cmajOPEN

Research

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

James H.B. Im MPH, Graham E. Trope MD, Yvonne M. Buys MD, Peng Yan MD, Michael H. Brent MD, Sophia Y. Liu MD, Ya-Ping Jin PhD

Abstract

Background: Diabetes, a leading cause of visual impairment, is on the rise in Canada. We assessed trends in the prevalence of visual impairment among people in Canada with and without diabetes to inform the development of strategies and policies for the management of visual impairment.

Methods: We analyzed self-reported data from respondents aged 45 years and older in 7 cycles of nationwide surveys (National Population Health Survey and Canadian Community Health Survey) from 1994/95 to 2013/14. The age- and sex-standardized prevalence of visual impairment was calculated. We assessed comparisons by levels of education and income, using sex-standardized prevalence owing to sparse data.

Results: Among people in Canada with diabetes, the age- and sex-standardized prevalence of visual impairment was 7.37% (95% confidence interval [CI] 5.31%–9.43%) in 1994/95 and 1996/97 combined, decreasing to 3.03% (95% CI 2.48%–3.57%) in 2013/14, giving a standardized prevalence ratio of 0.41 (95% CI 0.30–0.56) comparing 2013/14 with 1994/95 and 1996/97 combined. Among people in Canada without diabetes, visual impairment prevalence decreased from 3.72% (95% CI 3.31%–4.14%) in 1994/95 and 1996/97 combined to 1.69% (95% CI 1.52%–1.87%) in 2013/14, with a standardized prevalence ratio of 0.45 (95% CI 0.40–0.52). Decreased sex-standardized prevalence of visual impairment was observed among people with high and low education levels and incomes among those with and without diabetes.

Interpretation: Visual impairment prevalence was roughly 2 times higher among those with versus without diabetes in all survey years; from 1994 to 2014, visual impairment prevalence decreased among those with and without diabetes irrespective of education and income levels. These results suggest effective collective efforts by clinicians, researchers, the public and government.

Visual impairment substantially affects individuals' independence and quality of life, and risk of accidents, injuries, falls and depression.[1–4] Diabetes is a leading cause of visual impairment resulting from diabetic retinopathy and diabetic macular edema.[5] In Canada, the incidence of diabetes fluctuated and the prevalence of diabetes increased 37.3% between 2003/04 and 2013/14.[6] In 2016/17, the number of people in Canada living with diabetes was 3.2 million, which increased to 5.7 million in 2022.[7,8] Contributing factors to this increase include people in Canada with diabetes now living longer and the growth and aging of the Canadian population.[6]

Given the fast-rising prevalence of diabetes, it is important to know whether the prevalence of visual impairment has also increased so that strategies and policies for prevention and management of visual impairment can be developed. We sought to assess time trends in visual impairment prevalence among people in Canada with and without diabetes from 1994/95 to 2013/14 and to determine whether the trends were similar among people in Canada with different levels of education and income.

Methods

This study was set in 10 Canadian provinces (Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland and Labrador, Nova Scotia, Ontario, Prince Edward Island, Quebec and Saskatchewan). Data were collected via a series

Competing interests: Ya-Ping Jin reports research grant support from the Lindenfield Family Research Grant for this study, and from the Glaucoma Research Society of Canada outside the submitted work. No other competing interests were declared.

This article has been peer reviewed.

Correspondence to: Ya-Ping Jin, yaping.jin@utoronto.ca

***CMAJ Open* 2023 December 5. DOI:10.9778/cmajo.20220116**

of cross-sectional surveys conducted in 1994/95, 1996/97, 1998/99, 2000/01, 2008/09, 2009/10 and 2013/14 among people in Canada aged 45 years and older.

Data sources and participants

Data were from 7 cycles of nationwide surveys: the 1994/95, 1996/97 and 1998/99 cycles of the National Population Health Survey (NPHS) and the 2000/01, 2008/09 Healthy Aging, 2009/10 and 2013/14 cycles of the Canadian Community Health Survey (CCHS).

The CCHS and NPHS (household cross-sectional component) are cross-sectional surveys with participants randomly selected across the country by Statistics Canada, using a multi-stage stratified cluster design with 1 person being selected per household.[9,10] The NPHS targeted household residents of all ages and the CCHS targeted Canadians aged 12 years and older living in private dwellings, except for the CCHS 2008/09 Healthy Aging, which targeted Canadians aged 45 years and older. Data in NPHS and CCHS were collected using computer-assisted interviews. Overall response rates ranged from 69.7% to 92.8% for the NPHS and from 72.3% to 87.3% for the CCHS.[10–15] Only respondents aged 45 years and older were included since visual impairment is an age-related condition and the CCHS 2008/09 Healthy Aging included only individuals aged 45 years and older.[16]

Outcome measure

The study outcome was self-reported visual impairment, obtained using the Health Utilities Index Mark 3 (HUI3) in the NPHS and CCHS.[17–19] The HUI3 has a reliability of $\kappa = 0.728$.[17] Although visual impairment was not clinically measured, it is the individual's presenting or habitual vision, not their best-corrected visual acuity measured in the ideal clinic settings, that reflects their real-life vision challenges.[20,21]

The HUI3 asks the following questions:

- Are you usually able to see well enough to read ordinary newsprint without glasses or contact lenses?
- Are you usually able to see well enough to read ordinary newsprint with glasses or contact lenses?
- Are you able to see at all?
- Are you able to see well enough to recognize a friend on the other side of the street without glasses or contact lenses?
- Are you usually able to see well enough to recognize a friend on the other side of the street with glasses or contact lenses?

Replies were categorized by Statistics Canada into 5 mutually exclusive groups:[18] (i) no visual problems; (ii) problems corrected by lenses (distance, close or both); (iii) problems seeing distance not corrected; (iv) problems seeing close not corrected; and (v) problems seeing close and distance not corrected, or no sight at all.

In this analysis, vision problems not corrected by lenses for close vision, distance vision, or both, or no sight at all (i.e., the combination of groups [iii], [iv] and [v]) were considered as having self-reported visual impairment. Groups (i) and (ii) were categorized as not having self-reported visual impairment.

Diabetes measure

Participants who self-reported that they had (or did not have) diabetes diagnosed by a health professional were considered as having diabetes (or not having diabetes).

Other measures

Information on the highest level of education attained by participants was obtained through a series of questions and was categorized by Statistics Canada into 4 levels: (1) less than secondary school graduation; (2) secondary school graduation, no postsecondary; (3) some postsecondary education; and (4) postsecondary certificate/diploma or university degree. We further consolidated participants into low ([1] and [2] above) and high ([3] and [4] above) levels to avoid sparse data. Information on total household income was collected by Statistics Canada via income categories or an estimate. We grouped the income data into low (below middle) and middle–high (middle or higher) levels for adequate data analysis.

Statistical analysis

We calculated prevalence estimates by diabetes status and level of education and household income. Survey weights generated similarly by Statistics Canada for the NPHS and CCHS were used in all analyses to adjust for various factors.[23] Weighted prevalence estimates and 95% confidence intervals (CIs) were directly age- and sex-standardized to the 2016 Canadian census to allow for valid comparisons.[24] For analyses stratified by education and income, only sex-standardized prevalence was calculated owing to sparse data not meeting the data release rules and questionable test results when stratifying by both age and sex. We calculated standard errors and 95% CIs of prevalence estimates using the bootstrap weights with 500 subsamples drawn by Statistics Canada. Owing to small cell sizes, the 1994/95 and 1996/97 cycles of the NPHS and the 1998/99 and 2000/01 cycles of the NPHS and CCHS were combined (termed 1994~1997 and 1998~2001, respectively) for calculating overall prevalence estimates and education-stratified estimates.[25] For similar reasons, the 1998/99 cycle of the NPHS was combined with the 2000/01 cycle of the CCHS for calculating income-stratified estimates. Standardized prevalence ratios and 95% CIs were calculated to compare the visual impairment prevalence in 2013/14 versus the combined 1994~1997 data.[26] We assessed additive and multiplicative interaction for education–diabetes and income–diabetes on visual impairment prevalence.[27] Answers of "Don't know" or "Refuse" were treated as missing values.

Ethics approval

Statistics Canada obtained informed consent from all survey participants. The University of Toronto Research Ethics Board approved this study (no. 36562).

Results

The characteristics of participants are shown in Table 1. The weighted number of people in Canada with diabetes aged 45 years and older increased from 607 100 in 1994/95 to

1 772 200 in 2013/14. The weighted number of individuals with visual impairment decreased from 57 200 in 1994/95 to 53 900 in 2013/14 for people with diabetes and from 344 400 in 1994/95 to 205 900 in 2013/14 for those without diabetes. Weighted missing values for included variables ranged from 0% for age and sex to 18.9% for income. Unweighted missing values were 17–1224 (0.00%–0.02%) for visual impairment and 1–127 (0.00%–0.00%) for diabetes.

The age- and sex-standardized prevalence of visual impairment among people with and without diabetes is shown in Figure 1. In all survey years, visual impairment prevalence was about 2 times higher among people with diabetes than those without. Overall, a decreasing visual impairment prevalence was observed among the groups with and without diabetes. Among those with diabetes, the visual impairment prevalence decreased from 7.37% (95% CI 5.31%–9.43%) in the combined 1994~1997 to 3.03% (95% CI 2.48%–3.57%) in 2013/14, giving a standardized prevalence ratio of 0.41 (95% CI 0.30–0.56) for 2013/14 versus the combined 1994~1997. Among those without diabetes, the visual impairment prevalence decreased from 3.72% (95% CI 3.31%–4.14%) in the combined 1994~1997 to 1.69% (95% CI 1.52%–1.87%) in 2013/14, with a standardized prevalence ratio of 0.45 (95% CI 0.40–0.52) for 2013/14 versus the combined 1994~1997.

Figure 2 shows a decreasing visual impairment prevalence 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 visual impairment decreased from 9.96% (95% CI 6.91%–13.02%) in the combined 1994~1997 to 3.57% (95% CI 2.84%–4.29%) in 2013/14 for those with diabetes, and from 4.16% (95% CI 3.52%–4.79%) in the combined 1994~1997 to 2.18% (95% CI 1.87%–2.48%) in 2013/14 for those without diabetes. In the high-education stratum, the visual impairment prevalence similarly

Table 1 (part 1 of 2): Weighted characteristics of participants aged 45 years and older in the National Population Health Survey and the Canadian Community Health Survey, with and without diabetes, 1994–2014

People with diabetes: NPHS and CCHS cycles*														
	1994/95 (unweighted *n* = 525)		1996/97 (unweighted *n* = 2322†)		1998/1999 (unweighted *n* = 537)		2000/2001 (unweighted *n* = 5431)		2008/2009 (unweighted *n* = 4384)		2009/2010 (unweighted *n* = 8866)		2013/2014 (unweighted *n* = 10 566)	
Characteristic	No. (100s)‡	%	No. (100s)‡	%	No. (100s)‡	%	No. (100s)‡	%	No. (100s)‡	%	No. (100s)‡	%	No. (100s)‡	%
Age, yr														
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	15 505	100.0	15 677	100.0	17 722	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
Middle–high income	3713	61.2	2633	39.4	3177	43.9	4295	47.8	7026	45.3	7205	46.0	10 488	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	14 819	95.6	15 060	96.1	16 943	95.6
Missing	69	1.1	22	0.3	3	0.0	36	0.4	119	0.8	147	0.9	241	1.4

Table 1 (part 2 of 2): Weighted characteristics of participants aged 45 years and older in the National Population Health Survey and the Canadian Community Health Survey, with and without diabetes, 1994–2014

People without diabetes: NPHS and CCHS cycles*

Characteristic	1994/95 (unweighted *n* = 7059) No. (100s)‡	%	1996/97 (unweighted *n* = 30 039) No. (100s)‡	%	1998/99 (unweighted *n* = 6410) No. (100s)‡	%	2000/01 (unweighted *n* = 55 156) No. (100s)‡	%	2008/09 (unweighted *n* = 26 468) No. (100s)‡	%	2009/10 (unweighted *n* = 59 771) No. (100s)‡	%	2013/14 (unweighted *n* = 66 466) No. (100s)‡	%
Age, yr														
40–64	57 140	66.5	60 218	66.3	63 541	67.3	68 222	68.2	84 602	70.1	86 033	70.2	89 101	67.6
65–74	18 289	21.3	18 888	20.8	17 747	18.8	18 762	18.8	19 833	16.4	21 020	17.2	25 719	19.5
≥ 75	10 536	12.3	11 685	12.9	13 059	13.8	13 003	13.0	16 314	13.5	15 461	12.6	16 902	12.8
≥ 45	85 964	100.0	90 791	100.0	94 346	100.0	99 987	100.0	120 749	100.0	122 515	100.0	131 722	100.0
Sex														
Male	40 519	47.1	42 634	47.0	44 375	47.0	47 062	47.1	57 284	47.4	57 639	47.0	62 392	47.4
Female	45 445	52.9	48 157	53.0	49 972	53.0	52 925	52.9	63 465	52.6	64 876	53.0	69 330	52.6
Annual household income§														
Low income	21 201	24.7	29 913	32.9	31 363	33.2	26 440	26.4	28 414	23.5	28 848	23.5	36 393	27.6
Middle–high income	60 114	69.9	44 667	49.2	55 883	59.2	61 970	62.0	71 573	59.3	72 301	59.0	95 299	72.3
Missing	4649	5.4	16 211	17.9	7100	7.5	11 578	11.6	20 762	17.2	21 365	17.4	30	0.0
Highest level of education achieved														
No post-secondary education	44 692	52.0	45 833	50.5	44 915	47.6	49 601	49.6	48 754	40.4	43 195	35.3	48 942	37.2
Post-secondary education	41 105	47.8	43 878	48.3	49 385	52.3	49 325	49.3	70 509	58.4	75 587	61.7	80 189	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	81 801	95.2	87 689	96.6	90 717	96.2	97 333	97.3	118 297	98.0	119 689	97.7	128 280	97.4
Missing	720	0.8	400	0.4	177	0.2	403	0.4	504	0.4	865	0.7	1384	1.1

Note: CCHS = Canadian Community Health Survey, NPHS = National Population Health Survey.
*1994/95, 1996/97 and 1998/99 were from the NPHS; 2000/01, 2009/10 and 2013/14 were from the CCHS; 2008/09 was from the CCHS Healthy Aging.
†The 1996/97 NPHS cycle included a larger sample than other NPHS cycles owing to greater provincial support from Alberta, Manitoba and Ontario.[22]
‡No. (100s): weighted number of people in Canada in hundreds.
§Low income: an annual household income of \$0–\$19 999 for the 1994/95 NPHS cycle, \$0–\$29 999 for the 1996/97 and 1998/99 NPHS cycles as well as the 2000/01 CCHS cycle, and \$0–\$39 999 for the 2008/09, 2009/10 and 2013/14 CCHS cycles. In 2013/14, missing income data were imputed by Statistics Canada.[10]

decreased from 6.04% (95% CI 2.20%–9.88%) in the combined 1994~1997 to 3.06% (95% CI 2.21%–3.91%) in 2013/14 for those with diabetes, and from 2.68% (95% CI 2.19%–3.17%) in the combined 1994~1997 to 1.21% (95% CI 1.01%–1.41%) in 2013/14 for those without diabetes.

Figure 2 also shows that the sex-standardized prevalence of visual impairment was highest in people with low education levels and diabetes, and lowest in those with high education levels and no diabetes in all survey years. Evaluations of interactions regarding the joint effects of low levels of education and having diabetes on visual impairment prevalence are shown in Table 2. In 2013/14, the observed standardized prevalence ratios for the joint presence of low level of education and diabetes were smaller than the expected standardized prevalence ratio from both the additive (2.36 v. 2.82) and multiplicative model (2.95 v. 4.56), indicating the presence of negative additive and negative multiplicative interaction. However, positive additive interactions were present in other years for education–diabetes on visual impairment prevalence. Multiplicative interactions were negative in 3 of 5 and not present in 2 of 5 assessments.

After stratification by household income level and diabetes status, a decreased visual impairment prevalence over time was observed (Figure 3). The highest sex-standardized prevalence of visual impairment was found in Canadians with low level of

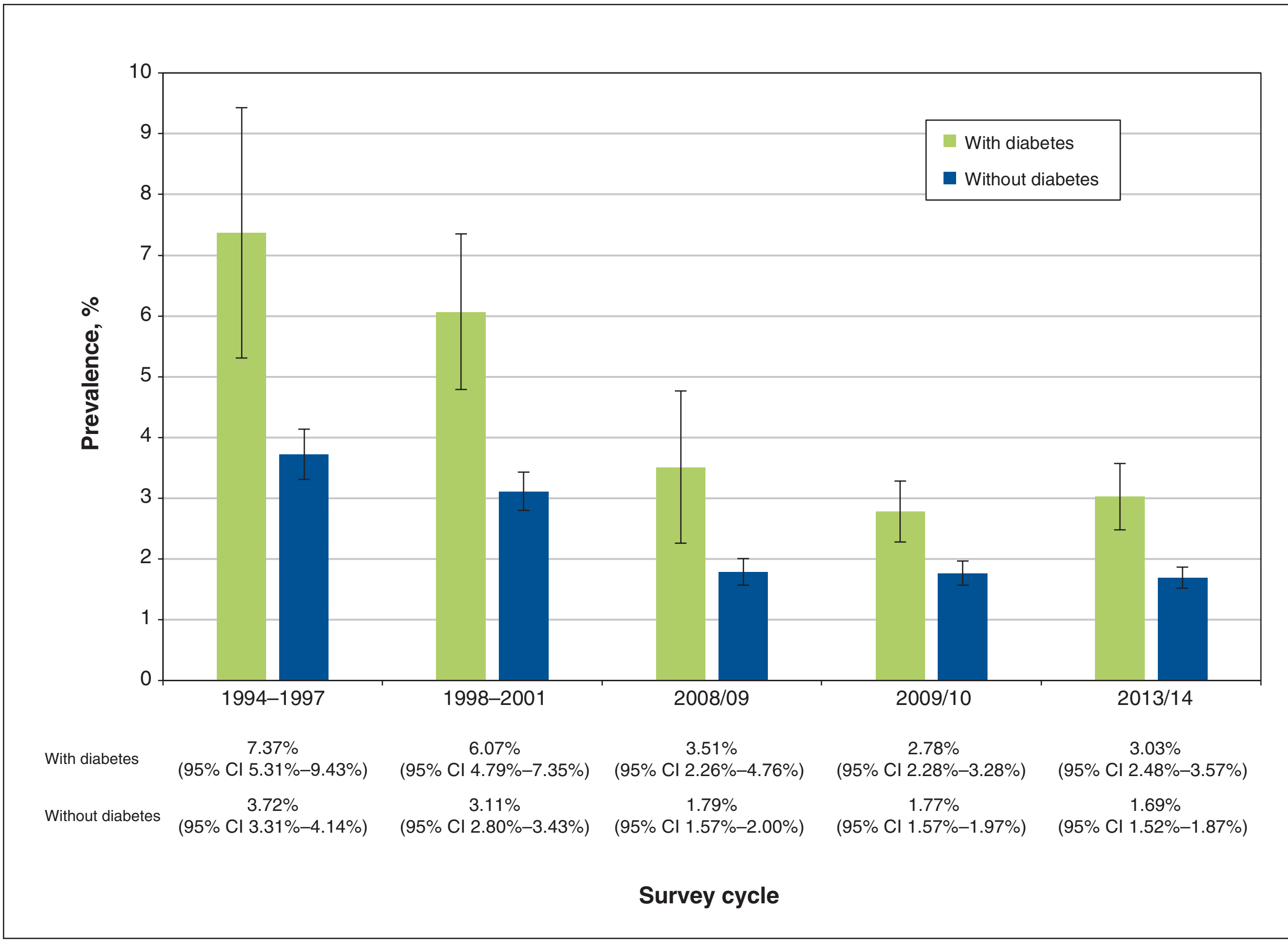

Figure 1: The age- and sex-standardized prevalence of visual impairment in the 10 Canadian provinces from 1994 to 2014. Note: CI = confidence interval.

income and diabetes, and the lowest was found in those with middle–high level of income and no diabetes in all survey years. Evaluations of interactions between the joint presence of low level of household income and diabetes on visual impairment prevalence are shown in Table 2. In 2013/14, there was evidence of positive additive interaction (standardized prevalence ratio observed 3.39 v. expected 2.86). However, negative additive interactions were observed for other years (e.g., 2008/09).

The visual impairment prevalence among those with missing household income data showed a similar decreasing trend over time (Appendix 1, Supplementary Table S1, available at www.cmajopen.ca/content/11/6/E1125/suppl/DC1).

The visual impairment prevalence stratified by age, education (or household income), and diabetes status are presented in Appendix 1, Supplementary Tables S2 and S3.

Interpretation

This study assessed visual impairment trends among people in Canada with and without diabetes over 2 decades. We report that whereas the number of participants who reported having diabetes nearly tripled from 1994/95 to 2013/14, the proportion of people with visual impairment decreased among those with and without diabetes. Adjusting for age and sex, visual impairment prevalence decreased by more than half (standardized prevalence ratio 0.41 for those with diabetes and 0.45 for those without). However, in 2009/10 and 2013/14, the visual impairment prevalence seems to have leveled off (Figure 1). Sex-adjusted analyses stratified by education and income levels also showed a decreasing trend from 1994 to 2014. Furthermore, we report the visual impairment prevalence was about 2 times higher among people with diabetes than those without in all survey years. The highest visual impairment prevalence was found in people with diabetes and low levels of education or income, and the lowest was found among those without diabetes and with middle–high levels of education or income. In 2013/14, a positive additive interaction between diabetes and low levels of household income on visual impairment prevalence was noted, suggesting that visual impairment interventions targeting those with diabetes and low levels of income may yield a benefit larger than expected. However, this additive interaction varied by year. Caution should be taken when applying this strategy to the most recent years.

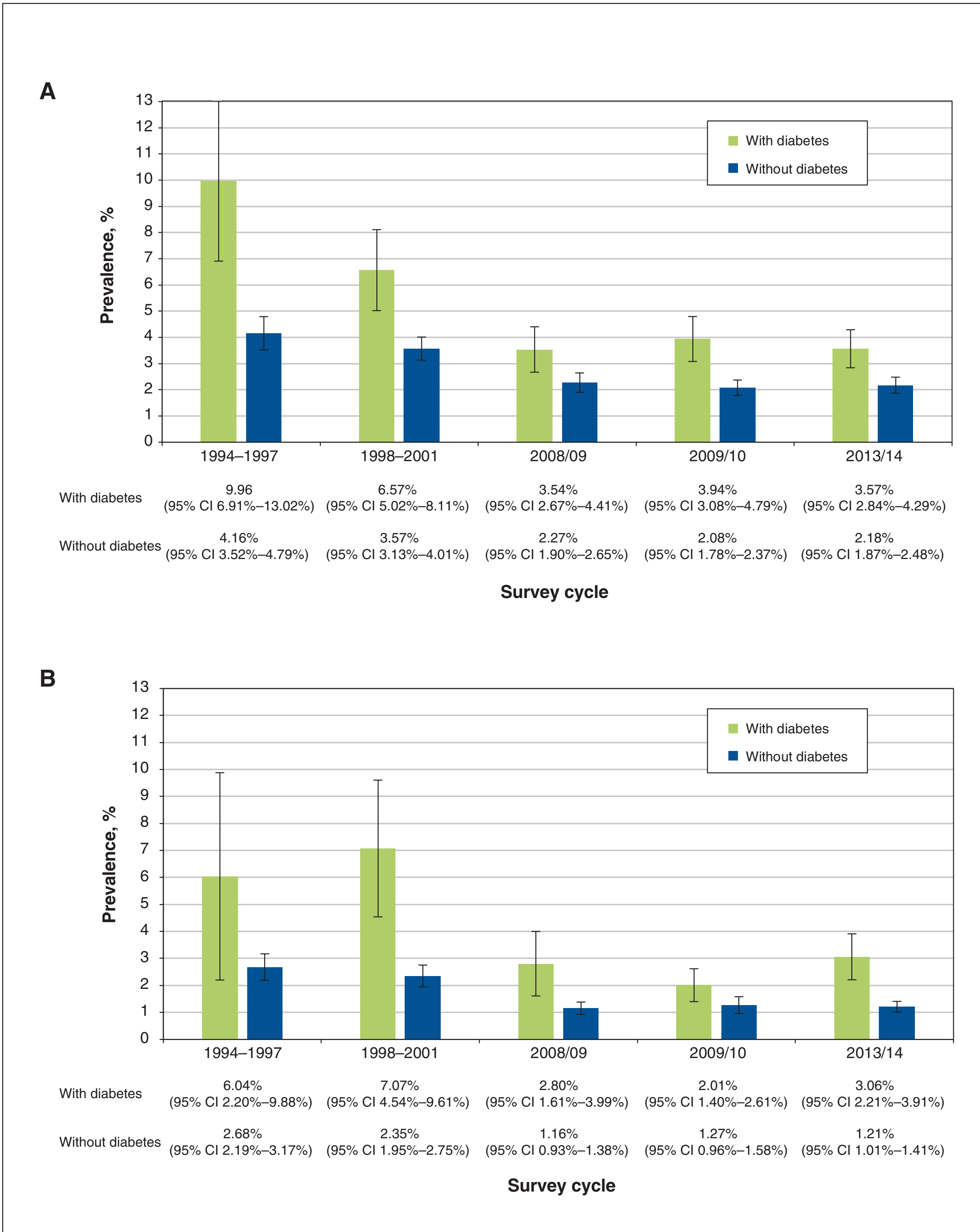

Figure 2: The sex-standardized prevalence of visual impairment in the 10 Canadian provinces stratified by education levels from 1994 to 2014. (A) Low level of education. (B) Middle–high level of education. Note: CI = confidence interval.

Table 2: The observed and expected joint standardized prevalence ratio from the additive and multiplicative models in assessing the joint effects of diabetes and level of education and level of household income on the prevalence of visual impairment

Year	Model	Observed joint SPR (95% CI)	Expected joint SPR	Suggested presence of interaction
Education + diabetes + v. education – diabetes –*				
1994~1997†	Additive model	7.28 (7.25–7.31)	4.84	Positive additive and no multiplicative
	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	
2008/09	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	
2009/10	Additive model	2.67 (2.66–2.68)	1.55	Positive additive and no multiplicative
	Multiplicative model	3.10 (2.49–3.87)	2.59	
2013/14	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 + v. income – diabetes –§				
1994/95	Additive model	9.48 (9.41–9.55)	8.14	Positive additive and no multiplicative
	Multiplicative model	3.72 (1.94–7.14)	4.73	
1996/97	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	
2008/09	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	
2009/10	Additive model	3.01 (3.00–3.02)	2.09	Positive additive and no multiplicative
	Multiplicative model	3.57 (2.84–4.49)	3.57	
2013/14	Additive model	3.39 (3.38–3.40)	2.86	Positive additive and no multiplicative
	Multiplicative model	3.90 (3.06–4.97)	4.91	

Note: CI = confidence interval, SPR = standardized prevalence ratio.
*Education – diabetes –: middle–high level of education without diabetes; Education + diabetes +: low level of education with diabetes.
†1994~1997: combining data from cycle 1994/95 and 1996/97 owing to sparse data.
‡1998~2001: combining data from cycle 1998/99 and 2000/01 owing to sparse data.
§Income – diabetes –: middle–high level of household income without diabetes; income + diabetes +: low level of household income with diabetes.

The decreased prevalence of visual impairment we report complements other reports of visual impairment.[28,29] In Europe, a meta-analysis involving individuals aged 55 years and older reported that prevalence of visual impairment decreased from 2.22% in 1991–2006 to 0.92% in 2007–2012.[28] Another meta-analysis similarly reported that the age-adjusted prevalence of visual impairment decreased from 1990 to 2015 globally.[29] However, these reports did not distinguish between people with and without diabetes, and used pooled data from countries with different health care systems. In 2022, Purola and colleagues reported that the visual impairment prevalence and incidence due to diabetic retinopathy in the Finish population peaked in the 1990s and decreased from 1996 to 2019.[30] Using Canadian data, we report that visual impairment prevalence decreased among people with and without diabetes from 1994 to 2014, irrespective of their level of education and income. The decreased visual impairment prevalence likely reflects the collective efforts by clinicians, researchers, the public and government to prevent vision loss, including better understanding of diabetic eye diseases,[31–33] better blood-glucose control,[34–38] recent effective treatment for advanced diabetic retinopathy and technology (e.g., optical coherence tomography) for early detection of diabetic retinal pathologies,[39–44] government coverage for new advancements and various initiatives for increased diabetic eye screening.[45–47]

Our results are also in accordance with studies that reported a significantly higher visual impairment prevalence among people with diabetes than those without.[48–50] Despite

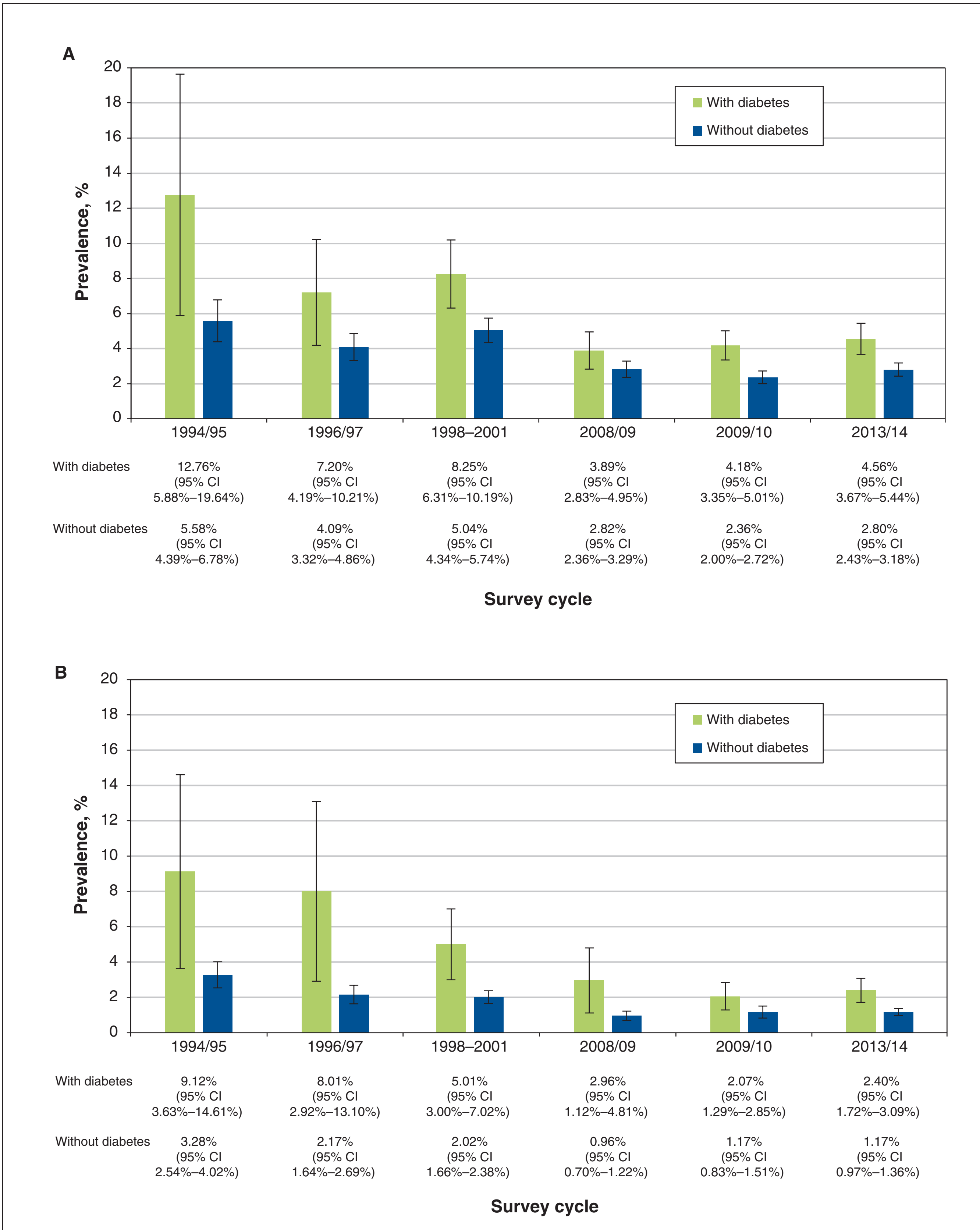

Figure 3: The sex-standardized prevalence of visual impairment in the 10 Canadian provinces stratified by household income levels from 1994 to 2014. (A) Low level of household income. (B) Middle–high level of household income. Note: CI = confidence interval.

a decreased visual impairment prevalence over time, the prevalence of visual impairment in 2013/14 was still significantly higher among Canadians with diabetes versus those without, demonstrating that diabetes was still a major cause of visual impairment in Canada in 2013/14. Preventing and treating diabetes and diabetic retinopathy must remain a priority in Canada.

Limitations

This study has limitations. We described visual impairment trends based on data from cross-sectional surveys at different times. Estimates from combining cycles represent an "artificial" population made up of populations surveyed at different times.[25]

Information on visual impairment was self-reported using HUI3, which may be susceptible to misclassifications, although the HUI3 performed well over other visual function questionnaires and has been successfully used in prior publications.[51–55]

Self-reported diabetes has excellent specificity (87.8%–98.6%) but only moderate sensitivity (41.5%–70.4%) in studies from China, Japan and Brazil.[56–58] Extrapolating the reported moderate sensitivity to people in Canada entails misclassification of some individuals with diabetes as not having diabetes, causing an overestimation of visual impairment prevalence among people in Canada without diabetes. We are not aware that the validity of self-reported diabetes changes with time. Therefore, misclassification of self-reported diabetes would likely not affect the decreasing trend reported.

Self-reported diabetes cannot distinguish between type 1 and type 2 diabetes.

The analysis excluded individuals residing in the 3 territories, those living on reserves and those not in private dwellings. The most recent available data on visual impairment is from the CCHS 2013/14 owing to survey content changes. Consequently, our conclusions may not be generalizable to Canadians living in the 3 territories or Indigenous communities, nor would they be applicable if extrapolated beyond 2014. Nonetheless, our results provide a valuable 20-year historical perspective for future comparisons.

Whereas we observed trends in visual impairment prevalence by age, we could not age-standardize prevalence of visual impairment when comparing by levels of education and income owing to sparse data. Our estimates for education and income should be interpreted with caution.

There may have been a few individuals who were randomly selected to participate in more than 1 survey cycle. Pooling the NPHS 1994/95 and 1996/97 cycles may have resulted in the inclusion of some repeat participants between 2 cycles. However, the chance of being selected for multiple surveys is low and the possibility of rejecting participation in multiple surveys, if selected, is high because of the burdens of answering the long questionnaire. In addition, survey weights were used to represent different groups in the population across different cycles. These factors may minimize the impact of repeated participation in surveys by the same respondents.

Conclusion

Visual impairment prevalence in Canada is higher among people with diabetes than those without, and decreased from 1994 to 2014 overall. The decreasing trend was observed in all subgroups stratified by diabetes–education and diabetes–income but was attenuated in 2009/10 and 2013/14. Efforts for visual impairment reduction should continue to focus on diabetes education, prevention, treatment and diabetic eye examinations.

References

1. Hong T, Mitchell P, Burlutsky G, et al. 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;55:7589-93.
2. Yip JLY, Khawaja AP, Broadway D, et al. Visual acuity, self-reported vision and falls in the EPIC-Norfolk Eye study. *Br J Ophthalmol* 2014;98:377-82.
3. Jin YP, Wong DT. Self-reported visual impairment in elderly Canadians and its impact on healthy living. *Can J Ophthalmol* 2008;43:407-13.
4. Crews JE, Chou CF, Zack MM, 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;23:145-53.
5. Diabetes Canada Clinical Practice Guidelines Expert Committee; Altomare F, Kherani A, Lovshin J. Retinopathy. *Can J Diabetes* 2018;42(Suppl 1):S210-6.
6. Diabetes in Canada. Ottawa: Public Health Agency of Canada; updated 2020 Aug. 17. Available: https://www.canada.ca/en/public-health/services/publications/diseases-conditions/diabetes-canada-highlights-chronic-disease-surveillance-system.html (accessed 2022 Mar. 26).
7. LeBlanc AG, Jun Gao Y, McRae L, et al. At-a-glance — Twenty years of diabetes surveillance using the Canadian Chronic Disease Surveillance System. *Health Promot Chronic Dis Prev Can* 2019;39:306-9.
8. Diabetes rates continue to climb in Canada [press release]. Toronto: Diabetes Canada; 2022 Mar. 3. Available: https://www.diabetes.ca/media-room/press-releases/diabetes-rates-continue-to-climb-in-canada (accessed 2023 Aug. 1).
9. *National Population Health Survey 1994–1995*. Ottawa: Statistics Canada; 1995.
10. *2010 and 2009–2010 CCHS microdata file user guide*. Ottawa: Statistics Canada; 2011.
11. *National Population Health Survey: household component, cross-sectional (NPHS). Detailed information for 1994–1995*. Ottawa: Statistics Canada; updated 2007 Oct. 24. Available: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&Id=3732 (accessed 2021 Jan. 10).
12. *National Population Health Survey: household component, cross-sectional (NPHS). Detailed information for 1996–1997*. Ottawa: Statistics Canada; updated 2007 Oct. 24. Available: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&Id=4520 (accessed 2021 Jan. 10).
13. *CCHS Cycle 1.1 (2000–2001), public use microdata file documentation*. Ottawa: Statistics Canada; 2002.
14. *Canadian Community Health Survey (CCHS) — healthy aging user guide*. Ottawa: Statistics Canada; 2008.
15. *2014 and 2013–2014 CCHS microdata file user guide*. Ottawa: Statistics Canada; 2015.
16. *Canadian Community Health Survey — healthy aging (CCHS)*. Ottawa (ON): Statistics Canada; updated 2008 Nov. 27. Available: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=5146 (accessed 2021 Jan. 10).
17. Boyle MH, Furlong W, Feeny D, et al. Reliability of the Health Utilities Index–Mark III used in the 1991 cycle 6 Canadian general social survey health questionnaire. *Qual Life Res* 1995;4:249-57.
18. *Canadian Community Health Survey (CCHS) derived variable (DV) specifications*. Ottawa: Statistics Canada; 2011. Available: http://www23.statcan.gc.ca/imdb-bmdi/pub/document/3226_D5_T9_V1-eng.pdf (accessed 2021 Jan. 10).
19. Horsman J, Furlong W, Feeny D, et al. The Health Utilities Index (HUI): concepts, measurement properties and applications. *Health Qual Life Outcomes* 2003;1:54.
20. Heintz E, Wiréhn AB, Peebo BB, et al. QALY weights for diabetic retinopathy — a comparison of health state valuations with HUI-3, EQ-5D, EQ-VAS, and TTO. *Value Health* 2012;15:475-84.
21. Dandona L, Dandona R. Revision of visual impairment definitions in the International Statistical Classification of Diseases. *BMC Med* 2006;4:7.
22. *National Population Health Survey: household component, cross-sectional (NPHS). Detailed information for 1998–1999*. Ottawa: Statistics Canada; updated 2007 Oct. 24. Available: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3236 (accessed 2021 Jan. 10).
23. *Canadian Community Health Survey (CCHS) household weights documentation*. Ottawa: Statistics Canada; 2010. Available: https://www23.statcan.gc.ca/imdb-bmdi/pub/document/3226_D57_T9_V1-eng.htm (accessed 2021 Jan. 10).
24. Naing NN. Easy way to learn standardization: direct and indirect methods. *Malays J Med Sci* 2000;7:10-5.

25. Thomas S, Wannell B. Combining cycles of the Canadian Community Health Survey. *Health Rep* 2009;20:53-8.
26. Boyle P, Parkin DM. Cancer registration: principles and methods. Statistical methods for registries. *IARC Sci Publ* 1991;95:126-58.
27. Szklo M, Nieto FJ. *Epidemiology: beyond the basics: fourth edition*. Burlington (MA): Jones & Bartlett Learning; 2019.
28. Delcourt C, Le Goff M, von Hanno T, et al. The decreasing prevalence of nonrefractive visual impairment in older Europeans: a meta-analysis of published and unpublished data. *Ophthalmology* 2018;125:1149-59.
29. Flaxman SR, Bourne RRA, Resnikoff S, et al. Global causes of blindness and distance vision impairment 1990–2020: a systematic review and meta-analysis. *Lancet Glob Health* 2017;5:e1221-34.
30. Purola PKM, Ojamo MUI, Gissler M, et al. Changes in visual impairment due to diabetic retinopathy during 1980–2019 based on nationwide register data. *Diabetes Care* 2022;45:2020-7.
31. Chhablani J, Sharma A, Goud A, et al. Neurodegeneration in type 2 diabetes: evidence from spectral-domain optical coherence tomography. *Invest Ophthalmol Vis Sci* 2015;56:6333-8.
32. Shahulhameed S, Vishwakarma S, Chhablani J, et al. A systematic investigation on complement pathway activation in diabetic retinopathy. *Front Immunol* 2020;11:154.
33. Daruich A, Matet A, Moulin A, et al. Mechanisms of macular edema: beyond the surface. *Prog Retin Eye Res* 2018;63:20-68.
34. UK Prospective Diabetes Study (UKPDS) Group. Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33). *Lancet* 1998;352:837-53.
35. Genuth S. Insights from the diabetes control and complications trial/epidemiology of diabetes interventions and complications study on the use of intensive glycemic treatment to reduce the risk of complications of type 1 diabetes. *Endocr Pract* 2006;12(Suppl 1):34-41.
36. Modi P. Diabetes beyond insulin: review of new drugs for treatment of diabetes mellitus. *Curr Drug Discov Technol* 2007;4:39-47.
37. Avgerinos I, Karagiannis T, Kakotrichi P, et al. Sotagliflozin for patients with type 2 diabetes: a systematic review and meta-analysis. *Diabetes Obes Metab* 2022;24:106-14.
38. Bellido V, Martínez J, Calvo F, et al. Beyond the glycaemic control of dapagliflozin: microangiopathy and non-classical complications. *Diabetes Ther* 2022;13:873-88.
39. Virgili G, Parravano M, Menchini F, et al. Anti-vascular endothelial growth factor for diabetic macular oedema. *Cochrane Database Syst Rev* 2018;(10):CD007419.
40. McKay BR, Berger AR; Canada Retina Society Executive. Canadian Retina Society (CRS) position paper on the necessity of sustained funding to ensure continued access to anti-vascular endothelial growth factor drugs to preserve vision for Canadians living with retinal diseases. Ottawa: Canadian Ophthalmological Society; 2019.
41. Keeping eye treatments safe, accessible and available for British Columbians [news release]. British Columbia: British Columbia Government News; 2019 May 24. Available: https://news.gov.bc.ca/releases/2019HLTH0078-001060 (accessed 2023 Feb. 11).
42. Bui BV, Downie LE, Lindsay RG. Optical coherence tomography: seeing the unseen. *Clin Exp Optom* 2019;102:193-4.
43. Swanson EA, Izatt JA, Hee MR, et al. In vivo retinal imaging by optical coherence tomography. *Opt Lett* 1993;18:1864-6.
44. Im JHB, Jin YP, Chow R, et al. Prevalence of diabetic macular edema based on optical coherence tomography in people with diabetes: a systematic review and meta-analysis. *Surv Ophthalmol* 2022;67:1244-51.
45. Cao J, Felfeli T, Merritt R, et al. Sociodemographics associated with risk of diabetic retinopathy detected by tele-ophthalmology: 5-year results of the Toronto Tele-Retinal Screening program. *Can J Diabetes* 2022;46:26-31.
46. Felfeli T, Alon R, Merritt R, et al. Toronto tele-retinal screening program for detection of diabetic retinopathy and macular edema. *Can J Ophthalmol* 2019;54:203-11.
47. NHS Diabetic Eye Screening Programme. England (UK): Public Health England.
48. Norris KL, Beckles GL, Chou CF, et al. Association of socioeconomic status with eye health among women with and without diabetes. *J Womens Health (Larchmt)* 2016;25:321-6.
49. 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:e0215329.
50. Perruccio AV, Badley EM, Trope GE. A Canadian population-based study of vision problems: assessing the significance of socioeconomic status. *Can J Ophthalmol* 2010;45:477-83.
51. Chan CH, Trope GE, Badley EM, et al. The impact of lack of government insured routine eye examinations on the incidence of self-reported glaucoma, cataracts and vision loss. *Invest Ophthalmol Vis Sci* 2014;55:8544-9.
52. Jin YP, Buys YM, Xiong J, et al. Government-insured routine eye examinations and prevalence of nonrefractive vision problems among elderly. *Can J Ophthalmol* 2013;48:167-72.
53. Lee EY, Cui K, Trope GE, et al. Eye care utilization in Newfoundland and Labrador: access barriers and vision health outcomes. *Can J Ophthalmol* 2018;53:342-8.
54. Jin S, Tam ALC, Chen L, et al. Canadians with visual impairment utilize home care services more frequently. *Can J Ophthalmol* 2019;54:196-202.
55. Jin S, Trope GE, Buys YM, et al. Reduced social participation among seniors with self-reported visual impairment and glaucoma. *PLoS One* 2019;14:e0218540.
56. Goto A, Morita A, Goto M, et al. Validity of diabetes self-reports in the Saku diabetes study. *J Epidemiol* 2013;23:295-300.
57. Yuan X, Liu T, Wu L, et al. Validity of self-reported diabetes among middle-aged and older Chinese adults: the China Health and Retirement Longitudinal Study. *BMJ Open* 2015;5:e006633.
58. Menezes TN, Oliveira ECT. Validity and concordance of self-reported diabetes mellitus by the elderly. *Cien Saude Colet* 2019;24:27-34.

Affiliations: Dalla Lana School of Public Health (Im, Jin), and Department of Ophthalmology and Vision Sciences (Trope, Buys, Yan, Brent, Jin), University of Toronto; Kensington Vision and Research Centre (Yan), Toronto, Ont.; Department of Family Medicine, Schulich School of Medicine and Dentistry (Liu), Western University, London, Ont.

Contributors: James Im led the data analyses, drafted and revised the manuscript, and prepared tables and figures. Ya-Ping Jin, Graham Trope, Yvonne Buys, Peng Yan, Michael Brent and Sophia 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.

Funding: This research was supported by funds from the Canadian Research Data Centre Network from the Social Science and Humanities Research Council, the Canadian Institute for Health Research, the Canadian Foundation for Innovation and Statistics Canada.

Disclaimer: Although the research and analysis are based on data from Statistics Canada, the opinions expressed do not represent the views of Statistics Canada or the Canadian Research Data Centre Network.

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 Canada's *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.

Acknowledgements: The authors acknowledge that the data used in this publication are from the National Population Health Survey in 1994/95, 1996/97, 1998/99, and the Canadian Community Health Surveys in 2000/01, 2008/09, 2009/10, 2013/14. Both surveys were run by Statistics Canada. The authors thank all participants of these surveys and the staff from Statistics Canada who assisted in the survey data collection and management.

Meeting presentation: The study abstract was presented at the Association for Research in Vision and Ophthalmology Annual Meeting in May 2021 and the Canadian Ophthalmological Society Annual Meeting in June 2021, both presented online owing to the COVID-19 pandemic.

Supplemental information: For reviewer comments and the original submission of this manuscript, please see www.cmajopen.ca/content/11/6/E1125/suppl/DC1.