VISUAL IMPAIRMENT AND EYE CARE UTILIZATION: BASELINE DATA FROM THE CANADIAN LONGITUDINAL STUDY ON AGING

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ABSTRACT

Introduction: Despite the high prevalence of visual impairment in older age, Canada does not have any high-quality data on the prevalence of visual impairment, nor current eye care utilization estimates. **Objectives:** By leveraging baseline data collected from the Canadian Longitudinal Study on Aging (CLSA), for the first time we were able to estimate the prevalence of measured visual impairment, provide current eye care utilization estimates in Canada, and their associations with geographic, socio-demographic, health and lifestyle characteristics. **Methods:** Visual acuity was measured using the Early Treatment of Diabetic Retinopathy Study chart from a 2-meter distance while participants wore their usual prescription for distance, if any. Eye care utilization was defined as the self-report of a visit to an optometrist or ophthalmologist in the past 12 months. Data from 30,097 middle-aged and older adults in the Comprehensive Cohort of the CLSA were used to estimate prevalence expressed as proportions with 95 percent confidence intervals. Associated factors were examined using logistic regression. The complex survey design was accounted for in all analyses. **Results:** In our sample, 5.7% (95% CI 5.4–6.0) had visual impairment. Variation in the provincial prevalence of visual impairment was observed ranging from a low of 2.4% (95% CI 2.0–3.0) in Manitoba to a high of 10.9% (95% CI 9.6–12.2) in Newfoundland and Labrador. Factors associated with a higher odds of visual impairment included older age, lower income, current smoking, type 2 diabetes, and memory problems ($P<0.05$). In the last year, 57% (95% CI 56.3–57.3) of Canadian adults visited an eye care provider although there was heterogeneity between provinces. The highest eye care utilization was found in Ontario at 62% (95% CI 60.9-63.7), whereas the lowest was in Newfoundland and Labrador at 50% (95% CI 47.9-52.8). Of concern, 25.3% of people with diabetes above the age

of 60 years had not seen an eye care provider in the last year, as they are recommended. Men compared to women, people with less than a bachelor's degree compared to more than a bachelor's degree, people making less income (linear trend $p < 0.05$) and current smokers compared to never smokers were less likely to use eye care ($P<0.05$). **Implication:** We hope these data will inform public health policies, planning of health service resource allocations, and allow for further scientific research in ophthalmology

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATION LIST

- Age-Related Eye Diseases (ARED)
- Age Related Macular Degeneration (AMD)
- Best Corrected Visual Acuity (BCVA)
- Canadian Community Health Survey (CCHS)
- Confidence Interval (CI)
- Canadian Longitudinal Study on Aging (CLSA)
- CNIB (CNIB)
- Canadian Ophthalmological Society (COS)
- Data Collection Site (DCS)
- Distance Visual Acuity (dVA)
- Early Treatment of Diabetic Retinopathy Study (ETDRS)
- Health and Activity Limitation Survey (HALS)
- Logarithm of the Minimum Angle of Resolution (LogMAR)
- Minimum Angle of Resolution (MAR)
- Missing at Random (MAR)
- Missing Completely at Random (MCAR)
- Missing not at Random (MNAR)
- National Health and Nutrition Examination Survey (NHANES)
- Odds Ratio (OR)
- Quebec Longitudinal Study on Nutrition and Aging (NuAge)
- Presenting Visual Acuity (PVA)
- United States (U.S.)
- Visual Acuity (VA)
- Visual Impairment (VI)
- World Health Organization (WHO)

CHAPTER ONE: INTRODUCTION

The ability to see is a central part of everyday life for humans. As the Canadian population continues to age due to demographic trends, there is an anticipated increase in the prevalence of visual impairment by nearly 30%.[1] Visual impairment, especially in the older population extends beyond ocular health; it has a personal as well as an economically damaging impact. Visual impairment has many disabling outcomes such as decreasing quality of life by affecting daily living independence, increasing the risk of injury due to falls[2], social isolation[3] and mental illness (e.g., depression).[4] Indeed, visual impairment is one of the most costly public health issues, with the current combined indirect and direct cost in Canada estimated at $15.8 billion per year, and anticipated to increase to $30.3 billion by 2032.[1]

Vision gets worse with age and is an important indicator of health and quality of life. With the anticipated demographic trends, we need to prepare and develop health care policies that ensure that the Canadian health care system is sustainable given the anticipated changes. The first step in the formation of a sustainable health care system for the aging population is to understand the magnitude of the problem. More specifically in the context of vision, understanding the prevalence and risk factors of visual impairment in the aging population will allow us to build capacity and strategies to promote vision care. Population-based studies of objectively measured visual function are the most valid method for determining prevalence. Unfortunately, Canadian large population-based epidemiologic data sources of measured visual function are non-existent, limiting the validity of the existing studies on the estimated frequency of visual impairment in Canada. Furthermore, some vision loss caused by certain age-related eye disease is avoidable with regular vision screening, but Canada has no up-to-date data on eye care utilization. These data are essential to enable recommendations in public health policies, planning of health service resource allocations, budgets and are critical for further scientific research in ophthalmology.

General and Specific Objectives

The general objective of this work is to estimate the prevalence of visual impairment and eye care utilization among people aged 45 to 85 years in Canada and their associations with geographic, socio-demographic, health and lifestyle characteristics. By leveraging baseline data collected from the Canadian Longitudinal Study on Aging (CLSA), for the first time, we will provide Canadian prevalence estimates of visual impairment as measured using a visual acuity chart. In, addition we will update eye care utilization estimates. More specifically, the objectives are:

- Objective 1: Determine the prevalence of visual impairment (binocular visual acuity worse than 20/40) in Canada.
- Objective 2: Determine factors associated with visual impairment including geographic (e.g., province), sociodemographic (e.g., age, sex, education, income, ethnicity, etc.), health (e.g., comorbid conditions), and lifestyle factors (e.g., smoking).
- Objective 3: Determine the prevalence of eye care utilization in the last 12 months.
- Objective 4: Determine factors associated with eye care utilization including geographic (e.g., province), sociodemographic (e.g., age, sex, education, income, ethnicity, etc.), health (e.g., comorbid conditions), and lifestyle factors (e.g., smoking).

Organization of Thesis

This section outlines the organization of this manuscript-based thesis. The first chapter is an introduction to the problem with general and specific objectives and this thesis organization section. The second chapter is a literature review beginning with an introduction to vision, visual acuity, the history of visual acuity measurements, as well as previous literature's estimates of the prevalence of visual impairment, followed by a section on eye care utilization and the conceptual framework used to look at determinants of eye care utilization. The third chapter describes the data source (i.e., CLSA) used for the two manuscripts, with a section on missing data. The fourth chapter is the first manuscript, answering objectives one and two, followed by additional analyses not included in the published version of the manuscript. The fifth chapter is the second manuscript answering objectives three and four. The thesis concludes with chapter five, which includes findings for the research objectives, comparison to previous work, strength and limitations, significance and implications of the work, and suggestions for future research.

CHAPTER TWO: LITERATURE REVIEW

Vision

The process of seeing is both complex and unique. A cross-sectional view of the eye (shown in Appendix 1) illustrates an eye is made up of three layers: 1) External layer: including the sclera and cornea 2) Intermediate layer composed of two sections: anterior (including iris and ciliary body) and posterior (choroid) sections and 3) Internal layer which is the retina. Inside the eye, there are three fluid-filled chambers: anterior, posterior and vitreous chambers. The anterior chamber is between the cornea and iris. The posterior chamber is between the iris, the lens, and its encircling suspensory ligament. The vitreous chamber is between the lens and back of the eye.[5]

The ability to see, or vision, starts by way of light entering the eye through the cornea. The iris directly in front of the lens regulates the pupil, which contracts or dilates based on the amount of light entering the eye. Behind the iris is a lens held by ciliary muscles that changes its curvature. The lens adjusts the focal length; it is convex and inverts the image, which is then focused or refracted through the vitreous humour onto the retina.[5] In the retina, photoreceptor cells called rods and cones are responsible for photoreception, which is the process by which light sent to the retina is converted to electric signals that are relayed to the visual cortex. Rods are located on the outer edges of the retina and are used for peripheral vision and work in low light settings. In contrast, cones are in the central retina, highly centralized in the fovea, and are essential for seeing color and fine detail.[5] Visual perception at its most basic form is the detection of light.[6]

Measuring Visual Function: Visual Acuity

The process of seeing involves many types of visual function yet in clinical and many research settings visual ability is often measured through only one: clarity or sharpness of vision often referred to as central resolution or visual acuity.[6,7] Visual acuity (VA) is a measure of the "resolving power of the eye," which quantified is the reciprocal of the minimal angle of resolution. The minimum angle needed to identify two points as different stimuli at a given distance is a person's visual acuity.[6] Visual acuity can be measured from near or more commonly at a distance; visual acuity measured at a distance is distance visual acuity (dVA). The unit of measurement to measure visual acuity is the arc minute or arc second. Angular degrees are too big with regards to optics and as such arc minutes (min) or seconds (sec) are used. One degree is equivalent to 60 arc min, and 1 min of arc is the smallest angle of resolution an unaided human eye can see; this is what people often cite as 20/20 vision. [6]

A look at the history of visual function and its measurement indicates measurements of visual acuity have existed as early as 1623.[8] The process of standardizing vision tests began in 1843, but it was only after the 1850s, a period referred to as the Golden Age of Ophthalmology, that significant advances in measurement tools started to occur.[8] The catalyst was Franciscus Cornelis Donders, an ophthalmologist, well known for creating the E that is often seen on the top of some acuity charts. Donders proposed a formula and reference standard, defining the "sharpness of vision" in terms of the ratio of letter size to viewing distance. Then during an annual ophthalmology meeting, he asked Herman Snellen to devise a standardized measurement tool to allow for the study of the function of the eye, and a year later in 1862, Snellen published his chart, which became the most widely used measure to assess distance visual acuity.[9,10]

The Snellen chart is made up of letter form designs called optotypes.[11] There are different letters in each row with decreasing size. Individuals being tested read rows one at a time at a distance of 6 meters (20 feet). Each letter on the chart forms an angle of 5 min of arc at the appropriate testing distance with each letter part subtending an angle of 1 min of arc. The Snellen chart is designed to measure acuity in angular terms, where "normal" acuity (the average healthy human eye) is defined as the ability to discriminate a pattern whose detail subtends a visual angle of 1 min of arc. An individual's visual acuity is given by the Snellen fraction, which consists of a numerator corresponding to the distance at which an individual can identify a threshold letter with a denominator as the distance at which an individual with normal vision can identify a letter of the same physical size. For example, a 20/60 visual acuity score means a person can identify at 20 feet what the person with normal vision can identify at 60 feet. In various countries, different notations are used. For example, in Europe instead of the fraction, acuity is given as a decimal. To convert the Snellen fraction into the minimum angle of resolution (MAR), one may use the reciprocal of the Snellen fraction. The base 10 logarithm of the reciprocal Snellen fraction approximates the logarithm of the minimal angle of resolution (LogMAR). [9-11]

While the Snellen chart was both an efficient and easy method to measure visual acuity, it had some limitations. There is a smaller number of letters at the top of the chart that makes it less precise in measuring visual acuity in individuals with severe visual impairment.[9] Certain letters (C, D, O, G, E) are harder than others (A, J, L), making it inconsistent.[6] The spacing between each row of letters and between letters has no systematic relationship to the width and height of letters. Consequently, visual acuity measured at a distance other than 6-meter cannot be converted to a 6-meter equivalent. Another limitation is that letters are crowded at the bottom, which is limiting in two ways 1) it makes the task more difficult as you go down the chart and 2) those with worse visual acuity read/ are tested with fewer letters than those with better visual acuity.[9]

Due to the number of limitations noted above, the logMAR acuity test was designed in 1976 by Ian Bailey and Jan E Lovie-Kitchin. In contrast to the Snellen chart, the logMAR acuity test had a systematic relationship in spacing between each letter and each row, proportional to letter size. The progression of letter sizes was uniform, increasing in a constant ratio of 1.26 (0.1 log unit steps). The results of the tests are in log minimum angle resolution or logMAR; a score of 0 logMAR is equivalent to 20/20 vision, and 1 logMAR is equal to 20/200 vision often classified as severe visual impairment/ blindness.[9]

In 1982, the National Eye Institute (NEI) in the U.S. improvised on the Bailey-Lovie design to produce charts for the use in the Early Treatment of Diabetic Retinopathy Study (ETDRS), a multi-center clinical trial. These charts became known as ETDRS charts.[8] They settled most of the disadvantages presented above. The ETDRS chart has ten letters chosen for their equivalence in difficulty (S, D, K, H, N, O, C, V, R, and Z).[6] There are five letters per row, and between letters, row spacing is proportional to letter size. There is a constant ratio of size progression (0.1 logMAR steps). The chart scoring is letter by letter, scored as the total number of letters read correctly where each letter is given a score of 0.02 logMAR, and one line of letters equals a score of 0.1 logMAR. The standard testing distance of visual acuity using the ETDRS chart is 4m, but the chart was designed to provide constant geometric proportions for all testing distances, and scoring can easily be adjusted if a different testing distance is used.[10,12]

Due to the standardization process, the ETDRS chart has now become the gold standard measure of visual acuity around the world. [8,10] Studies evaluating visual acuity as measured by the Snellen chart in comparison to the ETDRS chart demonstrated that there was a significant difference in visual acuity scores between the two charts; use of the ETDRS chart allows for more reliable and precise visual acuity scores, especially in participants with poor vision.[13,14]

Definitions of Visual Function

Visual acuity is usually measured either monocularly (one eye at a time) or binocularly (both eyes), with the person's habitual refractive correction for distance (glasses or contact lenses) in place. When measured monocularly, visual impairment is usually defined using the better eye or worse eye value; the better eye value is often used because it more accurately approximates acuity measured with both eyes open. When measured binocularly (two eyes) visual acuity is referred to as binocular acuity. Studies assessing visual functions have demonstrated that vision measured binocularly differs from vision measured monocularly.[15–17] Monocular visual impairment often has little impact on function or disability; therefore, binocular or bilateral visual impairment is a better indicator of overall visual function and should be used to estimate visual impairment prevalence.[15,17]

Visual acuity can also be measured with and without pinhole correction. Pinhole correction involves the use of an eye shield with several small holes that reduce light scattering and therefore remove most of the effect of uncorrected refractive errors. Visual acuity measured with pinhole correction is referred to as pinhole acuity. When vision is corrected to the best possible vision that can be achieved through autorefraction, it is referred to as best corrected visual acuity (BCVA).[18]

There are different binocular visual acuity thresholds used to define visual impairment (VI) (refer to Table 1).[19,20] The current definition of moderate visual impairment adopted by the World Health Organization (WHO) in the International Classification of Diseases-10 (ICD-10) is presenting visual acuity worse than 20/60 but equal to or better than 20/200.[19] For this work and corresponding manuscripts the North American criteria were used, which is binocular presenting visual acuity worse than 20/40 (0.301 logMAR) with habitual distance correction (i.e., glasses or contacts) in place.

Table 1: Classification of Visual Impairment: WHO vs. North American

WHO *(Presenting distance visual acuity)*			**North American** *(Presenting distance visual acuity)*		
Category	**Worse than**	**Equal to or better than**	**Category**	**Worse than**	**Equal to or better than**
Mild or no visual impairment		20/60 (0.5)	No visual impairment		20/40 (0.3)
Moderate visual impairment	20/60 (0.501)	20/200 (1)	Visual impairment	20/40 (0.301)	20/200 (1)
Severe visual impairment	20/200 (1.01)	20/400 (1.3)	Blindness	20/200 (1.01)	
Blindness	20/400 (1.3)	No light perception (4.0)			

* Units are in feet and (logMAR), table adapted from:[19,20]

Causes of Visual Impairment

Visual impairment can be caused by damage or malfunction to any part of the visual system. In adults, the main two causes of visual impairment are refractive error and age-related eye disease (e.g. cataract, glaucoma, age-related macular degeneration (AMD), and diabetic retinopathy). If U.S. data apply to Canada, the most frequent causes of visual impairment are refractive error at 66%, followed by cataract (16.4%), AMD (10.9%), diabetic retinopathy (3.7%) and glaucoma (3.1%).[1]

Refractive error

Malfunction of the cornea or lens, the refracting elements of the eye, leads to refractive error. When the shape of the eye does not bend light correctly, this can result in blurred vision (i.e., refractive error). The types of refractive errors are myopia, hyperopia, presbyopia, and astigmatism. Myopia (near-sightedness with blurry distant vision) is caused by a long eyeball or an over-curved cornea. In contrast, hyperopia (farsightedness with close objects being blurry) is caused by a short eyeball or if the cornea has too little curvature. While hyperopia can occur at any age, presbyopia is an age-related condition with an effect similar to hyperopia with close objects appearing blurry. An irregularly shaped cornea or lens cause astigmatism (uneven focus). Refractive error can be easily correctable by glasses, contacts or refractive surgery. Many studies have identified uncorrected refractive error as the leading cause of visual impairment in the developed world and a frequent cause of blindness in the developing world.[1,21–23]

Age-related eye disease

In addition to the age-related changes due to refractive error (e.g., presbyopia), a number of age-related eye diseases (ARED) such as cataracts, glaucoma, age-related macular degeneration (AMD) and diabetic retinopathy could cause vision loss. Cataract is opacity formation caused by clouding of the lens in the eye. The lens of the eye is made of protein fibers that are arranged in a precise manner for the lens to function appropriately and allow light to pass through. With aging, the structure of the protein fibers break down clumping together and clouding areas of the lens. Cataracts compromise visual function causing visual impairment. However, cataracts are treatable through changes in glasses and when severe enough reversible through surgery to remove the affected lens and replace it with an artificial lens.[24–26]

Glaucoma is an irreversible optic neuropathy resulting in the loss of retinal neurons and their axons and causing the gradual loss of peripheral and ultimately central vision. Glaucoma is a multifactorial hereditary disorder whose genes are still being characterized.[27] Intraocular pressure is the most cited risk factor for the optic neuropathy that occurs in glaucoma patients.

Glaucoma is often not noticed by individuals until late in the disease process because it starts with loss of peripheral vision. If left undiagnosed and untreated, glaucoma can result in complete vision loss. Eye drops to lower intraocular pressure are usually the initial treatment option for glaucoma; if the disease continues to progress, surgery to lower the intraocular pressure is the second option.

Age-related macular degeneration (AMD) is a disease of the retina, specifically the macular area. AMD causes loss of central vision. There are two kinds of AMD: dry (geographic atrophy) and wet (choroidal neovascularization). Anti-vascular endothelial growth factor (VEGF) injections are currently the gold standard treatment for wet AMD; there is no current effective treatment for dry AMD. [25,26,28] Evidence from the AREDS trial showed that taking an antioxidant plus zinc supplement slowed the progression to advanced AMD.[29] Other preventive strategies, such as dietary modifications, have been investigated but the evidence is not sufficient.[30]

Diabetic retinopathy is a complication of diabetes that affects the eye by injuring the small blood vessels in the retina. It progresses slowly, often with no vision changes in its early stage, but if left untreated vision loss can result from neovascularization. Neovascularization is the growth of new blood vessels caused by lack of oxygen in the retinal capillaries. The vessels are weak and easily torn leading to fluid leaks into the retina, hemorrhages, and other complications. Many of the complications of diabetic retinopathy can be delayed or prevented by controlling blood sugar levels, hypertension, and with timely intervention. Vision loss caused by diabetic retinopathy could be prevented or delayed with anti-VEGF injections, laser surgery to help seal leaking blood vessels, or removal of the vitreous gel (vitrectomy). These treatments are only useful for early diabetic retinopathy; as such, patients with prolonged hyperglycemia are encouraged to get regular eye examinations to avoid severe vision loss. [24,25,31–33]

Prevalence of Visual Impairment

Several aspects are of importance when reviewing epidemiological data on visual impairment. There is considerable heterogeneity in the quality of studies, which limits the conclusions that can be drawn, mainly due to the differences in the definition of visual impairment. Visual acuity thresholds vary by region making it harder to compare prevalence estimates between different areas. Also, there are differences in the measurements of visual acuity, with regards to the type of acuity chart (e.g., Snellen vs. ETDRS) used and the test distance.

Globally, the age-standardized prevalence of moderate and severe visual impairment (defined as presenting visual acuity $<20/60$ but $\geq 20/400$ in the better eye) in developed countries, from 1990 to 2010, has decreased from 1.6% to 1.0%.[34] But due to the demographic changes in population aging, overall the number of people with visual impairment has increased. A recent systematic review estimated the prevalence of visual impairment and blindness globally according to the current WHO definition of visual impairment (binocular visual acuity worse than 20/60). It determined that 285 million people are visually impaired around the world: 39 million were classified as blind, and the other 246 million were visually impaired. [35] Visual impairment is strongly related to age. Indeed, 65% of visually impaired people were 50 years and older.[35] With the current aging population, there will be an anticipated higher burden of visual impairment in the world.

While there is an abundance of American and European epidemiological studies on visual impairment in adults, only landmark studies that have used a comparable visual impairment definition and visual acuity threshold to this work will be reviewed. One of the earliest population-based studies on visual impairment was The Beaver Dam Eye Study, including nursing home and community-dwelling participants.[36] The study included 4926 adults, between the ages of 43 and 86, from Beaver Dam, Wisconsin. Participants best-corrected visual acuity (BCVA) was measured using an ETDRS chart at a 2-meter distance. Visual impairment was defined using BCVA in the better eye. Participants were categorized into one of four categories: no impairment if BCVA was better or equal to 20/40, mild impairment if BCVA was worse than 20/40 to 20/63, moderate impairment if BCVA worse than 20/80 to20/160, severe impairment if BCVA was 20/200 or worse. The prevalence of mild visual impairment in the better eye was 3.9%, moderate visual impairment was 0.8%, and the prevalence of severe visual impairment was 0.5%. Overall, 5.2% of participants had some degree of visual impairment in the better eye. [36]

The Beaver Dam study only included white participants. Due to the limitation in the generalizability of estimates based on one ethnic group, the Baltimore Eye Survey Research Group assessed visual impairment in a biracial (black/white) population (n=5431) of individuals aged 40 years and older in Baltimore, Maryland. [37] Visual acuity was measured using an ETDRS chart. Visual impairment was defined as BCVA in the better eye, worse than 20/40 but better than 20/200. The prevalence when stratified by race varied: 2.2% in whites and 3.9% in African-Americans. The overall prevalence of visual impairment after age adjustment was 1.8%.[37] One of the possible reasons for the lower prevalence of visual impairment in the Baltimore study in comparison to the Beaver Dam study is the exclusion of nursing home participants in the latter.

Another large population-based study, the Rotterdam study, had more comparable results to the Baltimore study; data were collected from 1990-1993 from 6775 participants ages 55 and over in the Netherlands. Participants completed an extensive ocular examination that included measurements of visual acuity. But, unlike the previous two studies mentioned above, the Rotterdam study utilized a modified version of the ETDRS chart, the Lighthouse Distance visual acuity test. Using the WHO definition for visual impairment instead of the North American definition (BCVA less than 20/60 but better than 20/200 in the better eye), the reported prevalence of visual impairment was 1.9%. Using the U.S. definition of visual impairment (best corrected visual acuity of less than 20/40 but better than 20/200 in the better eye) the reported prevalence of visual impairment was 4.8%. [38]

The Salisbury Eye Evaluation (SEE) project is another American population-based study.[39] The study used Medicare records to select a random sample of 2520 residents from Salisbury, Maryland, between the ages of 65 and 84 years. Participants' visual acuity was measured using an ETDRS chart, and standardized refraction testing was used for those with visual acuity worse than 20/30. The prevalence of visual impairment as defined by presenting acuity worse than 20/40 in the better-seeing eye was 7%. Using BCVA, the prevalence decreased by one third to 2.1%. [39]

Most of these studies mentioned above were completed in the 1980's and 1990's. Since there have been considerable changes in health and healthcare, it's important to take note of a more recent population-based study using the U.S. National Health and Nutrition Examination Survey (NHANES). The prevalence of visual impairment was estimated from a population of 5222 adults, 40 or older, using NHANES data from 2005-2008.[40] Presenting visual acuity was measured with the participant wearing usual distance vision correction and visual impairment was defined as presenting distance visual acuity in the better-seeing eye of worse than 20/40. The overall age-standardized prevalence of visual impairment was 7.5%. Prevalence varied by age: 5.01% in those aged 40-49, 4.4% in 50-59 years-olds, 6.7% in 60-69 year-olds, 10.1% in 70-79 year-olds and 26.3% in those aged 80 and older.[40]

The overall prevalence of visual impairment in all of the population-based studies in the United States and the one European study reviewed above varied. Studies defining visual acuity using BCVA estimates ranged from 1.8-5.2%,[36–39] while studies using presenting visual acuity ranged from 7-7.5%.[39,40] It's important to note that these changes can be due to variation in study design, population sampling, differences in age, and measurement of visual acuity, or in some cases geographic variation. Despite the heterogeneity in prevalence estimates across different studies within the same country, and given the vast gaps in epidemiological knowledge with regards to Canadian visual impairment data, extrapolated United States data are sometimes used to estimate Canadian visual impairment prevalence.[1,41,42]

Prevalence of Visual Impairment in Canada

The gold standard way to estimate prevalence is to use a population-based study with objectively measured visual function (i.e., visual acuity as measured by acuity charts). Unfortunately, no such Canada-wide eye survey with measured visual function is available. Furthermore, eye care in Canada is administered in community settings and as such health record data on visual impairment is limited. Most of the available data in Canada has been through population-based self-report surveys. Studies evaluating performance-based and self-reported measures of visual function have suggested that self-assessments and performance-based measures tap distinctly separate aspects of visual function and are only moderately correlated.[43,44] Despite their limitation, self-reported measures of visual function are used as a crude proxy of underlying problems in everyday visual function.[43]

The first ever peer-reviewed Canadian data published on the prevalence of visual impairment presented findings from the Health and Activity Limitation Survey (HALS) in 1986.[45] The survey used self-reporting, and visual impairment was ascertained through an affirmative answer to one or both of the following questions: " trouble reading ordinary newsprint with glasses if normally worn" and "trouble seeing clearly the face of someone 12 feet (for example across a room) with glasses if normally worn". The overall prevalence of self-reported vision problems in individuals aged 15 and over was 8.5%. According to Klein *et al* similar questions to the ones mentioned above have a correlation of ~0.25 to measured binocular distance acuity with current correction.[43] As such, data should be interpreted cautiously.

Another early Canadian prevalence study used data from the Canadian Study of Health and Aging (CSHA), which took place from 1991 to 1992.[46] A random sample of community-dwelling individuals (n=1777) 65 and older were randomly selected from 18 different sampling sites. Four of the 18 sites were from Quebec, and the prevalence data reported used only data from the Quebec sites. Participants were asked to self-report if they had "trouble seeing clearly the face of someone 12 feet away with glasses or contact lenses if normally working?" All participants who said yes to the above question were classified as distance vision impaired. The prevalence of distance vision impairment was 4.4% in the entire sample.[46]

Due to the limitation of self-report measures, two studies have used measured visual impairment, but were not population-based samples or were restricted to one area within Canada.[20,47,48] The first study was based in Prince George, British Columbia using data from medical charts from all of the ophthalmology offices in Prince George between 1996 and 2001 (n=962).

[20] The prevalence of visual impairment, defined as BCVA worse than 20/40 but greater than 20/200 in the better-seeing eye, was 2.4% in participants ages 65-74. While this study used an objective measure, selection bias through the sampling of only three ophthalmology offices and not optometric or family physician offices is an issue. Some people might have been missed because not all people with eye disease seek care from an ophthalmologist; in fact, ophthalmologists are secondary care providers by which patients are sometimes referred to by their family physician or optometrist.[20] Another limitation of this study is generalizability; the generalizability of results from one city in one province to other provinces in Canada is uncertain.

The second city-based prevalence study estimated the prevalence of visual impairment in Canada using data from Brantford, Ontario.[48] Participants were selected using a randomized sampling strategy based on postal codes. Participants were community-dwelling adults ages 40 and older (n=900). Distance visual acuity (dVA) was measured for each eye separately using the ETDRS letter chart. The prevalence of visual impairment, defined as presenting visual acuity <20/40 (0.3 logMAR) in the better eye with habitual correction in place (i.e., glasses or contacts), was 2.7%.[48] The advantages of this study are that they used a population-based sample and a visual acuity chart. The disadvantages are that they had a small sample size and it is a single urban site leading to questionable generalizability.

Finally, the Cost of Vision Loss in Canada, an initiative by the CNIB and the Canadian Ophthalmological Society (COS) estimated the prevalence and cost of vision loss in Canada. [1,41] The study used aggregated data from Canadian journal articles, surveys and old international population-based studies (e.g., The Beaver Dam Study).[41] In this report, it was estimated that in

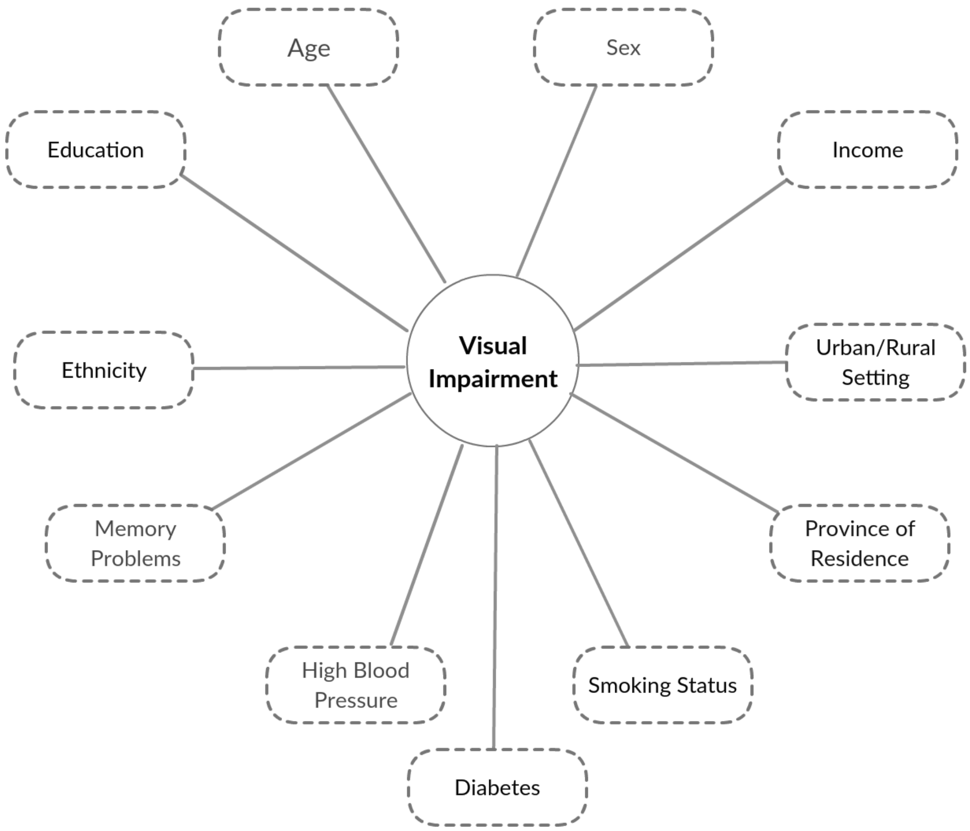
2007 over 800,000 or 2.5% of the Canadian population suffered from visual impairment, which was defined as visual acuity worse than 20/40 in the better eye.[1,42]

Taken together, the existing Canadian literature indicates that there is a lack of high-quality population-based data. The variability of prevalence estimates may be explained by the various methodological characteristics of studies. The small number of studies that exist are limited as they either extrapolate prevalence data from other countries,[1,41] sample single cities [20,47,48] or use self-reported data on visual impairment. [45,46] Extrapolation of U.S. rates or using data from single cities may be inaccurate because data from other places may not generalize to Canada. Furthermore, while self-reported data can be very useful, self-reported visual impairment is not as valid as measured visual impairment. The limitations of previous research may have resulted in visual impairment prevalence estimates that are biased, un-reliable or estimates with limited generalizability. There is a need for population-based studies of objectively measured visual impairment to determine visual impairment prevalence in Canada, which is the first objective of this work.

Factors Associated with Visual Impairment

Cross-sectional and longitudinal studies have reported on the association of visual impairment with many risk factors. The risk factors that this thesis will focus on tend to fall into one of three categories—namely, demographic, behavioural, and comorbid associations (refer to Figure 1 for factors to be examined in this work).

Figure 1. Factors to be investigated with visual impairment



Demographic variables like older age, sex, socioeconomic status, and ethnicity have consistently been identified as risk factors for the development of visual impairment.[49–51] Visual acuity declines with age—physiologically beginning by middle age, and accelerating by age 70 and older.[52] Female/male prevalence ratios of visual impairment suggest that women have a greater risk of developing visual impairment than men.[36] Similarly, individuals with lower socioeconomic status tend to have an increased risk of age-related eye disease and as such a greater risk for visual impairment.[39,49,51] Studies have also shown variability in prevalence ratios by ethnic and geographic background.[37,50,51] Behavioural factors, like cigarette smoking, are associated with a higher risk of development of age-related eye disease, especially cataracts and AMD.[53] Comorbid health conditions such as diabetes and high blood pressure have also been shown to be associated with visual impairment.[54,55]

Eye Care Policies in Canada

With the anticipated increase in the number of people with visual impairment as the population ages, eye care utilization estimates are needed to identify any disparities and to plan outreach activities for those at high risk. In Canada, after the publication of "The Cost of Vision Loss" report,[42] stakeholders created the *Canadian Patient Charter for Vision Care* in 2015.[56] The Charter outlines the rights and responsibilities of patients and eye care professionals with the goal of providing the highest level of vision care across Canada.

Currently, Canada has a public health care system that covers medically necessary vision-related costs such as treatments for eye injury and various eye diseases (e.g., cataract, glaucoma, and diabetic retinopathy). However, routine eye examinations, which are essential for the timely diagnosis of eye disease and the prevention of avoidable vision loss, are currently not insured for everyone. Some provinces cover vision care (i.e., annual eye examination) for those ≤18 and ≥ 65 years old, but there is inter-provincial variability on what is covered and how often (refer to Table 2 for provincial coverage of the seven provinces with CLSA data collection sites). Despite being recommended to see an ophthalmologist every year by the Canadian Ophthalmological Society (COS), some high-risk groups (e.g., patients 60+ with a family history of eye disease) are currently not covered. It is essential to identify the current patterns and frequency of eye care utilization, especially in high-risk groups. This information would help address vision health disparities in accessibility and improve Canada's vision and eye health services.

Table 2: Coverage of routine eye exams by seven provinces included in the CLSA

Province	**Vision Care Coverage:**
Alberta	Routine examinations are covered annually for individuals <19 or >65
British Colombia	Routine examinations are covered annually for individuals <18 or >65

Manitoba	Routine examinations are covered bi-annually for individuals <19 or >64
Newfoundland & Labrador	No provincial vision care coverage
Nova Scotia	Routine examinations are covered bi-annually for individuals <10 or >65
Ontario	Routine examinations are covered annually for individuals <20 or >65
Quebec	Routine examinations are covered annually for individuals <17 or >65

Table adapted from:[57]

Frequency of Eye Care Utilization in Canada

Surprisingly, there is little up-to-date research on the prevalence of eye care utilization in Canada. As mentioned in the section entitled "Prevalence of Visual Impairment in Canada", routine eye care in Canada is administered in community settings and as such the widespread use of centralized medical record or administrative data is not feasible. So far Canadian eye care utilization studies have relied on self-report health surveys (e.g., CCHS). While these data are limited by the nature of recall and reporting error, studies show a moderate agreement ($\kappa = 0.64$) between self-report of eye care utilization and medical records. [58,59] The availability of data is another limitation; in 2005 Statistics Canada decided to no longer include vision-related questions in their questionnaire, making up-to-date data on eye care utilization scarce.[60] This decision has since been revoked, but consequently, the most recent population-based data in Canada on eye care utilization is more than a decade old.[60]

The most recent population-based report on the prevalence of eye care utilization used the 2005 Canadian Community Health Survey (CCHS) to examine eye care utilization in individuals aged 12 and older and found that 40% of Canadians in this age group utilized eye care services from an optometrist or an ophthalmologist in a 12-month period. [61]

The other study estimating the frequency of eye care utilization in Canada was comparative and in a high-risk group.[62] Zhang and colleagues in 2009, using the 2002-2003 Joint Canada/United States Survey of Health (JCUSH) compared self-reported eye care utilization in adults (40-64 years old) with self-reported vision problems in Canada and the United States. Among adults with vision problems, 55% of Canadians reported annual eye care utilization.[62]

The above two studies to our knowledge are the only available population-based Canadian data that estimate eye care utilization in adults. Other studies on eye care utilization in Canada have focused on determinants and the effects of socioeconomic status and government insurance on eye care utilization.[54,63,64] There is a dire need for current up-to-date data on eye care utilization that would allow better planning for future eye care needs and the planning and delivery of interventions, if necessary, to improve eye care utilization and in turn prevent avoidable vision loss

Factors Associated with Eye Care Utilization in Canada & Theoretical Framework

The conceptual framework adopted in this thesis to examine factors associated with eye care utilization is the Andersen and Newman Framework of Health Services Utilization, sometimes referred to as Andersen's Behavioral Model of Health Services Use (refer to Figure 2).[65,66] The framework describes factors that either facilitate or impede health care utilization. According to the framework, the three groups of factors that determine health care utilization are 1) Predisposing factors 2) Enabling factors and 3) Need Factors.[65,66]

Predisposing factors are individual characteristics that occur prior to the illness but influence health care utilization. They fall into one of three categories: demographic (e.g., age and sex), social structural (e.g., education, occupation, ethnicity, social networks, and culture), and health belief (e.g., attitudes and values that people have towards the health care system).[65–68]

Enabling factors are resources that individuals have that would enable them to utilize health care. Enabling factors fall into one of three categories: personal/family (e.g., income, health insurance, travel resources), community (e.g., availability of health care providers and facilities in the community), and the third category, referred to as possible additions, is other enabling factors that have not been accounted for, such as genetic and psychological factors.[65–68]

Need factors are the immediate factors, such as the individual's actual or perceived health status, that require them to utilize health care. Need factors fall into one of two categories: perceived need (subjective assessment [e.g., self-perceived health status]) and evaluated need (clinical diagnosis).[65–68]

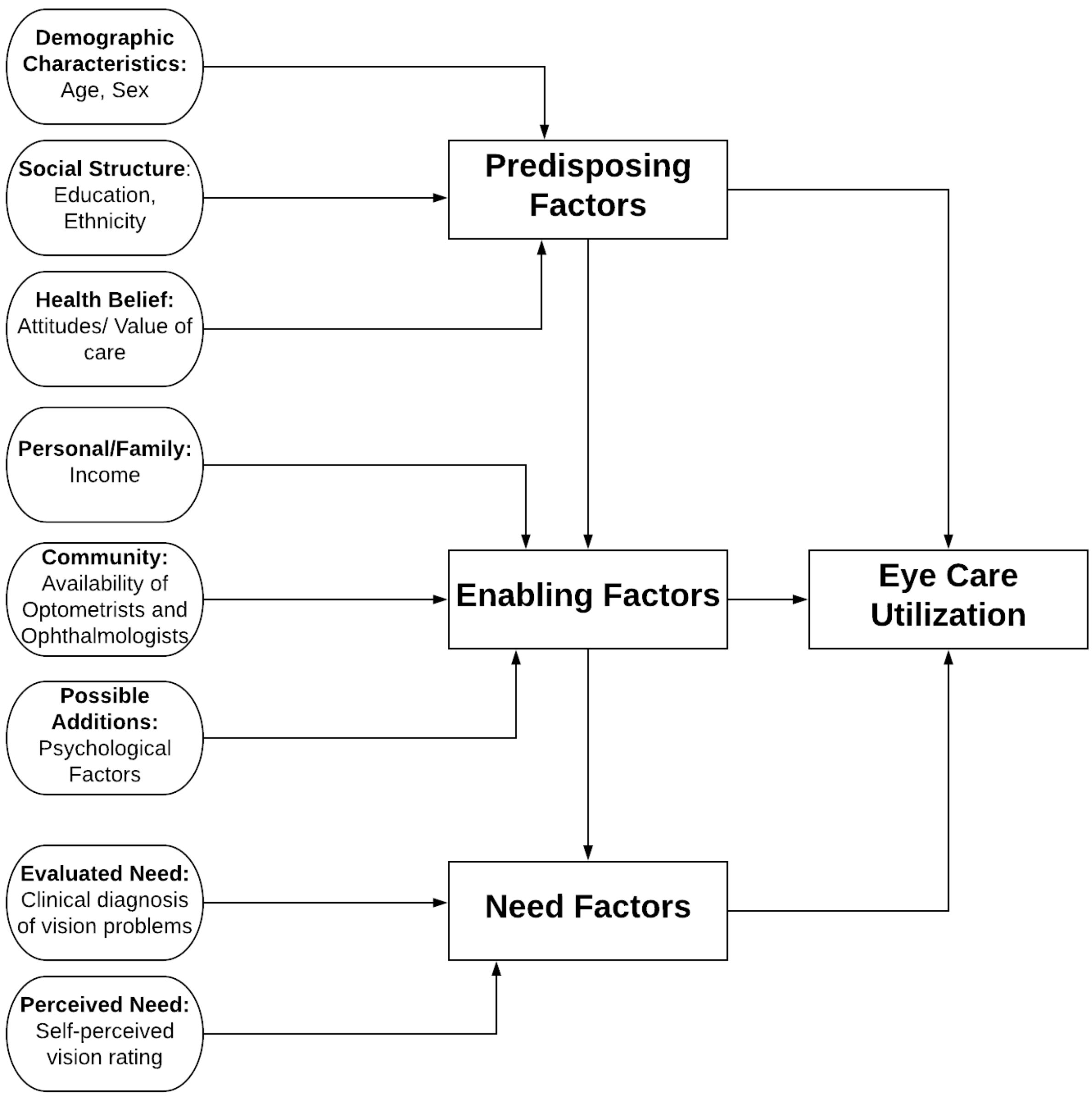
In the context of eye care utilization in Canada, no study has cumulatively looked at how the three groups of factors are related to eye care utilization; individual studies have looked at certain components of some of the three groups. For example, the Jin *et al* study on eye care utilization looked at a number of predisposing factors specifically demographic (age, sex), and social structural (education). They found that females, those who were older, and those who were more educated were more likely to utilize eye care in comparison to their counterparts.[61]

Health beliefs, attitudes and subjective norms are also a part of the predisposing factors. For individuals to utilize eye care, they must be aware and believe in the benefits of eye care utilization. A limited number of studies have investigated this in Canada. But, a survey done in British Columbia to assess public knowledge of the importance of vision care and risk factors for visual impairment indicated that while 28% of participants highlighted prevention of vision loss as a major medical concern, only 41.2% were familiar with glaucoma and 20.2% with macular degeneration. Men and younger participants were more likely to be unaware of risk factors associated with visual impairment.[69] Awareness, health beliefs and attitudes about preventive strategies are key factors that facilitate eye care utilization.

A few studies in Canada have focused on the enabling factors associated with eye care utilization (e.g., income, health insurance). Studies have consistently demonstrated that individuals with higher socioeconomic status (or higher income) have reported higher rates of eye care utilization in comparison to those with a lower income or socioeconomic status [54,61,63,70]. Similarly, a study looking at insurance reported that in individuals with less education, eye care utilization decreased by 7% in Ontario when a de-insurance policy was implemented.[64]

Studies looking at high-risk groups (those diagnosed with AMD, glaucoma, and cataracts) have demonstrated that those with eye disease are more likely to utilize eye care annually in comparison to those with no eye disease.[61,71,72] This aligns with the need factor, wherein individuals are more likely to utilize health care if they have an immediate (actual or perceived) need for it.

Figure 2 Adapted Andersen and Newman Framework for Eye Care Utilization



In Summary

Few studies have provided population-based estimates of visual impairment or current eye care utilization patterns in Canada. Indeed, Canada is one of the few developed countries that have not conducted high-quality population-based surveys on measured visual impairment. Previous studies estimating the prevalence of visual impairment in Canada have either extrapolated U.S. rates to the Canadian population, used a population-based sample from a single city with an unknown response rate, relied on self-report of visual impairment, or surveyed ophthalmology patients in a single city. Due to the limitations of these methods, the available prevalence estimates may be unreliable, biased, or have limited generalizability. Eye care utilization and its determinants have also been scarcely studied in Canada, with the most current study of eye care utilization using data from a decade ago. There is a dire need for valid visual impairment prevalence estimates and current up-to-date data on eye care utilization; these data would allow us to assess the burden of visual impairment and the need for eye health services in Canada. Using baseline data from the Canadian Longitudinal Study on Aging (CLSA), the purpose of this work is to estimate the current prevalence of visual impairment and eye care utilization in Canada, and their associations with geographic, socio-demographic, health & lifestyle characteristics.

CHAPTER THREE: DATA SOURCE

Canadian Longitudinal Study on Aging

Overview

The two manuscripts included in this thesis are based on baseline data from the Canadian Longitudinal Study on Aging (CLSA).[73] CLSA is a prospective cohort study of 51,338 Canadians aged 45–85 years at baseline and followed for at least 20 years. CLSA collects data from two cohorts, Tracking cohort (n=21,241) and Comprehensive cohort (n=30,097). Visual acuity data were only collected in the Comprehensive cohort, and as such only data from that cohort are used in this work. Exclusion criteria from the sampling frame of the Comprehensive cohort, included persons living on First Nations reserves, other First Nations settlements in the provinces, residents from the three territories, full-time members of the Canadian Armed Forces, and individuals living in institutions. Participants were also excluded if they were cognitively impaired at the time of recruitment. The methods used to screen for cognitive impairment included face-to-face assessment and telephone-administered cognitive screens.[73]

Participants in the Comprehensive cohort completed a core set of questionnaires over the phone and were asked to supplement the core set of questionnaires with in-depth information obtained via physical assessments and biospecimen collection done at their local Data Collection Site (DCS). As such, to be eligible to participate in the Comprehensive cohort, individuals had to live within 25-50 km of one of 11 data collection sites across 7 Canadian provinces (Victoria, Vancouver, Surrey, Calgary, Winnipeg, Hamilton, Ottawa, Montreal, Sherbrooke, Halifax, and St. John’s).

Sampling, Recruitment and Response Rates

The participants in the CLSA Comprehensive cohort were sampled using a combination of provincial health registries (14%) and random digit dialing [including participants sampled from Quebec Longitudinal Study on Nutrition and Aging (NuAge)] (86%). For those recruited using provincial health registries, a letter was sent to the randomly chosen, age-eligible person introducing the study and providing a consent form to be returned to the CLSA. For those recruited through random digit dialing, a random sample of landline telephone numbers was selected for a given geographic area. Prospective participants were called up to 10 times; once a call was answered, eligibility was established, and consent was obtained. Some participants were recruited from the Quebec Longitudinal Study on Nutrition and Aging (NuAge). The CLSA approached only the participants aged 75-85, from the NuAge study, that provided their contact information.

The CLSA used a complex survey design in which each survey participant represents a number of Canadians and is assigned a sample weight based on the inclusion probability. Sample weights are essential because the probability of selection of individuals from sub-groups varies. Stratified sampling was used to ensure adequate representation of various demographic groups (age group, sex) and distance from the data collection sites defined strata within a province. Response rates were calculated as the number of participants divided by the estimated number of those sampled who were eligible. All analysis in this work adjusted for the complex survey design using sample weights and strata information provided by the CLSA.

Ethics

The Ottawa Health Science Network Research Ethics Board (OHSN-REB) reviewed the plans for this research study, and ethics approval was granted in April 2017. All research conducted by the Canadian Longitudinal Study on Aging abides by the requirements of the Canadian Institutes of Health Research (CIHR) and the other institutions involved with data collection. After the release of the CLSA baseline data, a data access application (ID: 160601) was completed by Dr. Ellen Freeman to gain access to the data. The CLSA data and sample access committee reviewed the application and a CLSA access agreement (effective February 2017) between McMaster University and University of Ottawa was established and signed. Data were obtained in June 2017 (refer to Appendices 2 & 3 for a copy of the Ethics Approval & Data Access Agreement).

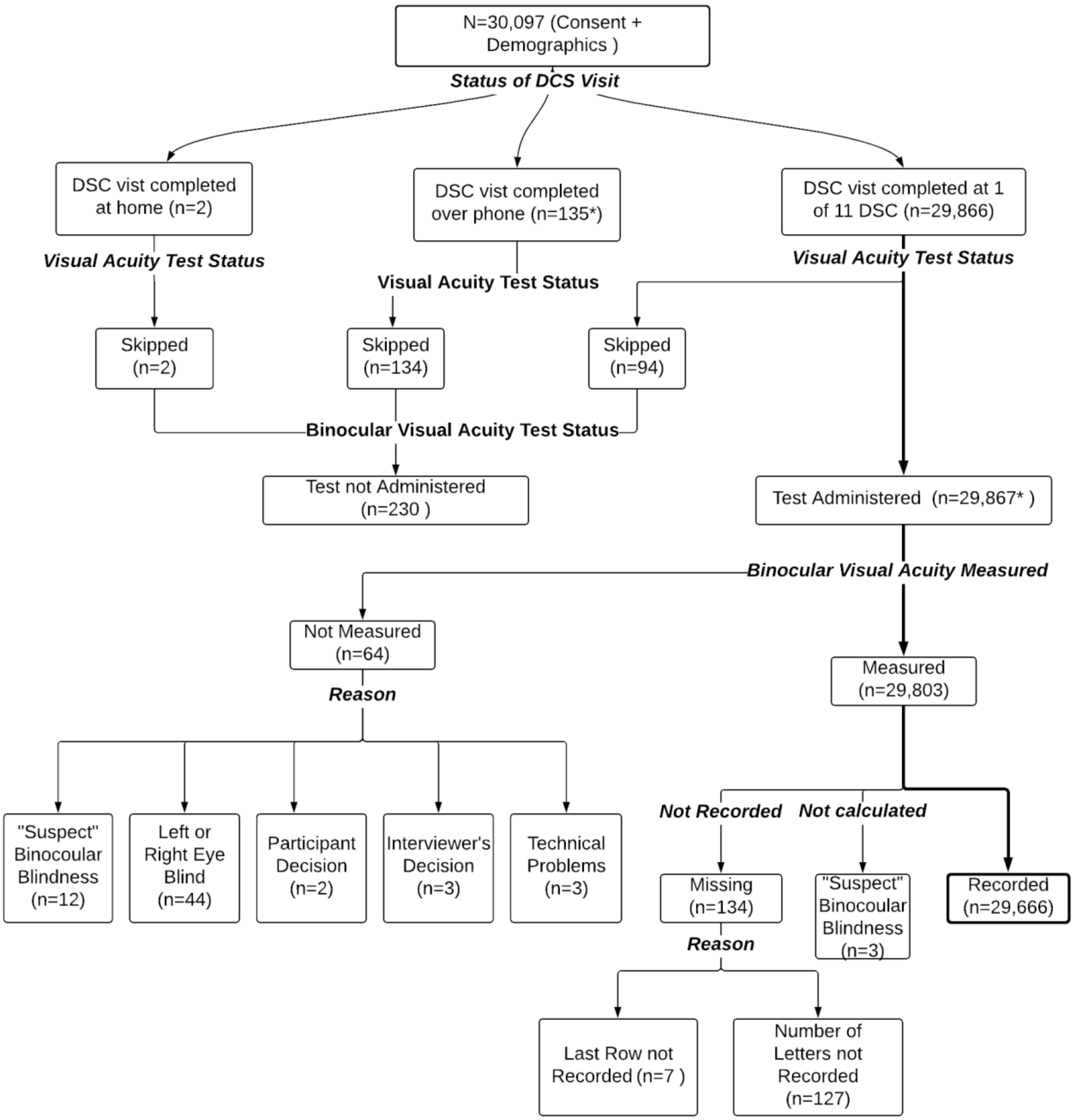
Missing Data

The completeness of the data was ascertained by monitoring the percentage of responders vs. non-responders for the two primary outcomes. The two primary outcomes in this work were visual acuity (measured through an ETDRS chart) and eye care utilization (self-report dichotomous question [yes/no] about annual eye care utilization).

While 30,097 participants in the CLSA Comprehensive cohort consented to participate and completed demographic and health history questionnaires over the phone or in their home, some participants did not complete the data collection site (DCS) (physical measurement) component. Visual acuity was measured during a participant's first DCS visit; for those participants who did not come to the DCS visit, the visual acuity test was not administered (n=230). For the 29,867 participants who did have a DCS visit, a total of 29,666 participants had measured and recorded binocular visual acuity scores with 201 having missing data for various reasons reported in Figure 3. In total, 431 (1.4%) were missing data on binocular visual acuity.

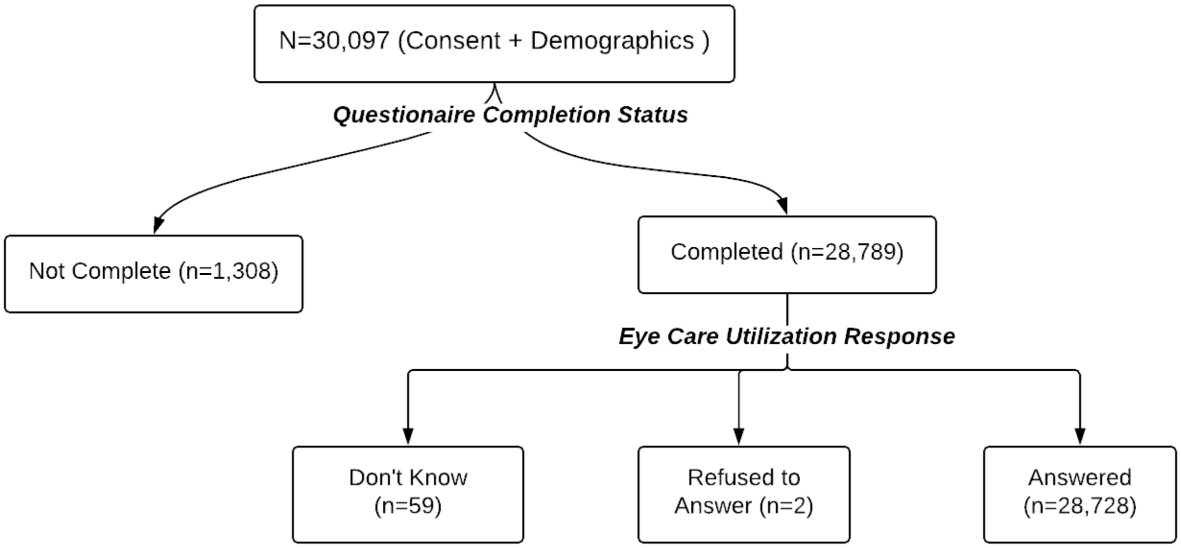
Similarly, for eye care utilization, which was asked in a secondary questionnaire, 1,308 participants (4.3%) did not complete the questionnaire. Out of the remaining 28,789 participants, two refused to answer the eye care utilization question, and 59 said they "don't know," and the remaining participants responded to the question. Refer to Figure 4 for the flow chart of missing data for the eye care utilization question.

Figure 3. Flow chart of missing data for the visual acuity measure



*1 participant completed questionnaire component over phone but came to a DCS for physical measurement test.

Figure 4. Flow chart of missing data for eye care utilization



Due to the heterogeneity of reasons for the missing data, the visual acuity non-responders were classified into subcategories based on the reason the visual acuity measure was missing; sub-categorization was as follows:

1. "Non-participants" – this group of participants (n=279) was not administered a binocular visual acuity test. They include 230 participants who were not administered any visual acuity testing and 49 participants who completed some of the visual acuity testing but did not complete the binocular visual acuity measure (n=44 "suspect" monocular blind group, n=3 interviewer's decision, n=2 participant's decision).

2. "Immeasurable" – the visual acuity score of this group of participants (n=15) was not assessed because they were reported to be blind in both eyes. This group of participants was suspected to have binocular visual acuity worse than 20/200 since they were unable to read any letters on the visual acuity chart.

3. “Missing” – the visual acuity score of these participants (n=137) was missing due to technical problems or a data recording errors (n=3 technical problems and n=134 had an error in recording or data input of their visual acuity score [i.e., assessors failed to report the last row or number of letters participants were able to read])

For the eye care utilization question, non-responders were classified into the following subcategories: 1) non-participant (n=1,308), 2) refusal group (n=2) and 3) don’t know group (n=59).

The characteristics of the participants who did not complete the visual acuity test and those who did not respond to the eye care question were compared to those who did complete them in preliminary analyses using chi-square tests.

The sociodemographic characteristics of the non-responders and the responders are reported in Table 3 for the visual acuity measure. Responders and non-responders were similar in their educational background. However, they were significantly different in age; responders were on average younger than non-responders (62.9 vs. 65.1; p<. 001). A greater proportion of non-responders were female in comparison to responders (55.9% vs. 50.8%; p <. 05). A greater proportion of responders reported one or more chronic illness in comparison to non-responders (92.1% vs. 88%; p <. 01). Responders and non-responders differed in household income; in the highest household income category (>$100,00) a larger proportion of responders had a higher income than non- responders (34.5% vs. 22.7%; p<. 001).

The sociodemographic characteristics of non-responders and the responders are reported in Table 4 for the annual eye care utilization question. There was no difference in the proportion of females and males between responders and non-responders. However, they were significantly different in age, household income and education ($p < .01$). Responders were on average younger than non-responders (62.9 vs. 63.7; $p < .01$). Responders and non-responders differed in household income; in the highest household income category (>$100,00), a larger proportion of responders had a higher income than non- responders (34.8% vs. 24.6%; $p < .001$). Responders and non-responders differed in educational backgrounds; a greater proportion (78%) of responders had a bachelor degree or more in comparison to 67.1% of non-responders $p < .001$.

Table 3: Distribution of sociodemographic and health characteristics by groups of visual acuity testing completion

	Type of non-responders				Responders	Target population
	Non-participant	Missing	Immeasurable	Total		
N	279	137	15	431	29,666	30,097
Mean Age	66.4 (10)	62.3 (9.2)	68.2 (10.73)	65.1 (9.96)	62.9 (10.3)	63 (10.3)
Age group:						
45-54	13.3	23.4	6.7	16.2	25.4	25.2
54-64	31.5	35	26.7	32.5	32.8	32.8
65-74	29	30.7	33.3	29.7	24.4	24.5
75+	26.2	10.9	33.3	21.5	17.5	17.6
Sex						
Female	49	68	73.3	55.9	51	50.9
Male	51	32	26.7	44.1	49	49.1
Household Income Per Year						
≥$100,000	20.4	28.5	13.3	22.7	34.5	34.3
$50,000 - $100,000	25.5	40.9	20	30.2	33	32.9
$20,000 - $50,000	31.5	25.5	33.3	29.7	21	21.3
<$20,000	13.6	2.9	33.3	10.9	5.1	5.2
Refused/Don't Know	9	2.2	-	6.5	6.4	6.6
Education						
Less than Secondary School	7.2	4.4	20.	6.7	5.4	5.5
Secondary School Graduation	9.3	11	13.33	10	9.4	9.4
Some post-secondary education	11.5	5.1	13.33	9.5	7.4	7.4
Bachelor, Diploma or more	72	79.6	53.3	73.8	77.6	77.5
Not answered	-	-	-	-	0.2	0.2
>=1 Reported Chronic Illness						
Yes	78.9	82.5	86.7	80.3	83	82.9
No	10	13.9	0	10.9	7.1	7.2
Not answered	11.1	3.7	13.3	8.82	9.9	9.9

Table 4: Distribution of sociodemographic characteristics by groups of non-responders compared with the responders for annual eye care utilization question

	Type of non-responders			Total	Responders	Target population
	Non-participant (A)	Refused (B)	Don't know (C)	(A+B +C)		
N	1,308	2	59	1,369	28,728	30,097
Mean Age	63.9 (11.4)	66 (12.7)	59.8 (10.3)	63.7 (11.4)	62.9 (10.2)	63 (10.3)
Age group:						
45-54	27.2	0	42.4	27.8	25.1	25.2
54-64	27.7	50	28.9	27.8	33	32.8
65-74	20.5	0	16.9	20.3	24.7	24.5
75+	24.6	50	11.9	24.1	17.2	17.6
Sex						
Female	51.3	50	52.5	51.3	50.9	50.9
Male	48.7	50	47.5	48.7	49.1	49.1
Household Income Per Year						
≥$100,000	23.9	0	40.7	24.6	34.8	34.3
$50,000 - $100,000	27.1	0	25.4	27	33.2	32.9
$20,000 - $50,000	28.2	100	25.4	28.2	20.8	21.3
<$20,000	12.6	0	0	12.1	4.9	5.2
Refused/Don't Know	8.2	0	8.5	8.2	6.4	6.6
Education						
Less than Secondary School	11.2	0	3.4	10.8	5.2	5.5
Secondary School graduation	13.2	50	6.8	13	9.3	9.4
Some post-secondary education	8.8	0	11.9	8.9	7.4	7.4
Bachelor or More	66.7	50	78	67.1	78	77.5
No answer	0.2	0	0	0.2	0.2	0.2

CHAPTER FOUR: MANUSCRIPT ONE

Preface

Purpose: Answer thesis objective 1 & 2

Required Ethics Approval: Ethics approval was received on April 2017, following review by the Ottawa Health Science Network Research Ethics Board (OHSN-REB).

Title: The Prevalence and Determinants of Visual Impairment in Canada: Cross-Sectional Data from the Canadian Longitudinal Study on Aging

Authors: Rumaisa Aljied, Marie-Josée Aubin MD, MSc, MPH, Ralf Buhrmann MD, PhD, Saama Sabeti MD, Ellen E. Freeman PhD.

Authors and their contribution:

- RA contributed to the analysis, the interpretation of the data, drafting the manuscript and revisions.
- MJA, RB, and SS contributed to the interpretation of the results and the revision of the manuscript.
- EEF contributed to the acquisition, analysis, and interpretation of the data and the revision of the manuscript.
- All authors gave final approval for the version published and agree to be accountable for all aspects of the work.

Publication Status: Accepted by Canadian Journal of Ophthalmology. Current status: *corrected proof published online*

Manuscript One

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ABSTRACT

Objective: To determine the prevalence and determinants of visual impairment in Canada.

Design: Cross-sectional population-based study

Participants: 30,097 people in the Comprehensive Cohort of the Canadian Longitudinal Study on Aging.

Methods: Inclusion criteria included being between the ages of 45 and 85 years old, community-dwelling, and living near one of the 11 data collection sites across 7 Canadian provinces. People were excluded if they were in an institution, living on a First Nations reserve, were a full-time member of the Canadian Armed Forces, did not speak French or English, or had cognitive impairment. Visual acuity was measured using the Early Treatment of Diabetic Retinopathy Study chart while participants wore their usual prescription for distance, if any. Visual impairment was defined as binocular acuity worse than 20/40.

Results: Of Canadian adults, 5.7% (95% (CI) 5.4-6.0) had visual impairment. A wide variation in the provincial prevalence of visual impairment was observed ranging from a low of 2.4% (95% CI 2.0-3.0) in Manitoba to a high of 10.9% (95% CI 9.6-12.2) in Newfoundland and Labrador. Factors associated with a higher odds of visual impairment included older age (odds ratio (OR)=1.07, 95% CI 1.06-1.08), lower income (OR=2.07 for those earning less than $20,000 per year, 95% CI 1.65-2.59), current smoking (OR=1.52, 95% CI 1.25-1.85), Type 2 diabetes (OR=1.20, 95% CI 1.03-1.41), and memory problems (OR=1.44, 95% CI 1.04-2.01).

Conclusions: Refractive error was the leading cause of visual impairment. Older age, lower income, province, smoking, diabetes, and memory problems were associated with visual impairment.

Keywords: visual impairment, prevalence, Canada, CLSA, visual acuity, income

INTRODUCTION

Despite the high prevalence of visual impairment in older age as demonstrated in previous research throughout the world,[1,2] Canada lacks high quality data on the prevalence of visual impairment. Previous Canadian studies have had limitations including extrapolating U.S. rates to the Canadian population,[3,4] relying on self-report of visual impairment,[5,6] or sampling people or patients from a single city.[7,8] First, relying on U.S. rates may not give an accurate picture of the burden of visual impairment in Canada given the differences between the two countries in healthcare systems, educational systems, ethnic backgrounds, and other factors that may affect vision.[9,10] Second, the self-report of visual impairment can result in substantial misclassification that can vary by demographic factors like age, gender, and education. Third, results from people from a single city may not generalize to the Canadian population and sampling eye care patients ignores people with visual impairment who have not yet sought treatment. Given these limitations, there is a pressing need for data on visual impairment from a population-based sample from sites across Canada.

Cross-sectional data collected as part of the Canadian Longitudinal Study on Aging (CLSA) offer an unparalleled opportunity to examine the frequency of vision loss throughout Canada.[11] Our objective is to report the prevalence of visual impairment and its determinants. These data will provide essential information to allow eye care professionals, health policy planners, and low vision rehabilitation providers to more adequately prepare for the needs of the aging population and identify groups in need of intervention.

METHODS

Study Population

The 30,097 adults in the CLSA Comprehensive study were randomly selected and had to meet the following inclusion criteria: aged between 45 and 85 years oldand living within 25-50 km of the 11 data collection sites in 7 Canadian provinces (Victoria, Vancouver, Surrey, Calgary, Winnipeg, Hamilton, Ottawa, Montreal, Sherbrooke, Halifax, and St. John's). To try to ensure maximum retention and follow-up in this longitudinal study, people were excluded from the CLSA if they were in an institution, living on a First Nations reserve or settlement, were a full-time member of the Canadian Armed Forces, did not speak French or English, or had obvious cognitive impairment as determined by trained interviewers. A face-to face interviewer-administered questionnaire was administered to patients and a physical assessment was conducted at the data collection site. Baseline recruitment was between the years 2012 and 2015. The project was approved by Research Ethics Boards in 7 different provinces. Research followed the tenets of the Declaration of Helsinki. Written informed consent was obtained for all participants.

Study Design

The participants in the CLSA Comprehensive cohort were sampled using a combination of provincial health registries (14%) and random digit dialing (86%). For those recruited using provincial health registries, a letter was sent to the randomly chosen, age-eligible person introducing the study and providing a consent form to be returned to the CLSA. For those recruited through random digit dialing, a random sample of landline telephone numbers was selected for a given geographic area. Once a call was answered, eligibility was established and consent was obtained. Stratified sampling was used to ensure adequate representation of various demographic groups. Strata within a province were defined by age group, sex, and distance from the data collection sites.[12]

Data Collection

All CLSA personnel underwent detailed training in all aspects of data collection. The training was standardized across all data collection sites. Data were collected at the data collection site.

Visual Acuity

During each participant's data collection site visit, visual acuity was evaluated by a trained assessor. Acuity was measured with the participant wearing prescribed glasses or contact lenses for distance vision, if any, both monocularly (right eye followed by left eye) and then binocularly using the Early Treatment of Diabetic Retinopathy Study (ETDRS) letter chart and its standard protocol.[13] The test distance was two meters. Acuity was scored as the total number of letters read correctly and then converted to the log of the minimum angle of resolution (logMAR units). Acuity measurements were also made with pinhole correction. Our primary outcome was visual impairment, which was defined as binocular acuity worse than 20/40 (0.301 logMAR) with the participant wearing prescribed glasses or contact lenses for distance vision, if any, as is standard in North America.[14]

Self-Reported Eye Disease and Corrective Lens Utilization

Self-reported eye diseases and corrective lens utilization were assessed using an interviewer-administered questionnaire at the data collection site. Participants were asked if they had ever been told by a doctor that they had glaucoma, cataract, or macular degeneration. People who reported having been told they had a cataract were then asked if they currently had a cataract. Those who said no were assumed to have had it removed. Participants were classified as using corrective lenses (wearing contact lenses or glasses) if they answered “yes” to either or both: “Do you wear glasses?”, “Do you wear contact lenses?”.

Demographic, Health and Lifestyle Data

Data on demographic variables (age, sex, race/cultural group, education, household income, urban versus rural residence), health conditions (diabetes and memory problems), and lifestyle (smoking status) were obtained as part of the interviewer-administered questionnaire. Household income was assessed by asking “What is your best estimate of the total household income received by all household members, from all sources, before taxes and deductions, in the past 12 months?”. Participants were classified as having diabetes if they answered “Yes” to “Has a doctor ever told you that you have diabetes, borderline diabetes or that your blood sugar is high”. They were then further classified as having Type 1 or Type 2 diabetes based on self-report. Memory problems were determined using the following question “Has a doctor ever told you that you have a memory problem?” Participants were classified as having memory problems if they responded “yes”. A former smoker was defined as someone who has smoked at least 100 cigarettes in life but who has not smoked in the last 30 days. A current smoker has smoked a cigarette in the last 30 days.

Statistical Analysis:

The primary outcome for this paper is the prevalence of binocular visual impairment. Associations between demographic, lifestyle, and health variables with visual impairment were tested in preliminary analyses using chi-square tests. Logistic regression was used to determine the adjusted relationships between these variables and visual impairment. We included the following variables as possible covariates due to prior research:[14-17] age, sex, ethnicity, education, income, rural residence, smoking, diabetes, and memory problems. The complex survey design was accounted for in all analyses by using the primary sampling unit, sample weight, and strata variables within the SVY commands in STATA Version 11 (College Station, Texas, USA). Age-standardization of the primary outcome was done by direct age adjustment in which age-stratified rates were applied to a standard population (arbitrarily picked as Alberta). Crude rates were presented for all other outcomes. Estimates of the numbers of Canadians aged 45-85 affected by visual impairment were calculated using data from the 2011 Canadian Census.[18]

RESULTS

Our analysis sample consisted of 29,666 people after excluding 431 people who were missing data for binocular visual acuity (1.4%). Those missing data on visual acuity were 2 years older, on average. The overall crude prevalence of visual impairment was 5.7% (95% CI 5.4, 6.0) while the age-standardized rate was 6.0%. There was heterogeneity in the rates of visual impairment by province as Manitoba, Quebec, and Ontario all had rates under 4% while Nova Scotia, Alberta, British Columbia, and Newfoundland and Labrador all had rates over 6.5% (Table 1).

As shown in Figure 1, between 64 and 80% of visual impairment was due to refractive error as can be seen by comparing the better eye rate of visual impairment while wearing usual correction to the better eye pinhole corrected rate of visual impairment, wherein the latter removes refractive error. Middle-aged participants with visual impairment were more likely to be affected by refractive error than older participants. As shown in Table 2, 86.1% of respondents reported wearing glasses or contact lenses, 5.6% reported a diagnosis of cataract currently in the eye, 3.9% reported a diagnosis of glaucoma, and 3.2% reported a diagnosis of macular degeneration.

In Table 3, demographic risk factors for visual impairment are presented. The prevalence of visual impairment increased substantially with age ranging from 2.7% in those 45-54 years old to 15.6% in those 75-84 years old. Women, those with less education, those living in urban or semi-urban areas, and those with lower income had higher rates of visual impairment in unadjusted analyses ($P<0.05$). There was no significant difference by race/cultural group although rates ranged from a low of 3.7% in Black participants to a high of 6.5% in Aboriginal participants and 8.0% in participants of other races than those listed. In Table 4, lifestyle and health factors and their relationship to visual impairment are shown. Former or current smokers, those with high blood pressure, those with Type 1 or Type 2 diabetes, and those with memory problems were more likely to have visual impairment ($P<0.05$).

In Table 5, demographic, lifestyle, and health variables are included in a logistic regression model. Education was dropped from the model for two reasons: 1) it was correlated with income, and 2) it was not significant with income in the model . Race/cultural group was also dropped from the model due to its lack of statistical significance. The lower the household income, the higher the odds of having visual impairment. In particular, those making less than $20,000 per year had 2.07 times the odds of visual impairment compared to those making $100,000 or more per year (95% CI 1.65-2.59). Other factors associated with a higher odds of visual impairment included older age (odds ratio (OR)=1.07, 95% CI 1.06-1.08), current smoking (OR=1.52, 95% CI 1.25-1.85), Type 2 diabetes (OR=1.20, 95% CI 1.03-1.41), memory problems (OR=1.44, 95% CI 1.04-2.01), and province.

The numbers of middle-aged and older adults estimated to be affected by visual impairment by province are shown in Table 6. The numbers range from 11,570 people in Manitoba to 191,094 people in Ontario.

DISCUSSION

In a large, population-based sample of 29,666 Canadians aged 45-85 years old, we found that the overall crude prevalence of visual impairment was 5.7% ranging from 2.7% in those 45 to 54 years old to 15.6% in those 75 to 85 years old. Out of the 7 provinces from which we had data, the rate of visual impairment was lower in Manitoba, Quebec, and Ontario (2.4-3.5%) while it was higher in Nova Scotia, Alberta, British Columbia, and Newfoundland and Labrador (6.9-10.9%). The risk factors for visual impairment included older age, lower income, current smoking, diabetes, and memory problems.

The primary cause of visual impairment was not determined by an eye care professional in the CLSA. However, it is clear from comparing the rate of visual impairment with and without pinhole correction (which removes most refractive error) that, as in other studies, refractive error is the leading cause of visual impairment in the CLSA data.[19] Refractive error is an easily correctable cause of visual impairment. Changes in refraction can occur in middle age due to cataract surgery, cataract itself, or presbyopia, which primarily affects near vision and the ability to quickly change your focus between near and far objects. Cataract, glaucoma, and macular degeneration were also reported by 2-7% of the population.

Prior population-based research in Canada done in the city of Brantford, Ontario found that 2.7% of adults ages 40 years and older had visual impairment.[7] This is consistent with our rate for the two cities in the province of Ontario (Hamilton and Ottawa), which was 3.5%. Our overall rate of 5.7% compares well with other U.S. and Australian data.[2,19] For example, Vitale *et al* found that 6.4% of Americans had visual impairment [19] while Taylor *et al* found that 4% of Australians had visual impairment.[2] However, we did see great heterogeneity in the rates of visual impairment by province ranging from a low of 2.4% in Manitoba to a high of 10.9% in Newfoundland and Labrador. These differences remained after adjustment for demographic, lifestyle, and health factors. The reason for these provincial differences is unclear. Differing provincial eye care coverage policies may explain some of this variation. For example, Newfoundland and Labrador, which had the highest rate of visual impairment, is one of the few Canadian provinces to not pay for a routine eye exam for seniors,[20] an exam that is recommended at least every two years by the Canadian Ophthalmological Society.[21] Indeed, prior research found that Newfoundland and Labrador had the lowest rate of eye care utilization in Canada.[22] Manitoba, which had the lowest rate of visual impairment, covers not only an eye exam every two years for seniors, but also at least part of the cost of eyeglasses for seniors and for visual field, tonometry, and dilated fundus exams performed by an optometrist.[23] Interprovincial differences in the number of eye care professionals could also affect the rates of visual impairment. However, prior research did not indicate an obvious shortage of eye care professionals in any province.[24]

Several risk factors were related to visual impairment. Lower personal income was linearly related to the prevalence of visual impairment, which is consistent with prior research [25-27]. People may delay getting appropriate eye care in the absence of adequate income or insurance. Smoking was also related to visual impairment and is a known risk factor for cataract and age-related macular degeneration.[16,17] People with diabetes were more likely to have visual impairment, likely due to the damage that high glycemic levels cause to the retina resulting in diabetic retinopathy. It is recommended that people with diabetes see an eye care provider at least every 1-3 years depending on their age.[21] Finally, memory problems were associated with visual impairment. People with obvious cognitive impairment were excluded at recruitment. However, a high percentage of participants reported a diagnosis of memory problems. A small proportion (10%) of this group with memory problems reported a diagnosis of dementia or Alzheimer's disease. The causes of the other 90% are assumed to be due to a variety of factors including mild cognitive impairment, medication side effects, blood flow problems, etc. Prior research has demonstrated a relationship between visual impairment and cognitive impairment although the reason for this relationship is unclear.[15,28,29] Female sex was not related to visual impairment after adjustment in our study. This is consistent with other studies that were done using presenting visual acuity.[7,19] By contrast, women are sometimes more likely to have visual impairment than men if best-corrected visual acuity is used.[1]

The main strength of this work is that this is the first national, population-based assessment of visual impairment in Canada using a visual acuity chart. There are a few limitations of this work. The cross-sectional nature of the data precludes our ability to determine the temporality of the risk factors and the onset of visual impairment. Some of the data used in the analysis were based on self-report such as the data on eye disease, demographic, lifestyle, and health factors. This could have led to misclassification although we suspect that it would have been non-differential with regard to visual impairment status and thus would have diluted our results. We did not have data from outside of the areas around the 11 data collection sites, particularly the far north where access to eye care may be more of a challenge. In addition, our exclusion criteria excluded those in institutions, those not speaking French or English, those living on a First Nations reserve, those in the military, and those with overt cognitive impairment. Also, those recruited by random digit dialing required a landline phone, although it was estimated by Statistics Canada that only 5% of people in this age range did not have a landline telephone in 2010. Therefore, generalizability of our results to other parts of Canada (more remote areas and excluded provinces) and to groups other than those studied is unknown. Also, a small percentage (1.4%) of the sample was missing data on visual acuity. These individuals were two years older, on average, indicating that our prevalence estimates may be somewhat under-estimated since visual impairment is so strongly related to age. Furthermore, the test distance of the ETDRS chart was 2 meters rather than the standard 4 meters, which due to accommodative difficulties for some people may have led to a slight overestimation of visual impairment. To conclude, visual impairment is a significant problem in Canada, especially among older adults. These data can be used by health policy planners, low vision rehabilitation providers, and eye care professionals to plan for the future eye care needs of Canada's aging population. Provinces with higher prevalence rates of visual impairment should consider ways to lower these rates. Concerted national efforts are needed to reduce refractive errors, increase access to regular eye care and smoking cessation programs, and to ensure that diabetics are educated about their eye care needs and have access to routine eye fundus exams.

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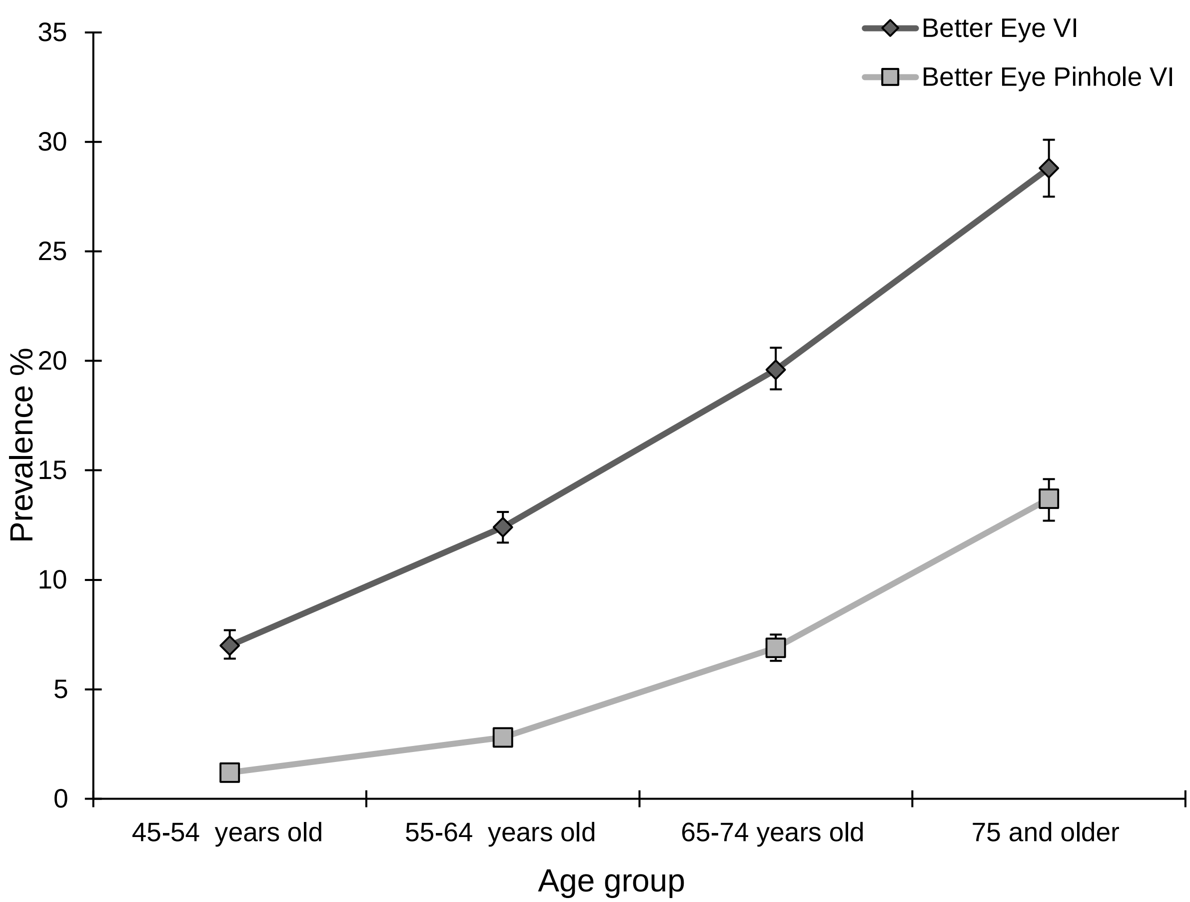
Manuscript 1-Table 1: Crude and age-adjusted prevalence rates of visual impairment by province

Province	**Crude VI** **% (95% CI)**	**Age-Standardized VI** **%**
Alberta (n=2,923)	7.8 (6.8-8.9)	8.7
British Columbia (n=6,212)	8.6 (7.9-9.3)	8.4
Manitoba (n=3,095)	2.4 (2.0-3.0)	2.3
Newfoundland & Labrador (n=2,203)	10.9 (9.6-12.3)	10.9
Nova Scotia (n=3,046)	6.9 (6.0-7.9)	6.9
Ontario (n=6,304)	3.5 (3.1-4.0)	3.4
Quebec (n=5,883)	3.2 (2.8-3.7)	2.9
Canada (n=29,666)	5.7 (5.4-6.0)	6.0

VI=visual impairment

Manuscript 1- Figure 1. Prevalence of visual impairment (VI) with and without pinhole correction by age group.

The prevalence of visual impairment, both with and without pinhole correction, increases with age. The proportion of visual impairment explained by refractive error is higher in the younger age group than the older age group.



Manuscript 1-Table 2: Prevalence rate of corrective lens usage and self-reported eye disease by province

Site	**Alberta** n=2,923 (%)	**BC** n=6,212 (%)	**Manitoba** n=3,095 (%)	**NF & L** n=2,203 (%)	**Nova Scotia** n=3,046 (%)	**Ontario** n=6,304 (%)	**Quebec** n=5,883 (%)	**Canada** n=29,666 (%)
Wear Glasses /Contact Lenses	89.8	87.3	72.5	86.9	83.1	90.9	86.3	86.1
Cataract								
None	90.0	88.7	88.2	90.3	92.6	88.3	90.0	90.0
Removed	6.0	5.1	4.8	4.9	3.3	5.6	4.4	4.9
Present	4.0	6.2	7.1	4.8	4.2	6.1	5.4	5.6
Glaucoma								
Yes	3.2	3.5	4.4	3.4	3.7	3.5	5.0	3.9
Macular Degeneration								
Yes	3.2	3.5	3.3	2.6	2.4	3.3	2.9	3.2

VI=visual impairment; BC=British Columbia; NF & L=Newfoundland and Labrador

Manuscript 1-Table 3: Rates of visual impairment by demographic factors

	Visually Impaired n=2,183 (%)	**Not Visually Impaired n=27,483 (%)**	**P-Value**
Age Group, Years			
45-54 (n=7,595)	2.7	97.4	<0.01
55-64 (n=9,716)	5.0	95.0	
65-74 (n=7,234)	8.3	91.7	
75-84 (n=5,191)	15.6	84.4	
Sex/Gender			
Male (n=14,587)	5.4	94.6	0.03
Female (n=15,079)	6.0	94.0	
Race/Cultural Group			
White (n=27,960)	5.7	94.3	0.73
Black (n=252)	3.7	96.3	
Asian (East, South, SE) (n=673)	5.6	94.4	
Arab and West Asian (n=141)	4.4	95.6	
Latin American (n=123)	6.3	93.7	
Aboriginal (n=357)	6.5	93.5	
Other (n=160)	8.0	92.0	
Education*			
No Post-Secondary Training (n=2,201)	6.9	93.1	<0.01
Some Post-Secondary Training (n=9,594)	5.6	94.1	
Bachelor's Degree (n=6,988)	4.9	95.1	
More than Bachelor's (n=6,413)	5.1	94.9	
Residence*			
Urban, Semi-urban (n=26,920)	5.9	94.2	<0.01
Rural (n=2,374)	3.7	96.4	
Household Income Per Year			
≥$100,000 (n=10,225)	3.7	96.3	<0.01
$50,000 - $100,000 (n=9,777)	5.8	94.2	
$20,000 - $50,000 (n=6,232)	8.5	91.5	
<$20,000 (n=1,519)	11.2	88.8	
Refused/Don't Know (n=1,913)	8.0	92.0	

n missing: education (n=4,470) **,**residence (n=372)

Manuscript 1-Table 4: Rates of visual impairment by lifestyle and health factors

	Visually Impaired (%)	Not Visually Impaired (%)	P-Value
Smoking*			
Never (n=14,060)	5.2	94.8	<0.01
Former (n=12,987)	6.2	93.8	
Current (n=2,517)	6.3	93.7	
High Blood Pressure*			
No (n=18,577)	4.9	95.1	<0.01
Yes (n=10,929)	7.4	92.6	
Diabetes*			
None (n=24,354)	5.3	94.7	<0.01
Type 1 (n=169)	8.4	91.6	
Type 2 (n=2,727)	8.7	91.3	
Suspect/Neither Type (n=2,090)	6.0	94.0	
Memory Problems*			
No (n=29,079)	5.6	94.4	<0.01
Yes (n=503)	9.7	90.3	

*n missing: Smoking (n=102), High blood pressure (n=160), Diabetes (n=326), Memory problems (n=84)

Manuscript 1-Table 5: Multiple logistic regression analysis of variables and their independent association with visual impairment using.

	Visual Impairment N=28,725 Adjusted Odds Ratio*	**95% CI**
Age, Per 1 Year	1.07	1.06-1.08
Female Sex	1.04	0.93-1.17
Household Income Per Year		
≥$100,000	1.00	
$50,000 - $100,000	1.14	0.98-1.32
$20,000 - $50,000	1.33	1.13-1.57
<$20,000	2.09	1.67-2.63
Refused/Don't Know	1.21	0.98-1.50
Rural vs Non-Rural	0.85	0.68-1.06
Smoking		
Never	1.00	
Former	1.04	0.93-1.17
Current	1.52	1.25-1.85
Diabetes		
None	1.00	
Type 1	1.57	0.84-2.97
Type 2	1.21	1.04-1.42
Suspect/Neither Type	0.95	0.77-1.17
Memory Problems	1.44	1.04-2.01
High Blood Pressure	1.02	0.91-1.15
Province		
Alberta	1.00	
British Columbia	0.98	0.82-1.18
Manitoba	0.23	0.17-0.30
Newfoundland & Labrador	1.32	1.07-1.64
Nova Scotia	0.76	0.61-0.94
Ontario	0.37	0.30-0.45
Quebec	0.29	0.23-0.36

*Adjusted for all variables in table and also for the complex study design

Manuscript 1-Table 6: Estimated numbers of people aged 45-85 with visual impairment by province

Site	Alberta	BC	Manitoba	NF & L	Nova Scotia	Ontario	Quebec
% with Binocular VI by age							
45-54	4.1	3.1	1.7	5.7	3.0	1.8	1.3
55-64	6.4	7.7	1.8	10.2	5.6	3.1	2.5
65-74	14.1	13.6	3.1	15.2	9.8	5.3	3.7
75-85	26.7	24.7	5.4	28.1	22.3	8.0	9.7
Population Size by Age							
45-54	560,340	705,215	180,060	85,405	153,735	2,062,015	1,272,270
55-64	415,945	614,380	148,670	81,780	137,385	1,630,275	1,092,110
65-74	220,470	371,615	88,665	48,855	85,315	1,004,270	694,965
75-85	133,765	224,425	57,120	24,695	47,670	627,660	408,775
45-85	1,330,520	1,915,635	474,515	240,735	424,105	5,324,220	3,468,120
Estimated # with Binocular VI							
45-54	22,974	21,862	3,061	4,868	4,612	37,116	16,540
55-64	26,620	47,307	2,676	8,341	7,694	50,539	27,303
65-74	31,086	50,540	2,749	7,426	8,3601	53,226	25,714
75-85	35,715	55,433	3,084	6,939	10,630	50,213	39,651
45-85	116,396	175,142	11,570	27,575	31,297	191,094	109,207

VI=visual impairment; BC=British Columbia; NF & L=Newfoundland and Labrador

References

1. Congdon N, O'Colmain B, Klaver CC, et al. Causes and prevalence of visual impairment among adults in the United States. *Arch Ophthalmol.* 2004;122(4):477-485.
2. Taylor HR, Keeffe JE, Vu HT, et al. Vision loss in Australia. *Med J Aust.* 2005;182(11):565-568.
3. Cruess AF, Gordon KD, Bellan L, Mitchell S, Pezzullo ML. The cost of vision loss in Canada. 2. Results. *Can J Ophthalmol.* 2011;46(4):315-318.
4. Gordon KD, Cruess AF, Bellan L, Mitchell S, Pezzullo ML. The cost of vision loss in Canada. 1. Methodology. *Can J Ophthalmol.* 2011;46(4):310-314.
5. Jin YP, Wong DT. Self-reported visual impairment in elderly Canadians and its impact on healthy living. *Can J Ophthalmol.* 2008;43(4):407-413.
6. Gresset J, Baumgarten M. Prevalence of visual impairment and utilization of rehabilitation services in the visually impaired elderly population of Quebec. *Optom Vis Sci.* 2002;79(7):416-423.
7. Robinson B, Feng Y, Woods CA, Fonn D, Gold D, Gordon K. Prevalence of visual impairment and uncorrected refractive error - report from a Canadian urban population-based study. *Ophthalmic Epidemiol.* 2013;20(3):123-130.
8. Maberley DA, Hollands H, Chuo J, et al. The prevalence of low vision and blindness in Canada. *Eye.* 2006;20(3):341-346.
9. Zhang X, Cotch MF, Ryskulova A, et al. Vision health disparities in the United States by race/ethnicity, education, and economic status: findings from two nationally representative surveys. *Am J Ophthalmol.* 2012;154(6 Suppl):S53-62 e51.
10. West SK, Duncan DD, Munoz B, et al. Sunlight exposure and risk of lens opacities in a population-based study: the Salisbury Eye Evaluation project. *JAMA.* 1998;280(8):714-718.
11. Raina PS, Wolfson C, Kirkland SA, et al. The Canadian longitudinal study on aging (CLSA). *Can J Aging.* 2009;28(3):221-229.
12. Canadian Longitudinal Study on Aging: For Researchers. https://www.clsa-elcv.ca/researchers. Accessed July 17, 2017.
13. Lovie-Kitchin JE. Validity and reliability of visual acuity measurements. *Ophthalmic Physiol Opt.* 1988;8(4):363-370.
14. Ko F, Vitale S, Chou CF, Cotch MF, Saaddine J, Friedman DS. Prevalence of nonrefractive visual impairment in US adults and associated risk factors, 1999-2002 and 2005-2008. *JAMA.* 2012;308(22):2361-2368.
15. Ong SY, Cheung CY, Li X, et al. Visual impairment, age-related eye diseases, and cognitive function: the Singapore Malay Eye study. *Arch Ophthalmol.* 2012;130(7):895-900.
16. Cong R, Zhou B, Sun Q, Gu H, Tang N, Wang B. Smoking and the risk of age-related macular degeneration: a meta-analysis. *Ann Epidemiol.* 2008;18(8):647-656.
17. Ye J, He J, Wang C, et al. Smoking and risk of age-related cataract: a meta-analysis. *Invest Ophthalmol Vis Sci.* 2012;53(7):3885-3895.
18. 2011 Census of Canada: Topic-Based Tabulations. http://www12.statcan.gc.ca/census-recensement/2011/dp-pd/tbt-tt/Index-eng.cfm. Accessed July 18, 2017.
19. Vitale S, Cotch MF, Sperduto RD. Prevalence of visual impairment in the United States. *JAMA.* 2006;295(18):2158-2163.

20. Medical Plan Care Coverage of Newfoundland and Labrador http://www.health.gov.nl.ca/health/mcp/healthplancoverage.html. Accessed June 27, 2017.
21. Canadian Ophthalmological Society evidence-based clinical practice guidelines for the periodic eye examination in adults in Canada. *Can J Ophthalmol.* 2007;42:39-45.
22. Jin YP, Trope GE. Eye care utilization in Canada: disparity in the publicly funded health care system. *Can J Ophthalmol.* 2011;46(2):133-138.
23. Government of Manitoba: Health, Seniors, and Active Living. http://www.gov.mb.ca/health/mhsip/#Q5. Accessed June 27, 2017.
24. Al Ali A, Hallingham S, Buys YM. Workforce supply of eye care providers in Canada: optometrists, ophthalmologists, and subspecialty ophthalmologists. *Can J Ophthalmol.* 2015;50(6):422-428.
25. Ryskulova A, Turczyn K, Makuc DM, Cotch MF, Klein RJ, Janiszewski R. Self-reported age-related eye diseases and visual impairment in the United States: results of the 2002 national health interview survey. *Am J Public Health.* 2008;98(3):454-461.
26. Tielsch JM, Sommer A, Katz J, Quigley H, Ezrine S. Socioeconomic status and visual impairment among urban Americans. Baltimore Eye Survey Research Group. *Arch Ophthalmol.* 1991;109(5):637-641.
27. Wah W, Earnest A, Sabanayagam C, et al. Composite Measures of Individual and Area-Level Socio-Economic Status Are Associated with Visual Impairment in Singapore. *PLoS One.* 2015;10(11):e0142302.
28. Harrabi H, Kergoat MJ, Rousseau J, et al. Age-related eye disease and cognitive function. *Invest Ophthalmol Vis Sci.* 2015;56(2):1217-1221.
29. Clemons TE, Rankin MW, McBee WL. Cognitive impairment in the Age-Related Eye Disease Study: AREDS report no. 16. *Arch Ophthalmol.* 2006;124(4):537-543.

Additional Analyses

Estimating interaction on an additive an multiplicative scale

Interaction effects between previously cited risk factors and visual impairment were evaluated using two different approaches. Interactions were first evaluated using the cross-product of the risk factors in a logistic regression model (multiplicative scale). Our second approach was then to estimate interactions on an additive scale, where we calculated the three measures of interaction (RERI, AP, and S) and their 95% confidence intervals. No statistically significant interactions were found on either the multiplicative or additive scale.

Classification of missing values and imputations

For the visual acuity measure, 1.4% (431) of the sample had missing data. Missing data can be classified as missing completely at random (MCAR), missing at random (MAR) and missing not at random (MNAR).[74] Data can be considered MCAR if there is no systematic underlying process as to why data are missing, except for random chance. Data can be considered MAR if they are missing because of some non-random, potentially observable, systematic process. Data is considered MNAR if it's missing due to the variable missing. Risk of bias depends on the type of data missing; MAR and MCAR data are ignorable, while MNAR data are non-ignorable.[74] In our manuscript, we used a complete case method, wherein individuals missing the primary outcome data were not included in the study.

While some of our data are MCAR (e.g., technical problems), a larger proportion of the missing data could be MAR or MNAR. It is very hard to truly know whether data are MAR or MNAR. On the assumption that our data were MAR or MNAR, to adjust the crude prevalence estimates for non-response bias, we used a mix of single and multiple imputation. We first substituted any score we could using data on the reason for missingness obtained from an open text field: 1) For anyone who was missing a binocular score but who had at least one monocular score, we used the better eye monocular score to define binocular visual impairment (n=170); 2) For all people who had neither a binocular score nor any monocular scores because they could not see any letters on the acuity chart, we assumed that they had binocular visual impairment (n=15). For the remaining binocular visual acuity scores (n=246), a multiple imputation method using the MI command in STATA Version 14.2 was implemented. Using the imputed visual acuity scores and ignoring the complex sample design (it cannot be used with the MI command), the prevalence of visual impairment was 7.4%. When using the complete case analysis without adjustment of the complex survey design, the crude prevalence of visual impairment was 7.3% which is very similar to 7.4%. Our use of this imputation method was done to ensure robustness in methodology. We can conclude that since the percentage of our missing data was very low (1.4%) and our imputed results were so similar to our complete case results, it appears that complete case analysis is an acceptable approach in these data.

WHO Categorization

Some sensitivity analyses were conducted using different visual acuity thresholds, specifically using the WHO categorization of visual impairment using binocular presenting visual acuity (refer to Table 1 for classifications). Results of the visual impairment prevalence using the WHO visual acuity thresholds in comparison to the North American thresholds are presented in Table 5. Also, the age-specific prevalence estimates of visual impairment (no blindness) using the WHO criteria (visual acuity worse than 0.501) are displayed in Table 6. By using the WHO categorization, we are now able to compare our prevalence estimates with the prevalence of developed and developing countries.

Table 5: Visual Impairment Prevalence per 100,000 using CLSA data: WHO vs. North American definitions (N=29,676)

WHO		North American	
Category	Per 100,000	**Category**	Per 100,000
Mild or no visual impairment	98,920	No Visual impairment	94,280
Moderate visual impairment	1040	Visual Impairment	5680
Severe visual impairment	---------	Blindness	40
Blindness	40		

Table 6: Age-Specific Prevalence of Visual impairment using CLSA data (WHO classification of moderate to severe VI

WHO	
Prevalence per 100 000	
45-54	520
54-64	920
65-74	1,420
75-85	2,910

*adjusting for complex survey design

CHAPTER FIVE: MANUSCRIPT TWO

Preface

Purpose: Answers thesis objective 3 & 4

Required Ethics Approval: Ethics approval was received on April 2017, following review by the Ottawa Health Science Network Research Ethics Board (OHSN-REB).

Title: Eye Care Utilization and its Determinants in Canada

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Authors and their contribution:

- RA contributed to the analysis, the interpretation of the data, drafting the manuscript and revision.
- MJA, RB, and SS contributed to the interpretation of the results and the revision of the manuscript.
- EEF contributed to the acquisition, analysis, and interpretation of the data and the revision of the manuscript.
- All authors gave final approval for the version published and agree to be accountable for all aspects of the work.

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ABSTRACT

Purpose: To provide the frequency and potential determinants of eye care utilization over the last 12 months among Canadians between the ages of 45 and 85 years old.

Design: Cross-sectional population-based study

Participants: 30,097 people in the Comprehensive Cohort of the Canadian Longitudinal Study on Aging.

Methods: Inclusion criteria included being between the ages of 45 and 85 years old, community-dwelling and living near one of the 11 data collection sites across 7 Canadian provinces. Eye care utilization was defined as the self-report of a visit to an optometrist or ophthalmologist in the past 12 months.

Results: Fifty-seven percent of 28,728 adults visited an eye care provider in the last year although there was great heterogeneity between provinces. The highest eye care utilization was found in Ontario at 62%, while the lowest was in Newfoundland and Labrador at 50%. Of concern, 25.3% of people with diabetes over age 60 had not seen an eye care provider in the last year. Our novel finding was that current smokers were less likely to use eye care compared to never smokers (odds ratio (OR)=0.76, 95% CI 0.67, 0.87). Confirming previous research, men compared to women (OR=0.67, 95% CI 0.62, 0.71), people with less than a Bachelor's degree compared to more than a Bachelor's degree (OR=0.87, 95% CI 0.79, 0.95), and people making less income (linear trend $P<0.05$) were also less likely to use eye care.

Interpretation: Disparities exist in eye care utilization in Canada. Efforts should be made to reduce these disparities to reduce avoidable vision loss.

INTRODUCTION

Visual impairment is a substantial economic burden in Canada costing approximately $15.8 billion per year. [1] The prevalence of visual impairment increases dramatically with age such that approximately 1 in 10 adults over age 60 is affected. [2] The majority of visual impairment is due to uncorrected refractive error. [2] Routine eye examinations are important for the timely detection of refractive error and the early identification and management of eye disease. [3]

The most recent study to examine rates and determinants of eye care utilization in Canada used data that are now over 10 years old. [4] Jin *et al* used the 2005 Canadian Community Health Survey to examine eye care utilization in individuals aged 12 and older and found that 40% of Canadians in this age group utilized eye care services from an optometrist or an ophthalmologist in a 12-month period. Being male, younger, having lower socioeconomic status, and living in Newfoundland and Labrador were factors associated with less utilization ($P<0.05$).

The Canadian Longitudinal Study on Aging (CLSA) Comprehensive Cohort, a large, national, population-based epidemiological study of over 30,000 people, allows us to provide up-to-date estimates of eye care utilization and its determinants in middle aged and older adults across 7 provinces of Canada. [5] Knowing the current patterns and frequency of eye care utilization would help to identify eye care access disparities which would allow policy makers, researchers, and healthcare providers to devise ways to close the gaps and improve Canada's vision and eye health.

METHODS

Setting

The CLSA is a national prospective cohort study of adult development and aging. A detailed description of the CLSA methodology is reported elsewhere [5]. This analysis used baseline data from the 30,097 participants in the Comprehensive Cohort of the CLSA collected between 2012 and 2015. Participants were community-dwelling adults between 45 and 85 years old living near one of 11 data collection sites across 7 Canadian provinces (Victoria, Vancouver, Surrey, Calgary, Winnipeg, Hamilton, Ottawa, Montreal, Sherbrooke, Halifax, and St. John's). People were not eligible if they lived in an institution, on a First Nations reserve or settlement, were full-time members of the Canadian Armed Forces, did not speak French or English, or had obvious cognitive difficulties. Written informed consent was obtained and the project was approved by Research Ethics Boards in 7 different provinces.

Design

The participants in the CLSA Comprehensive cohort were sampled using both provincial health registries (14%) and random digit dialing (86%). For those recruited using provincial health registries, a letter was sent to the randomly chosen, age-eligible person introducing the study and providing a consent form to be returned to the CLSA. For those recruited through random digit dialing, a random sample of landline telephone numbers was selected for a given geographic area. Stratified sampling was used to ensure adequate representation of various demographic groups. Strata within a province were defined by age group, sex, and distance from the data collection sites.

Sources of Data

All CLSA personnel underwent detailed training in all aspects of data collection. The training was standardized across all data collection sites. The following data were collected as part of a face-to-face, interviewer-administered questionnaire given either in the home or at a data collection site, unless otherwise specified.

Sociodemographic

Data on demographic variables such as age, sex, race/cultural group, highest level of education, and urban versus rural residence were obtained. Household income was assessed by asking “What is your best estimate of the total household income received by all household members, from all sources, before taxes and deductions, in the past 12 months?”. Respondents chose from 5 categories of household income: <$20,000; $20-$50,000; $50-$100,000; $100-$150,000; and $150,000 or more.

Lifestyle and Health

Participants were asked about former and current smoking. Depression was ascertained through the Center for Epidemiologic Studies Depression Scale Revised (CESD-R-10) questionnaire [6]. Participants who scored equal or greater than 10 points were classified as having depression. Memory problems were determined using the following questionnaire item: “Has a doctor ever told you that you have a memory problem?” Participants were classified as having diabetes if they answered “yes” to “Has a doctor ever told you that you have diabetes, borderline diabetes or that your blood sugar is high”. Those who said yes were then asked if they had Type 1 or Type 2 diabetes.

Eye Disease, Corrective Lenses, Visual Impairment, and Eye Care Utilization

Information on eye disease was obtained by asking “Has a doctor ever told you that you have [glaucoma, cataract, macular degeneration]”. People who said that they had been told they had cataract were then asked if they currently had a cataract. Those who said no were assumed to have had it removed. Participants were asked if they wore contact lenses or glasses. Participants were also asked to rate their visual health using a 5-item Likert scale ranging from “Excellent”, “Very good”, “Good”, “Fair”, to “Poor or Non-existent”. Visual acuity was assessed with both eyes open using the Early Treatment Diabetic Retinopathy Study (ETDRS) letter chart at a 2m distance, while participants wore their currently prescribed glasses or contact lenses for distance correction. [7] Participants who had a visual acuity of ≤ 20/40 were classified as visually impaired, as is standard in North America. [8] Information on eye care utilization was ascertained over the telephone with the question: “During the past 12 months, have you had contact with an ophthalmologist or optometrist about your health”? Previous research indicates that the self-report of eye care use in the previous year has good agreement with eye care use as confirmed in medical records (kappa=0.64). [9]

Number of Ophthalmologists and Optometrists by Province

Data on the number of optometrists per 100,000 people by province were obtained from the Canadian Institute for Health Information. [10] Data on the number of ophthalmologists per province were obtained from the Canadian Medical Association [11] while data on the number of people per province was taken from Statistics Canada .[12] All data are from the year 2013.

Statistical Analysis

The proportion who used eye care by province was plotted on a map using Stata/IC Version 14.2. [13] χ^2 tests of independence were used to determine the relationship between categorical variables and use of eye care. Variables that had a P-value of 0.1 or lower from the chi-square tests were retained for regression analysis to try to ensure that no important variables were missed. Logistic regression was then used for adjustment for the following: age, sex, ethnicity, education, marital status, income, rural residence, province, smoking, diabetes, self-reported eye disease, and visual impairment. [14-16] Only those variables that reached the Bonferroni-adjusted P-value of 0.0015 for the 34 tests in the logistic regression model were considered statistically significant. The complex survey design was accounted for in all analyses by using the primary sampling unit, sample weight, and strata variables within the SVY commands in STATA Version 14.2 (College Station, Texas, USA). Age-standardization of the primary outcome was done by direct age adjustment in which age-stratified rates were applied to a standard population (Alberta).

RESULTS

Of the 30,097 CLSA Comprehensive Cohort participants, a total of 28,728 participants completed the eye care utilization question (95%). The mean ages of those who did and did not answer the question was the same at 60 years and there was no difference by sex ($P>0.05$). However, those with missing data on eye care utilization were more likely to have lower household incomes, were more likely to currently smoke, and were more likely to have visual impairment ($P<0.001$). The annual frequency of eye care utilization among adults aged 45 to 85 years old was 56.9% (95% CI 56.3, 57.6).

The frequency of eye care utilization during a 12-month period significantly varied by province (P<0.001) as shown in Table 1 and Figure 1. The lowest frequency of eye care utilization was seen in the province of Newfoundland and Labrador at 50.4% while the highest was in Ontario at 62.3%. There was almost no difference between the crude and age-standardized rates of eye care utilization (Table 1).

Sociodemographic factors and their relationship with the frequency of eye care utilization are shown in Table 2. Utilization increased with age, ranging from 50.3% in those 45-54 years old to 73.3% in those 75-85 years old. The frequency of eye care utilization was higher in women than in men (P<0.05). Marital status, race/cultural group, education, household income, and urban residence were associated with eye care utilization in the unadjusted analyses (P<0.05).

In Table 3, lifestyle, health, and ocular factors and their relationship to eye care utilization are shown. Individuals who were current smokers, had self-reported Type 1 or Type 2 diabetes, cataracts, glaucoma, macular degeneration, those who wore glasses or contacts, and those with visual impairment were more likely to utilize eye care in a 12- month period in comparison to their counterparts (P<0.001).

In Figure 2A and 2B, the frequency of eye care utilization is plotted by A) the optometrist rate per 100,000 people, and B) the ophthalmologist rate per 100,000 people for each province. There is a positive linear relationship between the frequency of eye care utilization and the optometrist rate per 100,000 people in all the provinces, with the exception of Quebec. There was no relationship between the frequency of eye care utilization and the ophthalmologist rate per 100,000 people as the fitted line was flat.

Figure 3 shows the frequency of eye care utilization by age in the overall group and also in high-risk groups (diabetes and glaucoma). There is a positive linear trend between age and the eye care utilization rate in all groups. Eye care utilization in glaucoma participants ranged from 74.9% in the youngest group to 87.4% in the older group and in diabetic participants ranged from 64.1% of the youngest group to 76.6% of the oldest group.

In Table 4, sociodemographic, lifestyle, health, and ocular variables are included together in a logistic regression model. After adjusting for one another, being male (OR= 0.67, 95% CI 0.63-0.71) and having less than a Bachelor's degree (OR=0.85, 95% CI 0.77-0.92) were associated with a lower odds of utilizing eye care while older adults were more likely to use eye care (OR=1.02, 95% CI 1.02-1.03). Of the lifestyle and health variables, current smokers were less likely to use eye care (OR=0.74, 95% CI 0.66-0.84). People with both Type 1 (OR=4.50, 95% CI 2.51-8.08) and Type 2 diabetes (OR=2.01, 95% CI 1.64-2.10) were more likely to use eye care. Self-reported eye diseases like cataract, glaucoma, and macular degeneration were also associated with an increased odds of eye care utilization ($P<0.05$) while visual impairment was only associated in a borderline fashion taking into account the multiple comparisons (OR=1.18, 95% CI 1.02-1.35) ($P=0.024$).

DISCUSSION

Our study updates and extends the existing research on eye care utilization patterns in Canada. We found that 57% of Canadians aged 45-85 years utilized an eye care provider in a 12-month period. However, there was large provincial variability with a low of 50% of people in Newfoundland and Labrador and a high of 62% of people in Ontario having seen an eye care provider in the last 12 months. Furthermore, men, people with less education, with lower household income, and current smokers were less likely to use eye care. Of concern, over 16% of people aged 60 and older with glaucoma and 25% of people aged 60 and older with diabetes had not seen an eye care provider in the last year.

Reasons for the inter-provincial variability in eye care utilization are unclear although differences in provincial coverage of eye exams and access to optometrists may explain part of the heterogeneity. Consistent with our results, prior research from 2005 by Jin *et al* also found that Newfoundland and Labrador had the lowest proportion of people using eye care of all of the provinces. [4] Newfoundland and Labrador is one of the few Canadian provinces to not cover the cost of a routine eye exam for adults aged 65 and older so it is possible that this increased cost to the individual may deter some people from accessing eye care. Indeed, prior research found that provinces that did not cover the cost of eye exams had lower self-reported rates of cataract and glaucoma while they had higher rates of self-reported vision loss. [17] In addition, we found that provinces with a lower rate of optometrists per 100,000 people had less eye care utilization although Quebec did not fit this trend. Instead, Quebec had a high rate of optometrists but a relatively low proportion of people using eye care, which is consistent with prior research by Jin *et al.* [4]

We report a novel association in that current smokers were less likely to access eye care. We are not aware of previous reports of such an association in the general population, although one paper has reported that current smokers were less likely to use eye care in a population with diabetes. [18] This association was significant despite adjusting for educational differences between current and never smokers. Current smokers may have a more resistant attitude towards preventive health measures .[19] Current smokers are at a greater risk of eye diseases like cataract and age-related macular degeneration. [20,21] We identified a number of other factors associated with eye care utilization as well. Lower education, male sex, and lower household income were also related to less eye care use. Previous research has also identified these factors. [4,14,22-26] Those with lower education may be unaware of the need for routine eye examinations with increasing age. A study done in British Columbia examined public awareness of risk factors for eye disease and found that people had insufficient knowledge about eye disease and its associated risk factors.[27] Researchers in Australia have experimented with a public health campaign to increase awareness and found preliminary evidence that it helped.[28] Furthermore, provincial health care coverage of more eye care costs may lessen the financial burden of receiving routine eye care and may remove the income disparity.

People with diabetes and glaucoma were more likely to see eye care providers than people without these conditions. However, of great concern is that 1 out of 4 adults with diabetes over age 60 years did not see an eye care provider in the last year. Annual visits for diabetic patients of this age are recommended every year. [3] Prior research has also reported sub-optimal eye care in people with diabetes, and therefore, the development of educational programs for this group should be considered [18,29-31].

A strength of this analysis was the use of a very large, population-based dataset including people from 7 provinces of Canada. A limit of this analysis is that information on eye care utilization was obtained by self-report which may have resulted in some misclassification of our primary outcome. Furthermore, 4.5% were missing data on eye care utilization. They were similar in age and sex but were more likely to have lower incomes, to smoke, and to have visual impairment than those who had data on eye care utilization. Another limitation is that these data are cross-sectional so we cannot establish the temporal relationship of the risk factors and the use of eye care. In addition, the CLSA Comprehensive Cohort sample was recruited from within 25-

50km of the 11 urban data collection sites in 7 provinces. Therefore, generalizability of our results to other parts of Canada and to groups other than those studied is unknown.

The results of the current study provide up-to-date information on the frequency and determinants of eye care utilization in Canada and have highlighted the variability of eye care use across the country. Furthermore, our results have also for the first time indicated that current smokers are less likely to obtain eye care. Policy makers should consider ways to make eye care more affordable. Future research should examine the effectiveness of public health campaigns to improve eye care use, particularly in high risk groups.

ACKNOWLEDGEMENT

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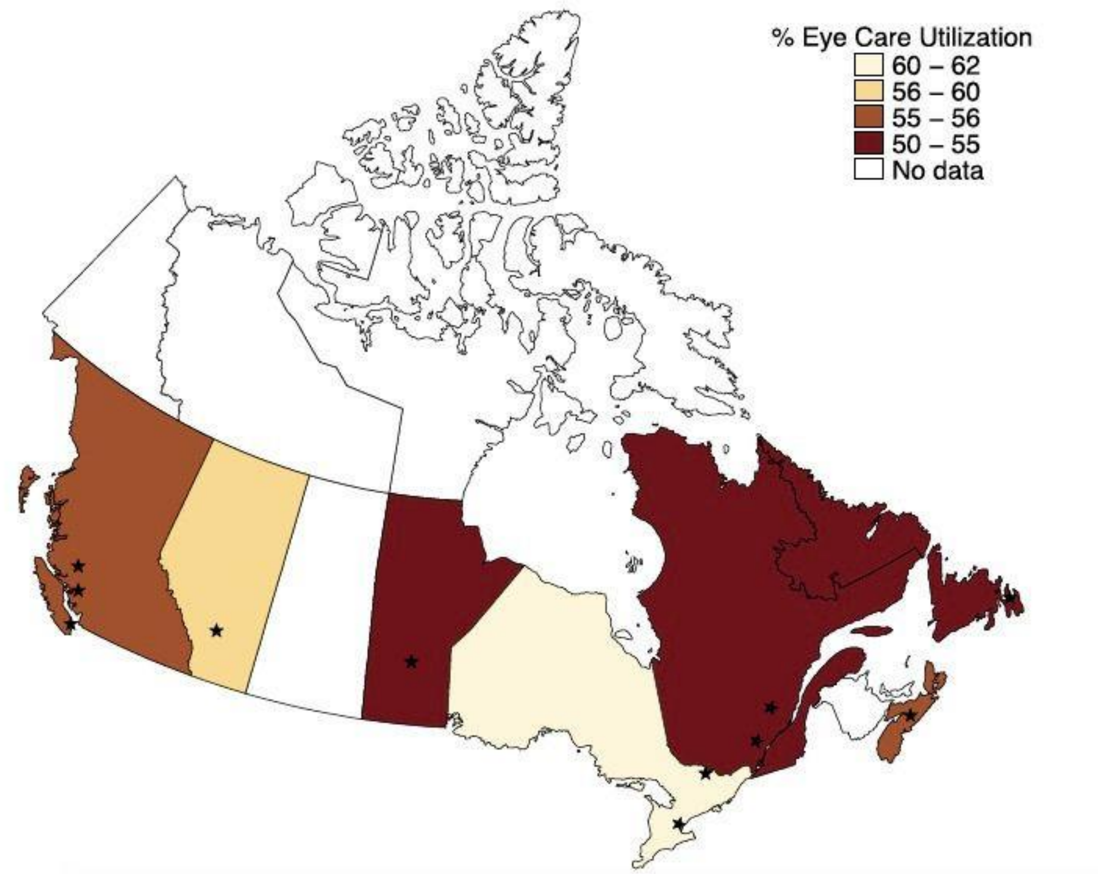
Manuscript 2- Table 1: Crude and age-standardized proportions of people who utilized eye care in the last year by province

Province	**Crude Eye Care Utilization % (95% CI)**	**Age-Standardized Eye Care Utilization %**
Alberta (n=2,860)	60.2 (57.9-62.5)	61.6
British Columbia (n=5,971)	56.1 (54.6-57.5)	55.7
Manitoba (n=2,968)	54.7 (52.6-56.7)	54.1
Newfoundland & Labrador (n=2,047)	50.4 (47.9-52.8)	50.2
Nova Scotia (n=2,909)	56.3 (54.2-58.3)	56.2
Ontario (n=6,122)	62.3 (60.9-63.7)	61.6
Quebec (n=5,851)	54.4 (52.9-55.8)	53.8
Canada (n=28,728)	56.9 (56.3-57.6)	57.2

P<0.001 for inter-provincial differences

Manuscript 2- Figure 1: Map of Canada showing frequency (%) of yearly eye care utilization.

The use of eye care in the last year varied by province. The starts indicate the locations of the 11 data collection sites. The frequencies of eye care utilization may be generalizable only to the areas 25-50 km from each data collection site.



Manuscript 2- Table 2: Demographic characteristics of participants by eye care utilization

	Eye Care Utilization, % n=28,728	χ^2 P-Value
Age Group, Years		
45-54 (n=7,214)	50.3	<0.001
55-64 (n=9,476)	54.3	
65-74 (n=7,084)	67.2	
75-85 (n= 4,954)	73.3	
Sex		
Female (n=14,617)	61.1	<0.001
Male (n=14,111)	52.6	
Marital Status*		
Married (n=19,860)	56.8	<0.001
Single (n=2,512)	51.4	
Divorced/Separated (n=3,722)	55.7	
Widowed (n=2,626)	68.1	
Race/Cultural Group		
White (n= 27,126)	57.1	0.019
Black (n=238)	52.0	
Asian (East, South, SE) (n=629)	58.9	
Arab and West Asian (n=133)	42.3	
Latin American (n=114)	54.4	
Aboriginal (n=335)	52.5	
Other (n=153)	54.6	
Education*		
More than Bachelor's (n=6,282)	59.5	<0.001
Bachelor's Degree (n=6,842)	58.7	
Less than Bachelor's (n=15,553)	55.3	
Household Income Per Year		
>=$100,000 (n=9,986)	56.9	0.028
$50,000 - $100,000 (n= 9,538)	57.4	
$20,000 - $50,000 (n=5,974)	55.7	
<$20,000 (n=1,401)	54.1	
Refused/Don't Know (n=1,829)	59.9	
Language Spoken at Home*		
English or French (n=27,024)	57.0	0.274
Other (n= 1,675)	55.5	
Residence*		

Urban, Semi-urban (n=26,055) Rural (n=2,316)	57.2 54.0	0.008

*n missing: marital status (n=8), education (n=51), language (n=29), residence (n=357)

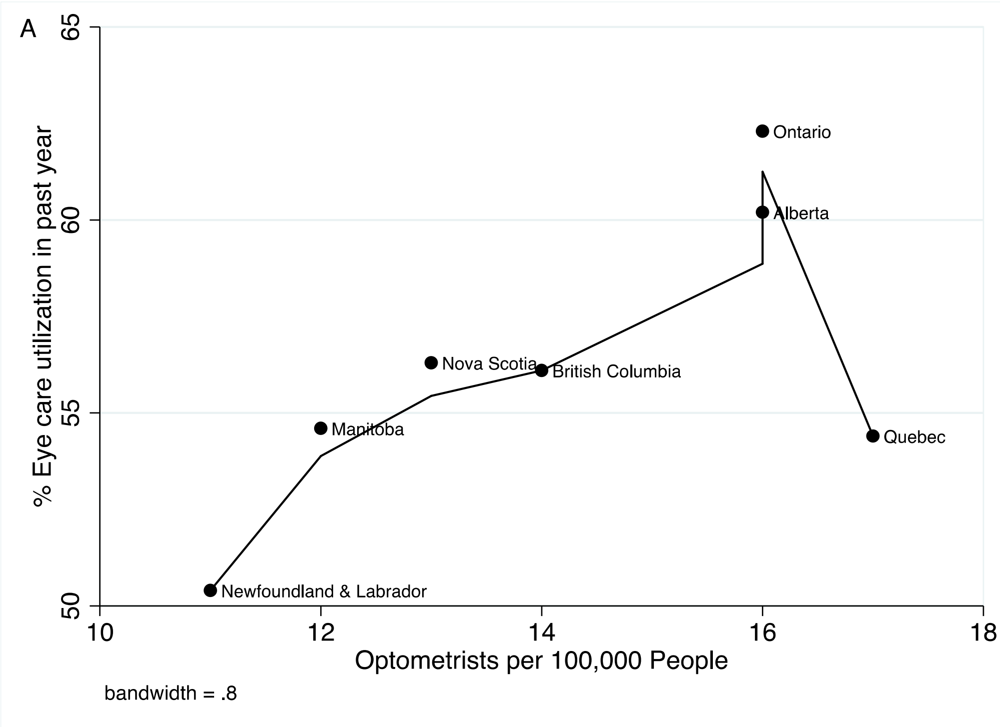
Manuscript 2- Table 3: Health/visual disease characteristics of participants by eye care utilization

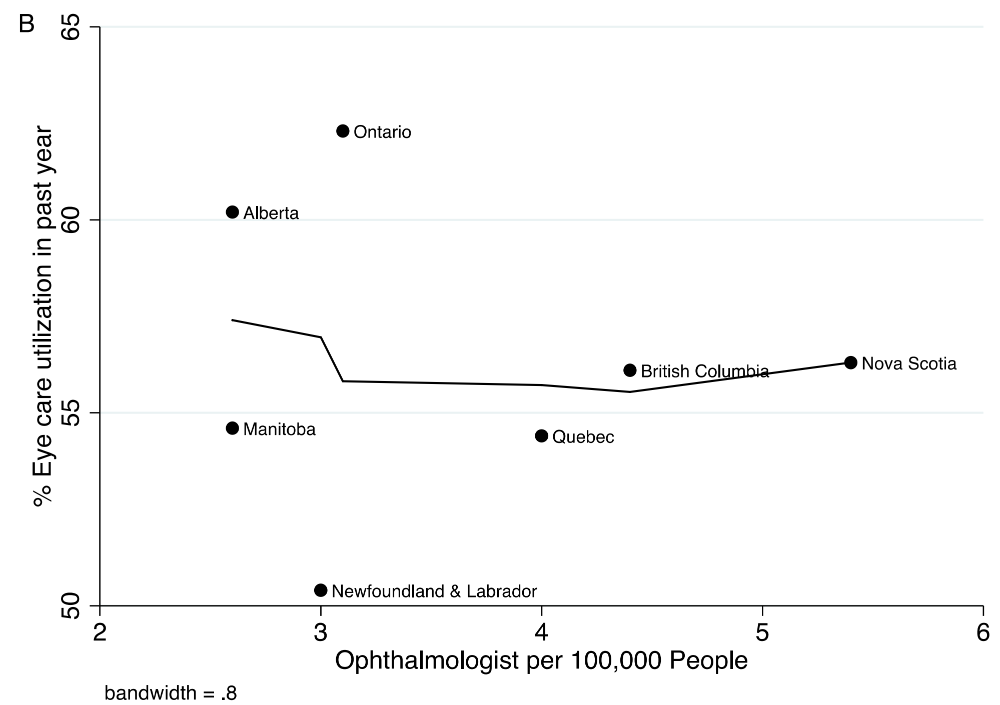
	Eye Care Utilization, % n=28,728	χ^2 P-Value
Smoking*		
Never (n=13,666)	57.7	<0.001
Former (n= 12,606)	58.4	
Current (n=2,357)	45.7	
Diabetes*		
None (n=23,618)	55.5	<0.001
Type 1 (n=157)	82.3	
Type 2 (n= 2,612)	70.6	
Suspect/Neither Type (n=2,019)	56.9	
Depression*		
Yes (n=4,375)	56.1	0.324
No (n=23,966)	57.0	
Memory Problems*		
Yes (n=471)	60.7	0.155
No (n=28,171)	56.9	
Cataracts*		
None (n=19,957)	52.0	<0.001
Past Cataract (removed) (n=1,867)	70.5	
Current Cataract (n=1,904)	77.1	
Glaucoma*		
Yes (n=1,453)	82.4	<0.001
No (n=27,135)	55.9	
Macular degeneration*		
Yes (n=1,206)	78.2	<0.001
No (n=16,010)	56.2	
Wears glasses or contacts*		
Yes (n= 25,273)	59.5	<0.001
No (n=3,453)	41.0	
Self-rated visual health		<0.001
Excellent (n=6,577)	55.3	
Very good (n=11,257)	55.9	
Good (n=8,735)	57.9	

Fair (n=1,827)	62.9	
Poor or non-existent (n=317)	72.1	
Visual impairment*		
Yes (n=2,037)	66.6	<0.001
No (n=26,300)	56.3	

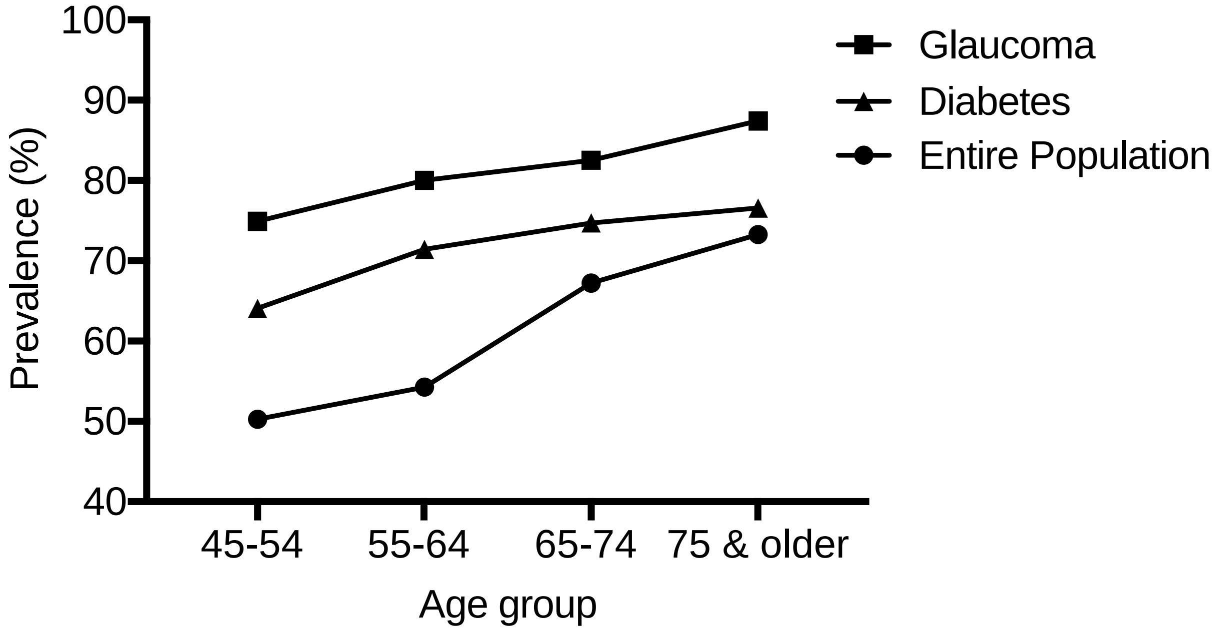
*n missing: smoking (n=99), diabetes (n=322), depression (n=387), memory problems (n=86), cataracts (n=5,000), glaucoma (n=140), macular degeneration (n=194), wears glasses or contacts (n=2), Self-rated visual health (n=15), visual impairment (n=391)

Manuscript 2- Figure 2: Lowess smoothed lines showing the provincial frequency of eye care utilization in past year by A) optometrists per 100,000 people or B) ophthalmologists per 100,000 people





Manuscript 2- Figure 3: Frequency of eye care utilization in past year by age group for the entire population and for the high-risk status groups of glaucoma and diabetes



Manuscript 2- Table 4: Factors associated with eye care utilization in a multiple logistic regression model.

	Eye Care utilization n= 22,649 Odds Ratio	**95% CI**
Age, Per Year	1.02	1.01-1.02
Male Sex	0.68	0.63-0.71
Marital Status		
Married	1.00	
Single	0.97	0.86-1.09
Divorced/Separated	1.01	0.91-1.11
Widowed	1.07	0.94-1.23
Race/Cultural Group		
White	1.00	
Black	0.85	0.60-1.18
Asian (East, South, SE)	1.01	0.81-1.25
Arab and West Asian	0.70	0.45-1.08
Latin American	1.08	0.67-1.75
Aboriginal	0.88	0.67-1.15
Other	0.77	0.49-1.20
Education		
More than Bachelor's	1.00	
Bachelor's Degree	1.02	0.94-1.12
Less than Bachelor's	0.85	0.77-0.92
Household Income Per Year		
>=$100,000	1.00	
$50,000 - $100,000	0.84	0.78-0.92
$20,000 - $50,000	0.64	0.57-0.71
<$20,000	0.65	0.55-0.78
Refused/Don't Know	0.81	0.70-0.93
Rural vs Non-Rural	0.91	0.81-1.02
Province		
Alberta	1.00	
British Colombia	0.76	0.67-0.87
Manitoba	0.72	0.62-0.83
Newfound & Labrador	0.61	0.53-0.72
Nova Scotia	0.78	0.67-0.90
Ontario	0.99	0.87-1.12
Quebec	0.83	0.73-0.94

Smoking Never Former Current	 1.00 0.97 0.74	 0.91-1.04 0.66-0.84
Diabetes None Type 1 Type 2 Suspect/Neither Type	 1.00 4.50 1.86 0.98	 2.51-8.08 1.64-2.10 0.88-1.12
Glaucoma	2.55	2.07-3.14
Cataract None Past Cataract (removed) Current Cataract	 1.00 1.43 2.35	 1.25-1.63 2.05-2.69
Macular degeneration	1.61	1.32-1.98
Visual Impairment No Yes	 1.00 1.18	 1.02-1.35
Glasses or contact lens No Yes	 1.00 1.81	 1.64 -1.98

*Adjusted for all variables in table and complex study design.

References:

1. Cruess AF, Gordon KD, Bellan L, Mitchell S, Pezzullo ML. The cost of vision loss in Canada. 2. Results. *Can J Ophthalmol.* 2011;46(4):315-318.
2. Vitale S, Cotch MF, Sperduto RD. Prevalence of visual impairment in the United States. *JAMA.* 2006;295(18):2158-2163.
3. Canadian Ophthalmological Society evidence-based clinical practice guidelines for the periodic eye examination in adults in Canada. *Can J Ophthalmol.* 2007;42:39-45.
4. Jin YP, Trope GE. Eye care utilization in Canada: disparity in the publicly funded health care system. *Can J Ophthalmol.* 2011;46(2):133-138.
5. Raina PS, Wolfson C, Kirkland SA, et al. The Canadian longitudinal study on aging (CLSA). *Can J Aging.* 2009;28(3):221-229.
6. Andresen EM, Malmgren JA, Carter WB, Patrick DL. Screening for depression in well older adults: evaluation of a short form of the CES-D (Center for Epidemiologic Studies Depression Scale). *Am J Prev Med.* 1994;10(2):77-84.
7. Lovie-Kitchin JE. Validity and reliability of visual acuity measurements. *Ophthalmic Physiol Opt.* 1988;8(4):363-370.
8. Ko F, Vitale S, Chou CF, Cotch MF, Saaddine J, Friedman DS. Prevalence of nonrefractive visual impairment in US adults and associated risk factors, 1999-2002 and 2005-2008. *JAMA.* 2012;308(22):2361-2368.
9. MacLennan PA, McGwin G, Jr., Searcey K, Owsley C. Medical record validation of self-reported eye diseases and eye care utilization among older adults. *Curr Eye Res.* 2013;38(1):1-8.
10. Canadian Institute for Health Information, Canada's Health Care Providers: Provincial Profiles, 2013 Data Tables. https://www.cihi.ca/en/spending-and-health-workforce/canadas-health-care-providers-provincial-profiles-2013-data-tables. Accessed August 30, 2017.
11. Canadian Medical Association, Number of Physicians by Province/Territory and Specialty, Canada, 2013. https://www.cma.ca/Assets/assets-library/document/en/advocacy/policy-research/physician-historical-data/2013-01-spec-prov.pdf. Accessed August 30, 2017.
12. Statistics Canada, Population by year, by province and territory. http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/demo02a-eng.htm. Accessed August 30, 2017.
13. Stepnor M. Maptile. https://michaelstepner.com/maptile/. Accessed August 30, 2017.
14. Orr P, Barron Y, Schein OD, Rubin GS, West SK. Eye care utilization by older Americans: the SEE Project. Salisbury Eye Evaluation. *Ophthalmology.* 1999;106(5):904-909.
15. Vela C, Samson E, Zunzunegui MV, Haddad S, Aubin MJ, Freeman EE. Eye care utilization by older adults in low, middle, and high income countries. *BMC Ophthalmol.* 2012;12:5.
16. Schaumberg DA, Christen WG, Glynn RJ, Buring JE. Demographic predictors of eye care utilization among women. *Med Care.* 2000;38(6):638-646.
17. Chan CH, Trope GE, Badley EM, Buys YM, Jin YP. 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(12):8544-8549.

18. Murchison A, Hark L, Pizzi L, et al. Non-adherence to eye care in people with diabetes. *BMJ Open Journal Res Care.* 2017;5:e000333.
19. Dryden R, Williams B, McCowan C, Themessl-Huber M. What do we know about who does and does not attend general health checks? Findings from a narrative scoping review. *BMC Public Health.* 2012;12:723.
20. Ye J, He J, Wang C, et al. Smoking and risk of age-related cataract: a meta-analysis. *Invest Ophthalmol Vis Sci.* 2012;53(7):3885-3895.
21. Cong R, Zhou B, Sun Q, Gu H, Tang N, Wang B. Smoking and the risk of age-related macular degeneration: a meta-analysis. *Ann Epidemiol.* 2008;18(8):647-656.
22. Vela C, Samson E, Zunzunegui M, Haddad S, Aubin M, Freeman E. Eye Care Utilization in Older Adults in Low, Middle, and High Income Countries. *BMC Ophthalmology.* 2012;12(5).
23. Morales LS, Varma R, Paz SH, et al. Self-reported use of eye care among Latinos: the Los Angeles Latino Eye Study. *Ophthalmology.* 2010;117(2):207-215 e201.
24. Keeffe JE, Weih LM, McCarty CA, Taylor HR. Utilisation of eye care services by urban and rural Australians. *Br J Ophthalmol.* 2002;86(1):24-27.
25. Zhang X, Beckles GL, Chou CF, et al. Socioeconomic disparity in use of eye care services among US adults with age-related eye diseases: National Health Interview Survey, 2002 and 2008. *JAMA Ophthalmol.* 2013;131(9):1198-1206.
26. Wagner LD, Rein DB. Attributes associated with eye care use in the United States: a meta-analysis. *Ophthalmology.* 2013;120(7):1497-1501.
27. Noertjojo K, Maberley D, Bassett K, Courtright P. Awareness of eye diseases and risk factors: identifying needs for health education and promotion in Canada. *Can J Ophthalmol.* 2006;41(5):617-623.
28. Muller A, Keeffe JE, Taylor HR. Changes in eye care utilization following an eye health promotion campaign. *Clin Exp Ophthalmol.* 2007;35(4):305-309.
29. Keenum Z, McGwin G, Jr., Witherspoon CD, Haller JA, Clark ME, Owsley C. Patients' Adherence to Recommended Follow-up Eye Care After Diabetic Retinopathy Screening in a Publicly Funded County Clinic and Factors Associated With Follow-up Eye Care Use. *JAMA Ophthalmol.* 2016;134(11):1221-1228.
30. Fathy C, Patel S, Sternberg P, Jr., Kohanim S. Disparities in Adherence to Screening Guidelines for Diabetic Retinopathy in the United States: A Comprehensive Review and Guide for Future Directions. *Semin Ophthalmol.* 2016;31(4):364-377.
31. McCarty CA, Lloyd-Smith CW, Lee SE, Livingston PM, Stanislavsky YL, Taylor HR. Use of eye care services by people with diabetes: the Melbourne Visual Impairment Project. *Br J Ophthalmol.* 1998;82(4):410-414.

CHAPTER SIX: DISCUSSION

To estimate the prevalence of visual impairment and eye care utilization among people aged 45 to 85 years in Canada and their associations with geographic, socio-demographic, health and lifestyle characteristics, this work sought to answer four objectives. This discussion section includes our findings for the four objectives, comparison of results to previous literature, strength and limitations, implications and significance of our work and future research.

Findings for the Research Objectives

Objective 1. Determine the prevalence of visual impairment (binocular visual acuity worse than 20/40) in Canada.

Prevalence estimates for visual impairment, defined as presenting binocular acuity worse than 20/40 (0.301 logMAR), ranged from a low of 2.7% to a high of 10.9% across the seven included provinces, with an overall prevalence of 5.7%. The age-standardized prevalence of visual impairment was 6%. This equates to an estimate of approximately 662,281 people with binocular visual impairment (referencing population Canada statistics from 2011 census) in those 45-85 years old in the 7 included provinces in the CLSA.

Objective 2. Determine factors associated with visual impairment including geographic (e.g., province), sociodemographic (e.g., age, sex, education, income, ethnicity, etc.), health (e.g., comorbid conditions), and lifestyle factors (e.g., smoking).

Factors associated with a higher odds of visual impairment included older age (OR = 1.07, 95% CI 1.06–1.08), lower income (OR = 2.07 for those earning less than $20 000 per year, 95% CI 1.65–2.59), current smoking (OR = 1.52, 95% CI 1.25–1.85), type 2 diabetes (OR = 1.20, 95% CI 1.03–1.41), and memory problems (OR = 1.44, 95% CI 1.04–2.01).

Objective 3. Determine the prevalence of eye care utilization in the last 12 months.

Eye care utilization in the 12 months before CLSA data collection was 56.9% in individuals aged 45-85 years old, across all 7 Canadian provinces. Eye care utilization ranged from a low of 50.4% in Newfoundland and Labrador to a high of 62.3% in Ontario.

Objective 4. Determine factors associated with eye care utilization including geographic (e.g., province), sociodemographic (e.g., age, sex, education, income, ethnicity, etc.), health (e.g., comorbid conditions), and lifestyle factors (e.g., smoking).

Men compared to women, people with less than a bachelor's degree compared to more than a bachelor's degree, people making less income (linear trend $p < 0.05$) and current smokers compared to never smokers were less likely to use eye care in the last 12 months. Also, people with diabetes glaucoma, cataracts, and macular degeneration were more likely to see eye care providers than people without these conditions.

Comparison with Other Findings

Prevalence of Visual Impairment and Associated Factors:

While this is the first population-based study to report the prevalence of measured visual impairment across different provinces in Canada, it's important to compare our results to prior studies. Our prevalence estimate (5.7%) is comparable to recent population-based studies using NHANES data in the United States (6.4%).[40,75] In comparison to the available Canadian data, our Ontario prevalence of 3.7% is consistent with the study conducted in the city of Brantford, Ontario in individuals aged 40 years and over, which reported a binocular visual impairment prevalence of 2.7%.[48] Similarly, our Quebec prevalence of 3.2% was also comparable to the CCHS study done including several Quebec sites, which found a self-reported prevalence of visual impairment of 4.4%. [46]

As in previous studies, [49–51] we were able to confirm associations between older age, lower income, current smoking, type 2 diabetes,[32,54] and memory problems[76] with visual impairment. Factors like smoking and diabetes may be modifiable. For example, some studies have reported that over 70% of cases of vision loss in individuals with diabetes could be prevented if detected early, and incidence of visual impairment is much lower in diabetic patients who undergo screening.[32,77] As such, education programs targeting high-risk participants can potentially be effective in the prevention of vision loss in individuals with diabetes. Analogously, education programs for current smokers can advise them on the potential ramifications of smoking to their visual health.

Eye Care Utilization and its Determinants:

The second manuscript in this thesis provided up-to-date estimates of annual eye care utilization in 7 Canadian provinces in adults ages 45-85 years old. Similar to the 2005 results from Jin et al., [61] we found that eye care utilization disparities still exist; this is problematic especially in high-risk groups (e.g., adults with diabetes over age 60 years) who are recommended to utilize eye care annually to prevent avoidable vision loss.

We assessed some of the factors that affect eye care utilization according to the Anderson framework (predisposing, enabling and need factors). Consistent with previous work, predisposing factors such as older age and education were associated with annual eye care utilization.[61] Enabling factors such as community resources (e.g., availability of eye care providers), and personal resources (e.g., income) were also found to be associated with annual eye care utilization. Our results showed a positive linear relationship between the frequency of eye care utilization and the optometrist rate per 100 000 people in most provinces, suggesting the availability of optometrists is associated with eye care utilization. As reported in some studies,[54,63,64] we were also able to confirm an association between the enabling factor of household income and eye care utilization. Affordability has been previously cited as a barrier to eye care utilization because often people with low income are unable to afford the cost of eye care services and eyewear.[54,63,64] Need factors, such as eye disease, were also associated with eye care utilization such that individuals who self-reported AMD, glaucoma, or cataracts had higher odds of annually utilizing eye care services.

A novel association that does not fall under the umbrella of the Anderson framework is smoking status. We found that current smokers were less likely to utilize eye care services. While some studies have shown smoking to be a key risk factor for visual impairment[53,78], our study suggests smokers do not utilize eye care services as per their need. We can only speculate on reasons for this, but as suggested previously, more public awareness of the consequential effects of smoking to vision may be a potential preventive strategy.

Strengths and Limitations

The large size of our study enabled us to precisely estimate the prevalence of visual impairment, the frequency of eye care utilization and to determine a number of associated factors with good statistical power. The results of this work, however, must be interpreted with several limitations in mind. First, the data are cross-sectional meaning that we only get a snapshot, and its difficult to make causal inference; we cannot assert the temporality of the associated factors and the outcomes as one could do in a longitudinal study.

Another key limitation is that the generalizability of the CLSA Comprehensive cohort estimates to the Canadian population at large has not been determined. As such, our results might not be representative of non-participating provinces and territories. Non-response bias is also a limitation that may have resulted in an unrepresentative sample. Non-responders were older, and as visual impairment increases with age, they may be at higher risk of our primary outcome (visual impairment). However, when we used an imputation method to examine the impact of missing data on our primary outcome (visual impairment), we found no difference between the crude visual impairment prevalence and the imputed prevalence estimate, suggesting that our small percentage of missing data (in large part due to non-response) did not bias our results.

Another limitation is that some of our data were collected by self-report possibly making these data susceptible to measurement bias. Self-report data are limited by the nature of recall and reporting error. For example, social desirability response bias can affect the validity of the health care utilization questionnaire. If individuals perceived it to be more socially acceptable to have utilized eye care services, then they would have responded accordingly and our estimates may have overestimated the annual frequency of eye care utilization. However, the validity of self-reported health care utilization has been previously studied, and there is a moderate agreement ($\kappa = 0.64$) between self-report of eye care utilization and medical records. [58,59]

Significance and Implications

This was the first population-based prevalence study of measured visual impairment across several different provinces in Canada. Furthermore, this work adds additional evidence to previous studies on the factors associated with visual impairment. We were also able to provide up-to-date data on eye care utilization, confirming as well as highlighting novel associations with eye care utilization.

Given the importance and consequences of visual impairment among older people, there are several important implications of this work. Our work suggests there may be a need for more provincial eye care coverage across the board but especially in provinces like Newfoundland and Labrador where the prevalence of visual impairment is high, and eye care service utilization is low. Eye care coverage, especially for individuals with low income may increase eye care utilization and in turn prevent avoidable vision loss. There is also a need for more public awareness/vision education programs, especially geared toward high-risk groups. Of key concern in our findings is that 1 out of 4 adults with diabetes over age 60 years, and over 16% of people aged 60 and older with glaucoma did not see an eye care provider in the last year. These results suggest that many high-risk Canadians do not adhere to the COS recommendations to visit eye care professionals annually. We suspect the lack of annual eye care utilization in high-risk groups may be due to cost considerations or a lack of awareness of the consequences.

Future Research

Moving forward there are several unresolved issues that should be investigated. Firstly, the CLSA did not collect data from the three territories or from people who identify as First Nation who live on reserves. First Nation people in Canada face unique health challenges, and it's important to identify these challenges in order to provide timely interventions.[79] There currently is no measured visual impairment estimates for this group. The self-reported prevalence for blindness or a serious vision problem in First Nation adults in 2015-2016 was 3.4%, as reported by the First Nations Information Governance Centre (FNIGC).[79] But due to the limitation of self-report data, these results may be unreliable and do not provide us with a valid estimate of the burden of visual impairment in that group, especially those who live in the Far North.

Secondly, our study was cross-sectional, and as such, we were unable to determine causation or consequences of visual impairment. The CLSA is a longitudinal study that in the upcoming years can be utilized to examine not only the prevalence of visual impairment over time but also the incidence so we can see how the risk of visual impairment is changing. We will also have the opportunity to examine how any health policy changes at the provincial level relate to changes in vision and eye care.

Future research is also needed to investigate the effectiveness of interventional trials aiming to improve ocular health either through preventive measures (e.g., dietary and lifestyle modifications) or increasing eye care utilization in high-risk groups (e.g., educational intervention trials in individuals with diabetes).

Conclusion

This thesis suggests that the prevalence of visual impairment is 6% and that 57% of the Canadian population annually utilize eye care. Taken together, these prevalence estimates provide more valid and up-to-date evidence for eye care professionals, health policy planners, and low vision rehabilitation providers to more adequately prepare for the needs of the aging population and identify groups in need of intervention in Canada.

REFERENCES

1. Cruess AF, Gordon KD, Bellan L, Mitchell S, Pezzullo ML. The cost of vision loss in Canada. 2. Results. Canadian Journal of Ophthalmology. 2011 Aug 1;46(4):315-8.

2. Ivers RQ, Cumming RG, Mitchell P, Attebo K. Visual impairment and falls in older adults: the Blue Mountains Eye Study. Journal of the American Geriatrics Society. 1998 Jan 1;46(1):58-64.

3. Crews JE, Campbell VA. Vision impairment and hearing loss among community-dwelling older Americans: implications for health and functioning. American Journal of Public Health. 2004 May;94(5):823-9.

4. Hong T, Mitchell P, Burlutsky G, Gopinath B, Liew G, Wang JJ. Visual impairment and depressive symptoms in an older Australian cohort: longitudinal findings from the Blue Mountains Eye Study. British Journal of Ophthalmology. 2015 Mar 11:bjophthalmol-2014.

5. Corbett JJ, Chen J. Chapter 20 - The Visual System. In: Haines DE, Mihailoff GA, editors. Fundamental Neuroscience for Basic and Clinical Applications (Fifth Edition). Elsevier; 2018 [cited 2018 Jan 9]. p. 286–305.e1. Available from: https://www.sciencedirect.com/science/article/pii/B9780323396325000207

6. Kniestedt C, Stamper RL. Visual acuity and its measurement. Ophthalmology Clinics of North America. 2003 Jun;16(2):155-70.

7. Rosser DA, Cousens SN, Murdoch IE, Fitzke FW, Laidlaw DA. How sensitive to clinical change are ETDRS logMAR visual acuity measurements? Investigative Ophthalmology & Visual Science;44(8):3278–3281.

8. Colenbrander A. The historical evolution of visual acuity measurement. Visual Impairment Research. 2008 Jan 1;10(2-3):57-66.

9. Eperjesi F, Rundström MM. Chapter 2 - Measurement of visual acuity. In: Practical Binocular Vision Assessment [Internet]. London: Butterworth-Heinemann; 2004 [cited 2018 Jan 12]. p. 5–19. Available from: https://www.sciencedirect.com/science/article/pii/B9780750650106500067

10. Bailey IL, Lovie-Kitchin JE. Visual acuity testing. From the laboratory to the clinic. Vision Research. 2013 Sep 20;90:2–9.

11. Rubin GS. Chapter 11 - Visual Acuity and Contrast Sensitivity. In: Ryan SJ, Sadda SR, Hinton DR, Schachat AP, Sadda SR, Wilkinson CP, et al., editors. Retina (Fifth Edition) [Internet]. London: W.B. Saunders; 2013 [cited 2017 Dec 17]. p. 300–6. Available from: https://www.sciencedirect.com/science/article/pii/B9781455707379000114

12. Bailey IL, Lovie JE. New design principles for visual acuity letter charts. American Journal of Optometry and Physiological Optics. 1976 Nov;53(11):740-5.

13. Falkenstein IA, Cochran DE, Azen SP, Dustin L, Tammewar AM, Kozak I, Freeman WR. Comparison of visual acuity in macular degeneration patients measured with snellen and early treatment diabetic retinopathy study charts. Ophthalmology. 2008 Feb 1;115(2):319-23.

14. Kaiser PK. Prospective evaluation of visual acuity assessment: a comparison of snellen versus ETDRS charts in clinical practice (An AOS Thesis). Transactions of the American Ophthalmological Society. 2009 Dec;107:311.

15. Rubin GS, Munoz B, Bandeen–Roche K, West SK. Monocular versus binocular visual acuity as measures of vision impairment and predictors of visual disability. Investigative Ophthalmology & Visual Science. 2000 Oct 1;41(11):3327-34.

16. Cagenello R, Halpern DL, Arditi A. Binocular enhancement of visual acuity. JOSA A. 1993;10(8):1841–1848.

17. Azen SP, Varma R, Preston-Martin S, Ying-Lai M, Globe D, Hahn S. Binocular Visual Acuity Summation and Inhibition in an Ocular Epidemiological Study: The Los Angeles Latino Eye Study. Investigative Ophthalmology Visual Science. 2002 Jun 1;43(6):1742–8.

18. Riggs, L. A. (1965). Visual acuity. In Vision and visual perception (pp. 321–349). New York: Wiley

19. ICD-10 Version:2016 [Internet]. [cited 2018 Jan 28]. Available from: http://apps.who.int/classifications/icd10/browse/2016/en#/H54

20. Maberley DA, Hollands H, Chuo J, Tam G, Konkal J, Roesch M, Veselinovic A, Witzigmann M, Bassett K. The prevalence of low vision and blindness in Canada. Eye. 2006 Mar;20(3):341.

21. Resnikoff S, Pascolini D, Mariotti SP, Pokharel GP. Global magnitude of visual impairment caused by uncorrected refractive errors in 2004. Bull World Health Organ. 2008;86(1):63–70.

22. Cheng D, Schmid KL, Woo GC. Myopia prevalence in Chinese-Canadian children in an optometric practice. Optomery and Vision Science. 2007 Jan 1;84(1):21–32.

23. Dandona R, Dandona L. Refractive error blindness. Bull World Health Organ. 2001;79:237–243.

24. Loewenstein JI, Lee S. Ophthalmology: Just the facts. McGraw-Hill; 2004.

25. Voleti VB, Hubschman J-P. Age-related eye disease. Maturitas. 2013;75(1):29–33.

26. Taylor HR, Pezzullo ML, Nesbitt SJ, Keeffe JE. Costs of interventions for visual impairment. American Journal of Ophthalmology. 2007;143(4):561–565.

27. Challa P. Glaucoma genetics. International Ophthalmology Clinics. 2008;48(4):73.

28. McPhee SJ, Papadakis MA, Rabow MW. Current medical diagnosis & treatment 2010. McGraw-Hill Medical New York:; 2010.

29. Seddon JM, Silver RE, Rosner B. Response to AREDS supplements according to genetic factors: survival analysis approach using the eye as the unit of analysis. British Journal of Ophthalmology. 2016 Dec;100(12):1731–7.

30. Chong EW, Kreis AJ, Wong TY, Simpson JA, Guymer RH. Dietary ω-3 fatty acid and fish intake in the primary prevention of age-related macular degeneration: a systematic review and meta-analysis. Archives of Ophthalmology. 2008 Jun 9;126(6):826-33.

31. Hassan SSA, Bong DB, Premsenthil M. Detection of neovascularization in diabetic retinopathy. Journal of Digital Imaging. 2012;25(3):437–444.

32. Perlstein R. Diabetes and visual impairment. British Journal of Visual Impairment. 1990;8(2):54–56.

33. Mohamed QA, Ross A, Chu CJ. Diabetic retinopathy (treatment). BMJ Clinical Evidence. 2011;2011.

34. Bourne RR, Jonas JB, Flaxman SR, Keeffe J, Leasher J, Naidoo K, Parodi MB, Pesudovs K, Price H, White RA, Wong TY. Prevalence and causes of vision loss in high-income countries and in Eastern and Central Europe: 1990–2010. British Journal of Ophthalmology. 2014 Feb 19.

35. Pascolini D, Mariotti SP. Global estimates of visual impairment: 2010. British Journal of Ophthalmology. 2012;96(5):614–618.

36. Klein R, Klein BE, Linton KL, De Mets DL. The Beaver Dam eye study: visual acuity. Ophthalmology. 1991;98(8):1310–1315.

37. Tielsch JM. Blindness and Visual Impairment in an American Urban Population: The Baltimore Eye Survey. Archives of Ophthalmology. 1990 Feb 1;108(2):286.

38. Klaver CC, Wolfs RC, Vingerling JR, Hofman A, de Jong PT. Age-specific prevalence and causes of blindness and visual impairment in an older population: the Rotterdam Study. Archives of Ophthalmology. 1998;116(5):653–658.

39. Munoz B, West SK, Rubin GS, Schein OD, Quigley HA, Bressler SB, Bandeen-Roche K. Causes of blindness and visual impairment in a population of older Americans: The Salisbury Eye Evaluation Study. Archives of Ophthalmology. 2000 Jun 1;118(6):819-25.

40. Chou CF, Cotch MF, Vitale S, Zhang X, Klein R, Friedman DS, Klein BE, Saaddine JB. Age-related eye diseases and visual impairment among US adults. American Journal of Preventive Medicine. 2013 Jul 1;45(1):29-35.

41. Gordon KD, Cruess AF, Bellan L, Mitchell S, Pezzullo ML. The cost of vision loss in Canada. 1. Methodology. Journal of Ophthalmology. 2011 Aug;46(4):310–4.

42. The Cost of Vision Loss in Canada: A Report by Access Economics Pty Limited for CNIB and COS [Internet]. 2009 Jun [cited 2017 Mar 28]. Available from: http://www.cnib.ca/eng/cnib%20document%20library/research/covl_full_report.pdf

43. Klein EB, Klein R, Lee EK, Cruickshanks JK. Associations of performance-based and self-reported measures of visual function The Beaver Dam Eye Study. Ophthalmic Epidemiology. 1999;6(1):49–60.

44. Klein BE, Klein R, Lee KE, Cruickshanks KJ. Performance-based and self-assessed measures of visual function as related to history of falls, hip fractures, and measured gait time: the Beaver Dam Eye Study. Ophthalmology. 1998;105(1):160–164.

45. Naeyaert KM, Grace G. Prevalence and Causes of Blindness and Visual Impairment in Canada. Journal of Visual Impairment and Blindness. 1990;84(7):361–63.

46. Gresset J, Baumgarten M. Prevalence of visual impairment and utilization of rehabilitation services in the visually impaired elderly population of Quebec. Optometry and Vision Science. 2002;79(7):416–423.

47. Maberley DAL, Hollands H, Chang A, Adilman S, Chakraborti B, Kliever G. The prevalence of low vision and blindness in a Canadian inner city. Eye. 2007;21(4):528–533.

48. Robinson B, Feng Y, Woods CA, Fonn D, Gold D, Gordon K. Prevalence of visual impairment and uncorrected refractive error–Report from a Canadian urban population-based study. Ophthalmic Epidemiology. 2013;20(3):123–130.

49. Varma R, Ying-Lai M, Klein R, Azen SP. Prevalence and risk indicators of visual impairment and blindness in Latinos: the Los Angeles Latino Eye Study. Ophthalmology. 2004;111(6):1132–1140.

50. Freeman EE, Roy-Gagnon MH, Samson E, Haddad S, Aubin MJ, Vela C, Zunzunegui MV. The global burden of visual difficulty in low, middle, and high income countries. PLoS One. 2013 May 10;8(5):e63315.

51. Varma R, Vajaranant TS, Burkemper B, Wu S, Torres M, Hsu C, Choudhury F, McKean-Cowdin R. Visual impairment and blindness in adults in the united states: Demographic and geographic variations from 2015 to 2050. JAMA Ophthalmology. 2016 Jul 1;134(7):802-9.

52. Sjöstrand J, Laatikainen L, Hirvelä H, Popovic Z, Jonsson R. The decline in visual acuity in elderly people with healthy eyes or eyes with early age-related maculopathy in two Scandinavian population samples. Acta Ophthalmologica (Copenh). 2011 Mar;89(2):116–23.

53. Zhang X, Kahende J, Fan AZ, Li Y, Barker L, Thompson TJ, Saaddine JB, Mokdad AH. Smoking and Visual Impairment Among Older Adults With Age-Related Eye Diseases. Preventing chronic disease. 2011 Jul;8(4).

54. Hwang J, Rudnisky C, Bowen S, Johnson JA. Socioeconomic factors associated with visual impairment and ophthalmic care utilization in patients with type II diabetes. Canadian Journal of Ophthalmology. 2015;50(2):119–126.

55. Wong T, Mitchell P. The eye in hypertension. The Lancet. 2007;369(9559):425–435.

56. Canadian Patient Charter for Vision Care [Internet]. [cited 2018 Jan 3]. Available from: http://www.cnib.ca/en/get-involved/join-anevent/Vision-Health-Month/Documents/CHARTER-12x18-ENG.pdf

57. The Canadian Association of Optometrists. An Overview of Provinical Health Coverage for Optometric Care in 2016 [Internet]. [cited 2018 Feb 21]. Available from: https://opto.ca/sites/default/files/resources/documents/prov_health_coverage_march_2016.pdf

58. MacLennan PA, McGwin Jr G, Searcey K, Owsley C. Medical record validation of self-reported eye diseases and eye care utilization among older adults. Current Eye Research. 2013 Feb 1;38(1):1-8.

59. Raina P, Torrance-Rynard V, Wong M, Woodward C. Agreement between self-reported and routinely collected health-care utilization data among seniors. Health Services Research. 2002;37(3):751–774.

60. Bellan L. Abandoning monitoring eye care utilization in Canada: something doesn’t smell right! Canadian Journal of Ophthalmology. 2011 Apr 1;46(2):123–4.

61. Jin YP, Trope GE. Eye care utilization in Canada: disparity in the publicly funded health care system. Canadian Journal of Ophthalmology. 2011 Apr 1;46(2):133-8.

62. Zhang X, Lee PP, Thompson TJ, Sharma S, Barker L, Geiss LS, Imperatore G, Gregg EW, Zhang X, Saaddine JB. Health insurance coverage and use of eye care services. Archives of Ophthalmology. 2008 Aug 11;126(8):1121-6.

63. Buys YM, Jin YP. Socioeconomic status as a risk factor for late presentation of glaucoma in Canada. Canadian Journal of Ophthalmology. 2013 Apr 1;48(2):83-7.

64. Jin YP, Buys YM, Hatch W, Trope GE. De-insurance in Ontario has reduced use of eye care services by the socially disadvantaged. Canadian Journal of Ophthalmology. 2012 Jun 1;47(3):203-10.

65. Andersen R, Newman JF. Societal and individual determinants of medical care utilization in the United States. The Milbank Memorial Fund Quarterly. Health and Society. 1973 Jan 1:95-124.

66. Andersen RM. Revisiting the behavioral model and access to medical care: does it matter?. Journal of Health and Social Behavior. 1995 Mar 1:1-0.

67. Aday LA, Andersen R. A framework for the study of access to medical care. Health Services Research. 1974;9(3):208.

68. Aday LA, Andersen RM. Equity of access to medical care: a conceptual and empirical overview. Medical Care. 1981 Dec 1:4-27.

69. Noertjojo K, Maberley D, Bassett K, Courtright P. Awareness of eye diseases and risk factors: identifying needs for health education and promotion in Canada. Canadian Journal of Ophthalmology. 2006 Oct 1;41(5):617-23.

70. Hong CJ, Trope GE, Buys YM, Robinson BE, Jin Y-P. Does government assistance improve utilization of eye care services by low-income individuals? Canadian Journal of Ophthalmology. 2014;49(4):320–325.

71. Balegamire S, Aubin MJ, Curcio CL, Alvarado B, Guerra RO, Ylli A, Deshpande N, Zunzunegui MV. Factors Associated With Visual Impairment and Eye Care Utilization: The International Mobility in Aging Study. Journal of Aging and Health. 2017 Jun 1:0898264317716360.

72. Elam AR, Lee PP. High-risk populations for vision loss and eye care underutilization: A review of the literature and ideas on moving forward. Survey of Ophthalmology. 2013;58(4):348–358.

73. Raina PS, Wolfson C, Kirkland SA, Griffith LE, Oremus M, Patterson C, Tuokko H, Penning M, Balion CM, Hogan D, Wister A. The Canadian longitudinal study on aging (CLSA). Canadian Journal on Aging/La Revue canadienne du vieillissement. 2009 Sep;28(3):221-9

74. Little RJ, Rubin DB. Statistical analysis with missing data. Vol. 333. John Wiley & Sons; 2014.

75. Vitale S, Ellwein L, Cotch MF, Ferris FL, Sperduto R. Prevalence of refractive error in the United States, 1999-2004. Archives of Ophthalmol. 2008;126(8):1111–1119.

76. de Boer MR, Pluijm SM, Lips P, Moll AC, Völker‐Dieben HJ, Deeg DJ, van Rens GH. Different aspects of visual impairment as risk factors for falls and fractures in older men and women. Journal of Bone and Mineral Research. 2004 Sep 1;19(9):1539-47.

77. Stefánsson E, Bek T, Porta M, Larsen N, Kristinsson JK, Agardh E. Screening and prevention of diabetic blindness. Acta Ophthalmol (Copenh). 2000;78(4):374–385.

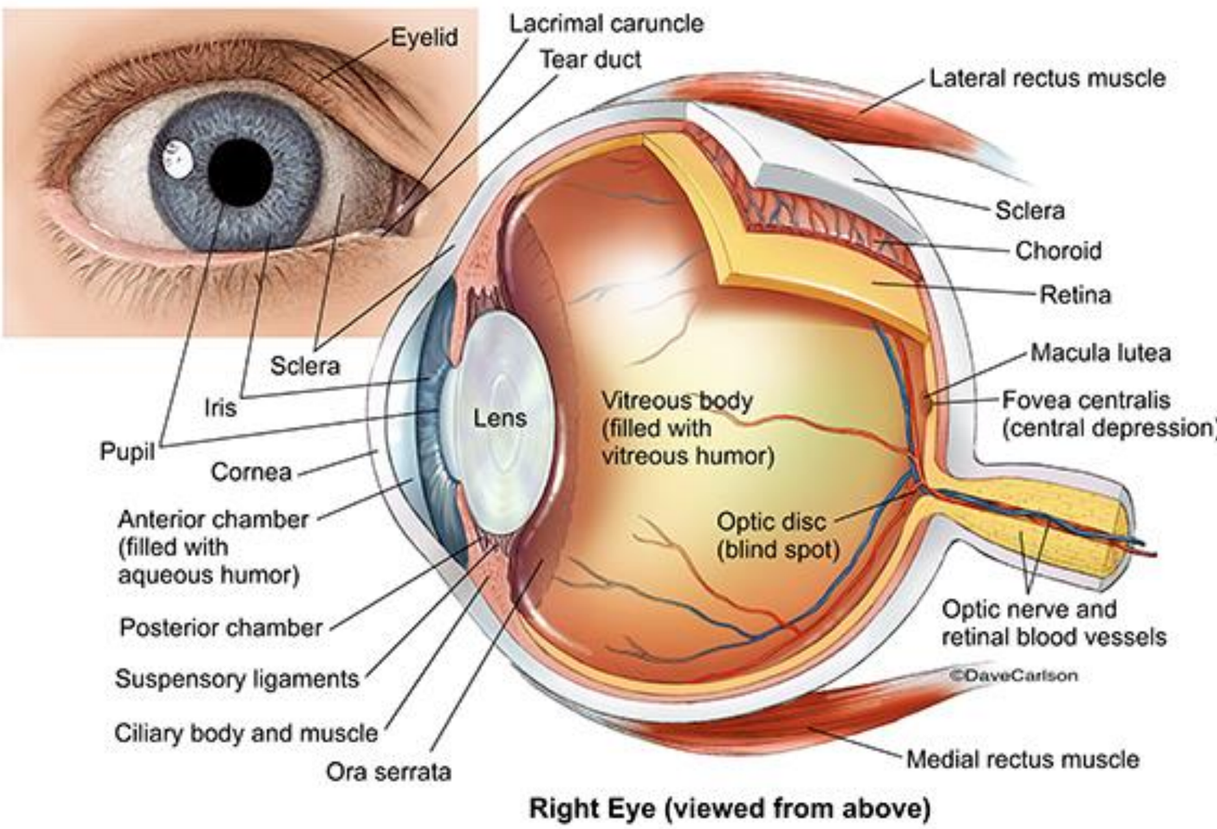
78. Tan JS, Wang JJ, Younan C, Cumming RG, Rochtchina E, Mitchell P. Smoking and the long-term incidence of cataract: the Blue Mountains Eye Study. Ophthalmic Epidemiology. 2008;15(3):155–161.

79. First Nations Information Governance Centre. National Report of the First Nations Regional Health Survey [Internet]. 2018 [cited 2018 Mar 24]. Report No.: Phase 3: Volume 1. Available from:

http://fnigc.ca/sites/default/files/docs/fnigc_rhs_phase_3_national_report_vol_1_en_final_web.pdf

APPENDICES

Appendix 1-Anatomy of the Eye



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Appendix 2- Ethics Approval

Ottawa Hospital Research Institute
Institut de recherche de l'Hôpital d'Ottawa

uOttawa

UNIVERSITY OF OTTAWA HEART INSTITUTE
INSTITUT DE CARDIOLOGIE DE L'UNIVERSITÉ D'OTTAWA

Ottawa Health Science Network Research Ethics Board/ Conseil d'éthique de la recherche du Réseau de science de la santé d'Ottawa

Civic Box 411 725 Parkdale Avenue, Ottawa, Ontario K1Y 4E9 613-798-5555 ext. 14902 Fax : 613-761-4311
http://www.ohri.ca/ohsn-reb

March 14, 2017

Dr. Ellen Freeman
c/o Mélanie R. Lalonde, Ph.D., CCRP
The Ottawa Hospital - General Campus
The University of Ottawa Eye Institute
501 Smyth Rd., W6261, Box 307
Ottawa, ON K1H 8L6

Dear Dr. Freeman:

Re: Protocol #	**20170184-01H**	**The Prevalence of Visual Impairment, its Risk Factors, and its Consequences in Canada**
Protocol approval valid until -		**March 13, 2018**

I am pleased to inform you that your Application for Chart Review underwent delegated review by the Ottawa Health Science Network Research Ethics Board (OHSN-REB), and is approved. No changes, amendments or addenda may be made to the protocol without the OHSN-REB's review and approval.

The approval includes the following:
-Protocol Version 1, dated February 22, 2017

If the study is to continue beyond the expiry date noted above, a Renewal Form should be submitted to the OHSN-REB approximately six weeks prior to the current expiry date. If the study has been completed by this date, a Termination Report should be submitted.

The Ottawa Health Science Network Research Ethics Board (OHSN-REB) was created by the merger of both the Ottawa Hospital Research Ethics Board (OHREB) and the Human Research Ethics Board (HREB) for meetings held at the University of Ottawa Heart Institute.

OHSN-REB complies with the membership requirements and operates in compliance with the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans; the International Conference on Harmonization - Good Clinical Practice: Consolidated Guideline and the provisions of the Personal Health Information Protection Act 2004.

Yours sincerely,

Appendix 3- Data Access Agreement

McMaster University

CLSA Access Agreement

This agreement is entered into this 2 February, 2017 (the "**Effective Date**"), at Hamilton, Ontario.

McMaster University, a University incorporated by special act of the Province of Ontario, Canada, with a main address at 1280 Main Street West, McMaster Innovation Park, Suite 309A, Hamilton, Ontario, Canada, L8S 4K1 ("**McMaster**") is the host institution of the Canadian Longitudinal Study on Aging ("***CLSA***").

AND

University of Ottawa, with a main address at **3042-800 King Edward, Ottawa, Ontario K1N 6N5("Approved User *Institution*")**

WHEREAS:

A. Dr. Parminder Raina (McMaster University) is the Lead Investigator for the CLSA funded by a grant from the Canadian Institutes of Health Research (CIHR) and is responsible for the academic obligations under this Agreement

B. Dr. Ellen Freeman (the "Approved User") is an associate professor at the Institution, where he/she carries or wishes to carry out a study entitled "The Prevalence of Visual Impairment, Its Risk Factors, and Its Consequences in Canada", for which access to CLSA samples or data (or both) will be required.

C. The document titled "CLSA Data and Sample Access Policy and Guiding Principles" attached as Schedule A is an integral part of this agreement. All obligations contained therein are part of this agreement.

The parties hereto agree as follows:

1. Definitions

"Agreement" means this CLSA *Access Agreement.*

"DSAC" means the CLSA's Data and Sample Access Committee.

"Study" means the **CLSA Data and/or Biospecimen Request Application** described in Schedule B attached hereto.

"Transferred Materials" means the CLSA data and/or the biological samples described in Schedule B attached hereto.

2. Sample and Data Security.

2.1 Security measures specified in Schedule C attached hereto will apply to all Transferred Materials. The Approved User undertakes to respect these security measures during the Study and afterwards, during storage of Transferred Materials where necessary.

2.2 The Approved User shall agree to the audit of his/her research facility by McMaster to ensure the security and confidentiality of Transferred Materials. These audits may be conducted with reasonable prior notice. Any discrepancies between the security measures specified in Schedule C and what is found at the Institution's research facility will have to be corrected within 60 days of notice by McMaster. The costs associated with these audits will be supported by McMaster.

2.3 Transferred Materials, including any copies thereof, may only be used for the Study described in Schedule B and may not be disclosed, transmitted or shipped to anyone except employees working directly with the Approved User or co-investigators including co-applicants or other personnel from other institution(s), indicated in the Study who will require direct access to the CLSA Data and who agree to be bound by the terms of this Agreement or to persons expressly designated in writing by McMaster. The Approved User shall retain control of the Transferred Material at all times. It is the responsibility of the

16.2 This Agreement is governed by and will be construed in accordance with the laws of the Province of Ontario, without regard to conflicts of laws principles.

16.3 The following provisions will survive termination of this Agreement: 5, 8, 9, 10, 11, 12, 14 and 15.

16.4 This Agreement shall not be amended, modified, varied or supplemented except in writing signed by each of the parties.

16.5 No party shall use, or authorize others to use, the name, symbols, or marks of another party hereto or its staff for any endorsement purposes without prior written approval from the party whose name, symbols or marks are to be used.

16.6 Neither party may assign any of its rights or obligations under this Agreement without the prior written consent of the other party.

16.7 Nothing in this Agreement creates, implies or evidences any partnership or joint venture between the parties, or the relationship between them of principal and agent. No party shall have the authority to act on behalf of any other party or to bind another party in any manner.

16.8 Each party represents that it is permitted to enter into this Agreement, to consent to its conditions and that each has authority to sign this Agreement. This Agreement may be executed in one or more counterparts, each of which will be deemed an original, but all of which will constitute one and the same instrument.

IN WITNESS WHEREOF, the parties hereto have signed this Agreement.

Back to Top