The prevalence of hearing and vision loss in older Canadians: An analysis of Data from the Canadian
Longitudinal Study on Aging

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Running Head: Hearing and vision loss in Canada

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1 **English Abstract (150 words)**

2 **Objective:** To describe the prevalence of hearing loss (HL), vision loss (VL) and dual sensory loss (DSL)
3 in Canadians aged 45-85.

4 **Methods:** Data from the first wave of the Canadian Longitudinal Study on Aging were used. Audiometry
5 and visual acuity were measured. Prevalence proportions for 2012-2015 and counts for 2011 and 2016
6 were estimated.

7 **Results:** In 2016, 1.5 million Canadian males aged 45-85 had HL, 1.8 million had VL, and 570,000 had
8 DSL. Among females, 1.2 million had HL, 2.2 million had VL, and 450,000 had DSL. Prevalence counts
9 increased 8.7-16.9% between 2011 and 2016. Prevalence proportions increased with age but decreased
10 exponentially with severity of impairment. Males were more likely to have HL and DSL; VL was more
11 common in females.

12 **Conclusion:** HL, VL and DSL are highly prevalent among older Canadian adults.

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14 **Résumé en Français (150 mots)**

15 **Objectif :** Décrire la prévalence de la perte auditive (PA), la perte de vision (PV) et la double déficience
16 sensorielle (DDS) chez les canadiens âgés de 45 à 85 ans.

17 **Méthode :** Les mesure de données de l'étude longitudinale canadienne sur le vieillissement ont été
18 utilisées. L'audiométrie et l'acuité visuelle ont été mesurées. Les proportions de prévalence pour 2012-
19 2015 ont été estimées.

20 **Résultats :** En 2016, 1,5 million d'hommes canadiens avaient PA, 1,8 million avaient une PV et 570 000
21 avaient une DDS. Parmi les femmes, 1,2 million avaient une PA, 2,2 millions avaient une PV et 450 000
22 avaient une DDS. Les proportions de prévalence ont augmenté avec l'âge.

23 **Conclusion :** PA, PV et DDS sont hautement prévalentes chez les adultes canadiens les plus âgés.

Introduction

A 2017 report on the Global Burden of Disease estimated that collectively, hearing and vision loss were the largest contributors to years lived with disability (YLD) among adults aged 65 years and older, the second largest contributor among adults aged 50-64 years, and the third largest contributor among adults aged 45-49 years (Vos et al., 2017). The prevalence of both impairments has increased rapidly over the past few decades due to population growth and aging. Their rise in disease burden rank reflects the more general epidemiological shift from communicable to non-communicable diseases. Importantly, recent research has drawn attention to the negative effects of age-related hearing and vision loss on interpersonal communication, psycho-social wellbeing, quality of life, economic opportunity, and independence (Kotby, Tawfik, Aziz, & Taha, 2008; Mick, Kawachi, & Lin, 2014; Shield, 2006), which are key domains that must be addressed to enable seniors to age well (Holt-Lundstad, 2017; Holt-Lundstad, Smith, Baker, Harris, & Stephenson, 2015). Furthermore, associations between age-related sensory loss and difficult-to-treat, widespread health problems including dementia, falls and depression have been reported consistently in the recent literature (Albers et al., 2015; F. Lin & Ferrucci, 2012; Livingston & Frankish, 2015; Mener, Joshua, Genther, David, & Lin, 2013). These findings raise the possibility that better treatment of sensory problems might prevent or delay such conditions, or mitigate the difficulties they impose on individuals, caregivers and families. Yet, the problem of age-related sensory loss has been overlooked by aging individuals, health care workers and policy makers (F. Lin, 2012; B. O. Olusanya, Neumann, & Saunders, 2014) because of perceptions that other health issues are more acute or pressing, that age-related sensory loss is normal or inconsequential, or that effective treatments are not available. Fortunately, it seems that such attitudes are changing in favour of a more proactive approach to sensory aging in the broader context of healthy aging (Davis et al., 2016; Lancet, 2016).

Over ninety percent of hearing loss in older age is classified as presbycusis (or age-related hearing loss) (Vos et al., 2016), which is a syndrome caused by the contributions of a lifetime of multifactorial insults to the auditory system (Gates & Mills, 2005). In contrast, vision loss in older age is

1 more likely to be caused by specific eye diseases such as glaucoma, age-related macular degeneration,
2 diabetic retinopathy, corneal opacity, cataracts, or uncorrected refractive error (Flaxman et al., 2017).
3 Flaxman *et al* (2017) estimated that in 2015, only 16.3% of moderate or severe vision impairment was
4 caused by “other” causes in high-income North American countries.

5 Setting national and international public health priorities requires a clear understanding of burden
6 of disease and healthcare needs. Population-level estimates of morbidity (e.g., years lived with disability)
7 are calculated by multiplying prevalence by an estimate of the severity of disease or illness. Other
8 countries have conducted national health surveys that included non-subjective measures of hearing (i.e.,
9 audiometry) and vision (i.e., visual acuity). However, only very recently have these data been collected in
10 Canada (Aljied, Aubin, Buhrmann, Sabeti, & Freeman, 2018a; Feder, Michaud, Ramage-Morin,
11 McNamee, & Beauregard, 2015) such that for the first time, prevalence can be measured accurately.

12 The present study utilized data from the first wave of the Comprehensive cohort of the Canadian
13 Longitudinal Study on Aging (CLSA). It offers a unique opportunity to generate national-level estimates
14 of hearing and vision loss because audiometry and visual acuity testing is included in the core battery of
15 measures. The large sample size provides the opportunity for subgroup analysis (e.g., according to 5-year
16 age categories, sex, and severity of impairment). The national representativeness of the results is
17 strengthened by having a population-based, cross-country sample from multiple test sites. Notably, this
18 analysis is the first to examine the prevalence of hearing loss and the combined prevalence of hearing and
19 vision loss (dual sensory loss) using CLSA data. A previous report described the prevalence of vision loss
20 using a single vision loss threshold ($>20/40$, or 0.3 logMAR) (Aljied et al., 2018a), but in contrast to our
21 analysis, its results were not stratified by age/sex groups or severity of impairment.

22 Hearing and vision care may be addressed using primary, secondary and tertiary prevention
23 strategies (World Health Organization, 2018b). In Canada, few hearing or vision health services are
24 provided by the publicly-funded universal healthcare system. A minority of individuals with hearing loss
25 use hearing devices (e.g., hearing aids or cochlear implants) even if they might be beneficial, and such
26 devices are not equitably distributed (Chien & Lin, 2012; Stevens et al., 2013). Uptake depends on

individual- and national-level factors including age, income, self-efficacy, readiness for change, perceived disability, availability of services and subsidies (Laplante-Lévesque, Hickson, & Worrall, 2012). National population-based studies examining hearing aid uptake have not been conducted in Canada. Recently, Aljied *et al* (2018b) reported that 57% of participants in the CLSA self-reported visiting an optometrist or ophthalmologist in the past year (Aljied, Aubin, Buhrmann, Sabeti, & Freeman, 2018b), a rate that likely depends on socio-economic status (Jin & Trope, 2011). Refractive error (i.e., the inability to properly focus light on the retina) can usually be corrected with lenses and/or surgery and may be a proxy measure of accessibility and quality of vision health care in the population. Previous studies in Canada suggest that 64-80% of individuals with vision loss >20/40 may have impairment that is correctable with refraction (Aljied et al., 2018a; Robinson et al., 2013). Refractive error prevalence stratified by sex and severity has yet to be estimated at the national level.

Our objectives were to determine the proportion of Canadian males and females aged 45-85 years in 2012-2015 who had varying degrees of hearing and/or vision loss. We also aimed to estimate the numbers of individuals with hearing and/or vision loss in 2011 and 2016, and the change in the count over that 5-year interval. Another goal was to describe the proportion of Canadians with specific eye diseases and degrees of refractive error. Finally, we sought to describe hearing aid use according to hearing ability. Sex differences were determined by performing sex-stratified analyses and by calculating directly age-standardized estimates to account for differences in age distributions between males and females.

Methods:

The study sample

Data from the CLSA Baseline Comprehensive Dataset version 3.2 were used in the analysis. The CLSA is a 20-year longitudinal closed cohort study consisting of approximately 50,000 Canadians aged 45-85 years at the time of baseline analysis (Raina et al., 2009). It consists of two sub-cohorts, the “Comprehensive” and “Tracking” cohorts. There are approximately 20,000 individuals in the Tracking cohort who respond to health surveys via telephone. Participants in the Tracking cohort were excluded from the present study because they did not undergo audiometry or visual acuity testing. Our analysis was

restricted to the approximately 30,000 members of the Comprehensive cohort whose information was obtained through in-person interviews and physical assessments (including audiometry and visual acuity testing) performed at one of eleven data collection sites across Canada.

Recruitment for the Comprehensive cohort began in 2012. The baseline or first wave of data was collected between 2012 and 2015 and released to researchers in 2017. At the time our analysis was conducted, follow-up data were not available and hence the study is a cross-sectional analysis of the first wave of the CLSA Comprehensive cohort data.

Sampling frames of the Comprehensive cohort of the CLSA

Comprehensive cohort participants were recruited by mail using Provincial Healthcare Registration Databases (14%) and by random digit dialing telephone sampling (86%). The CLSA excluded certain types of individuals from the two sampling frames. Sampling was restricted to individuals living within 25 km of the nearest data collection site (except for data collection site locations with lower population densities, where the radius was 50 km). Persons living in the three northern Canadian territories, persons living on First Nations reserves and other First Nations settlements in the provinces, full-time members of the Canadian Armed Forces, and persons living in institutions (e.g., long-term nursing homes, hospitals and penitentiaries) were also excluded from the sampling frames (*CLSA Technical Document: Response Rates and Sample Rates*, 2017). Individuals perceived to have cognitive impairment (i.e., individuals who CLSA interviewers judged unable to understand the purpose of the study and/or provide reliable data), were excluded, as were individuals who could not respond to questions in English or French. Persons living in census tracts with high proportions of persons with lower levels of education were over-sampled. (Raina, Wolfson, & Kirkland, n.d.)

The overall response rate (i.e., percentage of individuals who were successfully contacted by CLSA staff and agreed to participate) was 10%. Single-stage sampling was performed (i.e., there was no geographical clustering).

Inclusion/exclusion criteria for this analysis

We excluded participants from our study if they were missing data for audiometry or visual acuity.

Hearing measures

Hearing detection thresholds were determined using a digital screening audiometer in the automatic test mode and Audiocup headphones (Tremetrics RA300+) (*Tremetrics RA300 and RA300+ Operations Manual*, 2011). Each test was administered in a quiet room by a CLSA technician. Hearing aids were not worn during audiometric testing. Biological calibration listening checks were performed daily on the machines. Pulsed stimuli (3 tone bursts over 1 second) at 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz were presented in 5-dB increments from 0-100 dB HL using a modified Hughson-Westlake method (Margolis et al., 2015). Further details of the automated testing procedure can be found in the operations manual of the audiometer (*Tremetrics RA300 and RA300+ Operations Manual*, 2011). “No responses” (recorded by the audiometer as error code “EE”) were recoded as 105 dB HL for the purpose of our analyses. According to CLSA protocols (*CLSA Hearing-Audiometer DCS Protocol V3.0 Doc SOP_DCS_0020*, 2014), individuals were not tested if they used devices (e.g. Lyric and bone-anchored hearing aids) that could not be removed during testing.

The primary measure of hearing in our study was the 500, 1000, 2000 and 4000 Hz pure-tone average in the better ear; thus, people with hearing loss in only one ear are classified as having normal hearing according to this definition.

The pure-tone average can be classified according to various criteria. We report hearing loss severity using World Health Organization (WHO) criteria (i.e., mild: 25.1-40 dB HL; moderate: 40.1-59.9 dB HL; and severe: ≥ 60 dB HL) (World Health Organization, 2018c) which are also commonly used in clinical practice and epidemiology studies (e.g., Lin, Niparko, & Ferrucci, 2011). In supplementary tables, we also report prevalence using the categories applied in the Global Burden of Disease (GBD) studies (20-34.9 dB HL, 35-49.9 dB HL, 50-64.9 dB HL, 65-79.9 dB HL, 80-94.5 dB HL, and ≥ 95 dB HL) (Salomon et al., 2015) so that the data might be used in future GBD iterations.

Vision measures

Visual acuity was measured using a standard retro-illuminated Early Treatment Diabetic Retinopathy Study (ETDRS) chart placed 2 meters from the participants' eyes. Participants were instructed to wear their regular glasses or contact lenses for the test (in contrast to the hearing test, during which hearing aids were removed). Monocular habitually-corrected tests of visual acuity were performed first, followed by tests of monocular pinhole-corrected visual acuity, and then binocular habitually-corrected visual acuity. For each monocular condition, the right eye was tested before the left eye. (*CLSA Vision-Visual Acuity Protocol Version 2.2 Document SOP_DCS_0025*, 2017).

The primary measure of vision in our study was binocular visual acuity using habitual correction. Participants were scored on the logMAR scale (range: -0.3 to 1.0, equivalent 20/10 to 20/200 using the imperial system, or 6/3 to 6/60 using the metric system) according to the smallest line of letters on the chart for which they correctly identified all of the letters. Individuals who reported being unable to read any of the lines on the chart were excluded from the analysis. Refractive error was estimated by subtracting the pinhole-corrected from the habitually-corrected visual acuity in the eye with the better pinhole-corrected visual acuity.

For vision, we used WHO/International Classification of Diseases version 10 (ICD-10) criteria to classify moderate vision loss (worse than 0.48 logMAR [i.e., 20/60 or 6/18] and equal to or better than 1.0 logMAR [i.e., 20/200 or 6/60]). Since we excluded individuals who reported being unable to read the top line of the ETDRS chart (n=9), no one was classified as having severe vision loss (i.e., visual acuity worse than 1.0 logMAR [i.e., 20/200 or 6/60]) (Dandona & Dandona, 2006; World Health Organization, 2012, 2018a). Since the WHO does not have a definition for "mild" vision loss, we classified individuals with visual acuity equal to or worse than 0.2 logMAR and equal to or better than 0.48 logMAR as having mild vision loss based on similar definitions in the literature. An acuity of 0.2 (6/10, 20/32) corresponds to only moderate fluency in reading newsprint at 33 cm (Colenbrander, 2003; Leat, Legge, & Bullimore, 1999). We also reported the prevalence of vision loss worse than 0.3 logMAR (i.e., 20/40 or 6/12), which

is a common cutoff in epidemiological studies (Aljied et al., 2018a; Dandona & Dandona, 2006) and in clinical practice in North America.

Dual sensory measures

Note that we did not report dual sensory loss using the WHO moderate thresholds for both hearing (>40 dB HL) and vision loss (>0.48 logMAR) because only 89 of 29,002 (0.3%) members of the cohort fit these criteria, precluding age- or sex-stratified analyses. Instead, we defined the following three categories: >25 dB HL and ≥ 0.2 logMAR; >25 dB HL and >0.3 logMAR; and >40 dB HL and >0.3 logMAR.

Other Participant Characteristics

Information about participant characteristics were ascertained through questionnaires administered by trained interviewers. Age and sex information was collected at interviews at each participant's home. Data about eye diseases (self-reported recall about diagnostic information on glaucoma, macular degeneration, cataracts) and hearing aid use were collected during interviews at the data collection site.

Statistical Analysis

Comparisons of included and excluded participants: Differences in characteristics between individuals with complete data (who were included in the subsequent analyses) and incomplete data (who were excluded from subsequent analyses) were determined using two-tailed chi-square tests for categorical variables, and two-tailed Student's t-test for continuous variables.

Prevalence measures: Prevalence of sensory loss was calculated either as a percentage ("prevalence proportion"), or as a population estimate ("prevalence count"). Prevalence counts were calculated by multiplying the prevalence proportion by the national population in both 2011 and 2016, using census data from those years (Statistics Canada, 2011, 2016). We used both the 2011 and 2016 censuses to calculate count estimates because data collection for the first wave of the CLSA occurred in the intervening period (May 2012 through May 2015), and so we could generate estimates of change in prevalence between 2011 and 2016. Canadian national censuses are performed every 5 years; there were

no census performed between 2011 and 2016 that could be used instead. Estimates were stratified by 5-year age-sex categories (i.e., 45-49 years old, 50-54 years old, ..., 80-85 years old). Estimates of prevalence count for the entire age range (45-85 years old) were calculated by summing the 5-year estimates for each sex. The estimates of change were based on population increase and population aging but not on changes in prevalence proportion which was only estimated for one time period (2012-2015).

Locally-weighted regression of prevalence on age was used to generate smoothed curves to demonstrate age-specific prevalence trends.

Sex differences: To assess sex differences in prevalence proportion, directly age-standardized prevalence (for the entire age range) was calculated using the combined male and female population of adults aged 45-85 years in the 2016 Canadian census as the standard population (Statistics Canada, 2016). One-year age groupings were used to generate the age-standardized proportions used in the calculations. Sex differences were considered significant if 95% confidence intervals for males and females did not overlap. Age-standardized prevalence values are not reflective of real-world prevalence; rather, they reflect what the prevalence for males and females would be if the age distribution for each sex were equivalent to the standard population.

Inverse probability sampling weights were used in all of the analyses to improve the national representativeness of prevalence estimates. CLSA statisticians assigned each participant a sample weight that was inversely proportional to the probability of inclusion in the study according to their sex, age, and province of residence. In other words, individuals from age/sex/province groups that were under-represented relative to the national population were assigned higher weights, and individuals from age/sex/province groups that were over-represented were assigned lower weights. The strata variable specified in the complex survey software was the geographic strata variable for the Comprehensive cohort (WGHTS_GEOSTRAT_COM) as recommended by the CLSA. (*CLSA Technical Document: Response Rates and Sample Rates*, 2017) The Taylor linearization method was used for estimating standard errors that accounted for the survey weights.

Statistical significance was assumed for p-values that were less than 0.05 or for 95% confidence intervals that did not overlap. All analyses were conducted using Stata version 14.2 for Mac.

Results:

Of the 30,097 members of the CLSA Comprehensive cohort who completed the baseline assessment, 29,007 (96.4%) had complete audiometry and visual acuity data and were included in our analysis (1,090, or 3.6% had missing data and were excluded). Excluded participants were more likely to be older, have lower income and education, poorer self-rated health, and worse hearing and vision than participants with complete data (Table 1).

Prevalence of degrees of sensory loss by age and sex.

Table 2 breaks down the full cohort (i.e., all participants, aged 45-85 years) according to mild, moderate and severe hearing and vision loss categories. Among males and females, 66.8% and 65.7%, respectively, had no impairment. The majority of individuals with hearing and/or vision loss had mild impairment. For example, 13.4% of males had mild hearing loss, 3.7% had moderate hearing loss and 0.4% had severe hearing loss (compared to 11.3%, 2.3%, and 0.2% of females, respectively). For vision, 19.8% of males had mild impairment and 2.4% had moderate impairment (compared to 23.9% and 2.6% of females, respectively). Similarly, most individuals with dual sensory loss had mild hearing loss and mild vision loss. Out of the total population, 6.4% of males had dual sensory loss with 4.1% having both mild hearing and vision loss. The remainder (2.3%) had at least moderate impairment in one or both senses. Similarly, 6.0% of females had dual sensory loss with 4.3% having mild losses in both sensory modalities and 1.8% having moderate impairment in one or both senses.

Sex Differences

Males were more likely than females to have hearing loss and dual sensory loss. The age-standardized prevalence of hearing loss (PTA > 25 dB HL) for males was 20.7% (95% CI: 20.1-21.4) versus 15.3% (95% CI: 14.7-15.9) for females. The age-standardized prevalence of dual sensory loss (> 25 dB HL and ≥ 0.2 logMAR) for males was 8.1% (95% CI: 7.7-8.5) versus 6.8% (95% CI: 6.4-7.2) for

1 females. Females were more likely than males to have mild vision loss ≥ 0.2 logMAR but not vision loss
2 > 0.48 logMAR, for which there was no difference between sexes. The age-standardized prevalence of
3 vision loss ≥ 0.2 logMAR was 27.9% (95% CI: 27.1-28.7) for females and 24.6% (95% CI: 23.8-25.4) for
4 males.

5 **Hearing Loss.**

6 *Prevalence proportion and count:* Table 3 (and supplementary Figure 1) demonstrate that the
7 proportion of individuals with hearing loss increases exponentially with age. For many age groups, the
8 percentage of males with hearing loss appeared to be higher than the percentage of females, but despite
9 this trend, among 80-85-year olds, there were more females with hearing loss (> 25 dB HL) because of
10 the higher survival rate among females.

11 Between 2011 and 2016, the number of males aged 45-85 years with hearing loss (> 25 dB HL)
12 increased from 1.28 million to 1.48 million (15.7% increase), while the number with hearing loss (> 40
13 dB HL) increased from 309,000 to 356,000 (15.3% increase). The number of females aged 45-85 years
14 with hearing loss (> 25 dB HL) increased from 1.11 million to 1.24 million (11.8% increase), while the
15 number with hearing loss (> 40 dB HL) increased from 215,000 to 237,000 (10.3% increase).

16 *Prevalence of hearing loss as defined by the GBD study.* Similar prevalence results were obtained
17 using the GBD classification of hearing; details are presented in Supplementary Tables 1 and 2.

18 *Cumulative distributions according to pure-tone average.* Figure 1 (upper panel) describes the
19 reverse cumulative prevalence of hearing loss according to pure-tone average, stratified by age group.
20 Cumulative prevalence declines with increasing severity of loss following an inverse sigmoid curve. The
21 lines (each denoting a 5-year age group) become increasingly spread apart with advancing age, again
22 demonstrating the exponential increase in prevalence proportion with advancing age. This figure also
23 shows that while various categories are used to classify impairment, in reality, abilities exist in a
24 continuum across the population.

Use of hearing devices as a function of hearing ability. Table 4 shows the prevalence of hearing device use (hearing aid, amplification device or cochlear implant) according to pure tone average. Hearing device use was significantly more common among males than females. Devices were used by 20.1% (95% CI: 18.6-21.6) of males and 15.5% (95% CI: 14.1-17.0) of females with a PTA > 25 dB HL; they were used by 31.6% (95% CI: 28.5-34.7) of males and 24.7% of females (95% CI: 21.6-27.9) with a PTA > 40 dB HL. As expected, the likelihood of using a hearing device sharply increases with severity of hearing loss, ranging from 0.3% (PTA ≤ 25 dB HL) to 65.8% (PTA of 55-60 dB HL) in females, and from 0.9% (PTA ≤ 25 dB HL) to 73.0% (PTA of 55-60 dB HL) in males. In contrast, the absolute numbers of hearing device users were more evenly distributed across the PTA spectrum; note that 56.2% of female and 57.0% of male hearing device users had a PTA ≤ 40 dB HL. The discrepancy is explained by the much higher population of individuals with normal hearing or mild hearing loss compared to moderate-severe hearing loss. Glasses or contact lens use was nearly ubiquitous (84.2% of males [95% CI 83.3-85.0]; 88.4% of females [95% CI 87.8-89.1]) and thus a detailed analysis of their use was not performed. Aljied et. al. (2018a) have previously examined the frequency and predictors of visiting an eye care professional in Canada using data from the first wave of the CLSA.

Vision Loss.

Prevalence proportion and count: Table 5 (and supplementary figure 2) displays vision loss prevalence. The proportion of individuals with vision loss increases steadily with age but the increase is more gradual than for hearing loss. As a reminder, visual acuity in this study is measured with binocular habitual correction unless stated otherwise.

The prevalence count for visual acuity ≥ 0.2 logMAR increased in both males and females to a maximum among people age 65-69 years before slightly diminishing at older ages. The population of males with vision loss ≥ 0.2 logMAR increased from 1.57 million to 1.79 million (13.5% increase) between 2011 and 2016; the population with vision loss > 0.3 logMAR increased from 379,000 to 431,000 (13.7% increase). For females, the population with vision loss ≥ 0.2 logMAR increased from

2.00 million to 2.22 million (11.3% increase) and the population with vision loss > 0.3 logMAR increased from 444,000 to 493,000 (10.9% increase) during the same timeframe.

Cumulative distributions as a function of visual acuity. Figure 1 (lower panel) describes the reverse cumulative prevalence of vision loss according to visual acuity, stratified by age group. As for hearing, cumulative prevalence declines with increasing severity of impairment following an inverse sigmoid curve. In contrast to hearing, however, the separation between the age-specific lines is relatively uniform, demonstrating the more linear increase in prevalence proportion with age.

Prevalence of Causes of Vision Loss. Table 6 displays the national crude- and age-standardized prevalence of the eye diseases reported in the CLSA (also reported by Aljied *et. al.* (2018b), but in our paper stratified by sex), and the degree of refractive error among individuals with vision loss (binocular habitually-corrected visual acuity ≥ 0.2 logMAR). The prevalence of self-reported macular degeneration, cataracts or glaucoma was relatively low (range: 2.7-6.3%). When comparing crude values, macular degeneration was significantly more common among females than males, however the difference was not significant after adjustment for age. Cataracts (both previously corrected and current) were more common among females than males when comparing both crude and age-standardized prevalence values. In contrast, refractive error (among the population with binocular habitually-corrected visual acuity ≥ 0.2 logMAR) was more prevalent among males than females, even after adjusting for age differences. The prevalence of refractive error decreased exponentially with severity of refractive error.

Dual Sensory Loss.

Prevalence proportion and count: Table 7 and supplementary Figure 3 show dual sensory loss prevalence. The prevalence proportion of dual sensory loss increased exponentially with age for both males and females while the count increased monotonically. Below the age of 75 years, there were more males than females with dual sensory loss (> 25 dB HL and ≥ 0.2 logMAR), but the situation was reversed in older age groups. Across all age groups, there were more males than females with dual sensory loss when the stricter thresholds (> 40 dB HL and > 0.3 logMAR) were used. The population of

males with dual sensory loss (> 25 dB HL and ≥ 0.2 logMAR) increased from 487,000 to 569,000 (16.8% increase) between 2011 and 2016 while the population with more severe dual sensory loss (> 40 dB HL and > 0.3 logMAR) increased from 39,000 to 45,000 (15.4% increase). The population of females with dual sensory loss (> 25 dB HL and ≥ 0.2 logMAR) increased from 500,000 to 555,000 (10.9% increase) between 2011 and 2016 while the population with more severe dual sensory loss (> 40 dB HL and ≥ 0.4 logMAR) increased from 26,000 to 29,000 (8.8% increase).

Discussion

The prevalence of hearing and vision loss among Canadians aged 45-85 years is high and the proportion with sensory loss increases rapidly with age. In 2016, we estimated that approximately 2.7 million Canadians aged 45-85 years had hearing loss (PTA > 25 dB HL), 4.0 million had vision loss (logMAR ≥ 0.2) and 1.1 million had both impairments.

The high prevalence of hearing and vision loss among Canadian adults is generally in line with results from the Global Burden of Disease Studies. In the 2015 iteration of the GBD (Vos et al., 2016), for all ages, sensory impairment was the 2nd highest cause of YLD's globally and in high income countries. Between 2005 and 2015, the proportion of the global population with “disabling” hearing loss (PTA ≥ 35 dB HL) increased by 12.0% (from 5.73% to 6.42% of the total population) so that in 2015, 473 million people had disabling hearing loss (vs. 1.3 billion with hearing loss ≥ 20 dB HL). In 2015, 940 million had vision impairment, including 34.3 million who were blind, 24.3 million with severe impairment, 214 million with moderate impairment and 663 million with near-vision impairment. The largest identified cause was uncorrected refractive error. Between 1990 and 2015, the number of people who were blind increased by 17.9%, while the number of people with moderate and severe vision impairment increased by 35.5%, changes attributable to population growth, aging, and decreases in age-specific prevalence. The GBD numbers apply to all sexes and ages, preventing direct comparisons with our results, but the vast majority of individuals with hearing and vision loss in Canada and around the world are older adults (Vos et al., 2016).

Hearing loss prevalence estimates reported in this manuscript are generally better than reported previously for Canada (2012/2013 Canadian Health Measures Survey Cycle 3)(Feder et al., 2015), the United Kingdom (Cardiff, Glasgow, Nottingham and Southampton, 1980s)(A. C. Davis, 1989), Australia (Blue Mountains Study, 1997-2000)(Gopinath et al., 2009) and the United States (National Health and Nutrition Examination Surveys, 1999-2004 and 2005-2006) (Agrawal, Platz, & Niparko, 2008; F. Lin et al., 2011). The prevalence of vision loss reported in our study is similar to that reported in Australia (Tay, Wang, Rochtchina, & Mitchell, 2005) and the United States(Lee, Gómez-Marín, Lam, Zheng, & Jané, 2004). The prevalence of dual sensory loss was generally lower than previous reports from Australia (Blue Mountains Study, 1997-2004)(Chia et al., 2006; Schneider et al., 2012), but similar to data from the United States (National Health and Nutrition Examination Survey, 1999-2006) (Swenor, Ramulu, Willis, Friedman, & Lin, 2013).

Observed patterns in prevalence proportion were consistent with previous reports. As expected, we found a close association between prevalence proportion and age. For hearing loss, prevalence proportion increased exponentially with age, whereas for vision loss, the increase was more gradual. This difference resulted in a monotonic increase in the population with hearing loss between the ages of 45 and 85 years, but a peak in the 60-65-year old age group for vision loss (≥ 0.2 logMAR). Males were at higher risk of hearing loss and dual sensory loss, but in the oldest age groups more females had these impairments because of their higher rates of survival. Females were at higher risk of vision loss in general and cataracts specifically. At all ages, prevalence decreased exponentially as the severity of sensory loss increased. Whereas vision loss was very common, relatively few individuals had diagnoses of macular degeneration, cataracts or glaucoma (range: 3.2%-8.6% of the population).

There are several possible reasons for the sex differences. In regards to hearing loss, it has been reported that females have shorter cochlear ducts and greater stiffness in the basilar membrane, which may contribute to earlier latencies relative to males in speech-auditory brainstem responses. (Krizman, Skoe, & Kraus, 2012) Hormonal differences may impact auditory function with aldosterone, vasopressin, estrogen and melatonin having protective effects and testosterone, progesterone, and stress hormones

1 playing a role in auditory pathology.(Al-Mana, Ceranic, Djahanbakhch, & Luxon, 2008; Frisina, 2012)
2 Gender-related risk factors for hearing loss that are more prevalent in males include lower education
3 level, smoking, and industrial noise exposure.(Statistics Canada, 2018a) In contrast, males are also more
4 likely to consume alcohol, which when ingested in moderate amounts may be protective.(Kim et al.,
5 2010; Statistics Canada, 2018a)

6 Unlike hearing loss, vision loss appeared to be more slightly prevalent in females than males. In
7 analyses that adjusted for differences in age distributions (i.e., age-standardized analyses), females were
8 more likely to have cataracts than males but there were no sex differences in rates of macular
9 degeneration or glaucoma. Information on diabetic retinopathy was not available in the CLSA. Our
10 findings are consistent with a higher global prevalence of cataracts among females than males, possibly
11 due to harmful estrogen withdrawal effects after menopause (estrogen may reduce cataract formation due
12 to anti-oxidative properties) and differences in access to cataract surgery (Zetterberg, 2016). Aljied et al,
13 in their study of the CLSA Comprehensive cohort, reported that more females access eye care than males,
14 but prevalence of cataract surgery was not reported since the information is not collected in the CLSA
15 (Aljied et al., 2018b). In our study, we found that males with vision loss (visual acuity ≥ 0.2 logMAR)
16 were more likely to have refractive error ≥ 0.1 logMAR, which is consistent with the lower uptake of
17 vision care among older males in Canada reported by Aljied *et al.* Receiving eye care services would
18 increase the likelihood of being fitted with lenses that better correct refractive error. In other countries,
19 especially developing countries, the opposite appears to be true, i.e., access to optometry or
20 ophthalmology services is more prevalent among males than females with vision loss (Doyal & Das-
21 Bhaumik, 2018; B. A. Olusanya, Ashaye, Owoaje, Baiyeroju, & Ajayi, 2016). Previous studies show that
22 diabetic retinopathy may be more common in males (Zetterberg, 2016). In Canada, more males than
23 females have diabetes (Statistics Canada, 2018b), and studies from the United States have shown that
24 among people with diabetes, retinopathy is more likely among males than females. Females appear to be

at greater risk for angle closure glaucoma due to anatomic factors, but there is no clear sex association for open angle glaucoma, which is much more common (Vajaranant, Nayak, Wilensky, & Joslin, 2010).

The difference in prevalence between males and females was larger for hearing loss than for vision loss; this probably explains the male predominance for dual sensory loss.

Our estimates for change in prevalence count between 2011 and 2016 reflect population increases, with the population of males aged 45-85 years growing 8.0% and the population of females aged 45-85 years growing 7.6% (Statistics Canada, 2011, 2016) and aging of the population pyramid. The estimates do not take into account any changes in the age-specific risk of sensory loss that may have occurred over this time frame, but we have no reason to assume that such changes significantly influence our results because the prevalence proportions used were calculated from data collected in between the two censuses (i.e., during 2012-2015). The age-specific prevalence of hearing loss and vision loss does, however, appear to be decreasing, perhaps in response to reduced lifetime exposure to risk factors in later generations of seniors (Cruickshanks et al., 2017; Hoffman, Dobie, Losonczy, Themann, & Flamme, 2017; Zhan et al., 2010). Therefore, our estimates of change over time may be slightly overestimated and future increases may be lower than predicted based solely on changes in population size and age distribution. Barring dramatic reductions in the incidence of age-related sensory loss, prevalence count should continue to rise rapidly until at least 2030 when the youngest baby boomers will reach the age of 65 years, and the projected proportion of seniors in the population will have increased to 22.8% from 15.3% in 2013 (Statistics Canada, 2014).

The CLSA cohort analyzed in this study was healthier, wealthier and better educated than the general population of Canada and participants in the 2012/13 Canadian Health Measures Survey (CHMS). These differences may limit generalizability of the results and explain why hearing and dual sensory loss prevalence were lower than in estimates from the CHMS and studies from other parts of the world (Raina, Wolfson, Kirkland, & Griffith, n.d.). In 2011, 9.3% of those in the country aged 45-85 years vs. 5.2% of CLSA participants had annual household incomes less than \$20,000. In the general population, 54.2% of adults aged 45-65 years report having post-secondary education, vs. 72.6% of CLSA participants.

1 Furthermore, hearing and vision ability was worse among the 3.6% of participants who were excluded
2 from our analysis due to missing data than among those with complete data. Since lower health, income
3 and education are independently associated with worse hearing and vision (Fisher et al., 2014; JM,
4 Sommer, Katz, Quigley, & Ezrine, 1991; F. Lin et al., 2011), these factors suggest that our estimates may
5 underestimate the true national prevalence. Furthermore, it is likely that the bias is especially large for the
6 older age groups within the sample, because a larger proportion of them were likely to have been
7 censored from the CLSA, for example due to age-related impairments that may have prevented them from
8 participating or institutionalization in long-term care homes.

9 Visible minorities were also under-represented among CLSA participants. Ninety-four percent
10 reported white cultural background, which is significantly higher than the general population (Turcotte &
11 Schellenberg, 2007). It is unclear if visible minority status affects the risk of sensory loss in Canada,
12 although there is circumstantial evidence that being a visible minority could have a beneficial effect on
13 hearing. Nearly two thirds of visible minorities in Canada are immigrants, who are generally healthier (as
14 measured by age-standardized mortality rates) than native-born Canadians, and better health is associated
15 with improved hearing and vision (Fisher et al., 2014). The so-called “healthy immigrant effect” varies in
16 magnitude but is still present for all regions of origin. It diminishes with time lived in Canada, but is still
17 detectable 20 years after immigration (Ng, 2015). In the United States, race/ethnicity other than non-
18 Hispanic white is associated with equal or better hearing in multivariable analyses (Hoffman et al., 2017;
19 F. R. Lin et al., 2012). For vision, the prevalence of age-related macular degeneration and cataract surgery
20 was higher in non-Hispanic whites, but diabetic retinopathy and glaucoma were higher in non-Hispanic
21 blacks, relative to other groups in the United States. Visible minority groups differ in country of origin
22 and socioeconomic status between the United States and Canada, where the largest groups in descending
23 order are South Asian, Chinese, Black, Filipino and Latin American. Further studies are needed to
24 estimate sensory loss prevalence among Canadian visible minority groups. Separate studies are also
25 needed to determine the occurrence of hearing and vision loss among older Indigenous Canadians, who
26 were excluded from the CLSA if they lived on reserves or in the Northern Territories, and who in general

1 have more risk factors for hearing and vision loss than the general population (Harris, Bhattacharyya,
2 Dyck, Hayward Naqshbandi, & Toth, 2013; Langan, Sockalingam, Caissie, & Corsten, 2007).

3 Pure-tone thresholds and visual acuity are frequently-used measures of hearing and vision,
4 respectively, and thus allow comparisons with other studies in the literature. These measures do not rely
5 on self-reported ratings, providing more accurate assessments of biological functioning of the auditory
6 and visual systems. The continuous scales allow estimation of severity of impairment, and provide
7 statistical power. Despite these benefits, these measures only partially describe hearing and vision ability,
8 and incompletely predict restrictions in activity, participation and wellbeing in everyday life (World
9 Health Organization, 2001) resulting from hearing and/or vision loss. Compared to pure-tone audiometry,
10 tests of how well listeners can understand speech are better suited to assess the integrity of higher-level
11 auditory processing and may be more reflective of real-world functioning (Pichora-Fuller, 2003). Future
12 waves of the CLSA will include the Canadian Digit Triplet Test in French and English versions (Ellaham,
13 Giguère, Lagacé, & Pichora-Fuller, 2016) based on a protocol in which participants are asked to repeat
14 randomly presented digits against a noisy background. This type of speech-in-noise testing has been used
15 in other countries (e.g., Jansen, Luts, Wagener, Frachet, & Wouters, 2010) and in other population studies
16 such as the UK Biobank (Dawes et al., 2014). Compared to visual acuity testing, contrast sensitivity tests
17 may be more representative of functional limitations associated with age-related vision loss (Lord, Clark,
18 & Webster, 1991; Rubin, Roche, Prasada-Rao, & Fried, 1994). A person's ability to compensate for
19 sensory impairments may be just as important as behavioural measures of hearing and vision, in terms of
20 how sensory loss affects their lives. Such contextual factors (i.e., as described in the International
21 Classification of Functioning, Disability and Health) (World Health Organization, 2001) are not reflected
22 in our prevalence estimates. We are currently investigating factors in addition to pure-tone average and
23 visual acuity scores that predict subjective ratings of hearing and vision loss (Hämäläinen et. al.,
24 submitted). Determining who is most at risk for negative consequences of sensory loss is an important
25 research goal so that, given limited budgets, healthcare resources can be distributed equitably.

1 We found that a relatively low proportion of individuals with hearing loss used hearing
2 amplification devices. As expected, use increased with severity of impairment. The findings are on par
3 with figures from the 1999-2006 National Health and Examination Surveys (NHANES) in the United
4 States (Chien & Lin, 2012). Hearing aid use among CLSA participants was lower than among participants
5 of the 1997-2003 Australian Blue Mountains study, who were on average older than CLSA participants
6 (Hartley, Rochtchina, Newall, Golding, & Mitchell, 2010). Pure-tone average is only one of many factors
7 (including socio-economic status, self-rated hearing ability, age and activity limitations) that may affect
8 hearing aid use (Hartley et al., 2010; Helvik, Krokstad, & Tambs, 2016; Meyer & Hickson, 2012). In the
9 CLSA, hearing device use was more common in males than females. Some studies have shown an effect
10 of sex on hearing device use (Staehelin et al., 2011), whereas others have not (McKee et al., 2018;
11 Popelka et al., 2015). Multivariable analyses using CLSA data are required to determine if the differences
12 seen in our study may be explained by sex- or gender-related factors such as age distribution, hearing loss
13 severity, self-perceived disability, socio-economic status and/or audiogram configuration.

14 Over 50% of males and females with vision loss had refractive error ≥ 0.1 logMAR, and about
15 30% had refractive error ≥ 0.2 logMAR. Thus, a large number of Canadians with vision loss would likely
16 benefit from better correction of their refractive error. Further research is needed to understand the
17 reasons why so many individuals had refractive error, which is unexpected considering that 84-88% of
18 participants wore glasses or contact lenses, and previous research showed that 57% of CLSA participants
19 visited an optometrist or ophthalmologist in the past year (Aljied et al., 2018b).

20 In contrast to many studies in the literature, we compiled results for hearing loss, vision loss and
21 dual sensory impairment in a single paper. Individuals with an impairment in one modality usually rely on
22 their other sense to help them communicate and navigate, and thus the functional disability resulting from
23 a dual sensory loss may be synergistic rather than additive. Treatment strategies may differ for individuals
24 with dual sensory loss than for those with a single impairment. Thus, we feel it is important to focus on
25 individuals with both impairments, especially given the high prevalence of both hearing and vision loss in

1 older age. Notably, 25% of adults aged 70-75 years and 40% of adults aged 80-85 years had dual sensory
2 loss (>25 dB HL and ≥ 0.2 logMAR) and its prevalence has increased from 2011 to 2016 at a rate
3 comparable to the prevalence of vision or hearing loss alone. Other researchers should similarly consider
4 addressing hearing and vision simultaneously, which may require collaborations beyond traditional
5 professional silos.

6 **Limitations:**

7 The study results are specific to Canada in the early 2010s and may not be applicable to other
8 places and times. Furthermore, as elaborated previously, the CLSA is in general healthier, wealthier and
9 better educated than the general population and thus the study results may underestimate the true national
10 prevalence of hearing loss, vision loss and dual sensory loss. This was a population based study and
11 results thus do not reflect the clinical population. Most participants were recruited by telephone and thus
12 individuals with severe hearing loss may have been excluded due to difficulties with telephone
13 communication. Previous validation studies have shown that self-reported questionnaires have poor
14 sensitivity for ophthalmologic disease when compared against more objective measures and thus our
15 estimates of eye diseases may also underestimate the true prevalence (Foreman et al., 2017; Patty et al.,
16 2012). There was no information about why individuals were classified as unable to read the ETDRS
17 chart, but since only 9 were excluded for this reason, the results would unlikely have changed
18 significantly if they were classified as blind. There was no information at all about etiologies of hearing
19 loss, and a lack of bone-conduction audiometry prevents classification of hearing loss as conductive or
20 sensorineural. The self-reported hearing aid question provides no details about meaningful clinical use
21 (e.g., hours per day worn, benefit, satisfaction) and thus provides only a rough estimate of hearing health
22 care utilization. Questions about other types of hearing health care (e.g., auditory rehabilitation, surgery)
23 were not asked by the CLSA. There were no questions asked about tinnitus and other aspects of hearing
24 loss that contribute to quality of life. The limitations of audiometry and visual acuity as the sole measures
25 of hearing and vision loss, respectively, are discussed above. Briefly, they only reflect specific domains of
26 sensory function. In specific individuals, sensory functioning may be better reflected by other measures

(e.g., speech in noise testing or contrast sensitivity testing), or may be affected by contextual factors (e.g., a person's physical and social environments, co-morbidities, or access to health care).

Conclusions

To conclude, our study provides the first national estimates of hearing loss, vision loss and dual sensory loss prevalence among older Canadians. Consistent with studies from other parts of the world, the prevalence of sensory loss is high, varies according to sex, and is increasing rapidly due to population growth and aging. This information will be useful to health policy planners, clinicians, consumer groups, individuals and industry partners. The results of the study will act as a baseline against which future estimates of prevalence generated from the aging CLSA cohort may be compared. Although the CLSA is national in scope, certain important groups were excluded or under-represented from the survey, thus the estimations may not be entirely representative of the national population and likely underestimate true prevalence. Future population-based studies of sensory loss prevalence in Canada should focus on Indigenous Canadians, visible minority groups, people with low education and/or income, people living in rural areas, culturally Deaf sign-language users, people with cognitive problems, individuals living in institutions, and members of the Armed Forces. Research is also needed to identify individual factors that predict health and social problems that arise from sensory loss in order to facilitate the equitable delivery of new health care resources for sensory loss. This information could be used to develop a plan that incorporates primary, secondary and tertiary prevention strategies for sensory loss into broader efforts to improve seniors health.(Sinha et al., 2016; World Health Organization, 2007)

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FIGURES

Figure 1. Reverse cumulative prevalence curves for a.) hearing loss (upper panel) and b.) vision loss (lower panel). The value on the y-axis indicates the percentage of individuals with a.) hearing or b.) vision equal to or worse than the threshold on the x-axis.

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TABLES

Table 1. Characteristics of individuals with complete and missing data.

Variable		Group with complete data (n=29,007; 96.4%)	Group with missing data (n=1,090; 3.6%)	p
Hearing	Pure tone average (PTA) in better ear (SD)	18.2 dB HL (11.5)	23.5 dB HL (13.8)	<.001
	PTA>25 dB HL (n, col%)	6,263 (21.6%)	63 (39.4%)	<.001
	PTA>35 dB HL (n, col%)	2,813 (9.7%)	28 (17.5%)	<.001
	PTA>40 dB HL (n, col%)	1,428 (5.0%)	16 (10.1%)	0.003
	PTA>50 dB HL (n, col%)	424 (1.5%)	6 (3.8%)	0.017
Visual acuity	Average binocular, habitually corrected VA (logMAR, SD)	0.09 (0.17)	0.13 (0.19)	<.001
	logMAR>=0.2 (n, col%)	8,590 (29.6%)	310 (39.7%)	<.001
	logMAR>=0.3 (n, col%)	4,096 (14.1%)	174 (22.3%)	<.001
	logMAR>=0.4 (n, col%)	2,096 (7.2%)	97 (12.4%)	<.001
	logMAR>=0.5 (n, col%)	939 (3.2%)	48 (6.2%)	<.001
Sex (n, col%)	Females (n, col%)	14,765 (50.9%)	555 (50.9%)	0.992
	Males (n, col%)	14,242 (49.1%)	535 (49.1%)	
Age	Average years of age (SD)	62.8 (10.2)	65.9 (10.5)	<.001
Annual household income (n, col%)	\$150,000+	4,665 (16.1%)	134 (12.3%)	<.001
	\$100K-149K	5,345 (18.4)	175 (16.1)	
	\$50K-99K	9,604 (33.1)	303 (27.8)	
	\$20K-49K	6,078 (21.0)	282 (25.9)	
	<\$20K	1,462 (5.0)	104 (9.5)	
	Don't know/refused/missing	1,849 (6.4)	92 (8.4)	
Education (n, col %)	Post-secondary degree	22,524 (77.8%)	787 (73.6%)	<.001
	Post-secondary education, no degree	2,121 (7.3)	111 (10.4)	
	Secondary school graduate	2,737 (9.5)	99 (9.3)	
	Less than secondary school graduation	1,570 (5.4)	73 (6.8)	
"White" cultural background (n, col %)		27,349 (94.3%)	1,001 (93.2%)	0.135
Self-rated general health (n, col%)	Excellent	5,786 (20.0%)	206 (19.2%)	<.001
	Very good	12,014 (41.5)	400 (37.3)	
	Good	8,547 (29.5)	325 (30.3)	
	Fair	2,199 (7.6)	113 (10.5)	
	Poor	438 (1.5)	29 (2.7)	

- P-value reflects the difference in each characteristic between the groups with complete and missing data. The Student T-test was used for continuous variables, and the Chi-square test was used for categorical variables.

Table 2. Prevalence (proportion) of Canadians 45-85 years old with varying degrees of hearing and vision loss.

Vision loss (binocular visual acuity, habitual correction, in logMAR)		Hearing loss (pure tone average of 500, 1000, 2000 and 4000 Hz in the better ear)												Row total		
		None (<25 dB HL)			Mild (25-40 dB HL)			Moderate (40-60 dB HL)			Severe >60 dB HL)					
		n	%	95% CI	n	%	95% CI	n	%	95% CI	n	%	95% CI	n	%	95% CI
None (<0.2)	Males	8,151	66.8	65.8-67.7	1,597	8.7	8.2-9.2	426	2.1	1.8-2.3	38	0.2	0.1-0.3	10,212	77.8	77.0-78.6
	Females	8,776	65.7	64.8-66.6	1,171	6.5	6.0-6.9	229	1.2	1.0-1.4	29	0.2	0.08-0.2	10,205	73.5	72.7-74.3
Mild [0.2-0.48]	Males	2,236	14.2	13.4-14.9	941	4.1	3.8-4.4	344	1.4	1.2-1.6	38	0.1	0.08-0.2	3,559	19.8	19.0-20.6
	Female	2,982	18.5	17.8-19.3	872	4.3	3.9-4.6	222	1.0	0.09-1.2	16	0.07	0.03-0.1	4,092	23.9	23.1-24.7
Moderate (0.48-1.0)	Males	278	1.6	1.4-1.9	140	0.6	0.5-0.07	46	0.2	0.1-0.2	7	0.03	0-0.05	471	2.4	2.1-2.7
	Females	321	1.9	1.7-2.2	114	0.6	0.4-0.7	28	0.1	0.06-0.2	5	0.02	0-0.04	468	2.6	2.3-2.9
Column total		10,665	82.6	81.9-83.3	2,678	13.4	12.8-14.0	816	3.7	3.3-4.0	83	0.4	0.3-0.5	14,242	100	
		12,079	86.2	85.6-86.8	2,157	11.3	10.7-11.8	479	2.3	2.1-2.6	50	0.2	0.2-0.3	14,765	100	

- n refers to number of study participants (unweighted)
- % refers to the estimated percentage of the Canadian population aged 45-85 in the specified hearing and vision category (weighted estimate)
- 95% CI refers to 95% confidence interval for % (weighted estimate)
- Shaded area indicates dual sensory loss
- Note that there were no procedures in place to confirm “severe” vision loss in the CLSA (i.e., visual acuity worse than 1.0). Individuals who could not read the ETDRS chart (n=9) were excluded from analysis.

Table 3. Hearing loss prevalence among Canadians 45-85 years old based on pure-tone threshold average (PTA) of 500, 1000, 2000 and 4000 Hz in the better ear. Prevalence counts were calculated by multiplying the displayed prevalence proportion (which was based on data collected between 2012-2015) by the population of Canadians in each age category using data from a.) the 2011 census and b.) the 2016 census.

	Age (y)	PTA > 25 dB HL		Prevalence count		PTA > 40 dB HL		Prevalence count	
		Prevalence proportion (row %)	95% CI	2011	2016	Prevalence proportion (row %)	95% CI	2011	2016
Males	45-49	2.8	1.8-3.8	36,927	32,420	0.4	0.06-0.8	5,763	5,060
	50-54	5.6	4.5-6.8	73,661	74,209	0.8	0.4-1.2	10,618	10,697
	55-59	8.8	7.4-10.1	100,492	112,570	1.8	1.1-2.4	20,373	22,821
	60-64	16.2	14.5-17.8	162,264	180,421	2.7	2.0-3.4	26,954	29,970
	65-69	27.8	25.5-30.1	205,268	265,084	5.0	3.9-6.1	36,891	47,641
	70-74	38.3	35.4-41.2	208,206	259,750	7.6	6.1-9.2	41,542	51,826
	75-79	57.1	54.0-60.1	238,447	267,889	17.0	14.7-19.3	70,973	79,736
	80-85	75.9	72.6-79.1	251,359	284,750	28.9	25.2-32.7	95,812	108,540
	Σ 45-85			1,276,625	1,477,093			308,926	356,292
% change in Σ 45-85 yr prevalence count 2011-2016					15.7%				
Females	45-49	2.2	1.4-3.0	30,164	26,735	0.5	0.1-0.9	6,689	5,929
	50-54	3.0	2.2-3.7	40,572	40,854	0.3	0.1-0.5	3,775	3,801
	55-59	6.3	5.1-7.5	76,300	85,361	0.4	0.2-0.6	4,897	5,479
	60-64	10.2	8.8-11.7	107,580	120,454	1.4	0.9-2.0	14,845	16,621
	65-69	16.7	14.9-18.5	131,709	171,321	2.9	2.0-3.8	23,003	29,921
	70-74	29.2	26.4-31.9	176,736	215,371	4.4	3.2-5.5	26,662	32,491
	75-79	46.4	43.3-49.5	234,132	256,186	9.7	7.8-11.5	48,788	53,383
	80-85	64.8	61.2-68.4	310,219	321,645	18.1	15.2-21.0	86,558	89,746
	Σ 45-85			1,107,412	1,237,927			215,218	237,372
% change in Σ 45-85 yr prevalence count 2011-2016					11.8%				

- Row % refers to the percentage of males or females within each age group who have hearing worse than the thresholds listed.
- Prevalence counts were calculated by multiplying the prevalence proportion by the number of Canadians in the same age-sex category in 2011 and 2016 censuses.
- For reference, between 2011 and 2016 in Canada the total population of males age 45-85 increased 8.0% and the total population of females age 45-85 increased 7.6%.

Table 4. Prevalence of hearing device use (hearing aid, amplifier or cochlear implant)

Pure tone average (dB HL)	Females		Males	
	Percentage using a hearing device (row%, 95% CI)	Percentage of all hearing device users (col%, 95% CI)	Percentage using a hearing device (row%, 95% CI)	Percentage of all hearing device users (col%, 95% CI)
<25	0.3 (0.2-0.4)	10.8 (7.5-14.1)	0.9 (0.7-10.4)	16.7 (13.5-19.8)
(25-30]	4.7 (3.2-6.1)	10.0 (7.0-13.0)	8.1 (6.3-9.9)	12.3 (9.7-14.9)
(30-35]	12.6 (9.6-15.5)	17.8 (13.7-21.8)	13.4 (10.5-16.3)	12.9 (10.1-15.6)
(35-40]	20.9 (16.4-25.5)	17.6 (13.8-21.7)	22.5 (18.3-26.7)	15.1 (12.1-18.0)
(40-45]	30.9 (24.0-37.7)	14.3 (10.8-17.8)	38.6 (32.8-44.5)	16.7 (13.8-19.5)
(45-50]	49.5 (39.0-60.0)	12.3 (9.0-15.6)	44.4 (36.8-52.1)	11.1 (8.8-13.4)
(50-55]	55.5 (41.8-69.1)	7.0 (4.4-9.5)	49.1 (37.2-60.9)	6.0 (4.3-7.7)
(55-60]	65.8 (48.4-83.1)	5.0 (2.8-7.3)	73.0 (60.2-85.9)	4.4 (2.8-6.0)
>60	55.3 (38.6-72.0)	5.1 (2.9-7.4)	52.9 (38.7-67.1)	4.9 (3.3-6.6)
Total		100%		100%
>25	15.5 (14.1-17.0)		20.1 (18.6-21.6)	
>40	24.7 (21.6-27.9)		31.6 (28.5-34.7)	

- Row % refers to the percentage of females or males within each PTA group who use a hearing device.
- Col % refers to the percentage of female or male hearing device users who belong to each PTA group.

Table 5. Vision loss prevalence among Canadians aged 45-85 years. Prevalence counts were calculated by multiplying the displayed prevalence proportion (which was based on data collected between 2012-2015) by the population of Canadians in each age category using data from a.) the 2011 census and b.) the 2016 census.

Age (y)	Visual acuity ≥ 0.2 logMAR (20/32)				Visual acuity > 0.3 logMAR (20/40)				Visual acuity > 0.48 logMAR (20/60)			
	Prevalence proportion		Prevalence count		Prevalence proportion		Prevalence count		Prevalence proportion		Prevalence count	
	Row %	95% CI	2011	2016	Row %	95% CI	2011	2016	Row%	95% CI	2011	2016
Males												
45-49	8.3	6.6-10.0	109,176	95,850	2.0	1.1-2.8	25,956	22,788	0.7	0.3-1.2	9,328	8,190
50-54	13.7	12.0-15.4	179,117	180,449	2.5	1.7-3.2	32,601	32,843	1.3	0.8-1.8	16,861	16,987
55-59	18.0	16.1-20.0	207,020	231,901	3.3	2.4-4.2	38,212	42,805	1.9	1.2-2.6	21,846	24,472
60-64	23.9	22.0-25.8	239,542	266,346	5.9	4.8-7.0	59,415	66,063	2.5	1.7-3.2	24,662	27,421
65-69	32.3	29.9-34.7	238,166	307,569	7.0	5.7-8.3	51,918	67,048	3.1	2.2-3.9	22,789	29,430
70-74	40.9	38.0-43.8	221,997	276,955	10.0	8.2-11.8	54,276	67,713	4.0	2.8-5.2	21,859	27,270
75-79	45.5	42.5-48.5	190,226	213,714	13.3	11.3-15.3	55,517	62,372	6.0	4.7-7.3	25,033	28,124
80-85	56.9	53.0-60.7	188,316	213,332	18.4	15.6-21.3	61,099	69,215	9.3	7.2-11.5	30,859	34,958
Σ 45-85			1,573,560	1,786,116			378,995	430,848			173,238	196,852
% change in Σ 45-85 yr prevalence count 2011-2016				13.5%				13.7%				12.0%
Female												
45-49	10.6	8.8-12.5	144,446	128,023	2.3	1.4-3.1	30,748	27,252	1.4	0.7-2.1	18,678	16,398
50-54	16.3	14.5-18.0	219,650	221,177	2.8	2.0-3.5	37,511	37,772	1.2	0.7-1.7	16,114	16,234
55-59	22.2	20.2-24.2	264,859	296,313	4.4	3.4-5.4	52,592	58,838	1.8	1.1-2.4	20,251	22,686
60-64	27.9	25.8-30.0	292,969	328,027	5.5	4.4-6.6	57,829	64,750	2.6	1.8-3.4	26,008	28,918
65-69	33.7	31.3-36.0	263,789	343,124	6.8	5.6-8.0	53,274	69,296	3.0	2.1-3.8	21,852	28,219
70-74	44.3	41.3-47.4	270,350	329,451	9.9	8.2-11.6	60,203	73,364	4.6	3.3-5.8	24,825	30,971
75-79	51.5	48.4-54.7	260,180	284,688	12.9	10.9-15.0	65,280	71,429	5.7	4.2-7.1	23,757	26,691
80-85	58.7	55.0-62.4	280,791	291,133	18.2	15.3-21.0	86,958	90,161	8.6	6.6-10.7	28,647	32,453
Σ 45-85			1,997,034	2,221,936			444,396	492,862			180,132	202,569
% change in Σ 45-85 yr prevalence count 2011-2016				11.3%				10.9%				11.1%

- Visual acuity was measured with binocular habitual correction
- Row % refers to the percentage of males or females within each age group who have visual acuity worse than the thresholds listed.
- Prevalence counts were calculated by multiplying the row% value by the number of Canadians in the same age-sex category in 2011 and 2016 censuses.
- For reference, between 2011 and 2016 in Canada the total population of males age 45-85 increased 8.0% and the total population of females age 45-85 increased 7.6%.

Table 6. Prevalence of eye diseases among the entire sample, and refractive error among individuals with vision loss (i.e., binocular habitually corrected visual acuity ≥ 0.2 logMAR)

	Females				Males			
	Crude		Age standardized		Crude		Age standardized	
Eye diseases among the entire sample	%	95% CI	%	95% CI	%	95% CI	%	95% CI
Macular degeneration	3.5*	3.2-3.9	3.9	3.1-4.2	2.7*	2.5-3.0	3.2	2.9-3.5
Cataracts (previously corrected)	5.4*	5.0-5.8	8.4*	7.9-8.9	4.5*	4.1-4.8	6.9*	6.5-7.4
Cataracts (current)	6.3*	5.9-6.8	8.6*	8.0-9.1	4.9*	4.5-5.3	6.7*	6.2-7.2
Glaucoma	4.4	4.0-4.7	4.6	4.3-5.0	3.7	3.3-4.0	4.4	4.0-4.7
Refractive error among individuals with binocular habitually-corrected visual acuity ≥ 0.2 logMAR (20/32)								
	Col %	95% CI	%	95% CI	%	95% CI	%	95% CI
<0.1 logMAR	49.4*	47.6-51.2	64.7*	63.8-65.6	44.6*	42.6-46.6	62.6*	61.6-63.5
0.1 logMAR	22.2	20.7-23.7	21.0	20.2-21.8	23.2	21.6-24.9	21.2	20.4-22.0
0.2 logMAR	14.0	12.8-15.3	8.7	8.1-9.2	15.6	14.1-17.1	9.8	9.2-10.3
0.3 logMAR	8.6	7.5-9.6	3.7	3.4-4.1	8.9	7.7-10.0	4.0	3.6-4.3
0.4 logMAR	3.9	3.2-4.6	1.4	1.2-1.6	5.5	4.5-6.6	1.8	1.6-2.1
≥ 0.5 logMAR	1.9	1.4-2.5	0.6	0.4-0.7	2.1	1.5-2.7	0.6	0.5-0.8
≥ 0.1 logMAR	50.6*	48.8-52.4	35.3*	34.4-36.2	55.4*	53.4-57.4	37.4*	36.5-38.4

*Significant difference (non-overlapping confidence intervals) between males and females

- n refers to number of study participants (unweighted)
- “Crude” prevalence adjusts for survey weights. Age-standardized prevalence adjusts for differences in age distributions between males and females, and also adjusts for survey weights (see methods).
- % refers to the percentage of Canadian females or males aged 45-85 with the condition listed in the left-hand column
- 95% CI refers to 95% confidence interval for the percentage
- Refractive error was measured as the difference between habitual- and pinhole-corrected visual acuity in the eye with better pinhole-corrected visual acuity.

Table 7. Dual sensory loss prevalence among Canadians age 45-85 years. Prevalence counts were calculated by multiplying the displayed prevalence proportion (which was based on data collected between 2012-2015) by the population of Canadians in each age category using data from a.) the 2011 census and b.) the 2016 censuses.

Age (y)	PTA > 25 dB HL & visual acuity ≥ 0.2 logMAR (20/32)				PTA > 25 dB HL & visual acuity > 0.3 logMAR (20/40)				PTA > 40 dB HL & visual acuity > 0.3 logMAR (20/40)			
	Prevalence proportion (row %)	95% CI	Prevalence count		Prevalence proportion (row%)	95% CI	Prevalence count		Prevalence proportion (row %)	95% CI	Prevalence count	
Males	45-49	0.2	0-0.4	2,297	2,016	0.1	0-0.2	1,206	1,058	0	n/a	0
	50-54	0.8	0.4-1.2	9,915	9,989	0.2	0-0.5	3,156	3,180	.02	0-0.1	376
	55-59	2.1	1.5-2.8	24,236	27,149	0.6	0.2-1.0	6,910	7,740	0.2	0-0.5	2,814
	60-64	4.4	3.5-5.3	44,420	49,390	1.0	0.5-1.4	9,583	10,655	0.2	0.1-0.4	2,249
	65-69	9.8	8.3-11.3	72,559	93,703	2.2	1.5-2.8	15,893	20,525	0.5	0.2-0.9	4,024
	70-74	15.8	13.7-17.9	85,965	107,247	3.6	2.5-4.8	19,792	24,692	0.6	0.2-1.1	3,380
	75-79	25.6	23.0-28.2	106,956	120,163	7.5	6.0-9.0	31,323	35,190	2.1	1.3-2.9	8,638
	80-85	42.5	38.7-46.4	140,930	159,651	13.8	11.3-16.4	45,780	51,861	5.3	3.7-7.0	17,609
	Σ 45-85			487,277	569,307			133,643	154,902			39,090
% change in Σ 45-85 yr prevalence count 2011-2016				16.8%				13.7%				15.4%
Females	45-49	0.6	0.2-0.9	7,672	6,799	0.1	0-0.3	1,828	1,621	0.1	0-0.2	914
	50-54	0.4	0.1-0.8	6,028	6,069	.04	0-0.1	516	520	.04	0-0.1	516
	55-59	2.0	1.3-2.7	24,048	26,904	0.5	0.1-0.9	5,860	6,556	0	n/a	0
	60-64	3.1	2.3-3.9	32,644	36,550	0.6	0.2-1.0	6,448	7,220	0.2	0-0.4	1,946
	65-69	5.7	4.6-6.8	44,670	58,104	1.3	0.8-1.9	10,524	13,689	0.2	0-0.4	1,795
	70-74	12.6	10.6-14.5	76,691	93,456	3.0	2.0-3.9	18,252	22,242	0.5	0.1-0.9	2,893
	75-79	24.4	21.7-27.1	123,285	134,898	6.5	4.9-8.0	32,579	35,647	1.2	0.6-1.8	6,114
	80-85	38.7	35.1-42.3	184,972	191,785	10.9	8.7-13.2	52,159	54,080	2.6	1.5-3.6	12,238
	Σ 45-85			500,008	554,566			128,166	141,574			26,417
% change in Σ 45-85 yr prevalence count 2011-2016				10.9%				10.4%				8.8%

- Row % refers to the percentage of males or females within each age group who have dual sensory loss defined by the thresholds listed.
- Prevalence counts were calculated by multiplying the row% value by the number of Canadians in the same age-sex category in 2011 and 2016 censuses.
- For reference, between 2011 and 2016 in Canada the total population of males age 45-85 increased 8.0% and the total population of females age 45-85 increased 7.6%.
- Dual sensory loss using WHO moderate categories for hearing loss (>40 dB HL) and vision loss (>0.48 logMAR) are not displayed because only 89/29,002 (0.3%) of CLSA participants had DSL according to these criteria.

SUPPLEMENTARY FIGURES

Supplementary Figure 1. Prevalence (%) of hearing loss based on the 2012-2015 CLSA data and estimated for the population based on 2016 Canadian census data according to age and sex

Supplementary Figure 2. Prevalence (%) of vision loss based on the 2012-2015 CLSA data and estimated for the population based on 2016 Canadian census data according to age and sex

Supplementary Figure 3. Prevalence (%) of vision loss based on the 2012-2015 CLSA data and estimated for the population based on 2016 Canadian census data according to age and sex