Is ethnicity an appropriate measure of health care marginalization? A systematic review and meta-analysis of the outcomes of diabetic foot ulceration in Aboriginal populations

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Background: Aboriginal people have higher prevalence rates of diabetes than non-Aboriginal people in the same geographic locations, and diabetic foot ulcer (DFU) complication rates are also presumed to be higher. The aim of this systematic review and meta-analysis was to compare DFU outcomes in Aboriginal and non-Aboriginal populations.

Methods: We searched PubMed, Embase, CINAHL and the Cochrane Library from inception to October 2018. Inclusion criteria were all types of studies comparing the outcomes of Aboriginal and non-Aboriginal patients with DFU, and studies from Canada, the United States, Australia and New Zealand. Exclusion criteria were patient age younger than 18 years, and studies in any language other than English. The primary outcome was the major amputation rate. We assessed the risk of bias using the ROBINS-I (Risk Of Bias In Non-randomized Studies – of Interventions) tool. Effect measures were reported as odds ratio (OR) with 95% confidence interval (CI).

Results: Six cohort studies with a total of 244 792 patients (2609 Aboriginal, 242 183 non-Aboriginal) with DFUs were included. The Aboriginal population was found to have a higher rate of major amputation than the non-Aboriginal population (OR 1.85, 95% CI 1.04–3.31). Four studies were deemed to have moderate risk of bias, and 2 were deemed to have serious risk of bias.

Conclusion: Our analysis of the available studies supports the conclusion that DFU outcomes, particularly the major amputation rate, are worse in Aboriginal populations than in non-Aboriginal populations in the same geographic locations. Rurality was not uniformly accounted for in all included studies, which may affect how these outcome differences are interpreted. The effect of rurality may be closely intertwined with ethnicity, resulting in worse outcomes.

Contexte : Le taux de prévalence du diabète chez les Autochtones dépasse celui chez les Allochtones des mêmes régions géographiques. On présume qu'il en va de même pour le taux de complications d'un ulcère du pied diabétique (UPD). Le but de cette revue systématique et de cette méta-analyse était de comparer les issues d'UPD dans les populations autochtones et allochtones.

Méthodes : Nous avons interrogé PubMed, Embase, CINAHL et la Bibliothèque Cochrane, de leur création jusqu'à octobre 2018. Les critères d'inclusion étaient tous les types d'études comparant les résultats de patients autochtones et allochtones atteints d'UPD, et la réalisation au Canada, aux États-Unis, en Australie ou en Nouvelle-Zélande. Les patients de moins de 18 ans et les études dans une langue autre que l'anglais ont été exclus. L'issue primaire était le taux d'amputation majeure. Nous avons évalué le risque de biais à l'aide de l'outil ROBINS-I (Risk Of Bias In Non-randomized Studies – of Interventions). Les mesures de l'effet sont données sous forme de rapport de cotes (RC) avec intervalle de confiance (IC) de 95 %.

Résultats : Nous avons inclus 6 études de cohortes totalisant 244 792 patients atteints d'UPD (2609 Autochtones et 242 183 Allochtones). La population autochtone présentait un taux d'amputation majeure plus élevé que celle allochtone (RC 1,85; IC de 95 % 1,04–3,31). Le risque de biais était jugé modéré pour 4 études et important pour les 2 autres.

Conclusion : Notre analyse des études disponibles confirme l'hypothèse voulant que les issues d'UPD, en particulier le taux d'amputation majeure, soient pires chez les Autochtones que chez les Allochtones d'une même région. La prise en compte de la ruralité variait entre les études, ce qui pourrait fausser l'interprétation des disparités. Il est possible que l'incidence de la ruralité soit plus étroitement liée à l'ethnicité, causant ainsi une hausse des issues défavorables.

The health outcomes of Aboriginal populations in Canada, Australia, New Zealand and the United States have been frequently studied and discussed. These populations have higher disease prevalence rates than the non-Aboriginal populations in similar geopolitical regions (state, province or country).[1–5] Common chronic diseases with higher prevalence rates include chronic obstructive pulmonary disease,[1] heart failure,[2] ischemic heart disease, hypertension, diabetes, renal disease[3] and multimorbidity disease.[4] These higher rates can be explained by a number of variables, including not only ethnicity but social and economic factors as well.

Although Aboriginal populations may have worse outcomes with respect to some medical conditions, it is frequently assumed that the outcomes are universally worse without examining the evidence. This can potentially bias investigators studying Aboriginal health outcomes. Are we blinded by this ethnicity-based outcomes discrepancy bias that prevents us from examining other potentially confounding variables that may predict a worse outcome?

As of 2014, the number of people with diabetes worldwide was 422 million (8.5% of adults aged ≥ 18 yr), up from 108 million in 1980.[6] This is expected to rise to 552 million (9.9% of the adult population) by 2030.[6] This is a global phenomenon, and developed countries are not spared. In Canada, it is estimated that the prevalence will increase from 10% in 2021 to 12% by 2031.[7] The national age-adjusted prevalence is up to 4.5 times higher in the First Nations population than in the non–First Nations population.[8] The global prevalence of diabetic foot ulcer (DFU) is 6.3%, with North America having the highest prevalence (13.0%) and Oceania the lowest (3.0%). Among countries, Canada and the US have the second- and third-highest prevalence rates (14.8% and 13.0%, respectively), behind only Belgium (16.6%).[9] In Australia, Aboriginality is significantly associated with DFU.[10]

In Canada, the US, Australia and New Zealand, examination of the Aboriginal population informs us about the health outcomes of historically (and contemporaneously) marginalized groups in developed countries. Many of these outcomes depend on access to timely, high-quality medical and surgical care. Although an examination of DFU prevalence may inform us about differences between study groups, an examination of the outcomes of having a DFU will more accurately reflect the interaction patients have with the health care system. These interactions are heavily influenced by confounding variables, including ethnicity and social and economic factors, with the sum total of interactions being reflected in the outcomes of patients with DFUs.

We performed a systematic review and meta-analysis of the outcomes of DFU in Aboriginal populations. The purpose of the review was to answer the following question: Do Aboriginal patients with DFUs have worse outcomes than non-Aboriginal patients with DFUs?

Methods

We used the PICO (Participants, Intervention, Comparator, Outcome) format. The participants were patients with DFUs, the intervention was Aboriginality, and the comparator was non-Aboriginality; outcomes included good and bad outcomes, as identified in the studies that met our eligibility criteria. The primary outcome was the rate of major amputation, defined as surgical removal of part of a lower extremity by cutting through bone or joint proximal to the ankle.

The review was developed and reported as per the Preferred Reporting of Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[11]

Eligibility criteria

All types of studies, both published and unpublished, that reported on outcomes of DFU in both a cohort of Aboriginal patients and a cohort of non-Aboriginal patients were included. Outcomes included amputation (major and minor [surgical removal of part of a lower extremity at the level of the ankle joint and distally]) and infection. Included studies were limited to those with patient populations in Canada, the US, Australia or New Zealand. There was no restriction placed on publication date. Studies looking at patients younger than 18 years of age were excluded, as were those in any language other than English.

Literature search

An electronic database search strategy was designed, and the search was performed on Oct. 12, 2018. Databases searched were PubMed, Embase, CINAHL Plus with Full Text and the Cochrane Library (Appendix 1, available at canjsurg.ca). Keyword terms used in different combinations in the search were: diabetic foot, diabetic foot infection, diabetic osteomyelitis, diabetes mellitus, foot ulcer, diabetic feet, diabetic ulcer, diabet*, ulcer*, foot, feet, Alaska Native, Alaskan Native, American Indian, Australian Aborigine, Canadian Aboriginal, First Nation, First Nations, Indigenous Australian, indigenous health care, indigenous health services, indigenous people, indigenous

peoples, Maori, maori*, Native Hawaiian, aborigin*, aleut*, amerind*, bushmen, eskimo*, Hawaiian native, indigen*, innu*, inuit*, Inupiat*, kalaallit*, metis, native people, native population, Navaho*, Navajo*, pacific islander*, pasifika*, torres strait islander*, tribal, tribe* and zuni (Appendix 1). We also checked the references of included studies for relevant articles. A search was also carried out on Google Scholar and the Google Search engine to identify any other relevant studies, articles or editorials.

Study selection

One reviewer (D.I.) screened the titles of abstracts to identify articles that might meet the inclusion criteria. The full articles of potentially relevant studies were independently assessed by both reviewers (D.I. and D.P.) for inclusion. Disagreements were resolved by discussion.

Data extraction

Both reviewers extracted study data from the included studies into Microsoft Excel. Disagreements were resolved by discussion. Data were extracted on eligibility criteria, length of follow-up, country, year of publication, mean age, gender, ethnicity, clinical setting (inpatient or outpatient), outcomes and authors' conclusions. Outcomes included major and minor amputation rates, infection rates, length of hospital stay, revascularization rates, and whether the DFU was static, progressing, healing or healed.

Risk of bias assessment

We assessed articles deemed to have met our eligibility criteria using the Risk Of Bias In Non-randomized Studies – of Interventions (ROBINS-I) tool.[12] Studies were graded on risk of bias due to confounding, selection of participants, classification of interventions, deviations from intended interventions, missing data, measurement of outcomes and selection of the reported result. A final overall risk of bias was then determined. We placed overall risk of bias into 1 of 5 categories: low (the study is comparable to a well-performed randomized controlled trial [RCT]), moderate (the study provides sound evidence for an RCT but cannot be considered comparable to a well-performed RCT), serious (the study has important problems), critical (the study is too problematic to provide any useful evidence and should not be included in any synthesis) and no information on which to base a judgment about risk.

Summary measures and synthesis of results

Data were reported as whole numbers and ratios/percentages for outcomes. Although not all studies factored in confounding variables uniformly well, we decided to perform a meta-analysis on some outcomes. This was done by computing the odds ratio (OR) from the original data with the Mantel–Haenszel statistical method (with a 95% confidence interval [CI]). A p value of 0.05 was considered significant for all analyses. We performed synthesis and graphical representation of the meta-analysis using Rev-Man 5.3 software (Cochrane Collaboration). We used the random-effects model owing to the heterogeneity in the sample populations. For our primary outcome, we performed a sensitivity analysis to ensure that the effect measure was robust. We assessed interstudy heterogeneity using the I^2 statistic.

Results

The literature search retrieved 205 articles. After duplicates were removed, there were 117 articles to be screened. Of these, 103 were not relevant. Full texts of the 14 potentially relevant articles were reviewed (except for 1 article that had only an abstract, as the final manuscript was still being drafted).[13] After full-text review, 7 articles were excluded because the authors did not study the DFU population primarily,[14–20] and 1 was excluded because it had only an Aboriginal cohort, with no non-Aboriginal comparator.[21] The remaining 6 articles met the eligibility criteria to be included in the review[13,22–26] (Figure 1).

All studies included both Aboriginal and non-Aboriginal cohorts. There were a total of 244 792 patients (2609 Aboriginal, 242 183 non-Aboriginal) with DFUs. Sample sizes ranged from 129 participants[24] to 150 724 participants.[26] Studies were from Canada, Australia and the US. All studies were cohort studies: 5 retrospective and 1 prospective.[22] The abstract by Chang and colleagues[13] contained all relevant data needed for analysis. Tan and colleagues[26] provided us with primary data. Data sources were nationwide for 2 studies,[13,26] statewide for 1,[23] and hospital or clinic medical records for 3.[22,24,25] In 5 studies, the authors reported on amputation rates,[13,22,24–26] and in 1 study, the authors measured infection as the primary outcome.[23] Revascularization rates were measured as one of the outcomes in 1 study,[26] and 1 study reported on healing rates of DFUs.[25] Table 1 provides a summary of the findings of the included studies.

Risk of bias

Two studies had a serious risk of bias,[13,22] and the remaining 4 had a moderate risk.[23–26] The results of the determination of risk of bias for each study are presented in Table 2.

Results of studies and meta-analysis

The mean baseline age ranged from 54.4 to 71.9 years. The majority of study participants were male in all but 1 study.[13] Aboriginal patients with DFUs were almost twice as likely to undergo major lower-extremity amputation as non-Aboriginal patients with DFUs (OR 1.85, 95%

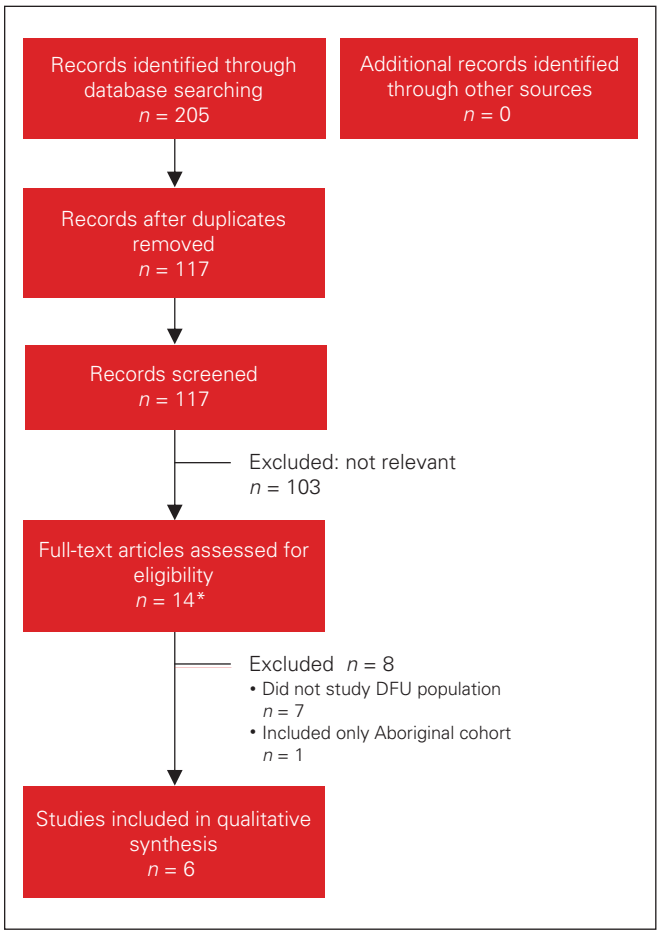

Fig. 1. Flow diagram showing study selection. *One article had only an abstract, as the final manuscript was still being drafted.[13] DFU = diabetic foot ulcer.

CI 1.03–3.32) (Figure 2). This still held true on sensitivity analysis excluding the largest study[22] (OR 2.23, 95% CI 1.24–4.01) and the severely biased studies[17,18] (OR 1.26, 95% CI 1.06–1.51). There was no significant difference in minor amputation rates between groups (OR 0.90, 95% CI 0.81–1.00) (Figure 3).

Commons and colleagues[22] reported a longer median length of hospital stay for Indigenous patients admitted with diabetic foot infection than for non-Indigenous patients admitted with diabetic foot infection (34 d [interquartile range (IQR) 12–57 d) v. 21 d [IQR 11–43 d]). Jia and colleagues[23] found no association between Indigenous background and infection in patients with uninfected DFUs. In their study, the Aboriginal population constituted 13.1% of the total study population analyzed that did not develop an infection and 12.9% of the population that did. We used the numbers provided in the study to calculate crude DFU infection rates and obtained a rate of 57.6% (38/66) for Aboriginal patients and 42.9% (189/441) for non-Aboriginal patients. Tan and colleagues[26] found that Native Americans had the lowest rates of open surgical bypass procedures (0.9%); other groups had rates of 2.0% (Whites), 2.1% (African Americans) and 2.3% (Hispanics). Native Americans also had lower rates of endovascular interventions (5.0%) compared to the White (5.5%), African American (5.9%) and Hispanic (6.7%) populations.

Commons and colleagues[22] reported longer duration of antibiotic therapy and higher cost of antibiotics in Indigenous patients with DFUs than non-Indigenous patients with DFUs. The median duration of antibiotic therapy per person was 37.5 (IQR 17–69.75) days among Indigenous patients and 21 (IQR 14–56) days among non-Indigenous patients. The median cost of antibiotics per person was A$1075 (IQR A$406–A$2210) for Indigenous patients and A$776 (IQR A$374–A$1969) for non-Indigenous patients.

Rose and colleagues[25] reported on good outcomes in the form of rates of healing or healed DFUs. The rates in the Aboriginal and non-Aboriginal populations were 52.5% (53/101) and 61.2% (137/224), respectively.

Risk of bias across studies

High heterogeneity was found in the overall analysis with respect to the primary outcome (major amputation). I^2 was calculated at 81%. Despite the high heterogeneity, we performed a random-effects meta-analysis as it provided a good summary of the overall study results. There was no inconsistency in the direction of effect across studies. To address some of the heterogeneity, we performed a sensitivity analysis after excluding studies with serious risk of bias[17,18] (I^2 = 68%) and another analysis after excluding the largest study (I^2 = 58%).[22] The overall direction of effect remained the same.

Analysis of the studies that reported on the outcome of minor amputation showed low heterogeneity (I^2 = 43%).

Discussion

Our review confirms that Aboriginal populations with DFU have worse outcomes than their non-Aboriginal counterparts. Rates of major amputation and infection were higher, revascularization rates were lower, and length of hospital stay was longer in the Aboriginal population with DFU than in the non-Aboriginal population with DFU.

The authors of the included studies put forward several possible explanations for the worse outcomes. Having a rural address was a major contributing factor. A large proportion of the Aboriginal population live in rural or remote areas in the countries of interest in this review. Chang and colleagues[13] showed that residing in a rural area was significantly associated with major amputation (hazard ratio 1.58, 95% CI 1.39–1.80). Tan and colleagues[26] postulated that Aboriginal patients present later in their disease course than do other ethnic groups, which contributes to their poorer outcomes. This rationale applies to all ethnic groups in a rural population, with rurality being the main factor.

Table 1. Summary of findings of included studies

Study	Country	Length of follow-up, yr	No. of Aboriginal patients/no. of non-Aboriginal patients	M/F gender, %	Baseline population age, mean ± SD,* yr	Findings
Chang et al.,[13] 2018	US	4	651/92 279	45.7/54.3	71.9 ± 11.9	• Incidence of major amputation within 1 yr after diagnosis of DFU was higher for Native American patients than White patients (4.1% v. 1.0%, $p < 0.001$) • In multivariable analysis, being Native American was associated with increased risk of major amputation compared to being White (HR 2.42, 95% CI 1.62–3.62)
Commons et al.,[22] 2015	Australia	1	114/63	59.9/40.1	54.4 (95% CI 28.8–80.1)	• Indigenous patients were younger than non-Indigenous patients (50.5 [95% CI 28.3–72.6] yr v. 61.6 [95% CI 36.1–87.1] yr) and had higher incidence of major amputation (RR 4.1 [95% CI 1.6–10.7]) and minor amputation (RR 6.2 [95% CI 3.5–11.1])
Jia et al.,[23] 2017	Australia	1	66/441	68/32	62.9 ± 12.8	• Independent risk factors for infection: ulcers healed between 3 and 12 mo (OR 2.3 [95% CI 1.6–3.3]), deep ulcers (OR 2.2 [95% CI 1.2–3.9]), peripheral neuropathy (OR 1.8 [95% CI 1.1–2.9]), previous foot ulcers (OR 1.7 [95% CI 1.2–2.4]), foot deformity (OR 1.4 [95% CI 1.0–2.0]), female gender (OR 1.5 [95% CI 1.1–2.1]) and age (OR 0.98 [95% CI 0.97–0.99]) • No association found between infection and Indigenous background
Rodrigues et al.,[24] 2016	Australia	3	23/106	62.8/37.2	63.43 ± 14.07 (CI 60.98–65.89)	• Indigenous group had higher amputation rate than non-Indigenous group (56.5% v. 29.2%) • Mean age at amputation was similar in Indigenous (62 [SD 12.5] yr [95% CI 55.09–70.14 yr]) and non-Indigenous (62.0 [SD 11.5] yr [95% CI 57.81–66.25 yr]) groups
Rose et al.,[25] 2008	Canada	1	101/224	63/37	59 ± 14 (Aboriginal 55 ± 13, non-Aboriginal 61 ± 14)	• Aboriginal patients had higher rate of any amputation than non-Aboriginal patients (24% v. 15%), but frequency of major amputation (defined in this study as amputation proximal to toes) was not influenced by ethnicity • Aboriginal patients had shorter average time from initial clinic visit to major lower-extremity amputation than non-Aboriginal patients (50 [SD 64] wk v. 62 [SD 56] wk, $p < 0.01$) • Living in rural or reserve community was correlated with shorter average time from initial clinic visit to major lower-extremity amputation than living in urban community (45 [SD 56] wk v. 66 [SD 61] wk, $p < 0.002$) • Aboriginal ethnicity was not associated with poorer clinical outcome when nonurban residence was controlled for • Earlier major lower-extremity amputation was significantly associated with nonurban residence, Aboriginal ethnicity and arterial insufficiency on univariate analysis; however, when nonurban residence was controlled for, Aboriginal ethnicity was not associated with earlier amputation
Tan et al.,[26] 2019	US	12	1654/149 070	66.6/33.4	59.2 ± 13.7 (Aboriginal 54.4 ± 13.3, White 60.7 ± 13.4)	• Native American patients had increasing trend of major amputation over study period • Native American patients had significantly higher major amputation rates than White patients (5.4% v. 7.1%, $p < 0.001$) and higher risk of major amputation (OR 1.47 [95% CI 1.2–1.8]) • Native American patients had lowest rates of open bypass (0.9%) and endovascular revascularization (5.0%) of all ethnic groups studied ($p < 0.001$)

CI = confidence interval; DFU = diabetic foot ulcer; F = female; HR = hazard ratio; M = male; OR = odds ratio; RR = relative risk; SD = standard deviation.
*Except where noted otherwise.

Table 2. Risk of bias within studies

Study	Overall bias: risk of bias judgment	Overall predicted direction of bias for this outcome
Chang et al.[13]	Serious	Unpredictable
Commons et al.[22]	Serious	Unpredictable
Jia et al.[23]	Moderate	Unpredictable
Rodrigues et al.[24]	Moderate	Unpredictable
Rose et al.[25]	Moderate	Unpredictable
Tan et al.[26]	Moderate	Unpredictable

Rose and colleagues[25] reported that, when nonurban residence was controlled for, a poor outcome was similar in Aboriginal and non-Aboriginal people. People living in urban centres have access to specialty care, whereas those in rural areas have limited specialty care and resources. Rural health practitioners may have insufficient diabetic foot knowledge and training to manage some DFU cases.[27] Accessing health facilities in rural areas may also be a challenge owing to travel distance, lost income and the financial cost of journeying to a health care facility. People in rural areas may be reliant on public transportation, which may be inadequate. All of these factors may result in reluctance to seek care. Difficulty in attracting and retaining physicians and other health care workers to maintain high standards of care is a universal problem faced in rural locales.[28]

Cultural constraints (e.g., alternative medicine practices, different perceptions of what can and cannot be done in health facilities, health beliefs) also factor into why some patients may delay seeking care.

Provider bias and preference, known to be present in medicine, may contribute to worse outcomes.[29] Aboriginal patients may have had bad experiences or felt judged in previous encounters with the health care system, and this may contribute to late presentation. This may lead the health care provider to judge them on their late presentation or other social determinants of health (consciously or unconsciously) when they do present, which may lead to biased treatment. A negative feedback loop is thus perpetuated.

Jia and colleagues[23] did not find any association between infection on one hand and geography and ethnicity on the other (including the Indigenous population). Holman and colleagues[30] also found no link between DFU outcomes and ethnic group or social deprivation. They studied a population in the United Kingdom, and an Aboriginal cohort was not represented. Peters and colleagues[31]

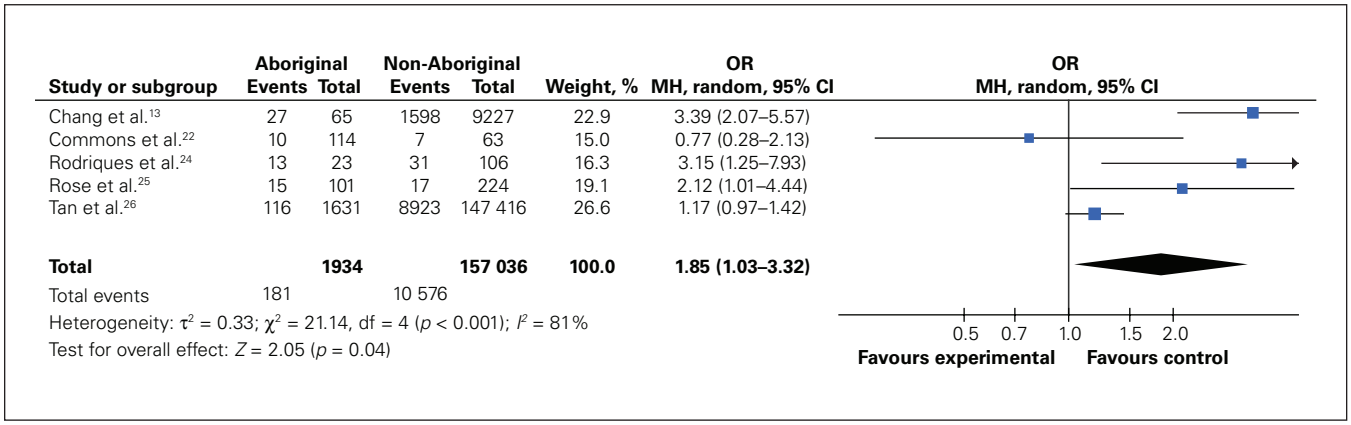

Fig. 2. Effect of Aboriginality on major lower-extremity amputation. CI = confidence interval; df = degrees of freedom; MH = Mantel–Haenszel; OR = odds ratio.

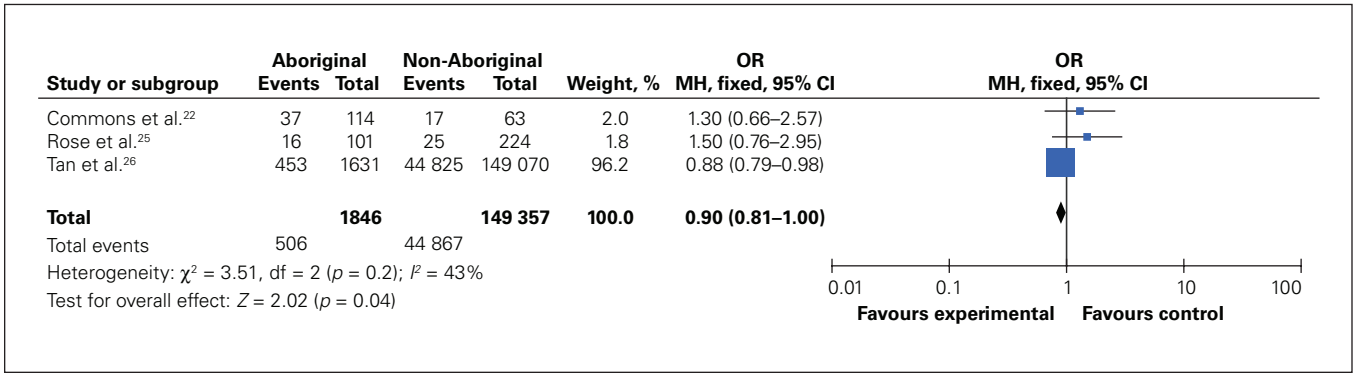

Fig. 3. Effect of Aboriginality on minor lower-extremity amputation. CI = confidence interval; df = degrees of freedom; MH = Mantel–Haenszel; OR = odds ratio.

examined whether socioeconomic factors were a specific risk factor for severe lower-extremity infection and found no association. However, their experimental group consisted of patients admitted with infected foot ulcers, and the control group was a matched cohort of patients with diabetes without a foot infection admitted for another medical or surgical reason. An analysis of the experimental group's sociodemographic characteristics based on their outcomes could perhaps answer the question more directly. All patients were treated in hospital. In a mainly publicly funded health care system such as that in Canada, socioeconomic variables may be more relevant in the community setting than in the hospital setting, as they may affect when a patient decides to seek care and may also determine the degree of outpatient care the patient receives (e.g., antibiotics, wound supplies, off-loading footwear).

Rodrigues and colleagues[24] suggested that the higher amputation rate in Indigenous Australians may be attributable to genetic predisposition. We are unaware of any definitive evidence in the literature confirming this linkage. It is more likely that extrinsic factors are involved. However, it is probable that genetic factors also affect outcomes (positively or negatively).

We suggest that future studies better account for potential confounding variables, especially rural versus urban residence, in their analysis when ethnicity is being studied in the context of DFU.

Knowing what minimum standard of care should be provided to all patients with DFU is a starting point in providing adequate care in such a way as to mitigate the negative effects of these extrinsic factors. The International Working Group on the Diabetic Foot produces practical, specific consensus guidelines on the management and prevention of the diabetic foot.[32] When finding ways to provide care according to these international guidelines to rural and remote areas and to marginalized populations, the specific local barriers faced and the local contexts (cultural and other) should be taken into consideration. Input from stakeholders at the local level would help tailor the way this care is ultimately delivered and may result in more effective care with better outcomes. It may also lead to more cost-effective interventions. With rising government spending on health care, aging populations and the increasing prevalence of chronic medical conditions, this becomes more relevant. A 2015 study by Hopkins and colleagues[33] showed that the per annum costs of DFUs in Canada were substantial: Can$320.5 million for acute institution care, Can$125.4 million for home care and Can$63.1 million for long-term care. The total annual cost associated with DFU-related care was Can$547 million (Can$21 371 per prevalent case). With the projected increase in diabetes prevalence, unless proper programs are in place to manage DFUs, the total costs can be expected to rise.

Finally, an important consideration with respect to studies involving marginalized populations is how to ensure that their voices and experiences are represented. This has implications for how questions are asked, what data are considered relevant, how data are interpreted, and how challenges and opportunities are identified. This could lead to a more responsive health care system and more sustainably beneficial health care policies.

Limitations

We found only 6 studies from 3 of the 4 countries of interest that met our inclusion criteria. Although we grouped the Aboriginal populations in those countries into the same category for this study, they are different and diverse populations. The risk of bias in the included studies was moderate to severe, and the studies were found to be heterogeneous, with varying lengths of follow-up.

Conclusion

There is a relative paucity of comparative data about DFUs in Aboriginal populations. Despite this, our review showed that Aboriginal people with DFUs are almost twice as likely to undergo major amputation as non-Aboriginal people. Individual studies also report poorer outcomes in terms of minor amputation rates, length of hospital stay, antibiotic costs, revascularization rates and rates of DFU healing. It is hoped that, with more widespread implementation of the International Working Group on the Diabetic Foot guidelines, outcomes centred on adherence to these guidelines (in addition to those mentioned in this review) will be reported. This would make analysis of studies across various global regions more accurate and generalizable.

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Contributors: D. Isa designed the study. D. Isa acquired the data, which D. Isa and D. Pace analyzed. D. Isa wrote the manuscript, which D. Pace critically revised. Both authors gave final approval of the article to be published.

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References

1. Ospina MB, Voaklander D, Senthilselvan A, et al. Incidence and prevalence of chronic obstructive pulmonary disease among aboriginal peoples in Alberta, Canada. *PLoS One* 2015;10:e0123204.
2. Teng TH, Katzenellenbogen JM, Hung J, et al. A cohort study: temporal trends in prevalence of antecedents, comorbidities and mortality in Aboriginal and non-Aboriginal Australians with first heart failure hospitalization, 2000–2009. *Int J Equity Health* 2015;14:66.
3. Zhao Y, Connors C, Wright J, et al. Estimating chronic disease prevalence among remote Aboriginal population of the Northern Territory using multiple data sources. *Aust N Z J Public Health* 2008;32:307-13.
4. Kuwornu JP, Lix LM, Shooshtari S. Multimorbidity disease clusters in Aboriginal and non-Aboriginal Caucasian populations in Canada. *Chronic Dis Inj Can* 2014;34:218-25.
5. Wu HX, Wu J, Wong T, et al. Incidence and risk factors for newly acquired hepatitis C virus infection among Aboriginal versus non-Aboriginal Canadians in six regions, 1999–2004. *Eur J Clin Microbiol Infect Dis* 2007;26:167-74.
6. Diabetes. Geneva: World Health Organization; 2021. Available: https://www.who.int/news-room/fact-sheets/detail/diabetes (accessed 2021 Sept. 2).
7. Diabetes in Canada: backgrounder. Ottawa: Diabetes Canada; 2021. Available: https://www.diabetes.ca/DiabetesCanadaWebsite/media/Advocacy-and-Policy/Backgrounder/2021_Backgrounder_Canada_English_FINAL_MAR.pdf (accessed 2021 Sept. 2).
8. Green C, Blanchard J, Young TK, et al. The epidemiology of diabetes in the Manitoba-registered First Nation population: current patterns and comparative trends. *Diabetes Care* 2003; 26:1993e8.
9. Zhang P, Lu J, Jing Y, et al. Global epidemiology of diabetic foot ulceration: a systematic review and meta-analysis. *Ann Med* 2017;49:106-16.
10. Baba M, Davis WA, Norman PE, et al. Temporal changes in the prevalence and associates of foot ulceration in type 2 diabetes: the Freemantle Diabetes Study. *J Diabetes Complications* 2015;29:356-61.
11. Moher D, Liberati A, Tetzlaff J, et al.; the PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ* 2009;339:b2535.
12. Sterne JAC, Hernán MA, Reeves BC, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. *BMJ* 2016;355:i4919.
13. Chang CY, Tan TW, Lo-Ciganic W. Racial and ethnic disparities in lower extremity amputation among Medicare beneficiaries with diabetic foot ulceration and infection in the United States. *Pharmacoepidemiol Drug Saf* 2018;27(Suppl 2):70.
14. Loewen K, Vigliarolo J, Lance B, et al. Rates of diabetes-related lower-limb amputation in northwest Ontario: an incidence study and introduction of a standardized diabetic foot ulcer management protocol. *Can J Rural Med* 2017;22:100-7.
15. O'Rourke S, Steffen C, Raulli A, et al. Diabetic major amputation in Far North Queensland 1998–2008: What is the gap for Indigenous patients? *Aust J Rural Health* 2013;21:268-73.
16. Reid KS, Martin BD, Duerksen F, et al. Diabetic foot complications in a northern Canadian Aboriginal community. *Foot Ankle Int* 2006; 27:1065-73.
17. Robinson TE, Kenealy T, Garrett M, et al. Ethnicity and risk of lower limb amputation in people with type 2 diabetes: a prospective cohort study. *Diabet Med* 2016;33:55-61.
18. Thompson C, McWilliams T, Scott D. Importance of diabetic foot admissions at Middlemore Hospital. *N Z Med J* 1993;106:178-80.
19. West M, Chuter V, Munteanu S, et al. Defining the gap: a systematic review of the difference in rates of diabetes-related foot complications in Aboriginal and Torres Strait Islander Australians and non-Indigenous Australians. *J Foot Ankle Res* 2017;10:48.
20. McIntyre I, Boughen C, Trepman E, et al. Foot and ankle problems of Aboriginal and non-Aboriginal diabetic patients with end-stage renal disease. *Foot Ankle Int* 2007;28:674-86.
21. Steffen C, O'Rourke S. Surgical management of diabetic foot complications: the Far North Queensland profile. *Aust N Z J Surg* 1998; 68:258-60.
22. Commons RJ, Robinson CH, Gawler D, et al. High burden of diabetic foot infections in the top end of Australia: an emerging health crisis (DEFINE study). *Diabetes Res Clin Pract* 2015;110:147-57.
23. Jia L, Parker CN, Parker TJ, et al.; Diabetic Foot Working Group, Queensland Statewide Diabetes Clinical Network (Australia). Incidence and risk factors for developing infection in patients presenting with uninfected diabetic foot ulcers. *PLoS One* 2017;12:e0177916.
24. Rodrigues BT, Vangaveti VN, Malabu UH. Prevalence and risk factors for diabetic lower limb amputation: a clinic-based case control study. *J Diabetes Res* 2016;2016:5941957.
25. Rose G, Duerksen F, Trepman E, et al. Multidisciplinary treatment of diabetic foot ulcers in Canadian Aboriginal and non-Aboriginal people. *Foot Ankle Surg* 2008;14:74-81.
26. Tan TW, Shih CD, Concha-Moore KC, et al. Disparities in outcomes of patients admitted with diabetic foot infections. *PLoS One* 2019;14:e0211481.
27. Schoen DE, Gausia K, Glance DG, et al. Improving rural and remote practitioners' knowledge of the diabetic foot: findings from an educational intervention. *J Foot Ankle Res* 2016;9:26.
28. Douthit N, Kiv S, Dwolatzky T, et al. Exposing some important barriers to health care access in rural USA. *Public Health* 2015; 129:611-20.
29. Schulman KA, Berlin JA, Harless W, et al. The effect of race and sex on physicians' recommendations for cardiac catheterization. *N Engl J Med* 1999;340:618-26.
30. Holman N, Young B, Stephens H, et al. Pilot study to assess measures to be used in the prospective audit of the management of foot ulcers in people with diabetes. *Diabet Med* 2015;32:78-84.
31. Peters EJ, Lavery LA, Armstrong DJ. Diabetic lower extremity infection: influence of physical, psychological, and social factors. *J Diabetes Complications* 2005;19:107-12.
32. Schaper NC, van Netten JJ, Apelqvist J, et al.; IWGDF Editorial Board. Practical Guidelines on the prevention and management of diabetic foot disease (IWGDF 2019 update). *Diab Metab Res Rev* 2020;36(Suppl 1):e3266.
33. Hopkins RB, Burke N, Harlock J, et al. Economic burden of illness associated with diabetic foot ulcers in Canada. *BMC Health Serv Res* 2015;15:13.