• Investigation •

Frequency of presenting visual acuity and visual impairment in Chinese college students

Jia-Min Cai, Ye Ye, Ping Liang, Tong Zhang, Jian-Hui Zheng, Jiao Wang, Jun Zhao

School of Ophthalmology & Optometry Affiliated to Shenzhen University, Shenzhen Eye Hospital, Shenzhen 518040, Guangdong Province, China

Co-first authors: Jia-Min Cai and Ye Ye

Correspondence to: Jun Zhao. Shenzhen Eye Hospital, Ze Tian Road #18, Shenzhen 518040, Guangdong Province, China. doctorzhaojun@163.com

Received: 2020-03-28 Accepted: 2020-10-12

Abstract

● **AIM:** To obtain the baseline data on presenting visual acuity (PVA) and evaluate the prevalence and associated factors for visual impairment based on PVA in 9070 Chinese college students.

● **METHODS:** The freshmen at a university in southern China, including 6527 undergraduate students and 2543 graduate students, were investigated for some socio-demographic characteristics and underwent routine medical examination, including measuring PVA, height, and weight. Visual impairment was defined according to the new World Health Organization criteria for blindness and visual impairment.

● **RESULTS:** In 9070 college students, the mean PVA in the better eye was 0.094±0.163 logMAR. The prevalence of visual impairment based on PVA was 2.7%. Only 38.3% college students had normal visual acuity [PVA equal to 0 logMAR (20/20) in both eyes]. There were 69.8% of students wearing spectacles. Logistic regression showed that home region (non-Guangdong provinces, P<0.0001, OR=1.70) was risk factor for visual impairment while BMI (P=0.001, OR=0.92) was protective factor from visual impairment. Ethnicity (Han Chinese, P<0.0001, OR=3.17) was risk factor for wearing spectacles while age (P=0.01, OR=0.90) was protective factor from wearing spectacles.

● **CONCLUSION:** This study provides the baseline data on PVA and the prevalence of visual impairment in Chinese college students. Our analyses reveal that BMI and home region are associated factors for visual impairment based on PVA, while age and ethnicity are associated factors for wearing spectacles.

● **KEYWORDS:** presenting visual acuity; prevalence; visual impairment; China; college student

DOI:10.18240/ijo.2020.12.22

Citation: Cai JM, Ye Y, Liang P, Zhang T, Zheng JH, Wang J, Zhao J. Frequency of presenting visual acuity and visual impairment in Chinese college students. *Int J Ophthalmol* 2020;13(12):1990-1997

INTRODUCTION

The eye is an important sensory organ of the human body, and more than 80% of the information entering the brain is gained by visual system[1]. Visual impairment is a serious global public health problem. According to the latest estimates on distance vision by World Health Organization (WHO), 188 million people had mild visual impairment, 217 million people had moderate to severe visual impairment, and 36 million people were blind. More than 80% of visual impairment can be prevented or cured. Uncorrected refractive error is the main cause of moderate and severe visual impairment[2]. In 2003, WHO proposed the use of presenting visual acuity (PVA) for estimating visual impairment and blindness[3]. PVA is defined as the uncorrected visual acuity of those who do not wear corrective spectacles, or the corrected visual acuity of those who wear spectacles in their daily life. With the introduction of PVA by WHO and the implementation of new standards for blindness and visual impairment in various countries, there have been several studies to evaluate the prevalence of visual impairment in various populations using PVA in recent years[4-7]. The VISION 2020 Global Initiative emphasizes the priority of prevention and treatment of refractive error, and recommends all countries to collect data on the prevalence of visual impairment and its associated factors in order to provide scientific basis for further improvement of eye health[8]. However, only a few surveys on visual acuity have been conducted in Chinese college students in recent years. Moreover, the participants in most studies were examined for uncorrected visual acuity or best corrected visual acuity instead of PVA[9-11], which did not well represent the visual quality of students' daily life. Surveys on PVA can indirectly represent the screening status of visual impairment in a region, the intensity of efforts to popularize the knowledge and acceptance of wearing spectacles, and the level of medical services of ophthalmology. In the present study, we investigated the status of PVA and evaluated the prevalence and associated factors

for visual impairment based on PVA in 9070 Chinese first-year college students, hoping to provide the baseline data on PVA and new reference data for prevention and control of visual impairment as a real-world study.

The study was conducted in Guangdong Province, a coastal province in south China on the north shore of South China Sea. According to the data from the National Bureau of Statistics of China, Guangdong is the 4th largest sub-national economy in the world with a GDP size of 1.47 trillion US dollars in 2018. It has also developed rapidly in terms of medical treatment. Therefore, the Guangdong study was motivated by interest in obtaining data on PVA and factors associated with visual impairment in a large urban setting for comparison with that obtained from surveys in other region.

SUBJECTS AND METHODS

Ethical Approval This study followed the tenets of the Declaration of Helsinki and was approved by the Ethical Committee of Shenzhen Eye Hospital, China. The data used in this study were retrieved from electronic medical records of the study participants, and informed consent was waived.

Subjects This is a cross-sectional study on first-year college students admitted in fall 2018 at a university in southern China, who participated in the admission physical examination, including undergraduate students and graduate students. Taking into account the age gap between undergraduate and graduate students, the difference in their education level and understanding of eye care, we defined undergraduates as group I and graduates as group II for the comparisons in the following study. The student health information was de-identified by removing the identifiable individual information such as name and identity number.

Physical Examination Physical examination was performed at the university hospital for all the freshmen. Demographic information including gender, age, ethnicity, home region, and clinical information including PVA, height and weight, were collected. Students who didn't wear spectacles were examined for uncorrected visual acuity, and those who wore spectacles were examined for corrected visual acuity and inquired for their eyeglass prescriptions. The visual acuity examination was strictly performed in accordance with the standard operation guidelines[12]. Under the standard illumination conditions, the E-type standard logarithmic visual chart light box was used at 5 m of distance. Visual acuity was recorded at a decimal scale, and then converted to the logarithm of MAR (logMAR) for data analysis. According to the new WHO classification for blindness and visual impairment[3,13], PVA in the better eye was categorized into 4 groups: 1) mild or no visual impairment: PVA≤0.5 logMAR (20/63); 2) moderate visual impairment: 0.5 logMAR (20/63)<PVA≤1.0 logMAR (20/200); 3) severe visual impairment: 1.0 logMAR (20/200)<PVA≤1.3 logMAR (20/400); and 4) blindness: PVA>1.3 logMAR (20/400). The better eye was defined as the eye with superior vision on the visual acuity examination. Moderate and severe visual impairment were defined as low vision. Visual impairment included low vision and blindness. To facilitate the comparison of our results with those of other studies, the prevalence of visual impairment was calculated according to published evaluation criterion for visual impairment (PVA≥0.3 logMAR (20/40) in the better eye)[14-16]. Undercorrection was defined as abnormal corrected visual acuity in the better eye of students wearing their own spectacles [PVA equal to 0 logMAR (20/20)]. Height and body weight with bare feet and light clothing were measured using standardized methods to nearest 0.1 cm or 0.1 kg. The body mass index (BMI) was calculated by dividing body weight (kg) by height squared (m^2).

Statistical Analysis Statistical analysis was performed using the statistical software package (SPSS version 20.0, SPSS Inc., Chicago, IL, USA). Chi-square test or rank sum test was used to compare the PVA and wearing spectacles between undergraduate and graduate students. Logistic regression was used to evaluate the associated factors for visual impairment and wearing spectacles. Odds ratio (OR) and 95% confidence intervals (CIs) were calculated for each independent variables. *P* values of less than 0.05 were considered to indicate statistical significance.

RESULTS

Background Characteristics of the Study Subjects A total of 9070 first-year college students were investigated, including 6527 undergraduate students in group I and 2543 graduate students in group II. All students included 4792 (52.83%) males and 4278 (47.17%) females. The average age was 20.01±2.69y, ranging from 15 to 42y. There were 8843 (97.50%) students who were Han Chinese and 6009 (66.25%) students lived in Guangdong Province and the rest were from other provinces in China. The average BMI was 20.79±3.15 kg/m^2, ranging from 13.44 to 46.28 kg/m^2 (Table 1).

The group I included 3385 (51.86%) males and 3142 (48.14%) females. The average age was 18.58±0.68y, ranging from 15 to 23y. There were 6336 (97.07%) undergraduate students who were Han Chinese and 5033 (77.11%) undergraduate students lived in Guangdong Province and the rest were from other provinces in China. The average BMI was 20.60±3.15 kg/m^2, ranging from 13.44 to 45.55 kg/m^2. The group II included 1407 (55.33%) males and 1136 (44.67%) females. The average age was 25.68±2.46y, ranging from 18 to 42y. There were 2507 (98.58%) graduate students who were Han Chinese and 976 (38.38%) graduate students lived in Guangdong Province and the rest were from other provinces in China. The average BMI was 21.31±3.07 kg/m^2, ranging from 14.24 to 46.28 kg/m^2 (Table 1).

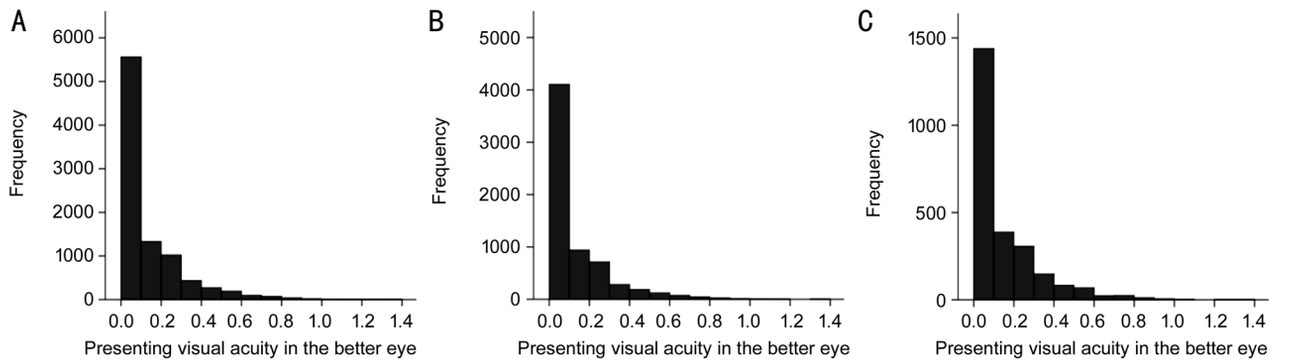

Figure 1 The distribution of PVA in 9070 students A: Overall students (*n*=9070): the mean PVA in the better eye was 0.094±0.163; B: Undergraduate students (*n*=6527): the mean PVA in the better eye was 0.089±0.159; C: Graduate students (*n*=2543): the mean PVA in the better eye was 0.107±0.173.

Table 1 Demographic information and prevalence of visual impairment and wearing spectacles in overall students, group I and group II

Parameters	Overall students			Group I			Group II		
	All (*n*)	Visual impairment, *n* (%)	Wearing spectacles, *n* (%)	All (*n*)	Visual impairment, *n* (%)	Wearing spectacles, *n* (%)	All (*n*)	Visual impairment, *n* (%)	Wearing spectacles, *n* (%)
No. of students	9070	249 (2.7)	6336 (69.8)	6527	174 (2.7)	4557 (69.8)	2543	75 (2.9)	1778 (69.9)
Age (y)	20.01±2.69			18.58±0.68			25.68±2.46		
Range	15-42			15 to 23			18 to 42		
Gender									
Male	4792	123 (2.5)	3308 (69.0)	3385	83 (2.5)	2327 (68.7)	1407	40 (2.8)	980 (69.7)
Female	4278	126 (2.9)	3028 (70.7)	3142	91 (2.9)	2230 (71.0)	1136	35 (3.1)	798 (70.3)
Ethnicity									
Han	8843	243 (2.7)	6232 (70.4)	6336	169 (2.7)	4477 (70.7)	2507	74 (3.0)	1754 (70.0)
Non-Han	227	6 (2.6)	104 (45.8)	191	5 (2.6)	80 (41. 9)	36	1 (2.8)	24 (66.7)
BMI (kg/m^2)	20.79±3.15			20.60±3.15			21.31±3.07		
Range	13.44-46.28			13.44-45.55			14.24-46.28		
Home region									
Guangdong Province	6009	139 (2.3)	4248 (70.6)	5033	122 (2.4)	3550 (70.5)	976	17 (1.7)	698 (71.5)
Non-Guangdong provinces	3061	110 (3.5)	2088 (68.2)	1494	52 (3.5)	1007 (67.4)	1567	58 (3.7)	1080 (68.9)

BMI: Body mass index.

PVA, Prevalence of Visual Impairment and Wearing Spectacles In overall college students, the mean PVA in the better eye was 0.094±0.163 (Figure 1A). There were 38.3% (*n*=3472) students who had PVA equal to 0 logMAR (20/20) in both eyes. There were 97.3% (*n*=8821) students without visual impairment, and 2.7% (*n*=249) students had visual impairment, including 2.6% (*n*=240) students with moderate visual impairment, 0.09% (*n*=8) students with severe visual impairment, and 0.01% blind student (*n*=1). A total of 69.8% (*n*=6335) students wore spectacles, and of them, 35.5% (*n*=2248) students were undercorrected (Table 2).

In group I, the mean PVA in the better eye was 0.089±0.159 (Figure 1B). There were 39.7% (*n*=2592) students who had PVA equal to 0 logMAR (20/20) in both eyes and it was significantly higher in males (42.7%) than females (36.4%; *P*<0.0001), while 23.2% (*n*=1512) students had PVA equal to 0 logMAR (20/20) in one eye only with no significant difference between male and female students (*P*=0.85). There were 97.3% (*n*=6353) students without visual impairment, and 2.7% (*n*=174) students had visual impairment, including 2.6% (*n*=169) students with moderate visual impairment, 0.06% (*n*=4) students with severe visual impairment, and 1 blind student (0.015%). A total of 69.8% (*n*=4557) students wore spectacles, and of them, 34.2% (*n*=1557) students were undercorrected (Table 2).

In group II, the mean PVA in the better eye was 0.107±0.173 (Figure 1C). There were 34.6% (*n*=880) students had PVA equal to 0 logMAR (20/20) in both eyes and it was significantly higher in males (36.6%) than females (32.1%; *P*<0.0001), while 22.7% (*n*=578) students had PVA equal to 0 logMAR (20/20) in one eye only and there was no remarkable gender difference (*P*=0.22). There were 97.1% (*n*=2468) students without visual impairment, and 2.9% (*n*=75) students had visual impairment, including 2.8% (*n*=71) students with moderate visual impairment, 0.16% (*n*=4) students with severe visual impairment, and no blind students. A total of 1778 (69.9%) students wore spectacles, and of them, 38.9% (*n*=691) students were undercorrected (Table 2).

Table 2 Comparison of PVA, visual impairment and wearing spectacles between group I and group II % (*n*)

Factor	Overall students	Group I	Group II	*P*
PVA≤0 logMAR (20/20) both eyes	38.3 (3472)	39.7 (2592)	34.6 (880)	<0.0001[a]
PVA≤0 logMAR (20/20) one eye only	23.0 (2090)	23.2 (1512)	22.7 (578)	0.66
PVA≤0.5 logMAR (20/63) (mild or no visual impairment)	97.3 (8821)	97.3 (6353)	97.1 (2468)	0.46
Low vison and blindness	2.7 (249)	2.7 (174)	2.9 (75)	0.46
0.5 logMAR (20/63)<PVA≤1.0 logMAR (20/200) (moderate visual impairment)	2.6 (240)	2.6 (169)	2.8 (71)	0.34
1.0 logMAR (20/200)<PVA≤1.3 logMAR (20/400) (severe visual impairment)	0.09 (8)	0.06 (4)	0.16 (4)	0.21
PVA>1.3 logMAR (20/400) (blindness)	0.01 (1)	0.015 (1)	0	0.40
PVA≥0.3 logMAR (20/40)	12.7 (1151)	11.8 (769)	15.0 (382)	<0.0001[a]
Wearing spectacles	69.8 (6335)	69.8 (4557)	69.9 (1778)	0.93
Undercorrection	35.5 (2248)	34.2 (1557)	38.9 (691)	<0.0001[a]

PVA: Presenting visual acuity. [a]*P*<0.05.

The mean PVA in the better eye of group I was significantly better than that of group II (0.089 *vs* 0.107; *P*<0.0001). The rate of PVA equal to 0 logMAR (20/20) in both eyes in group I was higher than that in group II (39.7% *vs* 34.6%; *P*<0.0001). The prevalence of visual impairment (PVA≥0.3 logMAR in the better eye) in group I was significantly lower than that in group II (11.8% *vs* 15.0%; *P*<0.0001). The rate of undercorrection in group I was significantly lower than that in group II (34.2% *vs* 38.9%; *P*<0.0001). There was no significant difference in the rate of PVA equal to 0 logMAR (20/20) in one eye only, mild or no visual impairment, low vision and blindness, wearing spectacles and between group I and group II (all *P*>0.05; Table 2).

Associated Factors for Visual Impairment and Wearing Spectacles In overall students, multivariate Logistic regression showed that home region (non-Guangdong provinces, *P*<0.0001, OR=1.70, 95%CI: 1.28-2.26) was risk factor for visual impairment while BMI (*P*=0.001, OR=0.92, 95%CI: 0.88-0.97) was protective factor from visual impairment. Ethnicity (Han Chinese, *P*<0.0001, OR=3.17, 95%CI: 2.04-3.53) was risk factor for wearing spectacles while age (*P*=0.01, OR=0.90, 95%CI: 0.93-0.99) was protective factor from wearing spectacles (Table 3).

In group I, multivariate Logistic regression showed that home region (non-Guangdong provinces, *P*=0.04, OR=1.25, 95%CI: 1.00-1.56) was risk factor for visual impairment while BMI (*P*<0.0001, OR=0.94, 95%CI: 0.91-0.97) was protective factor from visual impairment. Ethnicity (Han Chinese, *P*<0.0001, OR=3.17, 95%CI: 2.31-4.33) was risk factor for wearing spectacles while age (*P*=0.01, OR=0.90, 95%CI: 0.83-0.97) was protective factor from wearing spectacles (Table 3).

In group II, multivariate Logistic regression showed that home region (non-Guangdong provinces, *P*=0.007, OR=2.13, 95%CI: 1.23-3.71) was risk factor for visual impairment, while no factors were associated with wearing spectacles (*P*>0.05; Table 3).

DISCUSSION

For most of the previous studies focused on children or older adults, our findings provided supplemental information for the baseline data on PVA and the prevalence of visual impairment in Chinese college students. In this study, of the overall students examined, although 97.3% students didn't have visual impairment, only 3472 out of 9070 (38.3%) had normal visual acuity [PVA equal to 0 logMAR (20/20) in both eyes], while fewer students had normal visual acuity in the group II (34.6%) compared with group I (39.7%). The mean PVA in the better eye of group I was lower than that of group II (Figure 1), suggesting that undergraduate students had better PVA than graduate students. PVA is an important factor that affects the quality of vision, and the degree of vision diminution causes a considerable impact on the quality of life. Although visual impairment was defined as PVA worse than 0.5 logMAR (20/63) in the better eye by WHO, clinical experience points to the fact that students with mild or no visual impairment can experience symptomatic difficulties in reading at distance. Therefore, it should be considered to offer suitable diagnostic and therapeutic services or appropriate eye care services for college students to obtain good PVA.

In this study, the undercorrection rate in both group I and group II exceeded 30% (Table 2), which was higher than that in two previous studies of children wearing spectacles in China (26.1%[17] and 30%[18]). The remarkable undercorrection rate may be due to the failure to update eyeglass prescriptions in time or the poor quality of spectacles. Not only that, another study in China reported that 36.07% college students wore spectacles only when they needed in the specific circumstance[19]. Improper habits of wearing spectacles would

Table 3 Logistic regression of visual impairment and wearing spectacles in overall students, group I and group II

Parameters	Overall students				Group I				Group II			
	Visual impairment		Wearing spectacles		Visual impairment		Wearing spectacles		Visual impairment		Wearing spectacles	
	OR (95%CI)	*P*	OR (95%CI)	*P*	OR (95%CI)	*P*	OR (95%CI)	*P*	OR (95%CI)	*P*	OR (95%CI)	*P*
Age (y)	0.96 (0.87-1.07)	0.50	0.90 (0.93-0.99)	0.01[a]	1.05 (0.91-1.20)	0.51	0.90 (0.83-0.97)	0.01[a]	0.97 (0.82-1.07)	0.33	0.97 (0.94-1.01)	0.10
Gender												
M	1.00 (ref.)		1.00 (ref.)		1.00 (ref.)		1.00 (ref.)		1.00 (ref.)		1.00 (ref.)	
F	1.02 (0.79-1.31)	0.89	1.09 (0.99-1.20)	0.05	1.09 (0.90-1.32)	0.37	1.11 (0.99-1.24)	0.05	0.89 (0.55-1.46)	0.65	1.03 (0.86-1.24)	0.75
Ethnicity												
No-Han Chinese	1.00 (ref.)		1.00 (ref.)		1.00 (ref.)		1.00 (ref.)		1.00 (ref.)		1.00 (ref.)	
Han Chinese	1.35 (0.58-3.15)	0.48	3.17 (2.04-3.53)	<0.0001[a]	1.19 (0.66-2.13)	0.56	3.17 (2.31-4.33)	<0.0001[a]	1.21 (1.63-8.99)	0.85	1.13 (0.56-2.27)	0.74
BMI (kg/m^2)	0.92 (0.88-0.97)	0.001[a]	1.00 (0.99-1.02)	0.99	0.94 (0.91-0.97)	<0.0001[a]	0.99 (0.98-1.02)	0.87	0.97 (1.86-1.02)	0.14	0.99 (0.97-1.03)	1.00
Home region												
Guangdong Province	1.00 (ref.)		1.00 (ref.)		1.00 (ref.)		1.00 (ref.)		1.00 (ref.)		1.00 (ref.)	
Non-Guangdong Provinces	1.70 (1.28-2.26)	<0.0001[a]	0.94 (0.84-1.04)	0.22	1.25 (1.00-1.56)	0.04[a]	0.99 (0.87-1.14)	0.92	2.13 (1.23-3.71)	0.007[a]	0.86 (0.72-1.03)	0.10
Graduation					1.05 (0.91-1.20)	0.51	0.90 (0.83-0.97)	0.01[a]	0.97 (0.82-1.07)	0.33	0.97 (0.94-1.01)	0.10
Undergraduate	1.00 (ref.)		1.00 (ref.)									
Graduate	1.13 (0.62-2.07)	0.70	0.96 (0.93-1.99)	0.27								

OR: Odds ratio; CI: Confidence interval; ref.: Reference; BMI: Body mass index. [a]*P*<0.05.

lead to worse PVA of students; thus their daily activities can be affected to some extent. It has been reported that people with undercorrection were more likely to encounter difficulties in their daily life activities[20], and undercorrection might aggravate visual impairment[21-22]. Therefore, everyone with ametropia should be checked regularly so that appropriate spectacles can be fitted in time for better PVA.

Based on the WHO standards, most of the first-year undergraduate and graduate students in this study had mild or no visual impairment in their daily life, with only 2.7% and 3.0% visual impairment, respectively, which was a little lower than the prevalence of visual impairment in first-year undergraduate students at Tianjin Medical University from north China (3.2%)[19]. In previous studies among old adults (usually 40y and older), the rates of visual impairment were higher than our results, like the survey conducted in nine provinces in China (10.71%[23]) and the Iranian survey (6.43%[4]). In this study, according to the visual impairment defined as PVA ≥ 0.3 logMAR (20/40) in the better eye, the prevalence of visual impairment in group I was lower than that in group II (11.8% *vs* 15.0%; Table 2), which were higher than other studies of Chinese children in different regions (7.70%[14] and 10.3%[15]). These differences are probably due to the differences in age and region. In developed countries, visual acuity>0.3 logMAR (20/40) is the most common requirement for obtaining a driver's license, and studies have shown that the degree of visual impairment is related to the increase of social isolation[24-25]. The visual impairment information of young adults that was not much involved in previous studies was provided in the present study. Collectively, these findings suggest that the quality of daily life of Chinese undergraduate and graduate students should be concerned.

Generally, it was observed in previous studies among older adults (usually 40y and older) in China that gender and age were risk factors for visual impairment[9,26-27], while the Beijing Eye Study reported that visual impairment was not associated with gender[28]. In this study, Logistic regression analysis showed that gender and age were not associated with the prevalence of visual impairment in first-year college students (Table 3). For most of the previous studies focused on adults aged 40y and older, further studies are needed to determine whether gender and age are associated factors for visual impairment in college students. Uniquely, our study showed that lower BMI was a risk factor for visual impairment in all students and group I (Table 3), suggesting that poor diet might affect visual acuity. Studies have shown that the lack of certain vitamins and trace elements such as zinc, copper and selenium could affect normal development of the eye[29]. Previous studies have reported that high BMI in older adults was associated with prevalence of visual impairment[30-31], which was not consistent with our result probably due to different populations.

Our results suggest that home region in non-Guangdong provinces was a risk factor for visual impairment (Table 3) and no studies have been reported that. Regardless of undergraduate or graduate students, the prevalence of visual impairment in students outside Guangdong Province was higher than that in students from Guangdong Province. This geographical difference may be related to local education, eye care promotion and the ability to provide services. Apparently, large disparities in healthcare exist across geographical localities and socioeconomic groups. Due to the poor economic situation in some regions, the authorities provide fewer and lower quality services. Guangdong Province is responsible for 11 percent of the China' $14.4 trillion GDP and its economy is larger than that of any other province in the nation according to the data from the National Bureau of Statistics of China. The lower rate of visual impairment among students in Guangdong Province in our study may be related to the better economy and eye health care in Guangdong Province. However, given the lack of more direct information, further studies and evidences on the regional differences in visual impairment especially among the young adults are needed. Understanding the prevalence and associated factors related to visual impairment will be conducive to the prevention and control of visual impairment.

In this study, younger age and Han ethnicity were associated with wearing spectacles in all students and group I (Table 3), indicating that the prevalence of refractive error in younger students and Han Chinese might be higher. But a 5-year longitudinal study in Taiwan University and a 3-year longitudinal studies in Norway reported that older students were more myopic than younger ones[32-33]. Studies have shown that the prevalence of myopia increases with age before adulthood[34]. We supposed that these longitudinal studies were better in showing this progression pattern than the cross-sectional design of our study which might cause the result different. In addition, our results are consistent with previous studies in which the rate of myopia in non-Han Chinese was lower than that in Han Chinese[35-37]. It is unclear if this difference is due to genetic difference or different lifestyles between these ethnic groups. It has been reported that non-Han Chinese may spend more time outdoors in childhood than Han Chinese[37].

According to the data from the National Bureau of Statistics of China, there were 27.53 million undergraduate students and 2.63 million graduate students in 2017 in China. The data on the PVA and wearing spectacles in daily life of these college students are limited. Previous definition for visual impairment was based on best-corrected visual acuity, but there has been an increasing consensus that this is inappropriate because it may underestimate visual impairment caused by uncorrected

refractive error[38-39]. However, surveys based on PVA can avoid the underestimation of the actual visual impairment, which not only allows us to know the true state of visually impaired patients in daily life, but also provides a more accurate estimate of prevalence. We investigated 9070 Chinese first-year college students, including 6527 undergraduate students and 2543 graduate students, for their PVA and factors associated with visual impairment. As a real-world study, the data from this study showed the visual status for undergraduate and graduate students at a university in southern China in their daily life, and to some extent reflected their visual quality. To the best of our knowledge, this is the largest study of Chinese college students on PVA and visual impairment based on PVA to date. In addition, our study showed that lower BMI and home region in non-Guangdong province were associated with visual impairment in undergraduate students, which were not investigated in other relevant studies of college students. Our findings provides further epidemiologic data on the PVA in college students population in south China which can be used by health policy planners, low vision rehabilitation providers, and eye care professionals to plan for the future eye care needs of college students.

However, there were several limitations in this study. First, we did not acquire more socio-demographic characteristics that might be associated with visual impairment, such as family income and visual impairment in their parents. Second, we did not perform accurate refractive examinations to diagnose refractive errors, which may lead to an underestimation of the actual prevalence of refractive errors in this study. Third, the eyeglass prescriptions provided by the students were not verified so that the myopia rates at all levels might have been biased. Finally, we did not further study the causes of visual impairment. If the main causes of visual impairment in college students can be clarified, it will be more helpful for the prevention and control of visual impairment in young people. Future studies may focus on PVA in other populations and explore the causes of visual impairment in college students and the causes behind the excess in prevalence of visual impairment among students with lower BMI and students in Guangdong province. Large-scale study and wide age range will contribute to more accurate PVA in the population.

In summary, we provided the baseline data on PVA in 9070 Chinese college students. More than 60% of all students didn't have normal visual acuity in both eyes, while no more than 3% of them had visual impairment based on PVA in the better eye according to the new criteria of WHO. Our analyses suggest that lower BMI and home region in non-Guangdong provinces are risk factors for visual impairment, while younger age and Han ethnicity are risk factors for wearing spectacles. These findings can help public and policy makers aware and concern about the vision of college students in their daily life. Effective and systematic comprehensive prevention and treatment measures should be taken to further reduce the prevalence of visual impairment and improve the rate of appropriate correction to achieve better PVA, thus improving the quality of visual function of college students.

ACKNOWLEDGEMENTS

Authors' contributions: Conceptualization (Zhao J); Data curation, formal analysis (Cai JM, Ye Y, Zhang T, Zheng JH); Methodology (Zhao J, Cai JM, Ye Y, Liang P); Investigation (Cai JM, Ye Y, Wang J); Funding acquisition, supervision, validation (Zhao J); Resources (Liang R); Writing–original draft (Cai JM, Ye Y); Writing–review & editing (Zhao J).

Foundations: Supported by Science, Technology and Innovation Commission of Shenzhen Municipality (No. GJHZ20180420180937076; No.JCYJ20180228164400218); Sanming Project of Medicine in Shenzhen Grant (No. SZSM201812090).

Conflicts of Interest: Cai JM, None; **Ye Y,** None; **Liang P,** None; **Zhang T,** None; **Zheng JH,** None; **Wang J,** None; **Zhao J,** None.

REFERENCES

1 Jensen E. *Brain-based learning: the new paradigm of teaching*. London, UK: Sage; 2008.

2 World Health Organization (WHO). Visual impairment and blindness. https://www.who.int/en/news-room/fact-sheets/detail/blindness-and-visual-impairment. Updated October 8, 2019. Accessed on October 8, 2019.

3 World Health Organization (WHO). Consultation on development of standards for characterization of vision loss and visual function: WHO/PBL/03.91. https://apps.who.int/iris/bitstream/handle/10665/68601/WHO_PBL_03.91.pdf. Accessed on March 8, 2019.

4 Hashemi H, Yekta A, Jafarzadehpur E, Doostdar A, Ostadimoghaddam H, Khabazkhoob M. The prevalence of visual impairment and blindness in underserved rural areas: a crucial issue for future. *Eye (Lond)* 2017;31(8):1221-1228.

5 Nuertey BD, Amissah-Arthur KN, Addai J, Adongo V, Nuertey AD, Kabutey C, Mensah IA, Biritwum RB. Prevalence, causes, and factors associated with visual impairment and blindness among registered pensioners in Ghana. *J Ophthalmol* 2019;2019:1717464.

6 Darge HF, Shibru G, Mulugeta A, Dagnachew YM. The prevalence of visual acuity impairment among school children at arada subcity primary schools in Addis Ababa, Ethiopia. *J Ophthalmol* 2017;2017:1-7.

7 Suh YW, Lee JS, Heo H, Park SH, Kim SH, Lim KH, Moon NJ, Lee SJ, Park SH, Baek SH. Vision improvement with refractive correction does not completely exclude major eye diseases: analyses of visually impaired south Korean population in the Korea national health and nutrition examination survey 2009-2011. *J Ophthalmol* 2017;2017:3412904.

8 Gilbert C, Foster A. Childhood blindness in the context of VISION 2020—the right to sight. *Bull World Health Organ* 2001;79(3):227.

9 Chen X, Zhou DY, Shen J, Wu YB, Sun QZ, Dong JM, Yu JC. Prevalence and causes of visual impairment in adults in Binhu district, Wuxi, China. *Med Sci Monit* 2018;24:317-323.

10 Guo C, Wang ZJ, He P, Chen G, Zheng XY. Prevalence, causes and social factors of visual impairment among Chinese adults: based on a national survey. *Int J Environ Res Public Heal* 2017;14(9):1034.

11 Wang JY, Ying GS, Fu XJ, Zhang RH, Meng J, Gu F, Li JJ. Prevalence of myopia and vision impairment in school students in Eastern China. *BMC Ophthalmol* 2020;20(1):2.

12 Ferris FL III, Bailey I. Standardizing the measurement of visual acuity for clinical research studies. *Ophthalmology* 1996;103(1):181-182.

13 World Health Organization (WHO). ICD-11 for mortality and morbidity statistics (ICD-11 MMS) 2019 version. https://icd.who.int/browse11/l-m/en. Accessed on October 8, 2019.

14 Pi LH, Chen L, Liu Q, Ke N, Fang J, Zhang S, Xiao J, Ye WJ, Xiong Y, Shi H, Zhou XY, Yin ZQ. Prevalence of eye diseases and causes of visual impairment in school-aged children in Western China. *J Epidemiol* 2012;22(1):37-44.

15 He MG, Zeng JW, Liu YZ, Xu JJ, Pokharel GP, Ellwein LB. Refractive error and visual impairment in urban children in Southern China. *Invest Ophthalmol Vis Sci* 2004;45(3):793.

16 Sun BC, Lu Q, Zheng YY. Discussion on the new WHO classification of visual impairment. *Ophthalmol CHN* 2005;14(5):346-349.

17 He JN, Lu LN, Zou HD, *et al*. Prevalence and causes of visual impairment and rate of wearing spectacles in schools for children of migrant workers in Shanghai, China. *BMC Public Heal* 2014;14:1312.

18 He MG, Xu JJ, Yin QX, Ellwein LB. Need and challenges of refractive correction in urban Chinese school children. *Optom Vis Sci* 2005;82(4):E229.

19 Shi XY, Ke YF, Jin N, Zhang HM, Wei RH, Li XR. The prevalence of vision impairment and refractive error in 3654 first year students at Tianjin Medical University. *Int J Ophthalmol* 2018;11(10):1698-1703.

20 Owsley C, McGwin G, Scilley K, Meek GC, Seker D, Dyer A. Effect of refractive error correction on health-related quality of life and depression in older nursing home residents. *Arch Ophthalmol Chic Ill* 2007;125(11):1471-1477.

21 Zhang MZ, Lv H, Gao Y, Griffiths S, Sharma A, Lam D, Li LP, Tse YK, Liu XJ, Xu DC, Lu B, Congdon N. Visual morbidity due to inaccurate spectacles among school children in rural China: the see well to learn well project, report 1. *Invest Ophthalmol Vis Sci* 2009;50(5):2011.

22 Adler D, Millodot M. The possible effect of undercorrection on myopic progression in children. *Clin Exp Optom* 2006;89(5):315-321.

23 Ma XZ, Zhao JL, Ellwein LB, Wei B, Chen J, Ye Y, Tang XD, Yang M, Wang Y, Gao XC. Prevalence and causes of blindness and moderate and severe visual impairment among adults aged 50 years or above in Changji City of Xinjiang Uygur Autonomous Region: the China Nine-Province survey. *Zhonghua Yan Ke Za Zhi* 2013;49(9):795-800.

24 Ivers RQ, Cumming RG, Mitchell P, Attebo K. Visual impairment and falls in older adults: the blue mountains eye study. *J Am Geriatr Soc* 1998;46(1):58-64.

25 Rubin GS, Bandeen-Roche K, Huang GH, Muñoz B, Schein OD, Fried LP, West SK. The association of multiple visual impairments with self-reported visual disability: SEE project. *Investig Ophthalmol Vis Sci* 2001;42(1):64-72.

26 Zhao JL, Xu X, Ellwein LB, *et al*. Prevalence of vision impairment in older adults in rural China in 2014 and comparisons with the 2006 China nine-Province survey. *Am J Ophthalmol* 2018;185:81-93.

27 Aljied R, Aubin MJ, Buhrmann R, Sabeti S, Freeman EE. Prevalence and determinants of visual impairment in Canada: cross-sectional data from the Canadian Longitudinal Study on Aging. *Can J Ophthalmol* 2018;53(3):291-297.

28 Xu L, Cui TT, Yang H, Hu AL, Ma K, Zheng YY, Sun BC, Li JJ, Fan GZ, Jonas JB. Prevalence of visual impairment among adults in China: the Beijing eye study. *Am J Ophthalmol* 2006;141(3):591-593.

29 Amemiya T. The eye and nutrition. *Jpn J Ophthalmol* 2000;44(3):320.

30 Chong EW, Lamoureux EL, Jenkins MA, Aung T, Saw SM, Wong TY. Sociodemographic, lifestyle, and medical risk factors for visual impairment in an urban Asian population: the Singapore Malay eye study. *Arch Ophthalmol Chic Ill* 2009;127(12):1640-1647.

31 Abdianwall MH, Güçiz Doğan B. Prevalence of visual impairment and related factors in Nangarhar Province of Afghanistan: a cross sectional study. *Int J Ophthalmol* 2018;11(12):1968-1977.

32 Lin LL, Shih YF, Lee YC, Hung PT, Hou PK. Changes in ocular refraction and its components among medical students——a 5-year longitudinal study. *Optom Vis Sci* 1996;73(7):495-498.

33 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(1):26-29.

34 Matsumura H, Hirai H. Prevalence of myopia and refractive changes in students from 3 to 17 years of age. *Surv Ophthalmol* 1999;44:S109-S115.

35 Sun J, Zhou JB, Zhao PQ, *et al*. High prevalence of myopia and high myopia in 5060 Chinese university students in Shanghai. *Invest Ophthalmol Vis Sci* 2012;53(12):7504.

36 Wu LJ, You QS, Duan JL, Luo YX, Liu LJ, Li X, Gao Q, Zhu HP, He Y, Xu L, Jonas JB, Wang W, Guo XH. Prevalence and associated factors of myopia in high-school students in Beijing. *PLoS One* 2015;10(3):e0120764.

37 Chin MP, Siong KH, Chan KH, Do CW, Chan HHL, Cheong AMY. Prevalence of visual impairment and refractive errors among different ethnic groups in schoolchildren in Turpan, China. *Ophthalmic Physiol Opt* 2015;35(3):263-270.

38 Pascolini D, Mariotti SP, Pokharel GP, Pararajasegaram R, Etya'ale D, Négrel AD, Resnikoff S. 2002 Global update of available data on visual impairment: a compilation of population-based prevalence studies. *Ophthalmic Epidemiol* 2004;11(2):67-115.

39 Dandona L, Dandona R. Revision of visual impairment definitions in the international statistical classification of diseases. *BMC Med* 2006;4:7.