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RESEARCH

Refractive error, risk of amblyopia and eye care services utilisation among Nunavik Inuit in Northern Canada

Benoit Tousignant[a,b] and Julie Brûlé[a]

[a]School of Optometry, University of Montreal, Montreal, Canada; [b]Department of Social and Preventive Medicine, School of Public Health, University of Montreal, Montreal, Canada

ABSTRACT

Clinical relevance: Nunavik Inuit patients, in Northern Canada, have a significant burden of refractive error. The frequency at which they access eye care is insufficient. This exposes children of this population to a substantial risk of refractive amblyopia.

Background: No data are available on eye health and services among Nunavik Inuit in Quebec, Canada. This study aims to describe the prevalence of ametropias, risk of refractive amblyopia, and eye health services uptake amongst a sample of Nunavik Inuit.

Methods: Retrospective cohort using data from electronic records of the sole government-contracted eye team travelling to all 14 Nunavik villages, from 2006 to 2018.

Results: Some 26,541 examinations were analysed, with data from 6,341 patients (median age 27 years (IQR 30); 32% aged under 19 years; 60.3% female) representing 48% of the census population. Population weighted prevalence of ametropias was myopia 46.5% (95% CI 45.3 – 47.6), hyperopia 17.1% (95% CI 16.2 – 18.1), astigmatism 39.6% (95% CI 38.4 – 40.8) and presbyopia 30.0% (95% CI 28.9 – 31.0). Some 5.9% of patients aged 0–9 years present a risk of refractive amblyopia. Mean frequency of examinations for all ages was once per 4 years (95% CI 4.0 – 4.0) and for children aged 5 – 19 years, frequency was once per 4.8 years (95% CI 4.8 – 5.0). In 2018, 74% of patients who were prescribed spectacles purchased them, with a median time of procurement of 21 days (IQR 247, skewness 2.7).

Conclusion: There is a high prevalence of ametropias amongst the clinical population of Nunavik Inuit. Most patients needing spectacles obtain them within a few weeks. Frequency of eye health services is insufficient to meet recommended guidelines, especially in children, for whom the risk of refractive amblyopia is pervasive.

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Introduction

Visual impairment is recognised as a significant public health problem worldwide,[1–3] impacting quality of life of individuals[4,5] and causing important economic consequences.[5] Some 80% of the causes of visual impairment are avoidable, with the leading one being uncorrected refractive error.[3,6] In childhood, refractive amblyopia, which is linked to uncorrected ametropias,[7,8] is one of the leading causes of reduced visual acuity, although it can often be treated by spectacle correction.[9]

Indigenous communities have a higher prevalence of general poverty, house overcrowding, food insecurity and health problems,[10–12] as well as significant health disparities compared to the settler Canadian population.[13–15] Inuit communities have a particularly high burden of disease and of learning disabilities in children and more difficult access to care.[13,14,16]

To date, few recent studies document eye health and eye health services in Indigenous communities worldwide[17] and the same is true in North American Inuit or in other circumpolar locations. Since the 1950s, only a few clinical studies addressed the state of eye care for some specific arctic locations.[18–22] Prevalence for myopia has been described as ranging from 8% in children[22] and from 18% to 45% in adults, with a tendency towards decreasing myopia with age.[18,20,21] Refractive amblyopia in Inuit population is scarcely described in recent literature.[23]

With regard to utilisation of eye care services among circumpolar populations, no literature is currently available. In short, the available literature offers little information about refractive error in Inuit communities. Most studies are dated and provide little to no data on astigmatism, presbyopia or refractive amblyopia.

The present study aims to assess and characterise, amongst a clinical population of Nunavik Inuit, the prevalence of refractive error as well as the risk of refractive amblyopia in children. Furthermore, it aims to describe utilisation of government sponsored eye care services.

Methods

This is a retrospective cohort study, using clinical data gathered by the mobile eye care teams that regularly travel to Nunavik, which constitutes the northernmost third of the province of Quebec (Canada) and is situated between the 52nd and 62nd parallels. This arctic region has an area of over 660,000 km^2, with over 90% of its population of approximately 13,000 identified as Inuit. Nunavik residents are scattered in 14 rural villages along the coasts of the bays of Hudson and Ungava.[24]

Primary health care is offered by permanent nursing staff or visiting physicians in the community health centre of each village. Secondary and specialist health care (including ophthalmology) are typically delivered either in one of the

CONTACT Benoit Tousignant benoit.tousignant@umontreal.ca Department of Social and Preventive Medicine, School of Public Health, University of Montreal, Montreal, Canada

two large regional health centres (Kuujjuaq and Puvirnituq) or by flying patients to Montreal. A group of optometrists and opticians holds a contractual agreement with the Nunavik Regional Board of Health and Social Services[24] to be the provider of primary eye care needs for all 14 villages of the Nunavik region. As the only eye primary eye care provider in Nunavik, they hold mobile optometry clinics on a regular basis in each community, from one to three times per year, depending on the village size.

Comprehensive eye examinations include the assessment of refractive status (objective refraction, subjective refraction and prescription of spectacles) as well as the assessment of the ocular health, visual perception and binocular vision of the patient. Spectacles are chosen on the examination date and ordered on the same day or at a later date once the patient settles any outstanding cost. Spectacles are pre-fitted and shipped by mail to the patient once ready. The cost of the spectacles is subsidised in part by the Makivik Corporation, the organisation that administers, distributes and invests the compensation money payable to Nunavik Inuit, as provided for in the James Bay and Northern Quebec Agreement.[25]

The parts of the patient records, which were available in an electronic format, were analysed in this project. Information on visual acuity and methods of refraction was not available in electronic format. The variables used included age, sex, village of residence, date of examination, final prescription issued by the visiting optometrist (sphere, cylinder, axis and addition values), date of spectacles order and date of final spectacles payment. Records used spanned from February 2006 to December 2018 and covered all 14 Nunavik villages. Participants were those seeking eye care based on their needs from a referral from a village health care professional.

Definitions of ametropias and risk of refractive amblyopia were adopted from recent epidemiology literature on refractive error[26] and refractive amblyopia[27,28] (Table 1). Methods of refraction were not specified, but the reported ametropia data include a clinical judgement made by the optometrists, using a combination of static retinoscopy, autorefraction and/or subjective refraction.

Table 1. Definitions of ametropias and risk of refractive amblyopia amongst Nunavik Inuit.

Myopia[26]	
Children (age < 17 years)	Spherical equivalent power ≤ −0.5 dioptre
Adults (age ≥ 18 years)	Spherical equivalent power < −0.5 dioptre
Hyperopia[26]	
Children (age < 17 years)	Spherical equivalent power ≥ +2.0 dioptre
Adults (age ≥ 18 years)	Spherical equivalent power > +0.5 dioptre
Astigmatism[26]	Cylindrical power < −0.5 dioptre
Anisometropia[26]	Equivalent sphere difference ≥ 1.00 D between both eyes
Presbyopia (alone)	Any prescribed addition (≥ 35 years old), without other distance ametropia
Clinical emmetropia	
Children (age < 17 years)	spherical equivalent power between −0.5 and +2.0 dioptres (exclusive), with no cylindrical power < −0.5 dioptre
Adults (age ≥ 18 years)	Spherical equivalent power between −0.5 and +0.5 dioptres (inclusive), with no cylindrical power < −0.5 dioptre
Risk of refractive amblyopia[27,28]	Either eye with most myopic meridian ≤ −2.00 D
Myopic amblyopia	Both eyes with sphere ≥ +3.00 D
Hyperopic amblyopia	Both eyes with cylinder ≥ 1.50 D (axes 10 to 170 or 80 to 100)
Astigmatic amblyopia (regular)	Both eyes with cylinder ≥ 1.00 D (axes 11 to 79 or 101 to 169)
Astigmatic amblyopia (oblique)	Equivalent sphere difference ≥ 1.00 D between both eyes
Anisometropic amblyopia	

Statistical analyses were performed using the computing environment R (version 3.5.3, Development Core Team, 2018 http://www.r-project.org). Descriptive statistics, including weighted prevalence (adjusting for sex and age at first examination) of ametropias, were calculated using data from the first examination and the *svyciprop* function and *logit* method of the R survey package. Adjusting for age was performed using the rake function of the R Survey package. Data from the Canadian 2016 national census[29] and from Canadian Community Health Survey (CCHS, year 2014)[30] were used as comparatives.

Frequency of examinations was calculated as a rate, for which the numerator is the total number of examinations during the study period and for which the denominator (in person-years) is the total number of study participants during the study period, adjusting for individuals born after the start of the study period. The reciprocal of this rate (in years) was used as frequency of examinations. Analysis for the frequency of examinations was restricted to the categories used in evidence-based Canadian guidelines for frequency of comprehensive eye examinations[31] (ages 5-19, 20-39, 40-64 and 65+ years) to allow comparison, adjusting for individuals born after the start of the study period.

Variables relative to spectacles acquisition include 'order intention time', defined as the period between the examination date and the spectacles order date, and 'procurement time', defined as the period between the examination date and the date of final payment.

The study adhered to the tenets of Helsinki and ethical clearance was obtained from the University of Montreal's Institutional Review Board (Comité d'éthique de la recherche en santé – CERES certificate #17-119-CERES-D1). In order to palliate the absence of direct patient consent, approval was obtained from the Quebec Commission for Access to Information (*Commission d'accès à l'information*). The Nunavik Regional Board of Health and Social Services also approved the research protocol.

Results

Some 27,812 records of examinations were initially examined. After removing entries where village of residence was not in Nunavik, duplicates and erroneous records (for example, clinically impossible ametropia values), a total of 26,541 examinations remained, for which data were available for all variables. These examinations were from a total of 6,341 participants. Once adjusted for the individuals born after the start of the study, a total of 19,844 examinations remained. Combining this to the study observation period, the follow-up time totalled 79,005 person-years. The distribution of the cohort intake is reported in Table 2 and the characteristics and representation of the study population are reported in Table 3.

The median age was 27.0 years (IQR 30.0). Some 32.3% (n = 2,048) were of school age (5 – 19 years old) and 14.1% (n = 891) were within the amblyogenic period (0–9 years old). Sex was 60.3% female (n = 3,823). Data were collected for patients residing in all 14 villages of Nunavik. These data represent 48.2% of the 2016 census population of Nunavik (range by village 36.0–59.1%).

Table 2. Distribution of cohort intake amongst Nunavik Inuit seeking eye care (n = 6,341).

Year	Patient intake	%
2006	110	1.7
2007	942	14.9
2008	939	14.8
2009	756	11.9
2010	474	7.5
2011	553	8.7
2012	484	7.6
2013	389	6.1
2014	370	5.8
2015	344	5.4
2016	320	5.1
2017	352	5.6
2018	308	4.9
Total	6341	100.0

Table 3. Characteristics and census representation of clinical population amongst Nunavik Inuit (n = 6,341).

Age	median (interquartile range) n, (% of study population)	27 (30.0) N (% of census population)
0–4 years	92 (1.4)	1620 (12.3)
5–19 years	1658 (26.1)	4050 (30.8)
20–39 years	2098 (33.1)	4120 (31.4)
40–64 years	2004 (31.6)	2845 (21.7)
65+ years	489 (7.7)	500 (3.8)
Sex, female	3823 (60.3)	6500 (50.7)
Village of residence	n (% of study population)	N (% of census population)
Akulivik	228 (3.6)	633 (4.8)
Aupaluk	93 (1.5)	220 (1.6)
Inukjuak	829 (13.1)	1757 (13.3)
Ivujivik	180 (2.8)	414 (3.1)
Kangiqsualujjuaq	557 (8.8)	942 (7.1)
Kangiqsujuaq	397 (6.3)	750 (5.7)
Kangirsuk	285 (4.5)	567 (4.3)
Kuujjuaq	1344 (21.2)	2754 (20.9)
Kuujjuarapik	373 (5.9)	686 (5.2)
Puvirnituq	733 (11.6)	1779 (13.5)
Quaqtaq	209 (3.3)	403 (3.1)
Salluit	715 (11.3)	1483 (11.2)
Tasiujaq	158 (2.5)	369 (2.8)
Umiujaq	240 (3.8)	442 (3.4)
Total	6341	13,199
% of census population	48.2	100.0

Table 4. Sample prevalence of ametropias and risk of refractive amblyopia amongst a clinical population of Nunavik Inuit (n = 6,341).

	Crude prevalence (%)	Weighted prevalence for sex and age (%)	Confidence interval (95%)
Myopia		46.5	45.3 – 47.6
Age < 17 years[a]	43.1	34.0	32.3 – 35.8
Age ≥ 18 years[b]	52.4	54.0	52.6 – 55.5
Hyperopia		17.1	16.2 – 18.1
Age < 17 years[c]	11.2	14.5	12.8 – 16.3
Age ≥ 18 years[d]	20.0	18.7	17.6 – 19.7
Astigmatism[e]		39.6	38.4 – 40.8
Age < 17 years	25.7	26.4	24.3 – 28.5
Age ≥ 18 years	47.6	47.7	46.2 – 49.2
Anisometropia[f]		7.8	7.1 – 8.5
Age < 17 years	7.6	8.6	7.2 – 9.9
Age ≥ 18 years	7.6	7.3	6.6 – 8.1
Presbyopia (alone)[g]		30.0	28.9 – 31.0
Clinical emmetropia[h]		32.6	31.4 – 33.8
Age < 17[i]	41.7	46.8	44.5 – 49.7
Age ≥ 18[j]	23.9	24.0	22.7 – 25.3
Risk of refractive amblyopia		5.9	4.3 – 7.5

aSpherical equivalent power ≤ −0.5 dioptre
bSpherical equivalent power < −0.5 dioptre
cSpherical equivalent power ≥ +2.0 dioptre
dSpherical equivalent power > +0.5 dioptre
eCylindrical power < −0.5 dioptre
fSpherical equivalent difference ≥ 1.00 D between both eyes
gAny prescribed addition (≥ 35 years old), without other distance ametropia
hSpherical equivalent power between −0.5 and +2.0 dioptres (exclusive), with no cylindrical power < −0.5 dioptre
iSpherical equivalent power between −0.5 and +0.5 dioptres (inclusive), with no cylindrical power < −0.5 dioptre
jPatients at risk of myopic, hyperopic, astigmatic or anisometropic amblyopia, aged 0 – 9 years

The population-weighted prevalence of ametropias (adjusted for sex and age) is represented in Table 4. The prevalence of myopia is 46.5% (95% CI 45.3 – 47.6), astigmatism 39.6% (95% CI 38.4 – 40.8) and presbyopia 30.0% (95% CI, 28.9 – 31.0). Some 5.9% of patients aged 0 – 9 years were diagnosed with an ametropia consistent with a risk of developing refractive amblyopia.

Some 81.5% (n = 5,171) of the participants had at least one examination within the last 5 years (December 2013–December 2018) and 48.2% (n = 3,059) of participants having had more than one examination during the study period, for the calendar year 2014, 34.9% of study samples had an eye examination by the eye care team. The mean frequency of examinations for all ages was once per 4 years (95% CI, 4.0 – 4.0). For patients aged 5–19 years, this frequency was once per 4.8 years (95% CI, 4.8 – 5.0). Table 5 reports the frequency of eye examinations in the cohort compared to evidence-based recommendations for frequency of eye examinations.[31]

In the last year of the study period (December 2017–December 2018), 74% of participants (n = 1964) who were prescribed spectacles proceeded to purchase them, with a median order intention time of 0 (IQR 0, skewness 3.3) and a median procurement time of 21 days (IQR 247, skewness 2.7). Characteristics and intervals relative to the acquisition of the prescribed spectacles amongst study participants are reported in Table 6.

Discussion

This is the first report on refractive error and eye care utilisation among a Nunavik Inuit population. Whilst this cohort is not composed of a randomly sampled population, it has the advantage of a large sample size, from the only regional eye care provider contracted by local health authorities and representing 48.2% of the regional census population, with data spanning over 12 years.

The high prevalence of myopia and astigmatism amongst this cohort has important implications, given the impact of high rates of myopia on eye health[32] and productivity.[33] Indeed, a high proportion (46.5%) of our sample shows myopia. For children 0–17 years old, this figure stands at 34.0%. Although the figures presented here cannot be directly compared with population-level prevalence estimates, this level of myopia is still notably higher than the worldwide estimated pooled prevalence of myopia in children of 11.7%.[26] The level of myopia in the present sample is akin to that found in Asian populations.[34]

Other Canadian studies on Indigenous clinical populations describe myopia levels at 42.2% among Sagamok First Nations[35] and ranging from 22.4% to 64.1% in a clinical population of Chinese-Canadian children.[36] The level of astigmatism in the present cohort stands at 39.6% (all ages), which may indicate similar or slightly higher prevalence of astigmatism among Nunavik Inuit than the estimated pooled

Table 5. Frequency of eye examinations among Nunavik Inuit, actual compared to recommended.

	Examinations (n)	Person-yearsa	Rate	Frequency of eye examination (years, 95% CI)	Recommended frequency as per Canadian guidelines[31] (years)
All ages, years	19,844	79,006	0.25	4 (4.0 – 4.0)	
5 – 19	5188	25,038	0.21	4.8 (4.8 – 5.0)	1
20 – 39	6567	25,170	0.26	3.8 (3.7 – 4.0)	2.5
40 – 64	6272	23,308	0.27	3.7 (3.6 – 3.8)	2
≥ 65	1530	3731	0.41	2.4 (2.3 – 2.6)	1

aTotal number of study participants during the study period, adjusting for individuals born after the start of the study period

Table 6. Characteristics and intervals in spectacle acquisition amongst Nunavik Inuit (December 2017 – December 2018; n = 1964).

		Purchases		Procurement time (days)a
		n	%	Median (IQR, skewness)
Sex				
	Male	1361	69.3	22 (261, 2.6)
	Female	623	31.7	16 (217, 2.9)
Age, years				
	0 – 4	19	1.0	22 (149, 3.5)
	5 – 19	446	22.7	20 (180, 3.2)
	20 – 39	745	37.9	43 (365, 2.2)
	40 – 64	637	32.4	14 (201, 3.0)
	≥ 65	137	7.0	1 (31, 3.7)
Village of residence				
	Akulivik	82	4.2	38 (363, 2.1)
	Aupaluk	29	1.5	29 (357, 2.1)
	Inukjuak	275	14.0	21 (245, 2.5)
	Ivujivik	71	3.6	14 (166, 2.3)
	Kangiqsualujjuaq	210	10.7	23 (240, 2.2)
	Kangiqsujuaq	106	5.4	22 (184, 3.3)
	Kangirsuk	57	2.9	16 (253, 2.4)
	Kuujjuaq	375	19.1	12 (238, 2.7)
	Kuujjuarapik	126	6.4	10 (210, 2.8)
	Puvirnituq	222	11.3	32 (278, 2.1)
	Quaqtaq	61	3.1	12 (180, 3.6)
	Salluit	250	12.7	25 (266, 3.1)
	Tasiujaq	50	2.5	21 (188, 2.1)
	Umiujaq	70	3.6	26 (343, 2.2)
Total		1984	100	21 (247, 2.7)

aPeriod between the examination date and the spectacles order date

prevalence of astigmatism of 27.2% in the Americas.[26] The present data indicate that some 30% of patients were found to have an ametropia consistent with presbyopia. Given the implications of corrected presbyopia on the improvement quality of life,[37] this highlights the importance of having access to spectacle correction in this population.

Amblyopia is the second most common cause of functional vision loss in children[38] and requires regular attention from primary eye care providers in order to monitor and treat the condition to minimise long-term visual loss. In population surveys, the proportions of amblyopia have been reported to be between 2% and 5%.[39] Among children in the present cohort, 5.9% were found to have ametropias consistent with a risk of developing refractive amblyopia. Although comparison with population-level estimates is not feasible, this still indicates that an important number of Nunavik children need to access quality eye care on a regular basis to prevent or manage amblyopia, in order to reduce avoidable loss of visual function.[40]

For the calendar year 2014, 34.9% of participants had an eye examination; for the same reference year, CCHS data indicate that 41.4% of the Quebec population (and 41.6% of the Canadian population) had an eye examination. Although these figures do not seem to stand in stark contrast, meaningful comparisons are again limited because of the sampling methodology. However, frequency of eye examination in the present cohort is below the recommended intervals for all age groups. This is particularly evident in children, where the frequency between examinations reached 4.8 years, compared to the recommended yearly examination. This highlights a substantial unmet need in Nunavik Inuit children.

Considering the importance of maintaining appropriate correction of ametropia during school years and the aforementioned risk of visual loss related to amblyopia and its management, efforts should be deployed to increase frequency of eye care to this segment of the population. Given the logistical and financial challenges of increasing regular in-person care in remote communities, part of the solution may lie elsewhere. Indeed, avenues to explore could include combining telemedicine with the possibilities offered by multidisciplinary models. For example, nursing or ancillary health staff present in all villages could monitor and report key progress indicators (such as visual acuity, adherence to spectacle use and other components of amblyopia treatment) with a coordinating eye care professional located remotely, and co-manage occlusion or atropine therapy for amblyopia, using standardised protocols.

In this cohort, indicators related to the procurement of spectacle correction were encouraging. The median ordering time was null, indicating that patients needing spectacles chose and ordered spectacles during the same service trip. Furthermore, the median procurement time was 21 days (between the examination and the date of final payment). Despite some outliers, which skew this distribution (range 0 – 3,097, IQR 247, skewness 2.7), most patients, including children, seem to obtain their spectacles in an acceptable interval. This reveals a certain level of motivation and confidence in the optical dispensing services provided, as well as efficacy of the coverage of spectacle fees covered by the Makivik corporation, with no obvious barrier between diagnosis and accessing treatment of refractive error.

Whilst 60.3% of the participants were female, the spectacle purchases were 69.3% male. Certain differences in the distribution of ametropias were present between sexes (data not shown), with myopia being slightly more frequent in men, whilst hyperopia, astigmatism and presbyopia were slightly more frequent in women. It is not clear whether the difference between sexes for purchases is related to a difference in the distribution of ametropias among sexes, which has not been often described elsewhere. Rather, it is possible for there to be gender-based differences in the ability to afford spectacles. Although relatively few data yet have been published on gender equity relating to health and other social determinants among Inuit,[41] some reports indicate that Inuit women have more chronic health conditions than their male

counterparts, are less likely to be employed and typically have lower income.[42] However, this would require further investigation.

There are some limitations of this study. First, this report relates to a clinical population, presenting for services, rather than a randomly sampled population. Since little is known of the rest of the population, this implies that the proportions reported may either be overestimated (if care-seeking patients present more eye problems) or underestimated (if various barriers prevent the more affected patients to seek care). However, the present cohort shows a proportion of emmetropic patients at 32.6% (41.7% in children and 23.9% in adults), indicating that not all patients consulting have obvious eye disorders. Furthermore, because of the large sample size, comprising almost half of the population, some estimates remain concerning even if they were completely absent from the rest of the population. Such is the case, for example, for the high proportion of myopia (46.5%), which, if halved, would still stand higher than worldwide estimated pooled prevalence of 11.7%.[26]

Second, the present study sample does not include patients with eye conditions examined by visiting ophthalmologists. Although the potential absence of such patients may still contribute to a certain underestimation of disease burden, in comparison to the present cohort, those patients are relatively few. Indeed, during the time of this study, ophthalmology service trips typically occurred once a year in three of the larger villages, for a few days each time. Moreover, most patients seen by ophthalmologists are first seen by the visiting optometry team and would thus be included in this study.

Third, analysis was adjusted for individuals born after the start of the study period, but not for individuals dying during the study period. This could lead to a slight underestimation of the reported proportions.

Finally, without access to the method of refraction, there is a lack of uniformity in the measurement of ametropia. For example, there is no systematic measurement of paediatric cycloplegic refraction in the present sample. In theory, this may carry a risk of overestimation of myopia by the inclusion of pseudomyopia (accommodative spasm) or an underestimation of hyperopia. However, this risk of misclassification bias is considered to be minimal, since cycloplegia was regularly used by all concerned practitioners to obtain optimal spectacle correction (avoiding prescribing an overly myopic correction in pseudomyopia or under correcting cases of latent hyperopia), based on clinical judgement and other accommodative and binocular test results.

Conclusion

Refractive error, especially myopia, astigmatism and presbyopia, is largely prevalent amongst this clinical cohort of Nunavik Inuit, confirming the pertinence and need for regular provision of primary eye care services. Current utilisation of eye services does not seem markedly inferior to that of the national population. Procurement of spectacles appears to be successful and timely with the current model of care, with no obvious barrier to the uptake of treatment of refractive error. Many children have ametropias presenting a risk of developing refractive amblyopia, coupled to a frequency of eye examination considerably lower than the recommended yearly intervals, which would be needed for appropriate detection and management of amblyopia and evolving refractive error during school years. Alternatives to enhance the current model of eye care delivery in Nunavik should be explored, in order to decrease the risk of loss of visual function, especially amongst Nunavik children.

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ORCID

Benoit Tousignant http://orcid.org/0000-0002-0395-5027

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