer QoL (Khati et al., 2013), while another study only found a significant association between higher injury severity and decreased QoL via an indirect effect of posttraumatic stress (Moergeli et al., 2012). In contrast, Kenardy et al. (2015) have previously found that lower injury severity was associated with poorer mental HRQoL in those with predominately minor injury following an RTC (Kenardy et al., 2015b), although given that the relationship was more pronounced when PTSD was diagnosed, this finding may reflect the relationship between minor injuries such as whiplash and mental health problems that has been previously established in the literature (Sterling, Kenardy, Jull, & Vicenzino, 2003). Collectively, this body of literature indicates that there are a number of factors that are important to consider when examining how people report HRQoL following injury. Understanding how HRQoL relates to factors such as preinjury history of psychological disorders, demographics, and injury severity, would be important to help target interventions for at-risk individuals in order to improve outcome following RTC-related injury.

In the current study, we used a latent group-based trajectory framework. Trajectory modeling provides a novel approach to understanding patterns of HRQoL responses over time. A semiparametric analytic technique developed by Nagin (1999), known as latent group-based trajectory analysis, can be used to identify underlying latent trajectories that depict different longitudinal patterns of responding. Maximum likelihood methods are used to model underlying latent trajectories and their shape. These models can be used to determine whether particular factors, such as age or injury severity, are more likely to relate to one particular trajectory. In this way, potential factors that influence recovery trajectories could be used in the early identification of people at risk of poor recovery. This approach has been used previously to describe the longitudinal course of physical and mental HRQoL following mild traumatic brain injury (Chiang, Guo, Huang, Lee, & Fan, 2016).

The examination of HRQoL trajectories following RTC-related injury will help characterize the scope and course of perceived QoL, potentially identifying opportunities for interventions to maximize RTC survivors' long term outcomes. Overall, the aim of this study was to identify the longitudinal trajectories of physical and mental HRQoL following predominantly minor injuries sustained in an RTC. It was hypothesized that multiple distinct trajectories would be identified within the data. The second aim was to examine the influence of PTSD on HRQoL scores within each trajectory. It was hypothesized that the presence of PTSD would worsen both PCS and MCS HRQoL scores for each trajectory. The third aim was to investigate a range of covariates as predictors of trajectory group membership. Specifically, it was hypothesized that non-time-varying covariates of age, sex, injury severity, history of psychological disorder and road user type would influence trajectory group membership.

Method

Participants and Procedure

This analysis forms part of The University of Queensland Study of Physical and Psychological Outcomes for claimants with predominantly minor injuries following an RTC (UQ SuPPORT). The UQ SuPPORT study protocol is available elsewhere (Kenardy, Heron-Delaney, Bellamy, Sterling, & Connelly, 2014). In brief, participants were recruited from records held by the Motor Accident Insurance Commission (MAIC) across 18 months (April, 2009 – September, 2010), with survey and telephone interview data collected at approximately 6, 12, and 24 months post-RTC from these participants. Participants were claimants within the Queensland common law "fault-based" Compulsory Third Party (CTP) motor vehicle insurance scheme. Eligibility criteria were: (1) Driver/passenger of a car/motorbike, cyclist, or pedestrian involved in an RTC; (2) sustained predominantly minor physical injury defined as a maximum Abbreviated Injury Scale (AIS) score of ≤ 3 ; (3) aged 18 years or older; (4) sufficient English speaking ability; (5) RTC occurred within three months prior to claim notification; and (6) Australian resident. Exclusion criteria were: (a) cognitive impairment (subjectively assessed by trained interviewers based on the participants' capacity to answer initial telephone interview questions), and (b) a severe physical condition preventing the telephone interview or survey from being completed by the participant (e.g., stroke, paralysis). By using these inclusion and exclusion criteria, only people with non-catastrophic injuries (i.e., only minor, moderate, or serious injuries (not severe or critical), as defined by an AIS score ≤ 3), participated in the study.

The recruitment process was governed by legislation, and involved MAIC inviting all eligible participants to take part in the study via a letter of invitation. Claimants could then opt-in by returning their signed consent in a reply-paid envelope. A total of 3,146 eligible claimants were sent the letter of invitation, and 382 (12%) of these consented to participate.

The UQ SuPPORT study received ethical approval (Approval No.: 2009000035) from the Medical Research Ethics Committee at The University of Queensland, Brisbane, Australia.

Measures

Participants were assessed via Computer Assisted Telephone Interview (CATI) and paper questionnaires on a range of physical and psychosocial constructs at approximately 6 (Wave 1), 12 (Wave 2), and 24 months (Wave 3) post-RTC. Each measure (listed below) was collected at each wave, with the exception of demographics (Wave 1 only) and questions regarding the participant's mental health history (Wave 1 and Wave 2 only). See Kenardy et al. (2014) for further information on each measure and the study procedure.

Interview measures.

Posttraumatic Stress Disorder.

PTSD was assessed using the Composite International Diagnostic Interview module for PTSD (CIDI-PTSD; Peters et al., 1996), which is based on the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) criteria (American Psychiatric Association, 1994). PTSD diagnosis were dichotomized as 0 (no diagnosis) or 1 (diagnosis). The CIDI-PTSD has demonstrated good psychometric properties, including strong test-retest reliability and high agreement with clinical diagnosis (Andrews & Peters, 1998; Breslau, Kessler, & Peterson, 1998).

Prior history of psychological disorder.

History was assessed by asking participants whether they had ever seen a mental health professional and subsequently been given a diagnosis. Participants who had previously been diagnosed with a disorder were classified as having history of psychological disorder (coded 1), with the remainder classified as having no history (coded 0).

Questionnaire measures.

HRQoL.

HRQoL was assessed using the SF-36v2 (Ware, Kosinski, & Dewey, 2000). The SF-36 is a commonly used measure of HRQoL having strong psychometric properties (Ware, Snow, Kosinski, & Gandek, 1993), such that its use facilitates comparability between studies and populations. The SF-36 scale includes both physical and mental health component scores (PCS and MCS, respectively). These component scores reflect the multidimensional nature of HRQoL. The measure uses 36 questions to summarise the respondent's health in the past 4 weeks, and the respondent chooses one option (from among three to five options) on each question. The 36 questions make up eight sub-scales or domains (Physical Functioning, Role Limitation because of Physical Functioning, Bodily Pain, General Perception of Health, Vitality, Social Functioning, Role Limitation because of Emotional Functioning, and Mental Health). The eight scales are norm-weighted to form two constructs: the Physical Component Score (PCS) and Mental Component Score (MCS). PCS represents a person's physical HRQoL, and the MCS is the mental HRQoL. SF-36v2 items and scales are standardized to a 0 – 100 point scale, with higher scores indicating better QoL.

Demographics and injury factors.

Gender, age, and type of injured road user information were collected. Injured road users can be grouped in various ways, including by the amount of protection they have in traffic. As such, injured road users were defined as vulnerable (pedestrian, cyclist) and non-vulnerable (driver, passenger). MAIC provided AIS 2005 data for all consenting participants in April 2013 (2.5-4 years post-RTC), with this time lag ensuring all injuries had been recorded. The Injury Severity Score (ISS; Baker, O'Neill, Haddon, & Long, 1974), which relates to the severity of the combination of a person's physical injuries, was then calculated from the AIS data. Each participant's ISS was then categorized into two groups, similar to the groups reported used by Copes et al. (1988): ISS 1-3 and ISS 4+. According to the ISS classification system, an ISS of 1-3 generally includes superficial injuries, such as abrasions and cervical

spine strains (i.e., "whiplash"), while an ISS of 4+ often includes non-life-threatening injuries, such as simple upper or lower extremity long bone fractures, broken ribs, or a combination of superficial and other minor injuries.

Statistical Analyses

Missing responses for SF-36v2 items were estimated using mean substitution, providing the participant had completed at least 80% of the questionnaire, in line with the SF-36v2 manual instructions (Ware et al., 2000).

Trajectory analysis

A semi-parametric latent group-based trajectory analytical technique developed and designed by Nagin (1999), which does not require participant data to have complete outcome records across time, was used to investigate the possibility of different post-injury, longitudinal developmental trajectories for two outcomes: (a) physical HRQoL (as measured by PCS), and (b) mental HRQoL (as measured by MCS). The method uses maximum likelihood to model the probability of a specified number of underlying latent trajectories and their shape. Several such models are compared and an optimal model is selected based on several criteria. Initially, highest-order polynomial trajectories are fitted for 2, 3, 4, etc. groups, which are compared using the methods described in the article by Kass and Raftery (1995) in order to ascertain the optimal number of groups most likely present in the data. Once the optimal number of groups is established, models with various group-specific, simplified polynomial profiles, where non-significant higher-order polynomial terms are dropped, are sequentially compared with the saturated highest-order polynomial model. The final model chosen is the most parsimonious model, which retains statistically significant polynomial terms, but which is not statistically significantly different from the saturated model (where deviation from the saturated model is calculated using changes in twice the log-likelihood). Statistically significant concurrent, longitudinal covariates are included from

the outset in the above process, as they are integral to the trajectory outcome. In the current analysis, the presence of a PTSD diagnosis was the only longitudinal covariate added to the model, and this procedure allowed examination of the impact of a PTSD diagnosis on trajectory groups. Once the final trajectory model is established, pre-existing, possibly associated factors (namely demographic and other baseline [non time-varying] covariates) are introduced singly into the analysis in order to examine their impact on the probabilities of group membership, and they are tested using the 2-tailed standard normal distribution based on the estimated parameter and its standard error. In the current analysis, the following non-time varying factors were considered: age, gender, ISS (1-3 vs. 4+), psychiatric history (yes vs. no) and type of injured road user (driver/passenger vs. pedestrian/cyclist). The current analysis included 336 participants who had outcome data (PCS and MCS) for at least one time point, and who had complete data on the non-time varying factors analysed. Trajectory groups for both MCS and PCS were plotted, along with the mean and standard deviation (SD) from the Australian normative population (Hawthorne, Osborne, Taylor, & Sansoni, 2007). The statistical significance of the impact of a PTSD diagnosis on a trajectory group was also indicated on each figure. Data were analysed using SAS[®] software and Microsoft Excel. Statistical significance was evaluated at $\alpha = .01$ to avoid type 1 error.

Results

Sample Characteristics

Table 1 presents the descriptive statistics for the 336 participants included in the analysis. The average age of participants was 48.8 years (SD = 14.9) and a majority of the sample (62.5%) were female. The sample consisted of participants with very minor physical injuries (ISS 1-3; 64.6%). The number of participants who completed the SF36v2 questionnaire (PCS and MCS) at each time point, and the number who completed the CIDI-PTSD module of the telephone interview at each time point, are also noted in Table 1.

Overall, of the 271 participants completing the CIDI-PTSD at all three time points, 40 (14.8%) met the diagnostic criteria for PTSD at all time points (Table 1).

--Insert Table 1 about here--

Trajectories for Physical HRQoL (PCS)

The optimal number of underlying latent trajectories indicated in analysis for PCS was three (Figure 1). There was a "gradual recovery" trajectory, with an estimated percentage probability of 27.3%, for which the trajectory starts slightly below the Australian norm but after 12 months, displays estimated means close to the Australian norm (Figure 1). A second "low but improving" trajectory, with an initial starting point approximately 1 SD below the Australian norm, with an estimated 54.7% percentage probability. The third trajectory pattern was estimated to represent "severe and chronic" physical HRQoL with a percentage probability of 17.9%, and for which PCS remains approximately 2 SD below the Australian norm between 6 and 24 months post-RTC. Having a diagnosis of PTSD negatively impacted the "severe and chronic" and "low but improving" trajectories, reducing estimated average scores by approximately three points on the PCS ($p < .01$) at each time point.

--insert Figure 1 about here --

Table 2 shows the odds ratios of the predictors of PCS trajectory membership. Gender, type of injured road user, ISS, and psychiatric history did not statistically predict the probability of a PCS trajectory. Age, however, was predictive of the probability of PCS trajectory outcome ($p < .01$), where the odds of having a "severe and chronic" PCS trajectory in contrast to "gradual recovery" increased with increasing age ($p < .001$). As an example, a 60 year-old from this population, compared with a 30 year-old, was estimated to be 4.4 (95%

CI: 1.9-10.0) times more likely to have a "severe and chronic" trajectory than a "gradual recovery" trajectory.

-- Insert table 2 about here --

Trajectories for Mental HRQoL (MCS)

There were 336 participants who had a MCS score for at least one Wave. When the presence of a PTSD diagnosis was included in the model, analyses indicated that there were four probable, distinct MCS trajectory patterns, as shown in Figure 2. There was an estimated probability of 19.1% for a trajectory that remained close to the Australian norm at each Wave, and this trajectory was described as having an "unaffected" mental HRQoL. An MCS trajectory of "severe but improving" was estimated, with a probability of 24.1%. This trajectory was estimated to be 3 SD below the Australian norm at 6 months post-RTC, but showed an estimated 50% improvement by 24 months. Conversely, the probability of having a "severe and declining" MCS trajectory was estimated as 17.3%, starting at 1.5 SD below the norm at 6 months and being nearly 3 SD below the norm at 24 months post-RTC. Having a diagnosis of PTSD at all three time points exacerbated this decline even more, reducing the MCS trajectory by a further 1 SD ($p < .001$). The final trajectory demonstrated a less severe and "low but improving" MCS trajectory, with 39.5% probability. However, having a PTSD diagnosis at each wave significantly lowered this trajectory ($p < .001$), such that the outcome at 6 months post-RTC was estimated to be comparable to that of the "severe and declining" trajectory. Similarly, the estimated average MCS score was similar to the "severe but improving" trajectory at 24 months post-RTC.

-- Insert Figure 2 about here --

Table 3 shows the predictors of MCS trajectory membership. Age, gender, type of injured road user, and psychiatric history were not significantly linked to the probability of having a particular MCS trajectory. However, ISS was associated with the probability of having particular MCS trajectories ($p < .01$) in that the odds of a "low but improving" MCS trajectory was 4.24 more likely than a "severe but improving" trajectory (95% CI: 1.69 - 10.60, $p < 0.01$) for an ISS of 4+ when compared to an ISS of 1-3. The probability of "low but improving" categorization for an ISS of 4+ was 0.46 (95% CI: 0.18 - 0.76) compared with 0.10 (95% CI: 0.06 - 0.13) for an ISS of 1-3.

--Insert Table 3 about here --

Discussion

To our knowledge, this study is the first to define the longitudinal trajectories of physical and mental HRQoL following RTC-related injury. The key finding of this study was that physical and mental HRQoL scores are characterized by heterogeneous trajectories. This finding is consistent with the hypothesis that there would be multiple distinct HRQoL trajectories in this sample. The number and shape of the longitudinal trajectories of HRQoL were different depending on the component score (i.e., physical vs. mental). Specifically, three trajectories best fit the physical HRQoL scores whereas four trajectories best fit the mental HRQoL scores.

The MCS trajectories reveal four variable pathways of mental HRQoL following predominately minor injury sustained in an RTC. The number and type of MCS trajectories identified in this study are different than in the study by Chiang and colleagues (2016), who identified two MCS SF-36 trajectories: whereby a minority of patients (11%) were categorized as "persistently under average QoL" and the majority (89%) were categorized as "persistently fine QoL". That said, the three PCS SF-36 trajectories identified in the Chiang

and colleagues study (i.e., “under average QoL after TBI and worsening”, [14%]; “under average QoL after TBI and recovering” [35%], and “fine QoL after TBI and slightly worsening” [51%]) were more consistent with the PCS trajectories found in this study. The differences in MCS trajectories in the studies by Chiang et al. (2106) and our study may be related to sample differences. This study included participants seeking compensation for a broad range of non-catastrophic injuries, whereas Chiang and colleagues’ study was comprised of patients with mild TBI (compensation seeking status unspecified).

The emergence of the “severe and declining” MCS and “severe and chronic” PCS trajectories represent concerning patterns of change in HRQoL over time. The deterioration of HRQoL of the “severe and declining” MCS trajectory between 12 and 24 months post-injury suggest a need for early interventions that focus on psychological injury. The early timing of such interventions may be crucial given the lower than the population norm HRQoL reported at 6 months post-injury and then the steep deterioration that follows the 12 month post-injury assessment for the “severe and declining” MCS trajectory.

This study also examined the influence of PTSD on the predicted trajectories. The prevalence of PTSD at the 6-, 12-, and 24-month assessment was high (24%, 22%, and 25%, respectively), and within the range reported in a recent systematic review of predictors of PTSD in adult road traffic crash survivors (6% - 45%; Heron-Delaney et al., 2013). The lack of remission in PTSD prevalence over time, however, is concerning, in that one would usually expect a decline in PTSD rates as time from accident increases. Subsequent traumatic events occurring post-RTC were not captured in this study, and may be one factor contributing to prevalence stability. Notwithstanding the above, the inclusion of PTSD diagnosis as a longitudinal covariate in the models reported in this study negatively affected the majority of trajectories. The presence of a persistent PTSD diagnosis negatively impacted the “low but improving” and “severe and chronic” PCS trajectories, and the “low but

improving” and ”severe and declining” MCS trajectories, whereas the remaining trajectories showed no significant effect of a PTSD diagnosis on predicted QoL scores. Of note, the predicted MCS score for the ”severe and declining” trajectory was reduced by 1 SD when PTSD was present across each assessment point.

The variables that predicted trajectory group membership varied. Older age predicted the probability of group membership in the ”severe and chronic” PCS trajectory. This finding is consistent with other research that has found an association between older age and poorer QoL outcomes (Hours et al., 2014; Littleton et al., 2011; Nhac-Vu et al., 2014). This finding is also consistent with Chiang and colleagues (2016), who found that their ”under average and worsening” PCS SF-36 trajectory was associated with older age and unemployment at one month post-injury

Predictors of trajectories differed for the MCS compared to the PCS. Injury severity predicted MCS trajectories. Counterintuitively, more severe injuries ($ISS \geq 4$) were associated with greater probability of belonging to the ”low but improving” trajectory than the ”severe but improving” trajectory. This finding may be explained by our predominantly minor injury sample, where most of the sample had whiplash related injuries. Previous research has found that whiplash is associated with mental health problems, particularly PTSD (Sterling et al., 2003). Future research could examine the influence of specific injury types (e.g., whiplash) on QoL outcomes, as well as understanding the influence of time-varying covariates, such as pain.

Strengths and Limitations

This study has a number of limitations regarding the participant population. First, the opt-in consent procedure via post is likely to have affected the low participation rate in this study. Although previous studies using similar recruitment methods have reported similar participation rates (Smith, Mackenzie-Ross, & Scragg, 2007), this low participation rate may

have reduced the generalizability of study findings. As detailed in the study protocol (Kenardy et al., 2014), participants who consented were found to be older (mean age = 49 yrs) than those who declined to participate (mean age = 40 yrs) and had higher injury severity (ISS of $\geq 4 = 35\%$) than those who declined to participate (ISS of $\geq 4 = 18\%$). These factors may affect generalizability, and future reported prevalence estimates and comparisons to the general road traffic crash population should be interpreted with caution. An alternative explanation for the low participation rates is that the target population (i.e., claimants with minor injury) may be less inclined to participate in research if they have already recovered from the injury or their claim has already been resolved. The selection criteria limited participants to claimants within a fault-based CTP scheme. Thus, the sample does not represent the entire RTC population and thus should be very cautiously applied to users of different CTP schemes and those individuals who are considered "at-fault". Related, although we did not screen for exaggeration/malingering in this sample, self-reported symptoms may be biased in samples seeking financial compensation. In addition, it is possible that a predictor of the identified PCS and MCS trajectories is pre-crash quality of life. However, recall of pre-crash health status once injured can be biased, and as such, this information could not be reliably collected and was not available for analysis.

Despite these limitations, this study also has considerable strengths. . First, it is one of the few moderately large studies to prospectively assess outcomes following RTC in a predominantly minor injury cohort. Second, we examined survivors of RTCs over three waves, spanning two years, which allowed determination of variable trauma-response trajectories.

Conclusion

This study highlighted the heterogeneous health-related physical and mental health QoL trajectories that can follow an RTC-related injury. Of concern, a sizable minority of

participants had trajectories of persistently "severe and chronic" physical HRQoL, "severe and declining" mental HRQoL, or both. The heterogeneous HRQoL trajectories found in this study suggest that individualized care management approaches may be of benefit. Further research is needed to inform the planning and timing of interventions that could facilitate the move of RTC survivors from a severe and chronic/declining trajectory to a more positive (e.g., improving or unaffected) trajectory. This study assists with the identification of groups of individuals who may benefit most from such interventions and the modifiable factors that could be targeted in future interventions.

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References

- Alghnam, S., Palta, M., Remington, P. L., Mullahy, J., & Durkin, M. S. (2014). The association between motor vehicle injuries and health-related quality of life: A longitudinal study of a population-based sample in the United States. *Quality of Life Research, 23*(1), 119-127.
- American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders (4th ed.)*. Washington, DC: American Psychiatric Association.
- American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders (DSM-5®)*. Washington, DC: American Psychiatric Association.
- Andrews, G., & Peters, L. (1998). The psychometric properties of the composite international diagnostic interview. *Social psychiatry and psychiatric epidemiology, 33*(2), 80-88.
- Baker, S. P., O'Neill, B., Haddon, W. J., & Long, W. B. (1974). The injury severity score: A method for describing patients with multiple injuries and evaluating emergency care. *The Journal of trauma, 14*(3), 187-196. Retrieved from http://journals.lww.com/jtrauma/Fulltext/1974/03000/The_Injury_Severity_Score__A_Method_for_Describing.1.aspx
- Breslau, N., Kessler, R., & Peterson, E. L. (1998). Post-traumatic stress disorder assessment with a structured interview: reliability and concordance with a standardized clinical interview. *International Journal of Methods in Psychiatric Research, 7*(3), 121-127.
- Cassidy, J. D., Carroll, L. J., Cote, P., Lemstra, M., Berglund, A., & Nygren, Å. (2000). Effect of eliminating compensation for pain and suffering on the outcome of insurance claims for whiplash injury. *New England Journal of Medicine, 342*(16), 1179-1186.

- Chiang, C.-C., Guo, S.-E., Huang, K.-C., Lee, B.-O., & Fan, J.-Y. (2016). Trajectories and associated factors of quality of life, global outcome, and post-concussion symptoms in the first year following mild traumatic brain injury. *Quality of Life Research*, 25(8), 2009-2019. doi:10.1007/s11136-015-1215-0
- Connelly, L., & Supangan, R. (2006). The economic costs of road traffic crashes: Australia, states and territories. *Accident Analysis & Prevention*, 38(6), 1087-1093.
- Copes, W. S., Champion, H. R., Sacco, W. J., Lawnick, M. M., Keast, S. L., & Bain, L. W. (1988). The injury severity score revisited. *The Journal of trauma*, 28(1), 69-77. doi:10.1097/00005373-198801000-00010
- Economic Commission for Europe. (1995). *Statistics of road traffic accidents in Europe and North America*. New York, NY: United Nations.
- Fitzharris, M., Bowman, D., & Ludlow, K. (2010). Factors associated with return-to-work and health outcomes among survivors of road crashes in Victoria. *Australian and New Zealand journal of public health*, 34(2), 153-159.
- Fort, E., Bouffard, E., Charnay, P., Bernard, M., Boisson, D., Laumon, B., & Hours, M. (2011). Return to work following road accidents: Factors associated with late work resumption. *Journal of Rehabilitation medicine*, 43(4), 283-291.
- Gopinath, B., Jagnoor, J., Harris, I. A., Nicholas, M., Casey, P., Blyth, F., . . . Cameron, I. D. (2015). Prognostic indicators of social outcomes in persons who sustained an injury in a road traffic crash. *Injury*, 46(5), 909-917.
- Hawthorne, G., Osborne, R. H., Taylor, A., & Sansoni, J. (2007). The SF36 Version 2: critical analyses of population weights, scoring algorithms and population norms. *Quality of Life Research*, 16(4), 661-673.

- Heron-Delaney, M., Kenardy, J., Charlton, E., & Matsuoka, Y. (2013). A systematic review of predictors of posttraumatic stress disorder (PTSD) for adult road traffic crash survivors. *Injury, 44*(11), 1413-1422.
- Holbrook, T. L., & Hoyt, D. B. (2004). The impact of major trauma: Quality-of-life outcomes are worse in women than in men, independent of mechanism and injury severity. *Journal of Trauma and Acute Care Surgery, 56*(2), 284-290.
- Hours, M., Khati, I., Charnay, P., Chossegros, L., Tardy, H., Tournier, C., . . . Laumon, B. (2014). One year after mild injury: comparison of health status and quality of life between patients with whiplash versus other injuries. *The Journal of rheumatology, 41*(3), 528-538.
- Kass, R. E., & Raftery, A. E. (1995). Bayes factors. *Journal of the american statistical association, 90*(430), 773-795.
- Kenardy, J., Heron-Delaney, M., Bellamy, N., Sterling, M., & Connelly, L. (2014). The University of Queensland study of physical and psychological outcomes for claimants with minor and moderate injuries following a road traffic crash (UQ SuPPORT): design and methods. *Eur J Psychotraumatol, 5*, 22612. doi:10.3402/ejpt.v5.22612
- Kenardy, J., Heron-Delaney, M., Warren, J., & Brown, E. (2015a). Effect of mental health on long-term disability after a road traffic crash: Results from the UQ SuPPORT study. *Archives of physical medicine and rehabilitation, 96*(3), 410-417.
- Kenardy, J., Heron-Delaney, M., Warren, J., & Brown, E. (2015b). The effect of mental health on long-term health-related quality of life following a road traffic crash: Results from the UQ SuPPORT study. *Injury, 46*(5), 883-890.
- Khati, I., Hours, M., Charnay, P., Chossegros, L., Tardy, H., Nhac-Vu, H.-T., . . . Laumon, B. (2013). Quality of life one year after a road accident: Results from the adult ESPARR cohort. *Journal of trauma and acute care surgery, 74*(1), 301-311.

- Littleton, S., Cameron, I. D., Poustie, S., Hughes, D., Robinson, B., Neeman, T., & Smith, P. N. (2011). The association of compensation on longer term health status for people with musculoskeletal injuries following road traffic crashes: Emergency department inception cohort study. *Injury, 42*(9), 927-933.
- Mayou, R., & Bryant, B. (2001). Outcome in consecutive emergency department attenders following a road traffic accident. *The British Journal of Psychiatry, 179*(6), 528-534.
- Mayou, R., & Bryant, B. (2002). Outcome 3 years after a road traffic accident. *Psychological medicine, 32*(04), 671-675.
- McLean, S. A., Ulirsch, J. C., Slade, G. D., Soward, A. C., Swor, R. A., Peak, D. A., . . . Domeier, R. M. (2014). Incidence and predictors of neck and widespread pain after motor vehicle collision among US litigants and nonlitigants. *PAIN®, 155*(2), 309-321.
- Moergeli, H., Wittmann, L., & Schnyder, U. (2012). Quality of life after traumatic injury: A latent trajectory modeling approach. *Psychotherapy and psychosomatics, 81*(5), 305-311.
- Nagin, D. S. (1999). Analyzing developmental trajectories: A semiparametric, group-based approach. *Psychological Methods, 4*(2), 139-157. doi:10.1037/1082-989X.4.2.139
- Nhac-Vu, H.-T., Hours, M., Chossegras, L., Charnay, P., Tardy, H., Martin, J.-L., . . . Laumon, B. (2014). Prognosis of outcome in adult survivors of road accidents in France: One-year follow-Up in the ESPARR cohort. *Traffic injury prevention, 15*(2), 138-147.
- Peters, L., Andrews, G., Cottier, L. B., Chatterji, S., Janca, A., & Smeets, R. (1996). The Composite International Diagnostic Interview posttraumatic stress disorder module: Preliminary data. *International Journal of Methods in Psychiatric Research, 6*, 167-174.

- Read, K. M., Kufera, J. A., Dischinger, P. C., Kerns, T. J., Ho, S. M., Burgess, A. R., & Burch, C. A. (2004). Life-altering outcomes after lower extremity injury sustained in motor vehicle crashes. *Journal of Trauma and Acute Care Surgery*, *57*(4), 815-823.
- Scholten, A. C., Haagsma, J. A., Andriessen, T., Vos, P., Steyerberg, E., Van Beeck, E., & Polinder, S. (2015). Health-related quality of life after mild, moderate and severe traumatic brain injury: Patterns and predictors of suboptimal functioning during the first year after injury. *Injury*, *46*(4), 616-624.
- Smith, B., Mackenzie-Ross, S., & Scragg, P. (2007). Prevalence of poor psychological morbidity following a minor road traffic accident (RTA): The clinical implications of a prospective longitudinal study. *Counselling Psychology Quarterly*, *20*(2), 149-155.
- Sterling, M., Kenardy, J., Jull, G., & Vicenzino, B. (2003). The development of psychological changes following whiplash injury. *Pain*, *106*(3), 481-489.
- Ware, J. E., Kosinski, M., & Dewey, J. E. (2000). *How to Score Version 2 of the SF-36 Health Survey (Standard and Acute Forms)*. Lincoln: Quality Metric Inc.
- Ware, J. E., Snow, K., Kosinski, M., & Gandek, B. (1993). SF-36 health survey: Manual and interpretive guide. *Boston: The Health Institute, New England Medical Center*.
- World Health Organization. (2013). *WHO global status report on road safety 2013: Supporting a decade of action*: World Health Organization.

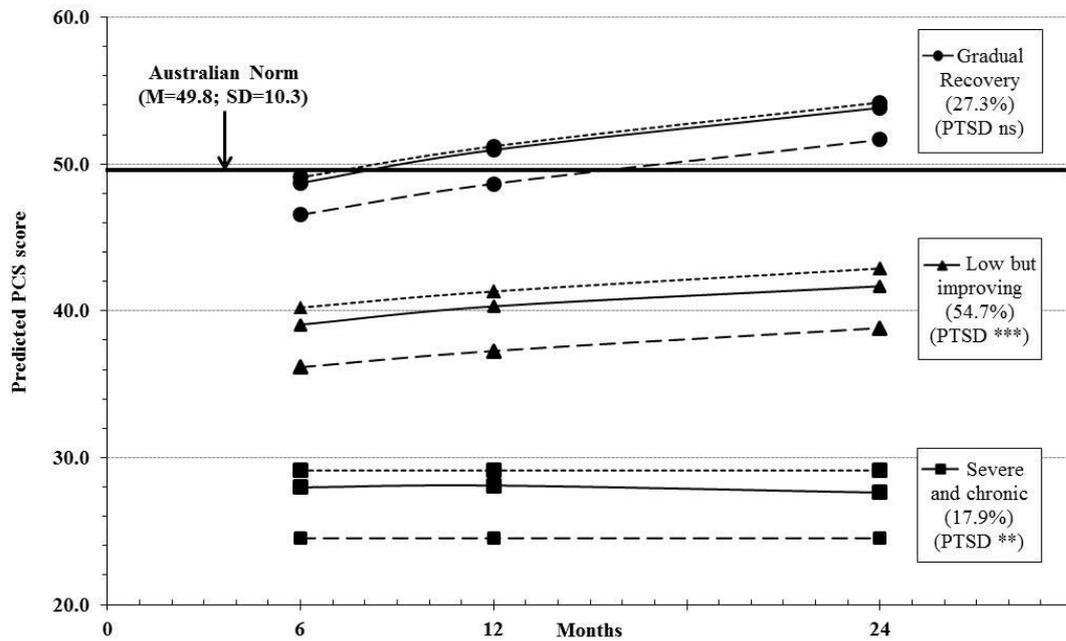


Figure 1. Estimated trajectories for physical HRQoL (Physical Component Summary score [PCS] n=336). _____ solid line for an average PTSD scenario; _____ dashed line below where PTSD diagnosis present; dotted line above where no PTSD present. ns = not significant ($p > .05$), * $p < .05$, ** $p < .01$, *** $p < .001$.

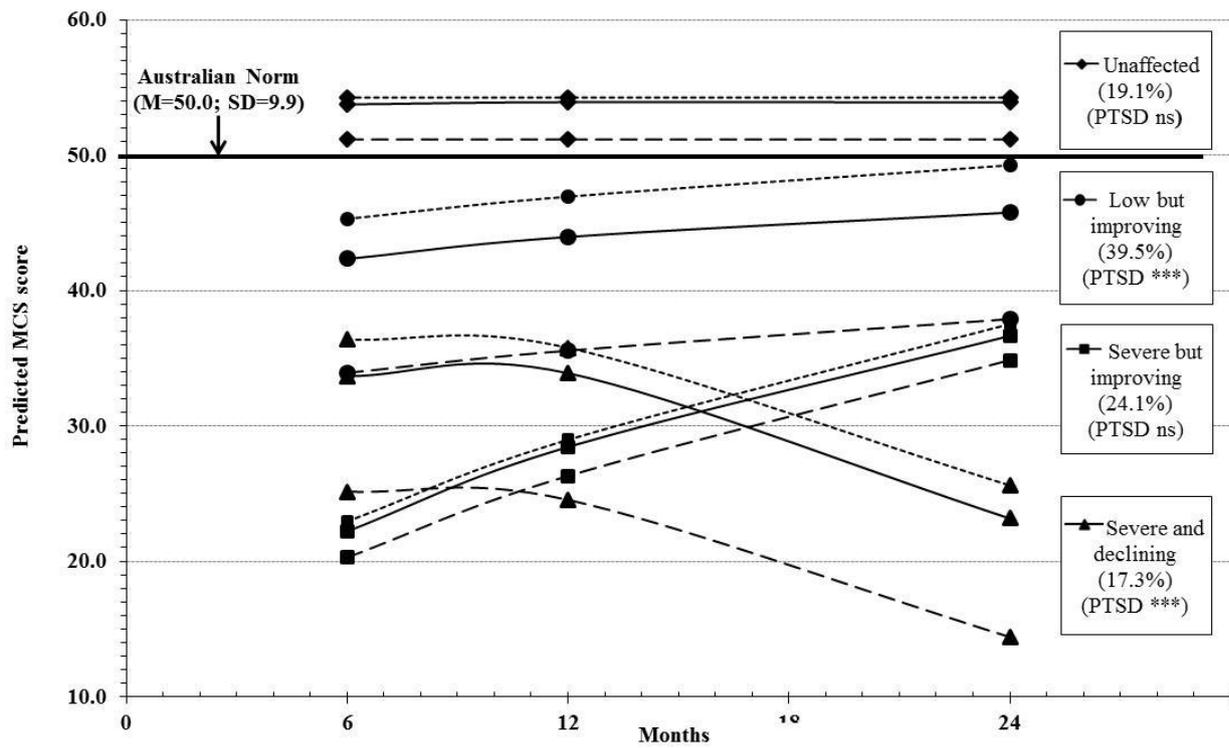


Figure 2. Estimated trajectories for mental HRQoL (Mental-health Component Summary score [MCS] $n=336$). ____ solid line for an average PTSD scenario; ___ dashed line below where PTSD diagnosis present; dotted line above where no PTSD present. ns = not significant ($p > .05$), * $p < .05$, ** $p < .01$, *** $p < .001$.

Table 1. Participant characteristics (N = 336¹)

	N (%)	Mean (SD)
<i>Age (years)</i>	336	48.8 (14.9)
<i>Gender</i>		
Female	210 (62.5%)	

Male	126 (37.5%)
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Road User Type

Driver/Passenger	268 (79.8%)
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Pedestrian/ Cyclist	68 (20.2%)
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Injury Severity (ISS)

ISS = 1-3	217 (64.6%)
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ISS = 4+	119 (35.4%)
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Psychiatric History

Yes - prior history	82 (24.4%)
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No prior history	254 (75.6%)
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Physical Component Summary (PCS) Score

Australian Norm ²		49.8 (10.3)
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6 months	296	39.7 (9.6)
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12 months	249	41.0 (9.7)
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24 months	248	43.0 (10.5)
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Mental Component Summary (MCS) Score

Australian Norm ²		50.0 (9.9)
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6 months	296	38.3 (14.1)
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12 months	249	40.6 (12.9)
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24 months	248	41.7 (13.1)
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PTSD Diagnosis

6 months [N=325]	78 (24.0%)
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12 months [N=299]	65 (21.7%)
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24 months [N=309]	78 (25.2%)
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At all time points [N=271]	40 (14.8%)
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Note. PTSD = Posttraumatic stress disorder; RTC = Road Traffic Crash;

¹ Percentages for Gender, Road User Type, ISS and Psychiatric history are based on the 336 participants who were included in the analysis. Percentages for PTSD diagnosis are based on the total number of participants who completed the CIDI-PTSD module within each time point (shown in square brackets).

²Hawthorne, G., Osborne, R. H., Taylor, A. & Sansoni, J. (2007). The SF36 Version 2: Critical analyses of population weights, scoring algorithms and population norms. *Quality of Life Research*, 16, 661-673.

Table 2. Predictors of Physical Health-Related Quality of Life (PCS) Trajectory Membership

	Low and Improving vs. Severe and Chronic OR [95% CI]	Gradual Recovery vs. Severe and Chronic OR [95% CI]
Age (years)	0.98 [0.95-1.00]	0.95***[0.93-0.98]
Gender		
<i>Female</i>	Ref.	Ref.
<i>Male</i>	1.15[0.50-2.67]	1.66[0.76-3.63]
Road User Vulnerability		
Driver/Passenger	Ref.	Ref.
Pedestrian/ Cyclist	2.50 [0.82-7.69]	3.50[1.13-10.78]
Injury Severity (ISS)		
Mild	Ref.	Ref.
Moderate/ Severe	0.66 [0.32-1.38]	0.83 [0.39-1.79]
Psychiatric History		
No	Ref.	Ref.
Yes	0.69[0.30-1.57]	0.57 [0.23-1.42]

Notes.

** $p < 0.01$,

*** $p < 0.001$.

Estimated membership for "Severe and Chronic" was 17.93%, "Low and Improving" was 54.74% and "Gradual Recovery" was 27.32%.

Table 3. Predictors of Mental Health-Related Quality of Life (MCS) Trajectory Membership

	Severe and Declining vs. Severe but Improving OR [95% CI]	Low but improving vs. Severe but Improving OR [95% CI]	Unaffected vs. Severe but Improving OR [95% CI]
Age (years)	1.02[0.98-1.06]	1.01 [0.98-1.04]	1.00 [0.97-1.03]
Gender			
<i>Female</i>	Ref.	Ref.	Ref.
<i>Male</i>	1.41 [0.47-4.21]	1.69 [0.72-3.98]	1.87 [0.72-4.88]
Road User Vulnerability			
Driver/Passenger	Ref.	Ref.	Ref.
Pedestrian/ Cyclist	0.00 [0.00-1.2517E]	0.77 [0.20-2.98]	1.51 [0.49-4.58]
Injury Severity (ISS)			
Mild	Ref.	Ref.	Ref.
Moderate/ Severe	1.28 [0.40-4.09]	4.24**[1.69-10.60]	2.70 [0.93-7.88]
Psychiatric History			
No	Ref.	Ref.	Ref.
Yes	3.70 [1.12-12.22]	1.38 [0.52-3.68]	0.48 [0.14-1.58]

Notes.

** $p < 0.01$.

Estimated group membership for "Severe and Improving" was 24.08%, "Severe and Declining" was 17.29%, "Gradually Improving" was 39.53% and "Unaffected" was 19.10%.

Ref. = reference group. OR = Odds ratio; CI = confidence interval.

Highlights

- Long term trajectories of mental and physical HR-QoL after road traffic injury are heterogeneous

- Prevalence of PTSD following non-catastrophic road traffic injuries is high
- PTSD negatively impacts HR-QoL trajectories characterized by poorer outcome.