Journal of the Formosan Medical Association (2020) 119, 134–143

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.jfma-online.com

Original Article

Ethnic disparity in prevalence and associated risk factors of myopia in adolescents

Shang-Yi Chiang [a,*], Tzu-Heng Weng [a], Che-Min Lin [b], Shih-Min Lin [c]

[a] *Department of Ophthalmology, Tri-Service General Hospital, National Defense Medical Center, No. 325, Sec.2, Chenggong Rd., Neihu District, Taipei City, 114, Taiwan*
[b] *Department of Ophthalmology, Taichung Armed Forces General Hospital, No. 348, sec.2, Chungshan Rd., Taiping District, Taichung City, 41152, Taiwan*
[c] *Department of Ophthalmology, Sin-Lau Hospital, No. 57, Sec. 1, Dongmen Rd., East Dist., Tainan City, 70142, Taiwan*

Received 16 March 2018; received in revised form 20 December 2018; accepted 7 March 2019

KEYWORDS
Adolescent;
Myopia;
Racial disparity;
Risk factor;
NHANES

Background/Purpose: To examine ethnic disparity in prevalence and associated factors of myopia in adolescents using the Unites States National Health and Nutrition Examination Survey (NHANES) dataset.
Methods: Participants who were aged 12–19 years were included from NHANES (1999–2008). Logistic regression analyses were applied to identify risk factors associated with myopia after stratification by race.
Results: A total of 9,960 participants were included in the prevalence analysis, and 6,571 in the risk factor analysis. Other race (excluded Mexican American, other Hispanic, non-Hispanic white, non-Hispanic black) participants had the highest frequency of myopia (42.77%). Multivariate analyses of the whole population suggested that the odds of myopia were significantly lower in participants with household smokers (odds ratio [OR] = 0.79, 95% confidence interval [CI]: 0.66–0.97), and significantly greater in Mexican American race (OR = 1.28, 95% CI: 1.01–1.62), other Hispanic (OR = 1.79, 95% CI: 1.10–2.92) and in participants with senior high school graduate education (OR = 1.79, 95% CI: 1.01–3.18), watched 2 hours of television daily (OR = 1.27, 95% CI: 1.02–1.59), used the computer for 1 hour daily (OR = 1.276, 95% CI: 1.02–1.57). When examined by race/ethnicity, 1 hour of computer use increased the odds of myopia in the non-Hispanic White group, in Mexican Americans a higher family poverty income ratio and 2 hours of television time was associated with myopia, and in the Other Hispanic group, a higher family poverty income ratio was associated with myopia, while males and those with a higher sugar had a lower risk of myopia.

* Corresponding author. Tri-Service General Hospital, National Defense Medical Center, No. 325, Sec.2, Chenggong Rd., Neihu District, Taipei City, 114, Taiwan. Fax: +886 8 792 7164.
E-mail address: csy2001@gmail.com (S.-Y. Chiang).

https://doi.org/10.1016/j.jfma.2019.03.004

Conclusion: Risk factors for myopia vary with race/ethnicity.

Introduction

Myopia is the most common refractive disorder, especially in young adults. The incidence of myopia is steadily increasing worldwide.[1–5] High prevalence of myopia among schoolchildren in East Asia and Singapore was found, which reported around 80% of high school students are myopic in Taiwan, some urban areas of China, and South Korea.[5–7] The high prevalence of myopia is associated with significant economic consequences on health care systems as a result of the costs for correction, as well as social and educational concerns.[8] High myopia or pathological myopia is associated with an increased risk of a number of potentially vision threatening complications including retinal detachment and degenerative conditions, cataracts, and primary open-angle glaucoma.[9]

The exact reasons for the increase in the prevalence of myopia remain undetermined. Genetic inheritance and predisposition for development of myopia has been established but does not explain the marked increase.[10] Myopia has been described to be a manifestation of insulin resistance as insulin has direct ocular growth promoting effects.[10] Environmental factors, included less time spent outdoors and increased work requiring near vision, such as working on a computer, have been reported in the association with the development of myopia.[11–14] Furthermore, multiethnic population-based studies have also suggested myopia prevalence varies by ethnicity.[15] Asians, especially the younger generations, show the relatively higher prevalence of myopia. It was possibly attributed to the near-work demands imposed by more intensive education.[6,16,17] There were few data available to address the myopia prevalence in the United States, and the main study subjects were black and white.[3,4]

The objective of the present study was to examine ethnic disparity in prevalence and associated risk factors of myopia in adolescents, using data from the Unites States National Health and Nutrition Examination Survey (NHANES). Identification of modifiable risk factors associated with myopia in different population settings may help to develop strategies to prevent and control myopia progression, which would benefit children and adolescences worldwide.

Methods

Participants

The NHANES program began in the early 1960s and has been conducted as a series of surveys focusing on different population groups and health topics. The sample for the NHANES survey is selected to represent the United States population of all ages. Further information about background, design and operation are available on the NHANES website (http://wwwn.cdc.gov/nchs/nhanes). All of the NHANES data are de-identified, and analysis of the data does not require Institutional Review Board approval or informed consent by participants.

Data from the NHANES program collected from 1999 to 2008 were used for this study. A total of 60,270 participants with completed mobile examination center (MEC) data were identified in the NHANES database from 1999 to 2008. Next, 50,310 participants were excluded for age <12 years, age >19 years, and having had myopia surgery. Subsequently, 9,960 participants from 5 cycles (1999–2008) were included in the prevalence rate evaluation, and 6,571 participants from 3 cycles (2001–2006) were included in the regression model estimation. Using the NHANES sample weight, the sample size for the prevalence rate evaluation ($n = 9,960$) was equivalent to a population-based sample of 31,627,822 persons, and the sample size for model estimation ($n = 6,571$) was equivalent to a population of 31,680,035 persons. Among the 6,571 participants, 1,826 were non-Hispanic White (27.8%), 2,053 (31.2%) were Mexican American, 2,191 (33.3%) were non-Hispanic Black, 233 (3.5%) were other Hispanic, and 268 (4.1%) were other races. A flow diagram for inclusion and exclusion of participants is shown in Fig. 1.

Measurement of myopia

All NHANES participants 12 or more years old were eligible receive a refraction examination unless they were blind or had a severe eye infection. A Nidek Auto Refractor (Model ARK-760) was used to calculate the refraction of the eye, sphere, cylinder and axis (http://www.nber.org/nhanes/2005_2006/downloads/vix_d.pdf). The refractive status of the eye was assessed objectively by non-cycloplegic refraction. Three measurements of sphere and cylinder were obtained, and averaged. Spherical equivalent (SphEq) was computed as the sphere measurement plus half the cylinder measurement. In this study, myopia was defined as a SphEq value of -1.0 diopter or less in the worse eye.[4]

Race/ethnicity

Race/ethnicity was included in this study as reported in the NHANES survey and organized into 5 categories: non-Hispanic white, Mexican American, non-Hispanic black, other Hispanic, and other race.

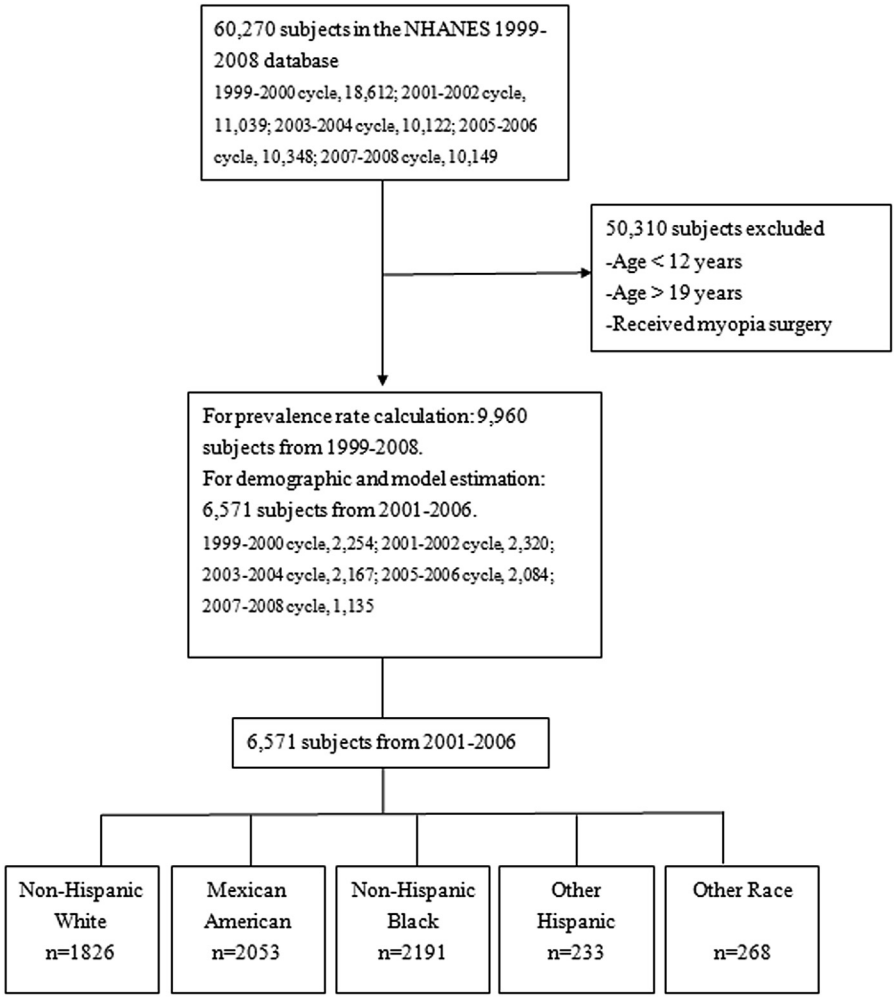

Figure 1 The flow diagram for inclusion and exclusion of participants.

Demographic and medical data

Subject sex, age, education level (elementary, junior, senior, senior graduate), and poverty income ratio (ratio of family income to poverty threshold) were obtained from the NHANES database. Diabetes was defined as a self-report of have been told by a doctor or health professional that the individual had diabetes or sugar diabetes, or the individual was taking an anti-diabetic medication. Those who responded "yes" were classified as having diabetes.

Physical activity

Information about hours of television or videos watched and hours of computer use per day over the past 30 days were obtained by the questions: "Over the past 30 days, on average about how many hours per day did you sit and watch TV or videos?" and "Over the past 30 days, on average about how many hours per day did you use a computer or play computer games?". Hours or television or video viewing were categorized as $\leq$ 1, 2, or $\geq$3, and hours of computer use were categorized as 0, 1, 2, and $\geq$3.

Environmental factors

Although the association of parental smoking and childhood myopia is inconsistent, information potential exposure to environmental tobacco smoke was included by the question "Does anyone who lives here (in your home) smoke cigarettes, cigars, or pipes anywhere inside this home?" A "yes" answer was defined as a household smoker.

Nutrition

Dietary intake was determined by an interviewer by asking the participant to recall all foods and beverages consumed during the 24-hour period prior to the interview (midnight to midnight). The interview files were imported into the University of Texas Food Intake Analysis System (FIAS) for coding. Dietary nutrient intake was calculated using the US Department of Agriculture (USDA) Nutrient Database. Detailed descriptions of the dietary interview methods are provided in the NHANES Dietary Interviewer's Training Manual. Daily dietary alpha-carotene (mcg), beta-cryptoxanthin (mcg), vitamin B2 (mg), and sugar intake (gm) was obtained from Total Nutrient Intakes files.

Serum vitamin A (retinol) was analyzed using an HPLC method performed at the CDC/NCEH in 2001–2002. In 2003–2004, serum vitamin A was analyzed using a comparable HPLC method at Craft Technologies, Inc. Detailed descriptions of blood collection and processing procedures are provided in the NHANES Laboratory/Medical Technologists Procedures Manual or NHANES website. Serum 25-hydroxy vitamin D (nmol/L) was measured at the National Center for Environmental Health, CDC, Atlanta, GA using the DiaSorin RIA kit (Stillwater, MN, USA) from 2001 to 2006. However, from 2007 to 2010 liquid chromatography-tandem mass spectrometry (LC-MS/MS) was used. NHANES 2001–2006 data were converted by regression analysis to equivalent 25-hydroxy vitamin D measurements from a standardized LC-MS/MS method. We used the LC-MS/MS-equivalent data for the present study, which is highly recommended by the National Center for Health Statistics (NCHS) (https://wwwn.cdc.gov/nchs/nhanes/VitaminD/AnalyticalNote.aspx).

Statistical analysis

Categorical variables were presented as unweighted counts and weighted percentage (%), with Rao-Scott χ^2-test performed to evaluate differences between races. Continuous variables were presented as weighted means and 95% confidence intervals (95% CIs), with Wald's F-test of analysis of variance performed to examine differences between races. Univariate and multivariate logistic regression analysis taking into account the parameters of complex survey design (i.e., stratification, primary sampling units, and sample weights [for 1999–2008: 2/5*WTMEC4YR {4-year MEC exam weight} for 1999–2002, and 1/5 * WTMEC2YR {2-year MEC exam weight} for 2003–2008; for 2001–2006: 1/3 * WTMEC2YR {2-year MEC exam weight}] was performed to investigate which factors were associated with myopia. The NHANES analytical guidelines for 1999–2010 are available at http://www.cdc.gov/nchs/data/series/sr_02/sr02_161.pdf. Variables with a value of $P < 0.05$ in the univariate analysis were selected and evaluated by multivariate logistic regression models. All logistic regression models were performed according to racial groups separately.

SAS survey analysis procedures (SAS Institute Inc., Cary, NC, USA) were used for all statistical analyses, which account for unequal probability of selection and nonresponse of sample, in order to generate unbiased estimates with national representativeness. A 2-tailed value of $P < 0.05$ indicated statistical significance. The prevalence rate was evaluated by SAS survey analysis procedures according to the NHANES web tutorial (https://www.cdc.gov/nchs/tutorials/NHANES/NHANESAnalyses/DescriptiveStatistics/Task4b.htm). Prevalence rate figures were generated by SigmaPlot 10.0 (Systat Software Inc., San Jose, CA, USA).

Results

Prevalence of myopia by study period

The prevalence rate of myopia in different races during 1999–2007 was showed in Fig. 2. The prevalence of myopia in non-Hispanic white participants was maintained steady at around 30% from 1999 to 2007 (31.69%, 30.85%, 32.54%, 30.02% and 30.22%, respectively). The prevalence rate of myopia in Mexican American participants was slightly increasing along with years by 8% (1999–2007: 30.05%, 31.15%, 36.44%, 35.11% and 38.08%, respectively). The prevalence rates in non-Hispanic Blacks and other Hispanics increased from 2003 to 2004, but then declined from 2005 to 2006 (non-Hispanic Blacks: 1999–2007: 30.75%, 33.55%, 28.05%, 35.32% and 30.40%; other Hispanics: 1999–2007: 35.49%, 39.34%, 28.72%, 46.86% and 35.59%, respectively). The prevalence rates of myopia in the other non-categorized races was suddenly increased by 20% between 1999 and 2001, and then maintained steady from 2001 to 2007 (1999–2007: 30.34%, 46.09%, 41.45%, 40.74% and 45.28%, respectively). Overall, the prevalence rates of myopia in the other non-categorized races was the highest among groups.

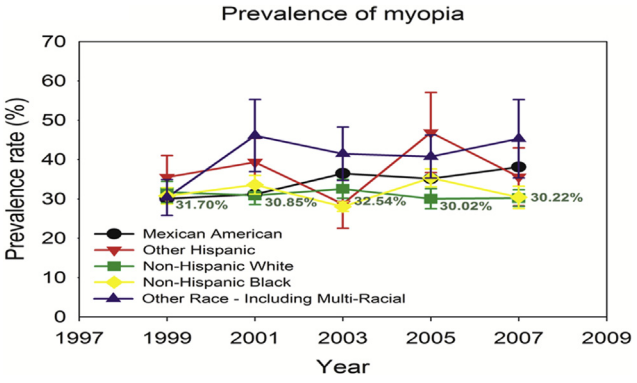

Figure 2 Prevalence rate of myopia in different races during 1999–2008.

Characteristics of study participants

Demographic and nutritional characteristics stratified by race are described in Table 1. The statistically significant differences between racial groups were observed in the presence of myopia, education level, family poverty income ratio, hours for television watched, hours of computer use, the occurrence of household smokers, the intake of nutrients (including vitamin B2, sugar, alpha-carotene, and beta-cryptoxanthin) as well as serum Vitamin A and D levels (all, $P < 0.05$).

Other race participants had the highest frequency of myopia (42.77%), followed by other Hispanic (38.43%), Mexican American (34.23%), non-Hispanic Black (32.26%), and non-Hispanic White (31.06%) (Table 2). Non-Hispanic whites had the highest mean family poverty income ratio (3.01 ± 0.08) and the highest percentage in senior graduate (17.33%). More than 50% of non-Hispanic black participants watched television for 3 hours or longer per day, which was higher than the other racial groups. The highest frequency of computer use for 3 hours or longer per day was the other race group (23.67%), followed by other Hispanic (15.90%), non-Hispanic White (15.50%), non-Hispanic Black (13.70%), and Mexican American (8.92%). The non-Hispanic Black group had highest frequency of household smokers (27.04%)

Table 1 Demographic and nutritional characteristics stratified by race (unweighted n = 6571, weighted n = 31,680,035).

	Total (n = 6571)	Non-Hispanic White (n = 1826)	Mexican American (n = 2053)	Non-Hispanic Black (n = 2191)	Other Hispanic (n = 233)	Other Race (n = 268)	P
Myopia							0.006*
Yes	2139 (32.67)	574 (31.06)	673 (34.23)	699 (32.26)	83 (38.43)	110 (42.77)	
Sex							0.803
Male	3307 (50.98)	911 (51.05)	1008 (51.65)	1138 (50.19)	115 (48.32)	135 (53.52)	
Female	3264 (49.02)	915 (48.95)	1045 (48.35)	1053 (49.81)	118 (51.68)	133 (46.48)	
Age (year)	15.39 ± 0.06	15.42 ± 0.07	15.29 ± 0.06	15.42 ± 0.09	15.26 ± 0.16	15.28 ± 0.18	0.296
Education (grade)							0.006*
Elementary	324 (4.82)	70 (4.12)	94 (5.02)	131 (6.23)	19 (9.87)	10 (3.9)	
Junior	2495 (39.02)	665 (38.14)	807 (43.0)	833 (39.67)	79 (38.48)	111 (40.16)	
Senior	2679 (40.42)	738 (40.41)	841 (40.85)	896 (39.89)	101 (40.52)	103 (40.86)	
Senior graduate	938 (15.74)	335 (17.33)	231 (11.13)	304 (14.21)	24 (11.14)	44 (15.09)	
Family poverty income ratio	2.6 ± 0.06	3.01 ± 0.08	1.78 ± 0.06	1.78 ± 0.08	1.96 ± 0.14	2.38 ± 0.18	<0.001*
Diabetes							0.728
Yes	50 (0.72)	14 (0.74)	15 (0.73)	18 (0.91)	1 (0.46)	2 (0.26)	
Hours television watched							<0.001*
≤1	1740 (38.62)	612 (42.20)	537 (33.39)	450 (25.45)	57 (38.74)	84 (42.62)	
2	1289 (25.33)	382 (26.61)	436 (26.85)	386 (21.48)	37 (18.57)	48 (24.05)	
≥3	2230 (36.04)	455 (31.19)	666 (39.76)	949 (53.07)	79 (42.69)	81 (33.33)	
Hours of computer use							<0.001*
0	1212 (17.91)	223 (14.79)	495 (29.58)	428 (23.94)	42 (22.59)	24 (10.11)	
1	2602 (51.00)	753 (52.58)	819 (50.03)	843 (47.50)	84 (49.96)	103 (44.93)	
2	759 (16.11)	249 (17.13)	184 (11.48)	266 (14.86)	19 (11.56)	41 (21.28)	
≥3	688 (14.98)	224 (15.50)	142 (8.92)	249 (13.70)	28 (15.90)	45 (23.67)	
Household smoker							<0.001*
No	5156 (78.14)	1351 (75.99)	1838 (90.24)	1565 (72.96)	187 (84.43)	215 (85.48)	
Yes	1340 (21.86)	459 (24.01)	189 (9.76)	601 (27.04)	40 (15.57)	51 (14.52)	
Vitamin B2 (mg)	2.25 ± 0.03	2.39 ± 0.05	2.12 ± 0.03	1.95 ± 0.03	2.12 ± 0.09	1.82 ± 0.08	<0.001*
Sugars intake (gm)	159.18 ± 1.57	164.53 ± 2.39	149.75 ± 2.05	154.43 ± 2.6	148.8 ± 6.13	139.74 ± 6.69	<0.001*
Alpha-carotene (mcg)	223.76 ± 16.49	239.82 ± 24.87	248.2 ± 18.62	145.26 ± 13.24	231.87 ± 52.78	188.06 ± 36.9	<0.001*
Beta-cryptoxanthin (mcg)	139.26 ± 5.9	133.09 ± 8.17	160.43 ± 8.05	134.58 ± 6.66	209.39 ± 26.16	112.26 ± 17	0.004*
Serum Vitamin A (umol/L)	1.68 ± 0.01	1.75 ± 0.02	1.61 ± 0.02	1.47 ± 0.01	1.66 ± 0.04	1.62 ± 0.02	<0.001*
Serum Vitamin D (nmol/L)	63.06 ± 0.95	71.08 ± 0.93	53.88 ± 0.97	41.24 ± 0.9	58.15 ± 1.65	52.74 ± 2.36	<0.001*

Continuous variables were shown mean ± standard error; categorical variables were shown unweighted count (weighted %).
*P < 0.05, significantly different between different race groups.

Table 2 Univariate analysis of the associations between myopia and possible risk factors.

	Total	Non-Hispanic White	Mexican American	Non-Hispanic Black	Other Hispanic	Other Race
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Gender						
Male	0.9 (0.76−1.05)	0.91 (0.73−1.13)	0.97 (0.78−1.2)	0.89 (0.73−1.09)	0.53 (0.29−0.98)*	1.09 (0.7−1.71)
Household smoker						
Yes	0.73 (0.62−0.86)***	0.75 (0.57−0.97)*	0.94 (0.67−1.32)	0.8 (0.67−0.96)*	0.56 (0.27−1.16)	0.61 (0.26−1.44)
Diabetes						
Yes	1.6 (0.1−25.21)	1.47 (0.4−5.38)	0.89 (0.27−2.96)	0.88 (0.34−2.28)		
Age (year)	1.05 (1.02−1.09)*	1.08 (1.03−1.13)**	0.99 (0.95−1.04)	1.02 (0.98−1.07)	0.99 (0.84−1.16)	1.12 (0.97−1.29)
Education (grade)						
Elementary	ref	ref	ref	ref	ref	ref
Junior	1.48 (1.002−2.17)*	1.65 (0.94−2.89)	1.49 (0.84−2.66)	1.49 (1−2.22)*	1.57 (0.4−6.15)	0.9 (0.18−4.39)
Senior	1.57 (1.06−2.32)*	1.83 (1.03−3.27)*	1.49 (0.8−2.78)	1.45 (0.98−2.16)	1.55 (0.33−7.16)	0.96 (0.18−5.05)
Senior graduate	2.09 (1.43−3.07)***	2.49 (1.39−4.45)**	1.6 (0.8−3.2)	1.7 (1.04−2.78)*	0.93 (0.17−5.1)	4.26 (0.8−22.63)
Family poverty income ratio	1.04 (0.99−1.1)	1.04 (0.96−1.12)	1.11 (1.01−1.22)*	1.11 (1.02−1.22)*	1.35 (1.13−1.62)**	1.01 (0.8−1.27)
Hours television watched						
≤1	ref	ref	ref	ref	ref	ref
2	1.31 (1.07−1.61)**	1.26 (0.96−1.66)	1.39 (1.04−1.85)*	1.18 (0.9−1.55)	2.31 (0.83−6.45)	1.85 (0.63−5.55)
≥3	1.04 (0.85−1.27)	0.90 (0.71−1.14)	1.26 (0.93−1.72)	1.48 (1.14−1.92)**	0.87 (0.32−2.33)	1.26 (0.58−2.72)
Hours of computer use						
0	ref	ref	ref	ref	ref	ref
1	1.44 (1.18−1.75)***	1.7 (1.26−2.31)***	1.06 (0.78−1.43)	1.09 (0.77−1.54)	1.48 (0.6−3.66)	2.47 (0.87−7.03)
2	1.36 (1.07−1.73)*	1.54 (1.04−2.28)*	1.24 (0.89−1.73)	1.34 (0.94−1.92)	1.68 (0.44−6.4)	1.36 (0.4−4.7)
≥3	1.49 (1.18−1.87)***	1.59 (1.09−2.32)*	1.31 (0.89−1.91)	1.88 (1.27−2.76)**	0.92 (0.35−2.45)	2.27 (0.76−6.74)
Serum Vitamin A (umol/L)	1.16 (0.95−1.41)	1.22 (0.92−1.61)	1.15 (0.9−1.49)	1.28 (0.95−1.72)	0.87 (0.39−1.92)	1.61 (0.72−3.61)
Serum Vitamin D (nmol/L)	0.998 (0.994−1.001)	1.001 (0.997−1.01)	0.99 (0.98−1.001)	0.992 (0.985−0.999)*	0.98 (0.96−1.01)	0.99 (0.97−1.01)
Vitamin B2	1.03 (0.98−1.09)	1.06 (0.98−1.14)	1.01 (0.93−1.09)	1.003 (0.94−1.07)	0.996 (0.77−1.3)	0.91 (0.72−1.16)
Sugar intake	0.99999 (0.9995−1.0005)	1.0006 (0.9998−1.001)	0.9992 (0.998−1.0001)	1.0005 (0.9995−1.001)	0.9976 (0.995−1.0002)	0.997 (0.994−0.9997)*
Alpha-carotene	0.99996 (0.9999−1.00003)	0.9999 (0.9998−1.00005)	1.00001 (0.9999−1.0001)	0.99999 (0.9999−1.0001)	1.0002 (0.9997−1.0008)	0.9995 (0.999−1.0002)
Beta-cryptoxanthin	1.0001 (0.9999−1.0003)	1.0001 (0.9998−1.0004)	0.9998 (0.9995−1.0001)	1.0003 (0.9999−1.0006)	0.9997 (0.999−1.0004)	1.0005 (0.999−1.002)
Race						
Non-Hispanic White	ref					
Mexican American	1.15 (0.97−1.38)					
Other Hispanic	1.38 (0.93−2.06)					
Non-Hispanic Black	1.06 (0.88−1.27)					
Other Race	1.66 (1.17−2.35)**					

CI, confidence interval; OR, odds ratio.

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, significantly associated with myopia.

Since only 1 subject in the other Hispanic group and 2 participants in the other race group had diabetes, diabetes was not included in model for these 2 race groups.

than other racial groups. The mean of serum Vitamin A and D levels, as well as the intake of vitamin B2 and sugar were higher in non-Hispanic white group compared to other racial groups. Mexican Americans had the highest alpha-carotene intake, and other-Hispanics consumed the greatest amount of beta-cryptoxanthin.

Risk factors associated with myopia in the whole study population

Univariate analyses were performed to evaluate the association between prevalence of myopia and different risk factors in the whole study population (Table 2). Results suggested that household smoker, age, education, hours of television watched, hours of computer use, and race were significantly associated with myopia. Age, junior education and above levels, 2 hours of television watched, 1 to $\geq$3 hr of computer use, and other race had higher odds in association with the presence of myopia. However, the presence of household smoker had significantly lower odds in the association with myopia.

After adjustment of confounding variables that were significant in the corresponding univariate analysis, multivariate logistic regression analyses revealed that household smoker, education, hours of television watched, hours of computer use, and race were significantly associated with myopia in the whole population (Table 3). Senior graduate (OR = 1.79, 95%CI: 1.01—3.18), 2 hours of television watched (OR = 1.27, 95%CI: 1.02—1.59), 1 hr of computer use (OR = 1.27, 95%CI: 1.02—1.57), Mexican American (OR = 1.28, 95%CI: 1.01—1.62) and other Hispanic (OR = 1.79, 95%CI: 1.10—2.92) had higher odds in association with the presence of myopia. However, the presence of household smoker (OR = 0.79, 95%CI: 0.66—0.97) had significantly lower odds in the association with myopia.

Risk factors associated with myopia stratified by racial groups

As shown in Table 2, the Results of univariate analyses suggested that household smoker, age, senior and senior graduate, hours of computer use were significantly associated with myopia in Non- Hispanic White group. In Mexican American group, only family poverty income ratio and hours of computer use had significantly higher odds in association with myopia. In Non-Hispanic Blacks group, household smoker, junior and senior graduate, with $\geq$3 hours of television watched, with $\geq$3 hours of computer use, and serum vitamin D level had significant association with myopia. Both gender and family poverty income ratio in the other Hispanic group had significantly greater odds in having myopia. Only sugar intake in the other race group had significantly higher odds in having myopia.

Furthermore, multivariate logistic regression was performed to evaluate the association between prevalence of myopia and various racial groups after adjusting for confounding variables that were significant in the corresponding univariate analyses (Table 3). The non-Hispanic White group with 1 hour of computer use had significantly higher odds of having myopia (OR = 1.48, 95% CI: 1.04—2.10). In the Mexican American group, participants with a higher family poverty income ratio had significantly higher odds of having myopia (OR = 1.12, 95% CI: 1.03—1.23), and those with 2 hours of television time had a higher odds of myopia (OR = 1.42, 95% CI: 1.04—1.96) (Table 3). In the Other Hispanic group, a higher family poverty income ratio was associated with higher odds of having myopia (OR = 1.41, 95% CI: 1.10—1.81). However, males had a lower odds of having myopia (OR = 0.38, 95% CI: 0.21—0.69) and higher sugar intake was associated with a lower odds of having myopia (OR = 0.99, 95% CI: 0.99—1.00) (Table 3).

Discussion

This study used a United States national database to examine the prevalence and risk factors of myopia based on race/ethnicity. Overall, the presence of household smokers was associated with a decreased risk of myopia, while higher education level, greater hours of television watching, and greater hours of computer use were associated with increased risk of myopia. The odds of myopia development were the highest in other races and followed by other Hispanic and Mexican Americans groups. When stratified by race, a greater number of hours of computer use was associated with risk of myopia in Whites. In Mexican Americans, a higher family poverty income ratio and 2 hours of watching television were associated with increased risk of myopia. In the other Hispanic group, a high family poverty income ratio was associated with increased risk of having myopia, while being male and having a higher sugar intake were associated with a lower risk of having myopia.

Genetic and cultural factors might be the most common factors among several possible explanations for our findings related to the race/ethnicity disparities in the prevalence of myopia. Several family-based studies had shown there was a high heritability of high myopia suggesting a definite genetic basis for high myopia. More than 25 candidate genes of high myopia have been reported.[18] For examples, the insulin-like growth factor 1 polymorphism has been reported to be a candidate genetic risk factor for high myopia in Chinese and Japanese.[18,19] Hepatocyte growth factor and hepatocyte growth factor receptor genes have a strong association with the myopia in Asians.[20] Another explanation for the racial disparities may be income. It is likely that many low-income participants were unable to afford the recommended glasses or contact lenses after the ophthalmic evaluation. A study based on 2008 NHIS database reported the higher rates of being unable to afford eyeglasses when needed among participants of Hispanic (26.7%) race/ethnicity than in non-Hispanic black (15.3%) and non-Hispanic white (16.0%) race/ethnicity.[21]

Myopia has become a worldwide health problem, and identification of factors, particularly modifiable factors, associated with the development of myopia has the potential to reduce the prevalence and burden on healthcare systems. A number of factors have been associated with the development of myopia and some of these factors were also identified by this study. Risk factors associated with myopia had been reported included higher socioeconomic background, shorter distance between computer screen or book when reading, hours of computer use per day, watching television and hours of outdoor activity.[11,14,22,23] A study

Table 3 Multivariate logistic regression analysis evaluating the association between myopia and race after adjusting for confounding variables.

	Total	Non-Hispanic White	Mexican American	Non-Hispanic Black	Other Hispanic	Other Race
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Gender						
Male	0.89 (0.74−1.08)	0.93 (0.71−1.21)	1.01 (0.77−1.32)	0.86 (0.66−1.01)	0.38 (0.21−0.69)**	1.22 (0.52−2.87)
Household smoker						
Yes	0.79 (0.66−0.97)*	0.74 (0.55−1.01)	0.92 (0.63−1.34)	0.81 (0.63−1.05)	1.16 (0.39−3.45)	0.99 (0.35−2.84)
Age (year)	1.03 (0.95−1.12)	1.07 (0.94−1.22)	0.93 (0.87−1.01)	1.01 (0.92−1.10)	0.95 (0.65−1.38)	0.87 (0.59−1.29)
Education (grade)						
Elementary	Ref	ref	ref	ref	ref	ref
Junior	1.32 (0.87−2.00)	1.53 (0.94−1.22)	1.37 (0.70−2.68)	1.31 (0.76−2.26)	0.71 (0.17−2.86)	0.89 (0.15−5.54)
Senior	1.24 (0.74−2.09)	1.24 (0.54−2.86)	1.88 (0.92−3.85)	1.19 (0.60−2.36)	0.87 (0.09−7.87)	1.48 (0.09−25.53)
Senior graduate	1.79 (1.01−3.18)*	1.55 (0.58−4.09)	2.01 (0.86−4.74)	1.62 (0.72−3.63)	1.04 (0.06−19.22)	19.53 (0.69−555.25)
Family poverty income ratio	1.02 (0.96−1.08)	0.94 (0.86−1.03)	1.12 (1.03−1.23)*	1.10 (0.99−1.22)	1.41 (1.10−1.81)**	1.11 (0.82−1.59)
Hours television watched						
≤1	ref	ref	ref	ref	ref	ref
2	1.27 (1.02−1.59)*	1.22 (0.90−1.64)	1.42 (1.04−1.96)*	1.06 (0.78−1.43)	1.94 (0.65−5.77)	2.00 (0.65−6.18)
≥3	1.05 (0.87−1.27)	0.97 (0.74−1.26)	1.32 (0.96−1.81)	1.31 (0.99−1.74)	0.99 (0.31−2.64)	1.31 (0.56−3.05)
Hours of computer use						
0	ref	ref	ref	ref	ref	ref
1	1.27 (1.02−1.57)*	1.48 (1.04−2.10)*	0.96 (0.73−1.27)	0.98 (0.70−1.37)	1.12 (0.51−2.49)	1.69 (0.45−6.39)
2	1.23 (0.96−1.59)	1.36 (0.93−1.97)	1.10 (0.78−1.54)	1.14 (0.78−1.66)	1.19 (0.27−5.34)	1.22 (0.26−5.74)
≥3	1.25 (0.96−1.63)	1.34 (0.87−2.05)	1.05 (0.65−1.69)	1.42 (0.95−2.12)	0.65 (0.21−2.02)	1.39 (0.41−4.77)
Serum Vitamin D (nmol/L)	1.00 (0.99−1.01)	1.00 (0.99−1.01)	0.99 (0.98−1.00)	0.99 (0.99−1.00)	0.98 (0.96−1.01)	0.99 (0.98−1.02)
Sugar intake	1.00 (1.00−1.00)	1.00 (1.00−1.00)*	0.99 (0.99−1.00)	1.00 (0.99−1.00)	0.99 (0.99−1.00)*	1.00 (0.09−1.01)
Race						
Non-Hispanic White	ref					
Mexican American	1.28 (1.01−1.62)*					
Other Hispanic	1.79 (1.10−2.92)*					
Non-Hispanic Black	1.10 (0.85−1.43)					
Other Race	1.48 (0.99−2.23)					

CI, confidence interval; OR, odds ratio.
*P < 0.05, **P < 0.01, ***P < 0.001, significantly associated with myopia.

reported by Qiu et al. suggested that Mexican American and non-Hispanic black race/ethnicities were the highest risk for myopia associated with their socioeconomic strata. Low annual household income and low education level may prevent adults from accessing and maintaining routine eye care for their children.[24] Reading and exposure to artificial light during childhood are environmental factors that increase the risk for the occurrence and development of myopia. It was established that better educational level is a possible risk factor for myopia with students.[25] A study in Poland had found that writing, reading, and working on a computer leads to a higher prevalence of myopia; however, watching television does not influence the prevalence of myopia.[26] Kinge et al. also suggested that watching TV has no impact on myopia progression.[27] For environmental protecting factors, studies have shown that increased outdoor time has a protective effect against the development of myopia.[22,28,29]

We found there was no association between nutrition and myopia in our study, except for sugar intake was associated with myopia in the non-Hispanic white and other race group. The energy intake, protein, fat, vitamins B1, B2 and C, phosphorus, iron, and cholesterol has been reported to have an association with myopia.[30] In addition, many studies have suggested a strong association between vitamin D levels and myopia. Teen and young adults with myopia had lower average vitamin D levels had been reported.[31] A study of the Korea NHANES (KNHANES) found that myopia development was associated with low serum vitamin D level after adjustment for confounding factors such as residence, parental income, total energy intake, dietary calcium intake, and smoking experience.[17]

The current study found an unusual inverse relation between myopia and household tobacco smoke exposure; increased exposure to tobacco smoke appeared to have a protective effect against the development of myopia. This finding is consistent with the results of the Strabismus, Amblyopia, and Refractive errors in Singaporean children (STARS) study.[32] The STARS study reported that maternal history of ever smoking, smoking during a child's life, and smoking during pregnancy were associated with a decreased OR of developing childhood myopia (OR = 0.05, 0.39, 0.30, respectively). Paternal history of smoking was also associated with a decreased odds of childhood myopia (OR = 0.72). The authors concluded that the results suggest that study of the role of nicotinic acetylcholine receptor pharmacology with respect to ocular development is necessary to understand the findings. However, some studies had found that there was no consistent evidence of association between secondhand smoking and myopia.[16]

We did not examine sleep duration in the current study. Prior study, however, has found an inverse relation between sleep duration and myopia. An analysis of the KNHANES database by Jee et al.[33] found the adjusted OR for myopia was decreased in subjects 12–19 years of age with >9 hours of sleep per night (OR = 0.59, 95% CI: 0.38–0.93, P for trend = 0.006) as compared with those with <5 hours of sleep. No association, however, was found between high myopia and sleep duration. As in this study, prior studies have reported associations between education level and income level and myopia.[34,35]

There are several limitations of this study. We utilized a survey database that was representative of the population of the United States, and hence the findings are likely generalizable to the overall United States population. The study was cross-sectional rather than longitudinal in design, and thus causality cannot be established. The presence of diabetes, a household smoker, and sedentary behavior (hours watching television or using a computer) were determined by patient self-report, and thus subject to potential error. Non-cycloplegic autorefractor for myopia assessment may not be very accurate since the effect of accommodation in adolescents was not excluded. The use of cycloplegic medication was also not specified in NHANES database before refracting the subjects. These might lead to classification bias in this study. Finally, some important factors such as parental myopia were not analyzed which may lead to some residual confounding.

Conclusions

This study confirmed the results of other studies of potentially modifiable risk factors for the development of myopia. Importantly, the results showed that risk factors varied by race/ethnicity. We believe the main reasons for the different results of this study and other prior studies are that different populations (race/ethnicity) were studies. Different races and ethnicities have different cultural norms and habits, which contributes to varied findings. These findings may help to tailor public health strategies for reduction of myopia by targeting risk factors based on race/ethnicity.

Conflicts of interest

All authors declare no conflicts of interest.

References

1. Warner N. Update on myopia. *Curr Opin Ophthalmol* 2016;**27**:402–6.
2. Williams KM, Bertelsen G, Cumberland P, Wolfram C, Verhoeven VJ, Anastasopoulos E, et al. Increasing prevalence of myopia in europe and the impact of education. *Ophthalmology* 2015;**122**:1489–97.
3. Vitale S, Sperduto RD, Ferris 3rd FL. Increased prevalence of myopia in the United States between 1971–1972 and 1999–2004. *Arch Ophthalmol* 2009;**127**:1632–9.
4. Vitale S, Ellwein L, Cotch MF, Ferris 3rd FL, Sperduto R. Prevalence of refractive error in the United States, 1999–2004. *Arch Ophthalmol* 2008;**126**:1111–9.
5. Holden BA, Fricke TR, Wilson DA, Jong M, Naidoo KS, Sankaridurg P, et al. Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050. *Ophthalmology* 2016;**123**:1036–42.
6. Pan CW, Dirani M, Cheng CY, Wong TY, Saw SM. The age-specific prevalence of myopia in Asia: a meta-analysis. *Optom Vis Sci* 2015;**92**:258–66.
7. Ding BY, Shih YF, Lin LLK, Hsiao CK, Wang IJ. Myopia among schoolchildren in East Asia and Singapore. *Surv Ophthalmol* 2017;**62**:677–97.

8. Smith MJ, Walline JJ. Controlling myopia progression in children and adolescents. *Adolesc Health Med Ther* 2015;**6**:133—40.
9. Verkicharla PK, Ohno-Matsui K, Saw SM. Current and predicted demographics of high myopia and an update of its associated pathological changes. *Ophthalmic Physiol Optic* 2015;**35**:465—75.
10. Galvis V, Lopez-Jaramillo P, Tello A, Castellanos-Castellanos YA, Camacho PA, Cohen DD, et al. Is myopia another clinical manifestation of insulin resistance? *Med Hypotheses* 2016;**90**:32—40.
11. Fernandez-Montero A, Olmo-Jimenez JM, Olmo N, Bes-Rastrollo M, Moreno-Galarraga L, Moreno-Montanes J, et al. The impact of computer use in myopia progression: a cohort study in Spain. *Prev Med* 2015;**71**:67—71.
12. Sherwin JC, Reacher MH, Keogh RH, Khawaja AP, Mackey DA, Foster PJ. The association between time spent outdoors and myopia in children and adolescents: a systematic review and meta-analysis. *Ophthalmology* 2012;**119**:2141—51.
13. You X, Wang L, Tan H, He X, Qu X, Shi H, et al. Near Work related behaviors associated with myopic shifts among primary school students in the Jiading District of Shanghai: a school-based one-year cohort study. *PLoS One* 2016;**11**:e0154671.
14. Zhou J, Ma Y, Ma J, Zou Z, Meng X, Tao F, et al. Prevalence of myopia and influencing factors among primary and middle school students in 6 provinces of China. *Zhonghua Liu Xing Bing Xue Za Zhi* 2016;**37**:29—34.
15. Au Eong KG, Tay TH, Lim MK. Race, culture and myopia in 110,236 young Singaporean males. *Singap Med J* 1993;**34**:29—32.
16. Saw SM, Chia KS, Lindstrom JM, Tan DT, Stone RA. Childhood myopia and parental smoking. *Br J Ophthalmol* 2004;**88**:934—7.
17. Choi JA, Han K, Park YM, La TY. Low serum 25-hydroxyvitamin D is associated with myopia in Korean adolescents. *Investig Ophthalmol Vis Sci* 2014;**55**:2041—7.
18. Zhang D, Zeng G, Hu J, McCormick K, Shi Y, Gong B. Association of IGF1 polymorphism rs6214 with high myopia: a systematic review and meta-analysis. *Ophthalmic Genet* 2017;**38**:434—9.
19. Yoshida M, Meguro A, Yoshino A, Nomura N, Okada E, Mizuki N. Association study of IGF1 polymorphisms with susceptibility to high myopia in a Japanese population. *Clin Ophthalmol* 2013;**7**:2057—62.
20. Yanovitch T, Li YJ, Metlapally R, Abbott D, Viet KN, Young TL. Hepatocyte growth factor and myopia: genetic association analyses in a Caucasian population. *Mol Vis* 2009;**15**:1028—35.
21. Zhang X, Cotch MF, Ryskulova A, Primo SA, Nair P, Chou CF, 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**. S53-62 e1.
22. Ramamurthy D, Lin Chua SY, Saw SM. A review of environmental risk factors for myopia during early life, childhood and adolescence. *Clin Exp Optom* 2015;**98**:497—506.
23. You QS, Wu LJ, Duan JL, Luo YX, Liu LJ, Li X, et al. Factors associated with myopia in school children in China: the Beijing childhood eye study. *PLoS One* 2012;**7**:e52668.
24. Qiu M, Wang SY, Singh K, Lin SC. Racial disparities in uncorrected and undercorrected refractive error in the United States. *Investig Ophthalmol Vis Sci* 2014;**55**:6996—7005.
25. Muhamedagic L, Muhamedagic B, Halilovic EA, Halimic JA, Stankovic A, Muracevic B. Relation between near work and myopia progression in student population. *Mater Sociomed* 2014;**26**:100—3.
26. Czepita M, Czepita D, Lubinski W. The influence of environmental factors on the prevalence of myopia in Poland. *J Ophthalmol* 2017;**2017**. 5983406.
27. Kinge B, Midelfart A, Jacobsen G, Rystad J. The influence of near-work on development of myopia among university students. A three-year longitudinal study among engineering students in Norway. *Acta Ophthalmol Scand* 2000;**78**:26—9.
28. He M, Xiang F, Zeng Y, Mai J, Chen Q, Zhang J, et al. Effect of time spent outdoors at school on the development of myopia among children in China: a randomized clinical trial. *JAMA* 2015;**314**:1142—8.
29. French AN, Ashby RS, Morgan IG, Rose KA. Time outdoors and the prevention of myopia. *Exp Eye Res* 2013;**114**:58—68.
30. Edwards MH. Do variations in normal nutrition play a role in the development of myopia? *Optom Vis Sci* 1996;**73**:638—43.
31. Mutti DO, Marks AR. Blood levels of vitamin D in teens and young adults with myopia. *Optom Vis Sci* 2011;**88**:377—82.
32. Iyer JV, Low WC, Dirani M, Saw SM. Parental smoking and childhood refractive error: the STARS study. *Eye (Lond)* 2012;**26**:1324—8.
33. Jee D, Morgan IG, Kim EC. Inverse relationship between sleep duration and myopia. *Acta Ophthalmol* 2016;**94**:e204—10.
34. Lim HT, Yoon JS, Hwang SS, Lee SY. Prevalence and associated sociodemographic factors of myopia in Korean children: the 2005 third Korea national health and nutrition examination survey (KNHANES III). *Jpn J Ophthalmol* 2012;**56**:76—81.
35. Wu HM, Seet B, Yap EP, Saw SM, Lim TH, Chia KS. Does education explain ethnic differences in myopia prevalence? A population-based study of young adult males in Singapore. *Optom Vis Sci* 2001;**78**:234—9.