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ORIGINAL ARTICLE

Motor vehicle collision-related injuries and deaths among Indigenous Peoples in Canada: Meta-analysis of geo-structural factors

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Abstract

Introduction: Indigenous Peoples are much more likely than non-Indigenous Peoples to be seriously injured or die in motor vehicle collisions (MVCs). This study updates and extends a previous systematic review, suggesting that future research ought to incorporate social–environmental factors.

Methods: We conducted a systematic review and meta-analysis of the published and grey literature on MVCs involving Indigenous Peoples in Canada between 2010 and 2020. We focussed on personal (e.g. driving an old vehicle) and community social–environmental–economic factors (e.g. prevalent low socioeconomic status).

Results: Eleven comparative cohorts that resulted in 23 at minimum, age-standardised, mortality or morbidity rate outcomes were included in our meta-analysis. Indigenous Peoples were twice as likely as non-Indigenous Peoples to be seriously injured (rate ratio [RRpooled] = 2.18) and more than 3 times as likely to die (RRpooled = 3.40) in MVCs. Such great risks to Indigenous Peoples do not seem to have diminished over the past generation. Furthermore, such risks were greater on-reserves and in smaller, rural and remote, places.

Conclusion: Such places may lack community resources, including fewer transportation and healthcare infrastructural investments, resulting in poorer road conditions in Indigenous communities and longer delays to trauma care. This seems to add further evidence of geo-structural violence (geographical and institutional violence) perpetrated against Indigenous Peoples in yet more structures (i.e. institutions) of Canadian society. Canada's system of highways and roadways and its remote health-care system represent legitimate policy targets in aiming to solve this public health problem.

Keywords: Canada, First Nations, hospitalisation, Indigenous, Inuit, Métis, morbidity, mortality, motor vehicle collision, reserve, rural

Résumé

Introduction : Les Autochtones ont beaucoup plus tendance que les non-Autochtones à subir des blessures graves ou à perdre la vie dans une collision de véhicules motorisés. La présente étude actualise et élargit une

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revue systématique antérieure qui avait conclu que la recherche future devait incorporer les facteurs socio-environnementaux.

Méthode : Nous avons réalisé une revue systématique et méta-analyse de la littérature publiée et parallèle sur les collisions de véhicules motorisés entre 2010 et 2020 chez les Autochtones du Canada. Nous nous sommes concentrés sur les facteurs socio-environnementaux personnels (p. ex. vieux véhicules) et communautaires (p. ex. prévalence de faible statut socio-économique).

Résultats : Onze cohortes comparatives ayant donné au minimum 23 paramètres d'évaluation du taux de mortalité ou de morbidité standardisés en fonction de l'âge ont été incluses dans notre méta-analyse. Les Autochtones avaient deux fois plus tendance que les non-Autochtones à subir des blessures graves (rapport des taux [$RT_{groupé}$] = 2,18) et présentaient un risque plus de 3 fois plus élevé de perdre la vie ($RT_{groupé}$ = 3,40) dans une collision de véhicules motorisés. La dernière génération d'Autochtones n'a pas vu cet énorme risque diminuer. En outre, le risque était supérieur dans les réserves et dans les agglomérations plus petites, plus rurales et plus éloignées.

Conclusion : Ces agglomérations sont parfois dépourvues de ressources communautaires, y compris d'un investissement important dans les infrastructures de transport et de santé, ce qui explique les routes en mauvaise condition et les délais prolongés pour recevoir des soins de traumatologie dans les communautés autochtones. Cela semble ajouter d'autres preuves de violence géostructurelle [violence géographique et institutionnelle] perpétrée contre les Autochtones dans encore plus de structures (les institutions) de la société canadienne. Le réseau canadien de routes et d'autoroutes, et son système de santé en région éloignée représentent des cibles légitimes pour les politiques qui visent à résoudre ces problèmes de santé publique.

Mots-clés : Canada, hospitalisation, Autochtone, Premières Nations, Inuit, Métis, morbidité, mortalité, collision de véhicules motorisés, réserve, rural

INTRODUCTION

As an Anishinaabe kwe, the genesis of my interest in the current study was serving as a research assistant for the project 'Motor Vehicle Collisions in First Nations, Métis, and Inuit Communities'.[1] However, my interest is not merely scholarly. I am a member of Walpole Island First Nation, Bkejwanong Territory, and during my tenure on the project, 2 members of our community died in a motor vehicle collision (MVC). I am also reminded of the fatal crash that occurred near Windsor, Ontario, on 3 September 1999, which took the lives of 8 people, including a Bkejwanong community member.[2] She was a grandmother, mother, auntie and traditional helper. Their deaths had a great impact on our community. Such premature deaths represent many years of lost life with an incalculable loss for our future. To reduce these tragic losses, we need to better understand their magnitude and causes among Indigenous Peoples.

A previous systematic review focussed on personal–behavioural causes of MVCs in Canada.[3] However, scholarly observations have indicted various structures (or institutions) of Canadian society, including banking, housing child welfare, education and healthcare, which also have a negative impact on Indigenous Peoples and may contribute to MVC morbidity and mortality.[4] For example, Indigenous Peoples, especially those living in rural or remote areas, may have limited access to emergency medical care and may have to travel great distances on highways, with higher speed limits than urban streets, putting people at greater risk.[5,6] Thus, structural factors should be assessed as they relate to Indigenous Peoples' MVC-related morbidity and mortality.

The purpose of this updated research synthesis was to systematically review this field's research over the past decade, focussing on social–structural explanations for prevalent MVCs in Indigenous communities. We also conducted a controlled meta-analysis as one had not yet been done. More statistically significant findings from research syntheses will assist decision-makers, Indigenous and non-Indigenous, in more clearly identifying and meeting the diverse needs of Indigenous communities to prevent MVCs and to diminish serious injury and death rates.

MORBIDITY AND MORTALITY DUE TO MOTOR VEHICLE COLLISIONS AMONG INDIGENOUS PEOPLES

One in every 6 or 7 Canadians is seriously injured each year, these injuries being the primary

cause of approximately one of every 15 deaths. Indigenous Peoples in Canada have been observed to experience 2- to 6-fold greater such risks than non-Indigenous Peoples.[7,8]

Road-related injuries, primarily from MVCs, account for more than 30,000 hospitalsations and 3000 deaths each year and cost Canadians more than 5 billion dollars annually.[9] Initial estimates of the prevalence of MVCs among Indigenous Peoples as well as the resultant seriousness of injuries and apparent greater risk of death are alarming.[6,10-12] The precise magnitude of the relative risks (RRs) of injury and death experienced by Indigenous Peoples in Canada is not yet known,[13] although a two-fold RR has been suggested.[3] Finally, it is unknown if such risks due to MVCs have changed significantly over this research field's generational timeframe, nor do we understand very well how such risks differ, if at all, among Indigenous groups in Canada: First Nations, Inuit and Métis. This study aims to advance such knowledge.

Oppression in Canada's remote social structures

Scholars emphasise the importance of transcending the study of personal characteristics and behaviours to study structural risks experienced by Indigenous Peoples. According to Jervis *et al.*, the impacts of trauma caused by high rates of MVC-related deaths among American Indians in the United States exemplify post-colonial oppression.[14] Mullaly has made similar inferences in Canada and Australia, suggesting that Indigenous morbid and mortal health disadvantages arise from the structural violence Indigenous Peoples experience across society.[15-18] Moreover, oppression may be intimately related to geography, especially in Canada, where far more Indigenous Peoples live in rural and remote places.[19] These geo-structural barriers also have an impact on non-Indigenous populations living in rural communities.[20] Often, there is a shortage of healthcare nurses and physicians as well as inadequate trauma care.[21,22] However, Indigenous communities are affected by colonial violence due to governmental values and policies, which further exacerbate health disparities among Indigenous Peoples.[23] Research in this field must begin to account for such geographic and structural factors. This study does.

'Place' is probably as or more important than the person in understanding this field. An example may bring this notion to life. First, a cursory glance at a map of Canada shows a pattern of 1000–2000 km separating each province's sparsely populated, remote northern places from densely populated, southern urban and relatively resource-rich places. Next, imagine an Indigenous family in a tragic single car crash that resulted in very serious injuries on a remote road more than 1000 km away from the nearest trauma centre. This Indigenous family would be at much greater risk than an otherwise similar non-Indigenous family in Toronto, for example. The reasons for their greater jeopardy may not have been at all personal, rather, geographic and structural or geo-structural. One could surmise that this family could have suffered from the lack of protective engineering of the northern road system and also from a lack of healthcare resources, resulting in transportation delays of emergency care to the scene, as well as to specialised trauma care.

Finally, research methodologists have become more interested in developing valid measures of community-level risks (and protections), especially in understudied rural and remote places. Their work has tended to de-emphasise personal-level risk factors while emphasising community-level structural factors.[24-28] This and related epidemiologic fields have long used ecological, community-level measures of socio-economic status (SES) as proxies for the SES of individuals living within those communities. Typical examples are the prevalence of low-income households/Peoples within census tracts or census subdivisions. Every effort was made to incorporate such geo-structural characteristics into this research synthesis related to Indigenous Peoples residing in geographically diverse places.

Previous reviews of motor vehicle collisions among Indigenous Peoples in Canada

Short *et al.* conducted a systematic review of 20 studies published between 1980 and 2010.[3] They valuably, but roughly estimated that Indigenous Peoples were twice as likely as non-Indigenous Peoples to be seriously injured or die in MVCs and began to explore primarily personal explanations for such observed Indigenous

disadvantages (e.g. gender, substance misuse and age of vehicle). Another relevant systematic review of interventions designed to prevent MVC-related injuries and deaths among Indigenous Peoples also focussed primarily on personal factors (e.g. responsible alcohol consumption and aspects of safe driving including child/booster seat and seatbelt use).[29] These previous reviews began to advance society's understanding of the extent of this public health problem in Canada and additionally provided hopeful evidence that there are ways to effectively diminish the magnitude of the problem. However, important contributions notwithstanding, the review by Megan Short *et al*. was limited in several ways. It did not include a meta-analysis, and its narrative findings did not account for potential confounds. For example, age is a fundamental covariate that should be accounted for in any study of health or healthcare, and it was not always included. There seemed to have been little collaboration between researchers and Indigenous community-based stakeholders.

Researchers have suggested that future research should incorporate social factors such as mores related to community attitudes towards safe versus reckless driving. We concur but would suggest additional foci on geo-structural factors related to physical and economic environments. This study will update and extend the previous systematic review,[3] adding a meta-analytic component that, at minimum, accounts for age in addition to primary study sample sizes. It will also explore the independent effects of geo-structurally vulnerable places where Indigenous Peoples tend to live on-reserve, in small urban or rural places, or relatively impoverished communities.

METHODS

Study selection

The following research literature databases were searched: *Cumulative Index of Nursing and Allied Health Literature Complete*, *First Nations Periodical Index*, *Google Scholar*, *HealthSTAR*, *Indigenous Peoples of North America*, *Indigenous Studies Portal*, *Medline via PubMed*, *Mètis Voyageur*, *ProQuest Dissertations and Theses Global*, *PsycINFO*, *Social Services Abstracts*, *Social Work Abstracts*, *Sociological Abstracts* and the *Web of Science: Conference Proceedings Citation Index*. Published peer-reviewed and gray, unreviewed and unpublished sampling frames were searched to guard against publication bias.[30,31]

Article titles or abstracts were searched with this broad keyword search scheme: (Indigenous or Aboriginal or First Nations or Inuit or Métis) and (mortality or morbidity or injury or hospitalisation or emergency department or trauma or potential years of life lost). Searches were then triangulated with the following full text search scheme: (motor vehicle or car or automobile or traffic or road) and (crash or collision or accident). Eligible studies had to meet these inclusion criteria: (1) conducted in Canada, (2) used a longitudinal cohort design, (3) compared an Indigenous with a non-Indigenous group and (4) mortality or morbidity rates were, at minimum, age-standardised. Studies that did not report results in enough detail to calculate an effect size metric were excluded. Bibliographies and authors of retrieved studies were snowball-searched for additional eligible studies. The study selection process, cross-validated by 2 reviewers, identified 11 relevant studies for this meta-analysis.[4,13,32-42]

Meta-analysis

This meta-analysis observed random effects on discrete outcomes.[41-46] The unit of analysis was the unique hypothesis test. Between-ethnocultural group comparisons were observed for mortal or morbid outcomes. These were treated as independent hypotheses. Each study could contribute only once to each hypothesis test. If a primary study provided multiple outcomes related to the same hypothesis, the estimated ethnocultural-outcome association was pooled so that that study would contribute only one data point for that hypothesis test.

Mortality or morbidity rate ratios that were at least age-standardised, estimated primary study RRs. Natural logarithms of study RRs were weighted by their inverse variances, computed from standard errors ($1/SE^2$) so that larger, more precise studies carried more weight. Standard errors were estimated from study statistics, generally from reported 95% confidence intervals (CIs). Such precision-weighted effects were then pooled within domains of interest using weighted regression models. Pooled RRs within 95% CIs were calculated from regression

statistics, as were tests of heterogeneity (χ^2) and meta-analytic-between-group comparisons (z). All statistical significance decisions were made at the α criterion of 0.05, and RRs greater than 1.00 indicated greater mortalities and morbidities among Indigenous Peoples. All authors agreed on data extraction from each study. Subsequently, the meta-analysis was completed by the third author. It was then cross-validated by the first two authors. On cross-validation, there was 90.9% agreement among the analysts. Consensus was reached through discussion.

The following hypotheses were tested. First, compared to non-Indigenous Canadians, Indigenous Peoples have significantly greater mortality after MVCs. Second, Indigenous Peoples have significantly more prevalent serious injuries after MVCs. Third and fourth, Indigenous disadvantages, mortal and morbid, are greater in geo-structurally vulnerable places where transportation and healthcare structures may be inadequately resourced. When possible, we explored the potential moderating influence of other available personal, contextual and research design characteristics of the primary studies and their participants.

RESULTS

Sample description

Descriptive characteristics and mortality or morbidity outcomes of the 11 studies retrieved for this meta-analysis are, respectively, displayed in Tables 1 and 2. Published between 2010 and 2019, 5 sampled Canadian national and 6 sampled provincial populations of Indigenous Peoples and non-Indigenous Peoples between 1990 and 2015: British Columbia (3), Alberta (2), Newfoundland and Labrador (1). The majority did not disaggregate the experiences of diverse Indigenous Peoples across Canada, while

Table 1: Description and outcomes of studies included in the meta-analysis: Indigenous versus non-Indigenous motor vehicle collision-related mortality

Reference	Populations Places Cohort years	Research design Sampling frame Analytic samples Covariate adjustments[a]	Outcomes risk ratios[b] (95% CI)
Tjepkema *et al.*, 2010	Aboriginal and non-Aboriginal 25 or older Urban Canada 1991 to 2001	Prospective cohort Canadian Mortality Database and Census 16,300 and 2,062,700 Age, gender and metro versus small urban	Mortality RR=3.75 (3.27-4.29) RR_{women}=4.13 (2.46-6.93) RR_{men}=3.51 (2.32-5.32)
Tjepkema *et al.*, 2011a	Métis, non-Status Indians and non-Aboriginal 25 to 74 years of age Canada 1991 to 2001	Prospective cohort Canadian Mortality Database and Census 11,600, 5400 and 2,475,700 Age and gender	Person-years of life lost RR=2.75 (2.54-2.98) RR_{women}=1.79 (1.31-2.43) RR_{men}=3.42 (2.75-4.24)
Tjepkema *et al.*, 2011b	Status Indians and non-aboriginal 25 to 74 years of age Canada 1991 to 2001	Prospective cohort Canadian Mortality Database and Census 55,600 and 2,475,700 Age and gender	Person-years of life lost RR=4.04 (3.68-4.44) $RR_{on\text{-}reserve}$=4.53 (4.07-5.05) $RR_{off\text{-}reserve}$=2.78 (2.34-3.31)
Yacoub, 2012	First Nations and non-First Nations All ages Alberta 2000 to 2009	Retrospective cohort Alberta Death File, FN Mortality Database and Census: 355 and 3461 Age	Mortality RR=3.76 (1.70-8.32)
BC coroners service and first nations health authority death review panel, 2017	First Nations and non-First Nations 15 to 24 years of age British Columbia 2010 to 2015	Retrospective cohort BC Coroners Service and First Nations Health Authority: 95 and 1115 Age	Mortality RR=2.38 (1.02-5.57)

[a]Potential confounds that were accounted for by sample restriction, matching, regression modeling or direct standardisation, [b]Risk ratios were adjusted in regressions or directly standardised. Risk ratios greater than 1.00 indicate greater Indigenous mortality. BC: British Columbia, CI: Confidence interval, FN: First Nations, RR: Rate ratio

Table 2: Description and outcomes of studies included in the meta-analysis: Indigenous versus non-Indigenous motor vehicle collision-related morbidity

Reference	Populations Places Cohort years	Research design Sampling frame Analytic samples Covariate adjustments[a]	Outcomes risk ratios[b] (95% CI)
Alaghehbandan *et al.*, 2010	Aboriginal and non-Aboriginal New-born to 19 years of age Newfoundland and Labrador 1995 to 2001	Retrospective cohort Hospital Discharge Database and Census 72 and 2032 Age and gender	Hospitalisations RR=1.71 (1.54-1.91) $RR_{passenger}$=1.75 (1.30-2.34) $RR_{pedestrian}$=1.65 (1.12-2.44)
George *et al.*, 2015	Aboriginal and General Population All ages British Columbia 1991 to 2010	Retrospective cohorts Population Data BC and Census 585 and 6756 Age, gender and HSDA	Hospitalisations RR=2.84 (2.78-2.89) RR_{1991}=2.89 (2.74-3.07) RR_{2010}=1.45 (1.06-1.87)
Brussoni *et al.*, 2018	Aboriginal and General Population All ages British Columbia 1991 to 2010	Retrospective cohort BC Health Insurance Registry and Census 12,683 and 262,819 Age, gender and HSDA	Hospitalisations RR=1.89 (1.85-1.94) RR_{women}=2.13 (2.03-2.24) RR_{men}=1.69 (1.63-1.75) $RR_{non\text{-}metro}$=2.71 (2.61-2.82) RR_{metro}=1.73 (1.63-1.84) $RR_{on\text{-}reserve}$=2.00 (1.93-2.07) $RR_{off\text{-}reserve}$=1.77 (1.71-1.83)
Oliver and Kohen, 2012	Aboriginal and non-Aboriginal[c] New-born to 19 years of age Canada (not Quebec) 2001 to 2006	Retrospective cohort Hospital Morbidity Database and Census 944 and 12,898 Age and gender	Hospitalisations RR=2.42 (2.30-2.55) RR_{women}=2.82 (2.54-3.14) RR_{men}=2.22 (2.02-2.43)
Finès *et al.*, 2013	Aboriginal and non-Aboriginal[c] 20 or older Canada (not Quebec) 2004 to 2010	Retrospective cohort Discharge Abstract Database and Census 26,000 and 704,000 Age and gender	Hospitalisations RR=2.92 (2.90-2.95) RR_{women}=3.42 (3.36-3.49) RR_{men}=2.50 (2.46-2.54)
Sanchez-Ramirez *et al.*, 2019	Métis and General Population All ages Alberta 2013	Retrospective cohort Alberta Health Insurance Registry and Métis Nation of Alberta: 4225 and 518,592 Age	Emergency department visits RR=1.44 (1.09-1.90)

[a]Potential confounds that were accounted for by sample restriction, matching, regression modeling or direct standardisation, [b]Risk ratios were adjusted in regressions or directly standardised. Risk ratios >1.00 indicate greater Indigenous mortality, [c]DA-based ecological analysis: DAs with 33% or more Aboriginal Peoples compared to DAs with fewer aboriginal peoples (respectively, 77.0% aboriginals and 2.8% aboriginals). DAs: Dissemination area, BC: British Columbia, CI: Confidence interval, FN: First Nations, HSDA: Health service delivery area, RR: Rate ratio

5 observed the unique experiences of First Nations (3) or Métis (2) People. Overall, these studies seemed representative of Canadians of all ages: All ages (4), adults 20–25 or older (4) infants to 19-year-old youths (2) and youths to emergent adults 15–24 (1).

The 11 studies were all population-based, cohort studies, 8 retrospective or historical, and 3 prospective. Moreover, with the exception of 2 studies that had fewer than 100 Indigenous participants, these were quite large, statistically powerful investigations. In aggregate, more than eight million people participated, however, Indigenous samples (range = 72–55,600, median = 4225) were markedly smaller than the non-Indigenous ones (range = 1115–2,475,700, median = 262,819). Consistent with inclusion criterion, all of the studies at least accounted for age in their multivariable analyses, 3 for age alone, 5 for age and gender, while 3 accounted for an additional covariate. Two of the studies were government-based reports while the remainder were peer-reviewed articles (2 had initially been released as grey documents). A total of 23 independent study results were included in our meta-analysis. The description of the 23 outcomes

were all statistically and practically significant and in the direction of hypothesis support, that is, Indigenous disadvantages.

Meta-analytic findings

The overall pooled RR of dying in a MVC among Indigenous Peoples in Canada was huge. Compared with their otherwise similar non-Indigenous counterparts, Indigenous victims were more than 3 times as likely to die; RR = 3.40 (95% CI 2.68, 4.31). The Indigenous risk of injury, typically serious injuries requiring hospitalisation, was also quite large, representing a two-fold greater risk among Indigenous victims: RR = 2.18 (95% CI 1.82, 2.61). These pooled mortality and morbidity RR estimates differed significantly (z = 18.02, P < 0.05) so they were meta-analysed separately.

Mortality

Table 1 displays primary study and meta-analytic findings related to mortality. First, the mortality outcomes were observed to be significantly heterogeneous ($\chi^2[4]$ = 41.92, P < 0.05) warranting the testing of their moderation, centrally by place. Second, one study allowed for the testing of the geo-structural vulnerability hypothesis. As hypothesised, Indigenous risks were significantly and substantially larger on-reserve (RR = 4.53 [95% CI 4.07, 5.05]) than off-reserve (RR = 2.78 [95% CI 2.34, 3.31]), z = 6.53, P < 0.05. Third, consistent with much previous research, men (RR = 3.44 [95% CI 3.16, 3.75]) were at significantly greater risk than women (RR = 2.28 [95% CI 2.19, 2.56]), z = 5.60, P < 0.05. Fourth and finally, RRs did not change significantly over time nor did any other participant, contextual, or research design characteristic significantly predict mortality risk.

Morbidity

Table 2 displays primary study and meta-analytic findings related to morbidity. Injury outcomes were also observed to be significantly heterogeneous ($\chi^2[5]$ =1,030.67, P < 0.05). Again, one study allowed for the testing of the geo-structural vulnerability hypothesis, but this time in two ways. As hypothesised, Indigenous risks were again significantly larger on-reserve (RR = 2.00 [95% CI 1.93, 2.07]) than off-reserve (RR = 1.77 [95% CI 1.71, 1.83]), z = 8.66, P < 0.05. Indigenous risks were also significantly larger in non-metropolitan (RR = 2.71 [95% CI 2.61, 2.82]) than in metropolitan areas (RR = 1.73 [95% CI 1.63, 1.84]), z = 31.83, P < 0.05. Counter-hypothetically, women (RR = 2.70 [95% CI 2.66, 2.74]) seemed to be at significantly greater risk of serious injury than men (RR = 2.07 [95% CI 2.05, 2.10]), z = 28.11, P < 0.05. Though one study in British Columbia suggested diminishing risks,[36] the overall pooled RR risk did not change significantly over time. Finally, only one study disaggregated RRs by passengers or pedestrians. Their risks did not differ significantly: $RR_{passengers}$ = 1.75 (95% CI 1.30, 2.34) versus $RR_{pedestrians}$ = 1.65 (95% CI 1.12, 2.44), z = 0.52, P = 0.61. No other personal, contextual or research design characteristic significantly predicted morbid risks.

Adjunct findings

Six predominantly ecological studies, 3 included in this meta-analysis along with 3 related studies, provided interpretive adjuncts.[4,37-39,47,48] Using multivariable regression models and related statistical techniques, they endeavoured to advance the understanding of how lack of community-level resources may explain Indigenous disadvantages, especially in rural and remote places. Substantial proportions (33%–90%) of the MVC-related injury and mortality rate differences between Indigenous Peoples and non-Indigenous Peoples could be explained by community-level socioeconomic factors. A case–control study of MVC-related injuries on- or off-reserve in Saskatchewan was particularly instructive.[47] It found greater on-reserve risks could be substantially explained by personal and community-level socioeconomic factors. For example, factors such as having a very old car and poor road conditions were extremely predictive of serious injury, ranging from RRs of 2.50 to greater than 6.00, community-level risks being consistently larger than personal ones. Such may reflect transportation infrastructural resources in Indigenous communities and a lack of related resources necessary to adequately treat the roads, particularly in the wintertime. Finally, Haas's dissertation study additionally implicated

healthcare infrastructure inadequacies in remote northern places.[48]

DISCUSSION

Our research cross-validated the most important finding of Short *et al.*'s previous systematic review of the relative risks of serious injuries and deaths post-MVCs among Indigenous Peoples in Canada.[3] They roughly estimated that Indigenous Peoples experience twice the risk of their non-Indigenous counterparts. The pooled estimates of this, more controlled, meta-analytic review concurred, but further suggested that the previous risk estimates were probably underestimates. We estimated that Indigenous Peoples in Canada were twice as likely as non-Indigenous Peoples to be seriously injured and 3–4 times as likely to die in MVCs. The outcomes of the investigations pooled in our updated review also strongly suggested that these profound Indigenous disadvantages have been longstanding, not having changed significantly over the past generational timeframe. Our review also aimed to build upon the previous review's emphasised person-level risks by incorporating geo-structural risk factors. Indigenous risks were observed to be even greater on-reserves in rural and remote places across Canada. Consistent with a contemporaneous systematic review of USA-based primary studies and a British Columbia-based ecological study, another structure of society, the potentially inadequately engineered or treated system of highways and roads in geographically vulnerable places was implicated.[5,49] Our results were consistent with those of Haas's Ontario-based dissertation study and a national study of remoteness in Canada,[48,50] indicting another structure of Canadian society – an inadequately resourced system of urgent triage/transport/trauma-care in such remote places.

Limitations and future research recommendations

As the overall pooled results related to the much greater incidence of MVC-related injuries and deaths among Indigenous Peoples were based upon the experiences of over 8 million people with the predominant retrospective cohorts systematically replicated by 3 prospective cohorts, we have great confidence in the validity of those estimates. For a number of reasons, though our results about potentially important moderations of those overall effects inspired less confidence and so were more tentative. First, the meta-analysis result of greater community-level risks experienced by Indigenous Peoples, on-reserves or in isolated rural and remote places, was based upon only three study outcomes. Second, the inference that community-level socioeconomic measures tell us more about community resources than personal resources was based upon a small number of ecological studies. Although the construct and predictive validities of such expansive geographical measures in Canada's remote reserves have been suggested, they have not yet been confidently clarified.[24,25] Finally, we had originally hoped to be able to advance an understanding of the potentially distinct experiences of diverse Indigenous groups in Canada. Unfortunately, we were unable to do so for lack of meta-analytic power.

Future research teams should consider the following. First, the few existing tests of the effects of geo-structural factors by comparing reserves and other geographically vulnerable places ought to be systematically replicated across the provinces and territories. Second, validating studies of community-level ecological measures, especially in Canada's most isolated places, would help solidify geo-structural inferences, that is, that it is primarily the structures of society that are implicated here. Towards this end, mixed-methods investigations might augment administrative databases. For example, photovoice-like methods might be used to learn more about MVC scenes.[51] Alternatively, the addition of sentinel quantitative measures may go a long way towards solidifying this field's knowledge about the effects of remoteness, for example: distances and/or delay times between residences, crash sites and trauma centres. Third, the experiences of distinct Indigenous communities and their people ought to be disaggregated in analyses and reporting. Fourth, we echo Short *et al.*'s suggestion that researchers in this field must work closely, indeed 'collaborate' with Indigenous communities.[3] Such involvement throughout the research project, from idea generation to dissemination of findings, is bound to produce results that are more face valid and so practically

useful to Indigenous communities as well as to scholarly and non-Indigenous decision-making communities.[52,53] At last, to address this health disparity, it is of great importance to consult with Indigenous communities and ensure all healthcare professionals are trained in cultural competency, as recommended by the Truth and Reconciliation Commission of Canada.[23] The hope is to mitigate MVC injuries and deaths that affect Indigenous Peoples by providing healthcare resources.

CONCLUSION

This meta-analysis affirmed a previous systematic review's concerns that Indigenous Peoples in Canada are much more likely than non-Indigenous Peoples to be seriously injured and die in MVCs. It also observed that Indigenous risks seem to be significantly greater on-reserves and in rural and remote places. Such places may lack community resources, including fewer transportation and healthcare infrastructural investments, resulting in poorer road conditions and longer delays to trauma care. Canada's system of highways and roadways and its remote healthcare system represent legitimate policy targets to solve this public health problem.

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REFERENCES

1. Angell GB, North J, Williams N. Utilizing Indigenous Pathways of Knowledge Transfer to Build Injury Free Communities. New Orleans, LA: Society for Social Work and Research; 2017.
2. MacGregor D. Sugar bear in the hot zone: Understanding and interpreting the political basis of traffic safety. In: Rothe JP, editor. Driving Lessons: Exploring Systems that Make Traffic Safer. Edmonton, MB: The University of Alberta Press; 2002. p. 125-42.
3. Short MM, Mushquash CJ, Bédard M. Motor vehicle crashes among Canadian Aboriginal people: A review of the literature. Can J Rural Med 2013;18:86-98.
4. Brussoni M, George MA, Jin A, Amram O, McCormick R, Lalonde CE. Hospitalizations due to unintentional transport injuries among Aboriginal population of British Columbia, Canada: Incidence, changes over time and ecological analysis of risk markers. PLoS One 2018;13:e0191384.
5. Pollack KM, Frattaroli S, Young JL, Dana-Sacco G, Gielen AC. Motor vehicle deaths among American Indian and Alaska Native populations. Epidemiol Rev 2012;34:73-88.
6. Community Health Programs Directorate. Unintentional and Intentional Injury Profile for Aboriginal Peoples in Canada. Ottawa, ON: Health Canada; 2001.
7. Billette J, Janz T. Injury in Canada: Insight from the Canadian Community Health Survey. Ottawa, ON: Statistics Canada; 2011.
8. Statistics Canada. Mortality: Summary List of Causes 2005. Ottawa, ON: Statistics Canada; 2009.
9. Parachute. The Cost of Injury in Canada. Available from: https://parachute.ca/wp-content/uploads/2019/06/Cost_of_Injury-2015.pdf. [Last accessed on 2021 June 25].
10. British Columbia Office of the Provincial Health Officer. Pathways to Health and Healing: 2nd Report on the Health and Well-Being of Aboriginal Peoples in British Columbia. Provincial Health Officer's Annual Report 2007. Victoria, BC: Ministry of Healthy Living and Sport; 2009.
11. Karmali S, Laupland K, Harrop AR, Findlay C, Kirkpatrick AW, Winston B, *et al*. Epidemiology of severe trauma among status Aboriginal Canadians: A population-based study. CMAJ 2005;172:1007-11.
12. Yao X, Skinner R, McFaull S, Thompson W. At-a-glance – 2015 injury deaths in Canada. Health Promot Chronic Dis Prev Can 2019;39:225-31.
13. Sanchez-Ramirez DC, Chen Y, Randall JR, Sporidis MJ, Svenson L, Voaklander B, *et al*. Injury-related health services use and mortality among Métis Peoples in Alberta. Can J Public Health 2019;110:422-9.
14. Jervis LL; Al-SUPERPFP Team. Disillusionment, faith, and cultural traumatization on a northern plains reservation. Traumatology 2009;15:11-22.
15. Mullaly B. Challenging Oppression: A Critical Social Work Approach. Don Mills, ON: Oxford University Press; 2002.
16. Alberton AM. Predictive Effects of (neo)Colonialism and other Forms of Structural Violence on Involuntary Contacts with the Criminal Justice System in Canada: A Statistical Analysis with an Autoethnographic Perspective (Doctoral Dissertation). ProQuest Dissertations Theses; 2020. p. 2487186463.
17. Maddison S. Indigenous identity, 'authenticity' and the structural violence of settler colonialism. Identities 2013;20:288-303.
18. Pedersen JS, Malcoe LH, Pulkingham J. Explaining aboriginal/non-aboriginal inequalities in postseparation violence against Canadian women: Application of a structural violence approach. Violence Against Women 2013;19:1034-58.
19. Banerji A; Canadian Paediatric Society; First Nations, Inuit and Métis Health Committee. Preventing unintentional injuries in Indigenous children and youth in Canada. Paediatr Child Health 2012;17:393-4.
20. Bell N, Simons RK, Lakha N, Hameed SM. Are we failing our rural communities? Motor vehicle injury in British Columbia, Canada, 2001-2007. Injury 2012;43:1888-91.
21. Jiang HY, MacLean A, Yoon J, Hughes S, Kim MJ, Anantha RV, *et al*. Evaluation of trauma resources in rural northern Alberta identifies opportunities for improvement. Can J Surg 2020;63:E383-90.
22. Wilson C, Rourke J, Oandasan I, Bosco C. Progress made on access to rural health care in Canada. Can Fam Physician 2020;66:31-6.
23. Truth and Reconciliation Commission of Canada. Honouring the Truth, Reconciling for the Future: Summary of the Final Report of the Truth and Reconciliation Commission of Canada. Available from: https://ehprnh2mwo3.exactdn.com/wp-content/uploads/2021/01/Executive_Summary_English_Web.pdf and indicate. [Last accessed on 2022 Feb 21].
24. Buajitti E, Chiodo S, Rosella LC. Agreement between area- and individual-level income measures in a population-based cohort: Implications for population health research. SSM Popul Health 2020;10:100553.
25. Fuller D, Neudorf J, Lockhart S, Plante C, Roberts H, Bandara T, *et al*. Individual- and area-level socioeconomic inequalities in diabetes mellitus in Saskatchewan between 2007 and 2012: A cross-sectional analysis. CMAJ Open 2019;7:E33-9.

26. Gorey KM. Regarding "Associations between socioeconomic status and cancer survival." Ann Epidemiol 2006;16:789-91.
27. Gorey KM, Holowaty EJ, Fehringer G, Laukkanen E, Richter NL, Meyer CM. An international comparison of cancer survival: Metropolitan Toronto, Ontario, and Honolulu, Hawaii. Am J Public Health 2000;90:1866-72.
28. Terashima M, Rainham DG, Levy AR. A small-area analysis of inequalities in chronic disease prevalence across urban and non-urban communities in the Province of Nova Scotia, Canada, 2007-2011. BMJ Open 2014;4:e004459.
29. Short MM, Mushquash CJ, Bédard M. Interventions for motor vehicle crashes among Indigenous communities: Strategies to inform Canadian initiatives. Can J Public Health 2014;105:e296-305.
30. de Smidt GA, Gorey KM. Unpublished social work research: Systematic replication of a recent meta-analysis of published intervention effectiveness research. Social Work Res 1997;21:58-62.
31. Grenier AM, Gorey KM. Effectiveness of social work with older Peoples and their families: A meta-analysis of conference proceedings. Soc Work Res 1998;22:60-4.
32. Alaghehbandan R, Sikdar KC, MacDonald D, Collins KD, Rossignol AM. Unintentional injuries among children and adolescents in Aboriginal and non-Aboriginal communities, Newfoundland and Labrador, Canada. Int J Circumpolar Health 2010;69:61-71.
33. British Columbia Coroners Service, First Nations Health Authority Death Review Panel. A Review of First Nation Youth and Young Adult Injury Deaths, 2010-2015. Victoria: BC Coroners Service; 2017.
34. Finès P, Bougie E, Oliver LN, Kohen DE. Hospitalizations for unintentional injuries among Canadian adults in areas with a high percentage of Aboriginal-identity residents. Chronic Dis Inj Can 2013;33:204-17.
35. George MA, Jin A, Brussoni M, Lalonde CE. Is the injury gap closing between the Aboriginal and general populations of British Columbia? Health Rep 2015;26:3-14.
36. Oliver LN, Kohen DE. Unintentional injury hospitalizations among children and youth in areas with a high percentage of Aboriginal identity residents: 2001/2002 to 2005/2006. Health Rep 2012;23:7-15.
37. Tjepkema M, Wilkins R, Pennock J, Goedhuis N. Potential years of life lost at ages 25 to 74 among Status Indians, 1991 to 2001. Health Rep 2011;22:25-36.
38. Tjepkema M, Wilkins R, Senécal S, Guimond É, Penney C. Mortality of urban Aboriginal adults in Canada, 1991-2001. Chronic Dis Canada 2010;31:4-21.
39. Tjepkema M, Wilkins R, Senécal S, Guimond E, Penney C. Potential years of life lost at ages 25 to 74 among Métis and non-Status Indians, 1991 to 2001. Health Rep 2011;22:37-46.
40. Yacoub W. First Nations Health Status Report: Alberta region 2010-2011. Edmonton, AB: Health Canada Alberta Region; 2012.
41. Greenland S. Quantitative methods in the review of epidemiologic literature. Epidemiol Rev 1987;9:1-30.
42. Cooper HM. Research Synthesis and Meta-Analysis: A Step-by-Step Approach. 5th ed. Los Angeles, CA: Sage; 2017.
43. Greenland S, O'Rourke K. On the bias produced by quality scores in meta-analysis, and a hierarchical view of proposed solutions. Biostatistics 2001;2:463-71.
44. Grizzle JE, Starmer CF, Koch GG. Analysis of categorical data by linear models. Biometrics 1969;25:489-504.
45. Hedges LV. Fixed effects models. In: Cooper H, Hedges LV, editors. The Handbook of Research Synthesis. New York: Russell Sage Foundation; 1994. p. 285-99.
46. Stroup DF, Berlin JA, Morton SC, Olkin I, Williamson GD, Rennie D, *et al.* Meta-analysis of observational studies in epidemiology: A proposal for reporting. Meta-analysis Of Observational Studies in Epidemiology (MOOSE) group. JAMA 2000;283:2008-12.
47. Desapriya E, Fujiwara T, Verma P, Babul S, Pike I. Comparison of on-reserve road versus off-reserve road motor vehicle crashes in Saskatchewan, Canada: A case control study. Asia Pac J Public Health 2011;23:1005-20.
48. Haas B. The Mortality Cost of Undertriage of Major Trauma in Ontario (Doctoral Dissertation). ProQuest Dissertations Theses; 2012. p. 1333382752.
49. Brussoni M, Jin A, George MA, Lalonde CE. Aboriginal community-level predictors of injury-related hospitalizations in British Columbia, Canada. Prev Sci 2015;16:560-7.
50. Subedi R, Greenberg TL, Roshanafshar S. Does geography matter in mortality? An analysis of potentially avoidable mortality by remoteness index in Canada. Health Rep 2019;30:3-15.
51. Catalani C, Minkler M. Photovoice: A review of the literature in health and public health. Health Educ Behav 2010;37:424-51.
52. Banner D, Bains M, Carroll S, Kandola DK, Rolfe DE, Wong C, *et al.* Patient and public engagement in integrated knowledge translation research: Are we there yet? Res Involve Engage 2019;5:8.
53. Harding T, Oetzel J. Implementation effectiveness of health interventions for indigenous communities: A systematic review. Implement Sci 2019;14:76.