Prevalence of self-reported visual impairment in Canadians with and without diabetes: findings from population-based surveys from 1994 to 2014

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Abstract:	Background: Visual impairment (VI) negatively impacts an individual's quality of life. Diabetes is a leading cause of VI. Approximately 1 in 11 Canadian adults are living with diabetes. We assessed trends in the prevalence of VI among Canadians with and without diabetes. Methods: Self-reported data from respondents aged 45+ in seven cycles of nationwide surveys (National Population Health Survey and Canadian Community Health Survey) from 1994/1995 to 2013/2014 were analyzed. The age- and sex-standardized prevalence of VI was calculated using the 2016 Canadian population as the standard. Comparisons by levels of education and income were assessed, utilising sex-standardised prevalence due to sparse data. Results: Among Canadians with diabetes, the age- and sex-standardized VI prevalence was 7.37% (95% confidence interval [CI] 5.31%-9.43%) in 1994/1997, decreasing to 3.03% (95% CI 2.48%-3.57%) in

	2013/2014, giving a standardized prevalence ratio (SPR) of 0.41 (95% CI 0.30-0.56) comparing 2013/2014 to 1994/1997. Among Canadians without diabetes, VI prevalence decreased from 3.72% (95% CI 3.31%-4.14%) in 1994/1997 to 1.69% (95% CI 1.52%-1.87%) in 2013/2014, with an SPR of 0.45 (95% CI 0.40-0.52). Decreased sex-standardized VI prevalence was observed among Canadians with high and low levels of education and incomes in both those with and without diabetes. Interpretation: VI prevalence was roughly two times higher in those with vs without diabetes. From 1994 to 2014, VI prevalence decreased in those with and without diabetes irrespective of education and income levels. These results suggest effective collective efforts by eye care clinicians, other medical clinicians, researchers, the public, and government.

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1,3
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5,6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6,7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6,7
Bias	9	Describe any efforts to address potential sources of bias	8
Study size	10	Explain how the study size was arrived at	6,7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6,7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	8
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	8
		(*e*) Describe any sensitivity analyses	NA
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9
		(b) Indicate number of participants with missing data for each variable of interest	9
Outcome data	15*	Report numbers of outcome events or summary measures	9
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9-11

		(*b*) Report category boundaries when continuous variables were categorized	7
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9-11
Discussion			
Key results	18	Summarise key results with reference to study objectives	11,12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13,14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	11,12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Research Paper

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Meeting Presentation: The study abstract was presented at the Association for Research in Vision & Ophthalmology (ARVO) Annual Meeting in May 2021 and the Canadian Ophthalmological Society (COS) Annual Meeting in June 2021, both presented online due to the COVID-19 pandemic.

Word Counts

Abstract: 250
Manuscript text: 2440
Number of Tables: 2
Number of Figures: 3

Abstract

Background: Visual impairment (VI) negatively impacts an individual's quality of life. Diabetes is a leading cause of VI. Approximately 1 in 11 Canadian adults are living with diabetes. We assessed trends in the prevalence of VI among Canadians with and without diabetes.

Methods: Self-reported data from respondents aged 45+ in seven cycles of nationwide surveys (National Population Health Survey and Canadian Community Health Survey) from 1994/1995 to 2013/2014 were analyzed. The age- and sex-standardized prevalence of VI was calculated using the 2016 Canadian population as the standard. Comparisons by levels of education and income were assessed, utilising sex-standardised prevalence due to sparse data.

Results: Among Canadians with diabetes, the age- and sex-standardized VI prevalence was 7.37% (95% confidence interval [CI] 5.31%-9.43%) in 1994/1997, decreasing to 3.03% (95% CI 2.48%-3.57%) in 2013/2014, giving a standardized prevalence ratio (SPR) of 0.41 (95% CI 0.30-0.56) comparing 2013/2014 to 1994/1997. Among Canadians without diabetes, VI prevalence decreased from 3.72% (95% CI 3.31%-4.14%) in 1994/1997 to 1.69% (95% CI 1.52%-1.87%) in 2013/2014, with an SPR of 0.45 (95% CI 0.40-0.52). Decreased sex-standardized VI prevalence was observed among Canadians with high and low levels of education and incomes in both those with and without diabetes.

Interpretation: VI prevalence was roughly two times higher in those with vs without diabetes. From 1994 to 2014, VI prevalence decreased in those with and without diabetes irrespective of

education and income levels. These results suggest effective collective efforts by eye care clinicians, other medical clinicians, researchers, the public, and government.

Trial registration: Not applicable

Key words: Visual impairment, prevalence, diabetes, population surveys, self-report

Visual impairment (VI) is recognised as a major public health issue due to its significant impacts on independence, risk of accidents/injuries, falls, depression, and quality of life.[1-4] Diabetes is a leading cause of VI in developed countries, particularly in working-age individuals, owing to the development of diabetic retinopathy and diabetic macular edema.[5] In Canada the prevalence of diabetes increased 37.3% between 2003/2004 and 2013/2014, with an annual increase rate of 1.2% since 2010.[6] Approximately 3.2 million Canadians, or 1 in 11 adults aged 20+, were living with diabetes in 2016/2017.[7]

Given the fast-rising prevalence of diabetes in recent decades, it is important to know whether the prevalence of VI has also increased. This will help us understand the magnitude and burden of VI, guide necessary health and social service planning, and aid in the development of strategies and policies for VI prevention and management. We assessed time trends in VI prevalence among Canadians with and without diabetes over the past two decades and determined if the trends were similar amongst Canadians with different levels of education and income.

Methods

Setting and Study Design

The study setting included the 10 provinces of Canada. The study design was repeated, population-based, cross-sectional surveys conducted in 1994/1995, 1996/1997, 1998/1999, 2000/2001, 2008/2009, 2009/2010, and 2013/2014.

Data Source and Participants

Data analyzed were obtained from seven cycles of nationwide surveys: the 1994/1995, 1996/1997 and 1998/1999 cycles of the National Population Health Survey (NPHS) and the 2000/2001, 2008/2009 Healthy Aging, 2009/2010 and 2013/2014 cycles of the Canadian Community Health Survey (CCHS).

The CCHS and NPHS are cross-sectional surveys with participants randomly selected across the country by Statistics Canada. The surveys covered 98% of Canadians aged 12+ living in private dwellings.[8,9] Overall response rates ranged from 69.7% to 92.8% for the NPHS and 72.3% to 87.3% for the CCHS.[8,10-15] Only respondents aged 45+ were included in the analysis since VI is an age-related condition and the CCHS 2008/2009 Healthy Aging cycle only included individuals aged 45+.[16]

Outcome Measure

The study outcome was self-reported VI. This information was obtained from the survey questions:

> *1. Are you usually able to see well enough to read ordinary newsprint without glasses or contact lenses?*
> *2. Are you usually able to see well enough to read ordinary newsprint with glasses or contact lenses?*
> *3. Are you able to see at all?*
> *4. Are you able to see well enough to recognize a friend on the other side of the street without glasses or contact lenses?*
> *5. Are you usually able to see well enough to recognize a friend on the other side of the street with glasses or contact lenses?*

In this analysis, respondents who provided a negative response to questions 2, 3, or 5 were considered as having self-reported VI. Respondents with a positive answer to the above questions were categorized as not having self-reported VI.

Diabetes Measure

Participants who self-reported that they had diabetes diagnosed by a health professional were considered as having diabetes. Conversely, those who responded as not having diabetes diagnosed by a health professional were deemed as not having diabetes.

Other Measures

Participant age and sex was self-reported. Information on the highest level of education attained by participants was obtained through a series of questions and was categorized by Statistics Canada into four levels: "Less than secondary school graduation", "Secondary school graduation, no post-secondary", "Some post-secondary education", and "Post-secondary certificate/diploma or university degree".[17] In this analysis, we further consolidated participants into low (less than secondary school graduation or secondary school graduation) and high (some post-secondary education or post-secondary certificate/diploma or university degree) levels to avoid sparse data. Similarly, data on total household income was collected through a series of questions by Statistics Canada, which were grouped into low (below middle) and mid/high (middle or higher) levels of household income for each survey (See details in Table 1 footnote).

Statistical Analyses

The prevalence of VI was calculated as the proportion of individuals with VI among all respondents. Prevalence estimates were stratified by diabetes status as well as level of education and household income. Survey weights provided by Statistics Canada were used in all analyses to account for sample selection, complex survey design, and adjust for seasonal effects, post-stratification, non-response and calibration.[18] Weighted data are more representative of the surveyed population and are required by Statistics Canada when reporting population estimates.[18] Weighted prevalence estimates and 95% confidence intervals (CIs) were directly age- and sex-standardized to the 2016 Canadian census to allow for valid comparisons.[19] For analyses stratified by levels of education and income, only sex-standardized prevalence was calculated due to small sample sizes when stratifying by both age and sex. The standard errors and associated 95% CIs of prevalence estimates were calculated using the bootstrap weights provided by Statistics Canada. Due to small cell sizes, the 1994/1995 and 1996/1997 cycles of the NPHS and the 1998/1999 and 2000/2001 cycles of the NPHS and CCHS were combined for calculating overall prevalence estimates and education-stratified estimates.[20] For similar reasons, the 1998/1999 cycle of the NPHS was combined with the 2000/2001 cycle of the CCHS for calculating income-stratified estimates. Standardized prevalence ratios (SPR) and associated 95% CIs were calculated to compare the prevalence of VI in 2013/2014 versus 1994/1997.[21] Additive and multiplicative interaction for education-diabetes and income-diabetes were assessed.[22] Participants who answered "Don't know" or refused to answer the relevant questions were treated as missing values and were excluded from the analyses. All statistical analyses were conducted using SAS 9.4 (SAS Institute, Inc., Cary, NC).

Ethics Approval

Informed consent was obtained by Statistics Canada from all survey participants. This study was approved by the University of Toronto Research Ethics Board.

Results

Participant Characteristics

The unweighted number of participants who had a valid answer to VI ranged from 6,930 in 1998/1999 to 75,808 in 2013/2014. For diabetes, this number ranged from 6,947 in 1998/1999 to 77,032 in 2013/2014. Unweighted missing values were 17-1,224 (0.00%-0.02%) for VI and 1-127 (0.00%-0.00%) for diabetes.

The characteristics of participants with and without diabetes are shown in **Table 1**. The weighted number of Canadians with diabetes aged 45+ increased from 607,100 in 1994/1995 to 1,772,200 in 2013/2014. Among Canadians with diabetes, the weighted number of individuals with VI decreased from 57,200 in 1994/1995 to 53,900 in 2013/2014. Among those without diabetes, the number of individuals with VI decreased from 344,400 in 1994/1995 to 205,900 in 2013/2014. Missing values for included variables ranged from 0% for age and sex to 18.9% for income.

Overall Trends in the Prevalence of VI

The trend in the age- and sex-standardized VI prevalence among people with and without diabetes is shown in Figure 1. In all survey years, the prevalence of VI was about two times higher among Canadians with diabetes than those without. A consistently decreasing VI prevalence was observed among both with and without diabetes groups. Among those with diabetes, the prevalence of VI decreased from 7.37% (95% CI 5.31%-9.43%) in 1994/1997 to

3.02% (95% CI 2.48%-3.57%) in 2013-2014, giving an SPR of 0.41 (95% CI 0.30-0.56) for 2013/2014 versus 1994/1997. Among those without diabetes, the prevalence of VI decreased from 3.72% (95% CI 3.31%-4.14%) in 1994-1997 to 1.69% (95% CI 1.52%-1.87%) in 2013-2014, with an SPR of 0.45 (95% CI 0.40-0.52) for 2013/2014 versus 1994/1997.

Trends in the Prevalence of VI Stratified by Levels of Education and Diabetes Status

Figure 2 shows a decreasing prevalence of VI in all subgroups stratified by level of education and diabetes status from 1994 to 2014. In the low-education stratum, the sex-standardized prevalence of VI decreased from 9.96% (95% CI 6.91%-13.02%) in 1994-1997 to 3.57% (95% CI 2.84%-4.29%) in 2013-2014 for those with diabetes, and from 4.16% (95% CI 3.52%-4.79%) in 1994-1997 to 2.18% (95% CI 1.87%-2.48%) in 2013-2014 for those without diabetes. In the high-education stratum, the VI prevalence similarly decreased from 6.04% (95% CI 2.20%-9.88%) in 1994-1997 to 3.06% (95% CI 2.21%-3.91%) in 2013/2014 for those with diabetes, and from 2.68% (95% CI 2.19%-3.17%) in 1994/1997 to 1.21% (95% CI 1.01%-1.41%) in 2013-2014 for those without diabetes.

Figure 2 also shows that the sex-standardized VI prevalence was highest in Canadians with low levels of education and diabetes, and lowest in those with high levels of education and no diabetes in all survey years, except for 1998/2001. Evaluations of interactions regarding the joint presence of low levels of education and having diabetes on the prevalence of VI are shown in Table 2 (upper part). In 2013-2014, the observed SPR for joint presence of low level of education and diabetes was smaller than the expected joint SPR from both the additive (2.36 vs 2.82) and multiplicative model (2.95 vs 4.56), indicating the presence of negative additive and

negative multiplicative interaction. Thus, interventions for VI tailored specifically to those with low levels of education and diabetes might not have a larger effect.

Trends in Prevalence of VI Stratified by Levels of Household Income and Diabetes Status

Similar to the results grouped by level of education and diabetes status, a decreased VI prevalence over time was observed after stratification by household income level and diabetes status (Figure 3). The highest sex-standardized VI prevalence was found in Canadians with low levels of household income and diabetes, and the lowest in those with high levels of income and no diabetes in all survey years, except for 1998/2001. Evaluation of the interaction between the joint presence of low level of household income and diabetes on the prevalence of VI are shown in Table 2 (lower part). In 2013/2014, there was evidence of positive additive interaction (observed SPR of 3.39 vs. expected SPR of 2.86), suggesting VI interventions targeting those with low levels of household income and diabetes may likely yield a benefit larger than expected based on the additive model.

Interpretation

This study assessed VI trends amongst Canadians with and without diabetes over two decades. We report that while the number of Canadians aged 45+ with diabetes nearly tripled from 1994/1995 (607,100) to 2013/2014 (1,772,200), the number of people with VI amongst those with diabetes decreased (57,200 in 1994/1995 to 53,900 in 2013/2014). Among both people with and without diabetes, the age- and sex-adjusted VI prevalence decreased by more than half, with an SPR of 0.41 for those with diabetes and 0.45 for those without diabetes. Sex-adjusted analyses after stratification by education and income levels also showed a decreasing trend from 1994 to

2014. Furthermore, we report the prevalence of VI was about two times higher in Canadians with diabetes than those without in all survey years. The highest prevalence of VI was found in Canadians with diabetes and low levels of education or income, and the lowest amongst those without diabetes and with mid/high levels of education or income. In 2013/2014, a positive additive interaction between diabetes and low levels of household income was noted. Thus, VI interventions should be targeted at those with diabetes and low levels of household income.

Our finding of decreased prevalence of VI from 1994 to 2014 complements reports from other countries regarding VI.[23,24] In Europe, a meta-analysis by Delcourt *et al.* on the age-adjusted prevalence of VI and blindness in individuals aged 55+ reported that VI prevalence decreased from 2.22% for the period of 1991-2006 to 0.92% for the period of 2007-2012.[23] In another meta-analysis, Flaxman *et al.* similarly reported that the age-adjusted prevalence of VI in people aged 50+ decreased from 1990 to 2015 globally.[24] However, these reports did not distinguish between people with and without diabetes, and used pooled data from different countries with different healthcare systems. Using data from Canada, which has universal healthcare, we report that VI prevalence decreased in people with and without diabetes from 1994 to 2014, irrespective of their level of education and income. We believe these results likely reflect the collective efforts by eye care clinicians, other medical clinicians, researchers, the public, and government to prevent vision loss.

Our results also agree with studies that have reported a significantly higher prevalence of VI in people with diabetes than those without.[25-27] We report that despite the prevalence of VI continuously decreasing over time, the prevalence of VI in the most recent survey year

2013/2014 was still significantly higher in Canadians with diabetes vs. those without (3.03% vs. 1.69%). This demonstrates that diabetes is still a major cause of VI in Canada. Preventing and treating diabetes and diabetic retinopathy needs to remain a priority in Canada. Amongst those with diabetes, early detection, good blood sugar control, and treatment of VI through screening programs and diabetic eye exams are essential to protect vision, since vision loss from diabetic retinopathy and diabetic macular edema can be irreversible. Low income earners with diabetes are less likely to utilise recommended diabetic eye examinations despite universal health coverage.[28-30] Reported barriers include limited accessibility to eye care clinicians due to geographic challenges and lack of knowledge about eye screening services.[31-33] Programs to increase the uptake of diabetic eye exams, particularly those aimed at poor neighborhoods, including diabetic eye screening services in primary care settings (e.g. the tele-retinal screening program in Toronto) are effective and highly recommended.[34]

Limitations

This study has several limitations. First, information on VI was self-reported, not clinically confirmed, and in some cases may be correctable through corrective eyewear and surgery. However, regardless of whether the reported VI is correctable, people continue to live with this condition, which reflects real-life vision challenges faced by many individuals. Second, although self-reported diabetes has an excellent specificity (87.8%-98.6%), it has only a moderate sensitivity (41.5%-70.4%).[35-37] Moderate sensitivity may lead to misclassification of some individuals with diabetes as not having diabetes, resulting in an over-estimation of VI prevalence. However, we are not aware of evidence that suggests the validity of self-reported diabetes changes with time. Therefore, we do not think misclassification of self-reported diabetes

would impact the decreasing trend reported. Third, the most recent data available on VI is the CCHS 2013/2014 due to survey content changes by Statistics Canada. Although VI data from more recent years are desirable, our results provide a 20-year historic picture for use in future comparisons.

Conclusion

In conclusion, the prevalence of VI in Canada is higher in people with diabetes versus those without. Overall, the prevalence of VI in Canada decreased from 1994 to 2014. This trend was observed in all subgroups stratified by diabetes status and level of education and income. Statistics Canada should be encouraged to keep VI questions in future surveys to allow for ongoing analysis of the vision health of Canadians. To reduce VI burden in Canada, efforts and research should continue to focus on diabetes education, treatment and prevention as well as improving access to diabetic eye exams particularly for those from lower-income households.

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Author Contributions: James H.B. Im led data analyses, drafted and revised the manuscript, and prepared tables and figures. Ya-Ping Jin, Graham E. Trope, Yvonne M. Buys, Peng Yan, Michael H. Brent, and Sophia Y. Liu conceived the study. Ya-Ping Jin designed the study, acquired data access, resolved analysis related issues and led the manuscript revision. All authors contributed to data interpretation, revised the manuscript critically for important intellectual content, gave final approval of the version to be published and agreed to act as guarantors of this work and take responsibility for the contents of the article.

Data Sharing: Access to this third-party data set is through the Statistics Canada Research Data Centres (RDCs) Program, which has centres at universities across Canada. Research Data Centres are operated under the provisions of the Canadian Statistics Act, which states that persons retained under contract to perform special services under this act are deemed to be persons employed under this act while performing those services, in accordance with all the confidentiality rules. Anyone may apply to access the data by submitting a research proposal that justifies the need for access to confidential microdata to address a question that has relevance for the Canadian population. On approval, researchers undergo a deeming process, and a contract is granted. Thus, access to the data is granted on a need-to-know basis. For those interested in obtaining access to these data sets, detailed contact information and application processes to gain access and guidelines to use RDC data can be found at https://www.statcan.gc.ca/eng/rdc/process.

References

1. Hong T, Mitchell P, Burlutsky G, Samarawickrama C, Wang JJ. Visual Impairment and the Incidence of Falls and Fractures Among Older People: Longitudinal Findings From the Blue Mountains Eye Study. Invest Ophthalmol Vis Sci. 2014;55(11):7589-93.
2. Yip JLY, Khawaja AP, Broadway D, Luben R, Hayat S, Dalzell N, et al. Visual acuity, self-reported vision and falls in the EPIC-Norfolk Eye study. Br J Ophthalmol. 2014;98(3):377-82.
3. Jin Y-P, Wong DT. Self-reported visual impairment in elderly Canadians and its impact on healthy living. Can J Ophthalmol. 2008;43(4):407-13.
4. Crews JE, Chou CF, Zack MM, Zhang X, Bullard KM, Morse AR, et al. The Association of Health-Related Quality of Life with Severity of Visual Impairment among People Aged 40–64 Years: Findings from the 2006–2010 Behavioral Risk Factor Surveillance System. Ophthalmic Epidemiol. 2016;23(3):145-53.
5. Diabetes Canada Clinical Practice Guidelines Expert Committee; Altomare F, Kherani A, Lovshin J. Retinopathy. Can J Diabetes. 2018;42 Suppl 1:S210-S216.
6. Government of Canada. Diabetes in Canada [Internet]. Ottawa (ON): Government of Canada; [updated 2020 Aug 17; cited 2022 Mar 26]. Available from: https://www.canada.ca/en/public-health/services/publications/diseases-conditions/diabetes-canada-highlights-chronic-disease-surveillance-system.html.
7. LeBlanc AG, Jun Gao Y, McRae L, Pelletier C. At-a-glance - Twenty years of diabetes surveillance using the Canadian Chronic Disease Surveillance System. Health Promot Chronic Dis Prev Can. 2019;39(11):306-9.
8. Statistics Canada. National Population Health Survey: Household Component, Cross-sectional (NPHS). Detailed Information for 1998-1999 [Internet]. Ottawa (ON): Statistics Canada; [updated 2007 Oct 24; cited 2021 Jan 10]. Available from: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3236.
9. Statistics Canada. Canadian Community Health Survey - Annual Component (CCHS) [Internet]. Ottawa (ON): Statistics Canada; [updated 2021 Dec 29; cited 2021 Jan 10]. Available from: https://www.statcan.gc.ca/en/survey/household/3226.
10. Statistics Canada. National Population Health Survey: Household Component, Cross-sectional (NPHS). Detailed Information for 1994-1995 [Internet]. Ottawa (ON): Statistics Canada; [updated 2007 Oct 24; cited 2021 Jan 10]. Available from: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&Id=3732.
11. Statistics Canada. National Population Health Survey: Household Component, Cross-sectional (NPHS). Detailed Information for 1996-1997 [Internet]. Ottawa (ON): Statistics Canada; [updated 2007 Oct 24; cited 2021 Jan 10]. Available from: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&Id=4520.
12. Statistics Canada. CCHS Cycle 1.1 (2000-2001), Public Use Microdata File Documentation. Ottawa (ON): Statistics Canada.
13. Statistics Canada. Canadian Community Health Survey (CCHS) – Healthy Aging User Guide. Ottawa (ON): Statistics Canada.
14. Statistics Canada. 2010 and 2009-2010 CCHS Microdata File User Guide. Ottawa (ON): Statistics Canada.

15. Statistics Canada. 2014 and 2013-2014 CCHS Microdata File User Guide. Ottawa (ON): Statistics Canada.
16. Statistics Canada. Canadian Community Health Survey - Healthy Aging (CCHS) [Internet]. Ottawa (ON): Statistics Canada; [updated 2008 Nov 27; cited 2021 Jan 10]. Available from: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=5146.
17. Statistics Canada. Canadian Community Health Survey (CCHS) Derived Variable (DV) Specifications. Ottawa (ON): Statistics Canada; [2011 Jun; cited 2021 Jan 10]. Available from: http://www23.statcan.gc.ca/imdb-bmdi/pub/document/3226_D5_T9_V1-eng.pdf.
18. Statistics Canada. Canadian Community Health Survey (CCHS) Household Weights Documentation. Ottawa (ON): Statistics Canada; [2010 May; cited 2021 Jan 10]. Available from: https://www23.statcan.gc.ca/imdb-bmdi/pub/document/3226_D57_T9_V1-eng.htm.
19. Naing NN. Easy way to learn standardization : direct and indirect methods. Malays J Med Sci. 2000;7(1):10-5.
20. Thomas S, Wannell B. Combining cycles of the Canadian Community Health Survey. Health Rep. 2009;20(1):53-8.
21. Boyle P, Parkin DM. Cancer registration: principles and methods. Statistical methods for registries. IARC Sci Publ. 1991;95:126-58.
22. Szklo, & Nieto, F. J. (2019). Epidemiology : beyond the basics (Fourth edition.). Jones & Bartlett Learning.
23. Delcourt C, Le Goff M, von Hanno T, Mirshahi A, Khawaja AP, Verhoeven VJM, et al. The Decreasing Prevalence of Nonrefractive Visual Impairment in Older Europeans: A Meta-analysis of Published and Unpublished Data. Ophthalmology. 2018;125(8):1149-59.
24. Flaxman SR, Bourne RRA, Resnikoff S, Ackland P, Braithwaite T, Cicinelli MV, et al. Global causes of blindness and distance vision impairment 1990–2020: a systematic review and meta-analysis. Lancet Glob Health. 2017;5(12):e1221-e1234.
25. Norris KL, Beckles GL, Chou CF, Zhang X, Saaddine J. Association of Socioeconomic Status with Eye Health Among Women With and Without Diabetes. J Womens Health (Larchmt). 2016;25(3):321-6.
26. Yan X, Chen L, Yan H. Socio-economic status, visual impairment and the mediating role of lifestyles in developed rural areas of China. PLoS One. 2019;14(4):e0215329.
27. Perruccio AV, Badley EM, Trope GE. A Canadian population-based study of vision problems: Assessing the significance of socioeconomic status. Can J Ophthalmol. 2010;45(5):477-83.
28. Pampel FC, Krueger PM, Denney JT. Socioeconomic Disparities in Health Behaviors. Annu Rev Sociol. 2010 Aug;36:349-70.
29. Mcmaughan DJ, Oloruntoba O, Smith ML. Socioeconomic Status and Access to Healthcare: Interrelated Drivers for Healthy Aging. Front Public Health. 2020;8:231.
30. Ballios BG, Park T, Chaudhary V, Hurley B, Kosar S, Sheidow T, et al. Identifying gaps in patient access to diabetic screening eye examinations in Ontario: a provincially representative cross-sectional study. Can J Ophthalmol. 2021;56(4):223-30.
31. Egunsola O, Dowsett LE, Diaz R, Brent MH, Rac V, Clement FM. Diabetic Retinopathy Screening: A Systematic Review of Qualitative Literature. Can J Diabetes. 2021;45(8):725-33.

32. Leese GP, Boyle P, Feng Z, Emslie-Smith A, Ellis JD. Screening uptake in a well-established diabetic retinopathy screening program: the role of geographical access and deprivation. Diabetes Care. 2008;31(11):2131-5.
33. Maberley DAL, Koushik A, Cruess AF. Factors associated with missed eye examinations in a cohort with diabetes. Can J Public Health. 2002;93(3):229–32.
34. Felfeli T, Alon R, Merritt R, Brent MH. Toronto tele-retinal screening program for detection of diabetic retinopathy and macular edema. Can J Ophthalmol. 2019;54(2):203-11.
35. Goto A, Morita A, Goto M, Sasaki S, Miyachi M, Aiba M, et al. Validity of diabetes self-reports in the Saku diabetes study. J Epidemiol. 2013;23(4):295-300.
36. Yuan X, Liu T, Wu L, Zou Z-Y, Li C. Validity of self-reported diabetes among middle-aged and older Chinese adults: the China Health and Retirement Longitudinal Study. BMJ Open. 2015;5(4):e006633.
37. de Menezes TN, Oliveira ECT. Validity and concordance of self-reported diabetes mellitus by the elderly. Cien Saude Colet. 2019;24(1):27-34.

Figure Legend

Figure 1. The age- and sex-standardized prevalence of visual impairment in the 10 Canadian provinces from 1994 to 2014

Figure 2. The sex-standardized prevalence of visual impairment in the 10 Canadian provinces stratified by education levels from 1994 to 2014. **A.** Low level of education. **B.** Mid/high level of education

Figure 3. The sex-standardized prevalence of visual impairment in the 10 Canadian provinces stratified by household income levels from 1994 to 2014. **A.** Low level of household income. **B.** Mid/high level of household income

Table 1. Weighted characteristics of participants aged 45+ in the National Population Health Survey (NPHS) and the Canadian Community Health Survey (CCHS) with and without diabetes, 1994-2014

People with Diabetes														
	NPHS and CCHS Cycles													
	1994/1995 (unweighted n=525)		1996/1997 (unweighted n=2,322)		1998/1999 (unweighted n=537)		2000/2001 (unweighted n=5,431)		2008/2009 (unweighted n=4,384)		2009/2010 (unweighted n=8,866)		2013/2014 (unweighted n=10,566)	
	n (100's)	%	n (100's)	%	n (100's)	%	n (100's)	%	n (100's)	%	n (100's)	%	n (100's)	%
Age														
45-64	2438	40.2	3109	46.5	3231	44.7	4356	48.5	7986	51.5	7715	49.2	8478	47.8
65-74	2272	37.4	2064	30.9	2177	30.1	2767	30.8	4239	27.3	4347	27.7	5400	30.5
75+	1361	22.4	1511	22.6	1824	25.2	1855	20.7	3280	21.2	3615	23.1	3845	21.7
45+	6071	100.0	6683	100.0	7232	100.0	8978	100.0	15505	100.0	15677	100.0	17722	100.0
Sex														
Male	3102	51.1	3655	54.7	3868	53.5	4752	52.9	8198	52.9	8881	56.6	9827	55.5
Female	2969	48.9	3027	45.3	3365	46.5	4226	47.1	7307	47.1	6796	43.4	7895	44.5
Annual Household Income*														
Low Income	2044	33.7	2952	44.2	3557	49.2	3638	40.5	5762	37.2	5516	35.2	7230	40.8
Mid/High Income	3713	61.2	2633	39.4	3177	43.9	4295	47.8	7026	45.3	7205	46.0	10488	59.2
Missing	314	5.2	1097	16.4	498	6.9	1045	11.6	2717	17.5	2956	18.9	4	0.0
Highest Level of Education Achieved														
No Post-Secondary Education	3896	64.2	4159	62.2	4422	61.1	5522	61.5	8260	53.3	7321	46.7	8660	48.9
Post-Secondary Education or higher	2055	33.8	2472	37.0	2773	38.3	3341	37.2	6941	44.8	7768	49.6	8557	48.3
Missing	120	2.0	52	0.8	37	0.5	115	1.3	304	2.0	587	3.7	506	2.9
Visual Impairment														
Yes	572	9.4	473	7.1	525	7.3	521	5.8	567	3.7	470	3.0	539	3.0

No	5431	89.4	6188	92.6	6705	92.7	8420	93.8	14819	95.6	15060	96.1	16943	95.6
Missing	69	1.1	22	0.3	3	0.0	36	0.4	119	0.8	147	0.9	241	1.4
People without Diabetes														
	NPHS and CCHS Cycles													
	1994/1995 (unweighted n=7,059)		1996/1997 (unweighted n=30,039)		1998/1999 (unweighted n=6,410)		2000/2001 (unweighted n=55,156)		2008/2009 (unweighted n=26,468)		2009/2010 (unweighted n=59,771)		2013/2014 (unweighted n=66,466)	
	n (100's)	%	n (100's)	%	n (100's)	%	n (100's)	%	n (100's)	%	n (100's)	%	n (100's)	%
Age														
40-64	57140	66.5	60218	66.3	63541	67.3	68222	68.2	84602	70.1	86033	70.2	89101	67.6
65-74	18289	21.3	18888	20.8	17747	18.8	18762	18.8	19833	16.4	21020	17.2	25719	19.5
75+	10536	12.3	11685	12.9	13059	13.8	13003	13.0	16314	13.5	15461	12.6	16902	12.8
45+	85964	100.0	90791	100.0	94346	100.0	99987	100.0	120749	100.0	122515	100.0	131722	100.0
Sex														
Male	40519	47.1	42634	47.0	44375	47.0	47062	47.1	57284	47.4	57639	47.0	62392	47.4
Female	45445	52.9	48157	53.0	49972	53.0	52925	52.9	63465	52.6	64876	53.0	69330	52.6
Annual Household Income*														
Low Income	21201	24.7	29913	32.9	31363	33.2	26440	26.4	28414	23.5	28848	23.5	36393	27.6
Mid/High Income	60114	69.9	44667	49.2	55883	59.2	61970	62.0	71573	59.3	72301	59.0	95299	72.3
Missing	4649	5.4	16211	17.9	7100	7.5	11578	11.6	20762	17.2	21365	17.4	30	0.0
Highest Level of Education Achieved														
No Post-Secondary Education	44692	52.0	45833	50.5	44915	47.6	49601	49.6	48754	40.4	43195	35.3	48942	37.2
Post-Secondary Education	41105	47.8	43878	48.3	49385	52.3	49325	49.3	70509	58.4	75587	61.7	80189	60.9
Missing	167	0.2	1080	1.2	46	0.0	1062	1.1	1486	1.2	3732	3.0	2591	2.0
Visual Impairment														
Yes	3444	4.0	2702	3.0	3452	3.7	2252	2.3	1948	1.6	1961	1.6	2059	1.6
No	81801	95.2	87689	96.6	90717	96.2	97333	97.3	118297	98.0	119689	97.7	128280	97.4

Missing	720	0.8	400	0.4	177	0.2	403	0.4	504	0.4	865	0.7	1384	1.1

* Low income: an annual household income of $0-$19,999 for the 1994/1995 NPHS cycle, $0-$29,999 for the 1996/1997 and 1998/1999 NPHS cycles as well as the 2000/2001 CCHS cycle, and $0-$39,999 for the 2008/2009, 2009/2010 and 2013/2014 CCHS cycles. In 2013/2014, missing income data were imputed by Statistics Canada.[18]

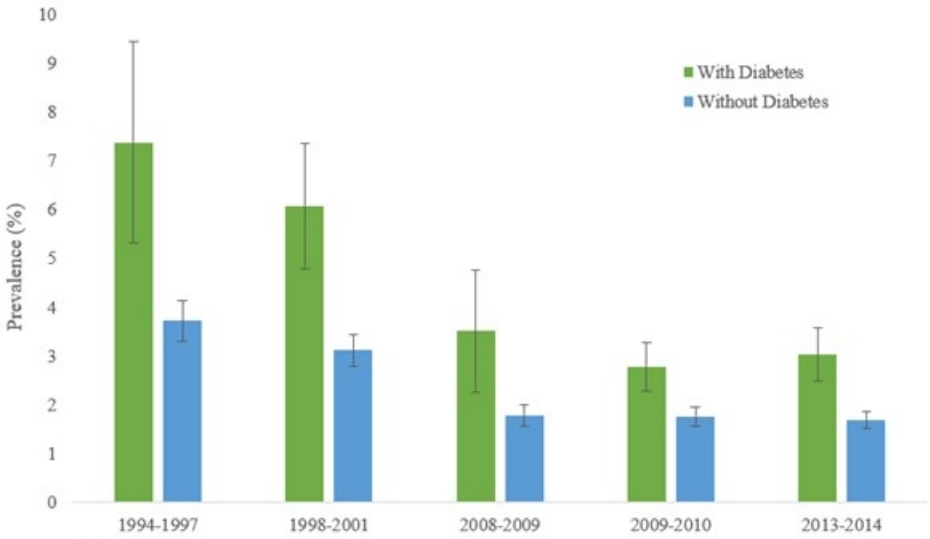
Table 2. The observed (95% CI) and expected joint standardized prevalence ratio (SPR) from the additive and multiplicative models in assessing the joint effects of diabetes and level of education (upper part) and level of household income (lower part) on the prevalence of visual impairment (VI)

		Observed joint SPR	Expected joint SPR	Suggested presence of interaction
Education+Diabetes+ vs Education-Diabetes-[a]				
1994/1997	Additive Model	7.28 (7.25-7.31)	4.84	Positive additive
	Multiplicative Model	3.72 (2.39-5.79)	3.50	
1998/2001	Additive Model	4.22 (4.20-4.24)	5.94	Negative additive and negative multiplicative
	Multiplicative Model	2.80 (2.11-3.71)	4.57	
2008/2009	Additive Model	2.38 (2.37-2.39)	2.75	Negative additive and negative multiplicative
	Multiplicative Model	3.05 (2.45-3.80)	4.72	
2009/2010	Additive Model	2.67 (2.66-2.68)	1.55	Positive additive
	Multiplicative Model	3.10 (2.49-3.87)	2.59	
2013/2014	Additive Model	2.36 (2.35-2.37)	2.82	Negative additive and negative multiplicative
	Multiplicative Model	2.95 (2.42-3.60)	4.56	
Income+Diabetes+ vs Income-Diabetes-[b]				
1994/1995	Additive Model	9.48 (9.41-9.55)	8.14	Positive additive
	Multiplicative Model	3.72 (1.94-7.14)	4.73	
1996/1997	Additive Model	5.03 (5.00-5.06)	7.76	Negative additive and negative multiplicative
	Multiplicative Model	3.32 (2.18-5.05)	6.96	
1998/2001	Additive Model	6.23 (6.21-6.25)	6.01	Positive additive and negative multiplicative
	Multiplicative Model	4.08 (2.83-5.89)	6.19	
2008/2009	Additive Model	2.93 (2.91-2.94)	3.86	Negative additive and negative multiplicative
	Multiplicative Model	4.05 (3.09-5.31)	9.06	
2009/2010	Additive Model	3.01 (3.00-3.02)	2.09	Positive additive

	Multiplicative Model	3.57 (2.84-4.49)	3.57	
2013/2014	Additive Model	3.39 (3.38-3.40)	2.86	Positive additive
	Multiplicative Model	3.90 (3.06-4.97)	4.91	

[a]Education-Diabetes-: Mid/high level of education without diabetes; Education+Diabetes+: Low level of education with diabetes

[b]Income-Diabetes-: Mid/high level of household income without diabetes; Income+Diabetes+: Low level of household income with diabetes

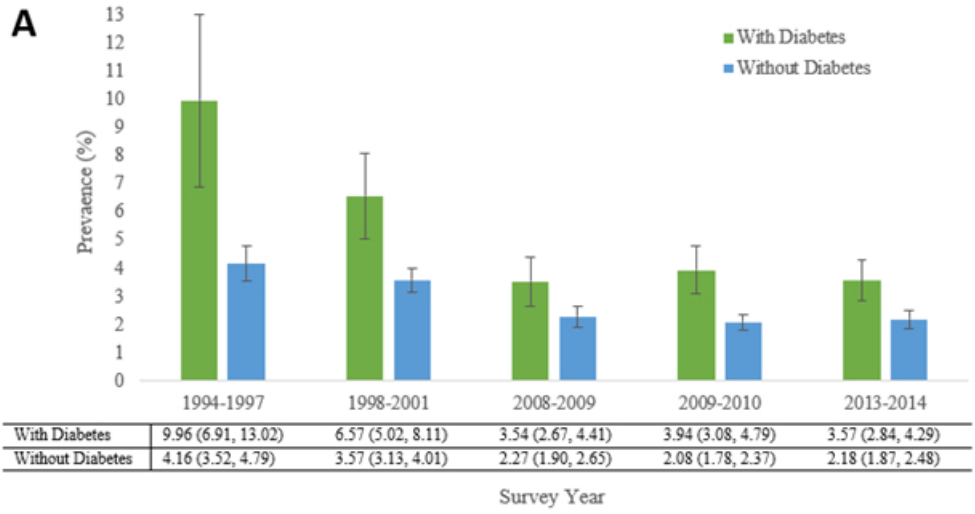


	1994-1997	1998-2001	2008-2009	2009-2010	2013-2014
With Diabetes	7.37 (5.31, 9.43)	6.07 (4.79, 7.35)	3.51 (2.26, 4.76)	2.78 (2.28, 3.28)	3.03 (2.48, 3.57)
Without Diabetes	3.72 (3.31, 4.14)	3.11 (2.80, 3.43)	1.79 (1.57, 2.00)	1.77 (1.57,1.97)	1.69 (1.52, 1.87)

Survey Cycle

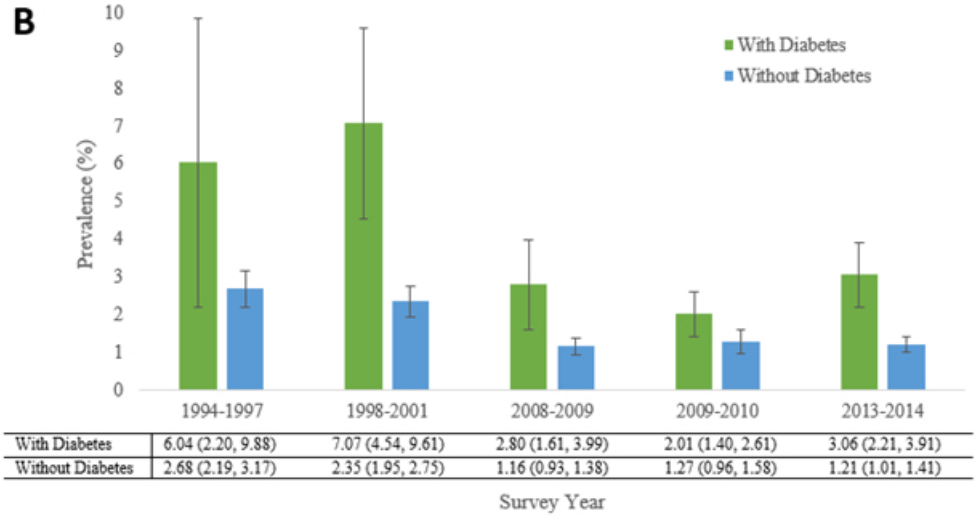
Figure 1. The age- and sex-standardized prevalence of visual impairment in the 10 Canadian provinces from 1994 to 2014

165x106mm (96 x 96 DPI)



	1994-1997	1998-2001	2008-2009	2009-2010	2013-2014
With Diabetes	9.96 (6.91, 13.02)	6.57 (5.02, 8.11)	3.54 (2.67, 4.41)	3.94 (3.08, 4.79)	3.57 (2.84, 4.29)
Without Diabetes	4.16 (3.52, 4.79)	3.57 (3.13, 4.01)	2.27 (1.90, 2.65)	2.08 (1.78, 2.37)	2.18 (1.87, 2.48)

Survey Year

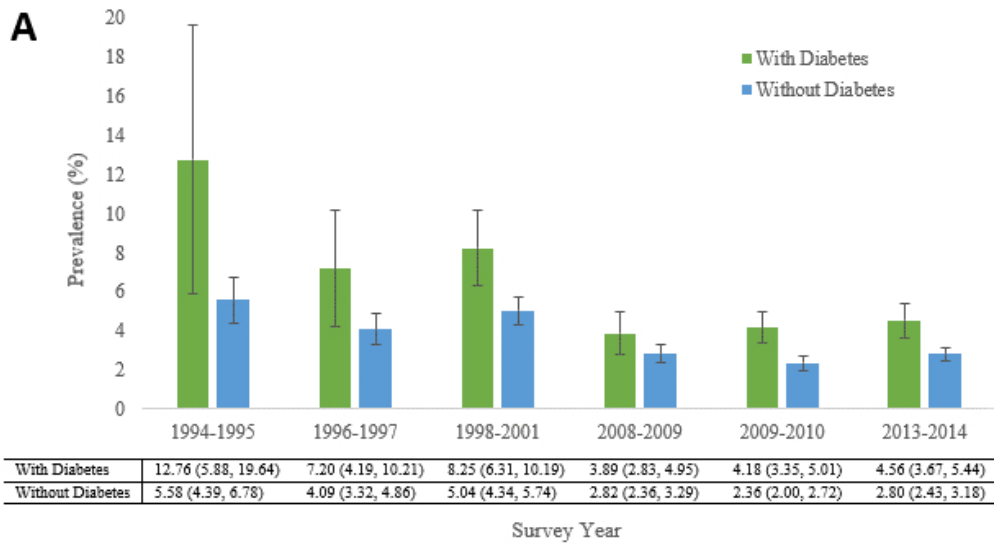


	1994-1997	1998-2001	2008-2009	2009-2010	2013-2014
With Diabetes	6.04 (2.20, 9.88)	7.07 (4.54, 9.61)	2.80 (1.61, 3.99)	2.01 (1.40, 2.61)	3.06 (2.21, 3.91)
Without Diabetes	2.68 (2.19, 3.17)	2.35 (1.95, 2.75)	1.16 (0.93, 1.38)	1.27 (0.96, 1.58)	1.21 (1.01, 1.41)

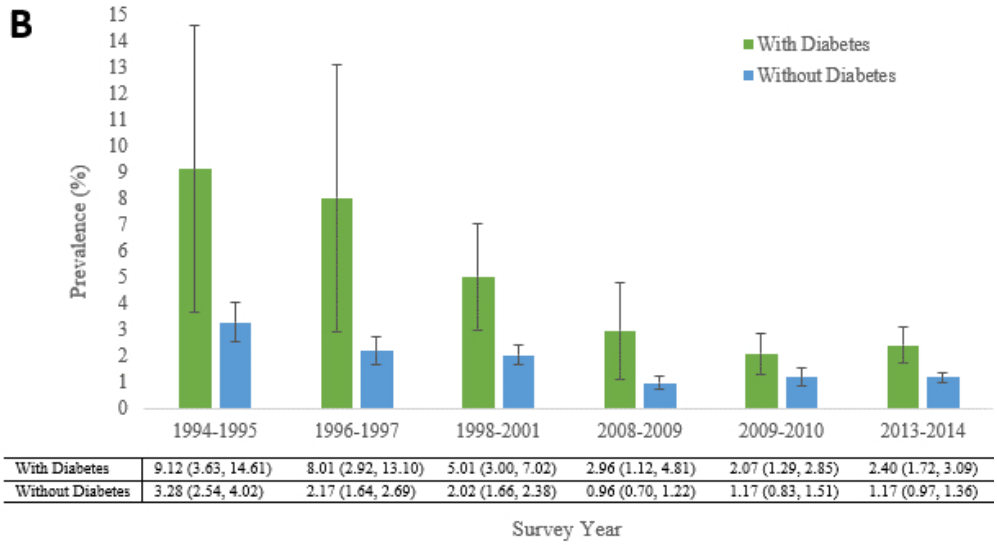
Survey Year

Figure 2. The sex-standardized prevalence of visual impairment in the 10 Canadian provinces stratified by education levels from 1994 to 2014. A. Low level of education. B. Mid/high level of education

417x447mm (38 x 38 DPI)



	1994-1995	1996-1997	1998-2001	2008-2009	2009-2010	2013-2014
With Diabetes	12.76 (5.88, 19.64)	7.20 (4.19, 10.21)	8.25 (6.31, 10.19)	3.89 (2.83, 4.95)	4.18 (3.35, 5.01)	4.56 (3.67, 5.44)
Without Diabetes	5.58 (4.39, 6.78)	4.09 (3.32, 4.86)	5.04 (4.34, 5.74)	2.82 (2.36, 3.29)	2.36 (2.00, 2.72)	2.80 (2.43, 3.18)



	1994-1995	1996-1997	1998-2001	2008-2009	2009-2010	2013-2014
With Diabetes	9.12 (3.63, 14.61)	8.01 (2.92, 13.10)	5.01 (3.00, 7.02)	2.96 (1.12, 4.81)	2.07 (1.29, 2.85)	2.40 (1.72, 3.09)
Without Diabetes	3.28 (2.54, 4.02)	2.17 (1.64, 2.69)	2.02 (1.66, 2.38)	0.96 (0.70, 1.22)	1.17 (0.83, 1.51)	1.17 (0.97, 1.36)

Figure 3. The sex-standardized prevalence of visual impairment in the 10 Canadian provinces stratified by household income levels from 1994 to 2014. A. Low level of household income. B. Mid/high level of household income

408x453mm (38 x 38 DPI)