·Investigation·

Ocular biometry in the adult population in rural central China: a population-based, cross-sectional study

Ting Fu, Yin-Wei Song, Zhi-Qi Chen, Jun-Wen He, Kun Qiao, Xu-Fang Sun, Hong Zhang, Jun-Ming Wang

Department of Ophthalmology, Tongji Hospital, Tongji Medical College Huazhong University of Science and Technology, Wuhan 430030, Hubei Province, China

Correspondence to: Jun-Ming Wang. Department of Ophthalmology, Tongji Hospital, Tongji Medical College Huazhong University of Science and Technology, 1095 Jiefang Avenue, Wuhan 430030, Hubei Province, China. eyedrwjm@163.com

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Abstract

• **AIM: To describe the distribution and determinants of ocular biometric parameters and to ascertain the relative importance of these determinants in a large population of adults in rural central China.**

• **METHODS: A population-based, cross-sectional study performed in rural central China included 1721 participants aged 40 or more years. Ocular biometrical parameters including axial length (AL), anterior chamber depth (ACD), radius of corneal curvature (K) and horizontal corneal diameter [white-to-white (WTW) distance] were measured using non-contact partial coherence interferometry [intraocular lens (IOL)-Master].**

• **RESULTS: Ocular biometric data on 1721 participants with a average age of 57.0±8.7y were analyzed at last. The general mean AL, ACD, mean corneal curvature radius (MCR), WTW were 22.80±1.12, 2.96±0.36, 7.56±0.26 and 11.75±0.40 mm, respectively. The mean values of each parameter in 40 to 49, 50 to 59, 60 to 69, and 70 to 91 years age groups were as follows: AL, 22.77±0.87, 22.76±1.06, 22.89±1.41, 22.92±0.80 mm; ACD, 3.10±0.32, 2.98±0.34, 2.86±0.36, 2.77±0.35 mm; MCR, 7.58±0.25, 7.54±0.26, 7.55±0.26, 7.49±0.28 mm; WTW, 11.79±0.38, 11.75±0.40, 11.72±0.41, 11.67±0.41 mm. The AL, ACD, MCR and WTW were correlated with age and the AL was correlated with height and weight.**

• **CONCLUSION: Our findings can serve as an important normative reference for multiple purposes and may help to improve the quality of rural eye care.**

• **KEYWORDS:** epidemiological investigation; axial length; anterior chamber depth; Chinese population

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INTRODUCTION

Ocular biometry is an important predictor for ocular diseases, which has been frequently measured in clinical diagnosing, surgical planning and monitoring progress of ocular disease.

Ophthalmological epidemiology on biometry had been studied continuously, even several for Chinese population: *e.g.* the Handan eye study[1] and the Beijing eye study[2] in the northern China, the Liwan eye study[3] in the southern China, Tanjong Pagar study [4] in Singapore. As geography and ethnic groups differ greatly from the north China to the south, epidemiological survey in different region offsets one another. As we can see, it is still lack of ocular biometric data from central China. Thus we launched an investigation on ocular biometry in a rural Chinese population in Tianmen District, Hubei Province, which was obtained by intraocular lens (IOL)-Master.

Glaucoma is an important disease that can lead to blindness, clinic observation indicates that long ocular axis is associated with primary openangle glaucoma [5], while short ocular axis and shallow anterior chamber account for the onset of primary angle-closure glaucoma (PACG) [6]. Besides, both PACG and openangle glaucoma prevalence rate increased with increasing age, while most studies on ocular biometric parameters have focused on children and adolescents or on selected groups. Thus data from elder population is of great significance.

Furthermore, rural population accounts for about 50.32% of the total population in China [7] and rural health care constitute a decisive part of the whole medical and health system. Collecting data from rural area provide a reliable evidence for rural eye health care.

SUBJECTS AND METHODS

Date from a population-based, cross-sectional study launched in Tianmen District, Hubei Province, which located in the central part of China. In brief, the study was conducted from October 2011 to January 2012, and the population comprised of 40-year-old and older residents, which was distributed in

13 villages in Tianmen District. One thousand and eight hundred subjects were selected by using an age-stratified random sampling process. Exclusion criteria are lack of integrity data, or with an ophthalmological operation, ocular trauma which may impact on ocular biometric parameters. All the participation was voluntary without a stipend and informed consent was signed from the subjects in written or in fingerprint. The principles outlined in the Declaration of Helsinki (2008) were fully followed.

A standard questionnaire was administered by a trained interviewer, such as age, gender, education level, and medical history. Height and weight were measured with the subject standing and without shoes, using a standard calibrated scale. Body mass index was calculated as the weight in kilograms divided by the square of the height in centimeters.

Ocular biometric parameters of axial length (AL), anterior chamber depth (ACD), radius of corneal curvature (K) and horizontal corneal diameter [white-to-white (WTW) distance] were measured using noncontact partial coherence interferometry (PCI; IOL Master, ver, 3.01; Carl Zeiss Meditec AG, Jena, Germany). Radius of corneal curvature in the vertical and horizontal meridian (K_1 and K_2) was initially estimated, and the mean corneal curvature radius (MCR) was calculated as the average of the steep and flat curvatures. Optometry was done by auto refractor. Four experienced ophthalmologist from Tongji hospital did the measurements.

Since ocular biometric parameters for the right and left eyes correlated highly ophthalmologist analyses were performed on right eyes only. Statistical analysis was overall assessment, age group evaluation, gender comparison, correlation analysis. Distributions for ocular biometric parameters were tested for normality with the Kolmogorov-Smirnov test and were considered significantly different from normal when $P \leqslant 0.05$. Mean biometry data were compared across each age group stratified by sex, and linear test for trend was used to investigate significance for each age group. Possible predictors for each biometric parameter were assessed in univariate analyses. All the analysis was done by SPSS14.0.

RESULTS

Of the 1800 subjects selected by using an age-stratified random sampling process, 1721 eligible subjects had participated in the study, among which 497 are men and 1224 women, whose age ranging from 40 to 91 (57.0±8.7) years old.

The distribution of ALs is shown in Figures 1A and 2A. ALs for the overall population did not demonstrate normal distribution (Shapiro-Wilk test, $P<0.01$). When stratified by age groups, the distributions of ALs were all positively skewed. Men had significantly shorter ALs (22.64 mm versus 22.87 mm, Kolmogorov-Smirnov test, $P<0.01$) than women. And ALs increased as the age increased ($P<0.05$), especially for aged 50+. AL correlated slightly positive with height and body weight ($P<0.01$).

Table 1 Pearson correlation matrix of all parameters

Parameters	AL	ACD	WTW	MCR
AL	-	0.441^b	0.229^b	0.470^b
ACD	0.441^b	-	0.194^b	0.318^b
WTW	0.229^b	0.194^b	-	0.471^b
MCR	0.470^b	0.318^b	0.471^b	-

AL: Axial length; ACD: Anterior chamber depth; WTW: White-to-white distance; MCR: Mean corneal curvature radius. $^bP<0.01$.

The distribution of ACDs is shown in Figures 1B and 2B and all positively skewed (Shapiro-Wilk test, $P<0.01$). Men had significantly shallower ACDs (2.88 mm versus 2.99 mm, Kolmogorov-Smirnov test, $P<0.01$) than women. And ACDs decreased as the age increased ($P<0.01$). ACD has no significant linear correlation with height or body weight.

The distribution of MCRs is shown in Figures 1C and 2C and all positively skewed (Shapiro-Wilk test, $P<0.01$). Men had significantly shorter MCRs (7.51 mm versus 7.58 mm, Kolmogorov-Smirnov test, $P<0.01$) than women. And MCRs decreased as the age increased ($P<0.01$). MCR had no significant linear correlation with height or body weight. AL/MCR ratio had a significant linear correlation with age ($P<0.05$, Pearson correlatio n =0.6), but showed no difference between male and female.

The distribution of WTWs is positively skewed (Shapiro-Wilk test, $P<0.01$). Men had shorter WTWs (11.49 mm versus 11.85 mm, Kolmogorov-Smirnov test, $P<0.01$) than women. And WTWs decrease as the age increase.

ACD correlated positively with AL (r=0.44, $P<0.01$; Figure 3A). MCR also showed a weak positive relationship with AL (r=0.47, $P<0.05$; Figure 3B). So persons with a longer AL had longer ACD and MCR. Table 1 shows the complete correlation matrix.

DISCUSSION

Tianmen County located in the hinterland of Jianghan plain. It is a typical rural city in the middle of China. So we choose Tianmen to represent for rural central China.

IOL-Master is a non-contact optical biometry measurement which uses PCI technology. It could provide rapid, objective, accurate ocular biometry and there is no need of cornea contacting so that it has been widely used in clinic practices, since IOL-Master has been introduced to ophthalmic use in 1999. It was suggested that the IOL Master is a better predictor of normative ocular biometric data than ultrasound biometry [8]. As far as we know, there are only a few surveys using IOL Master until now.

Axial Length and Distribution and Its Related Factors

Comparing the mean AL among different population-based studies would help to clarify the interethnic variation in AL and its association with refractive errors. The AL in our

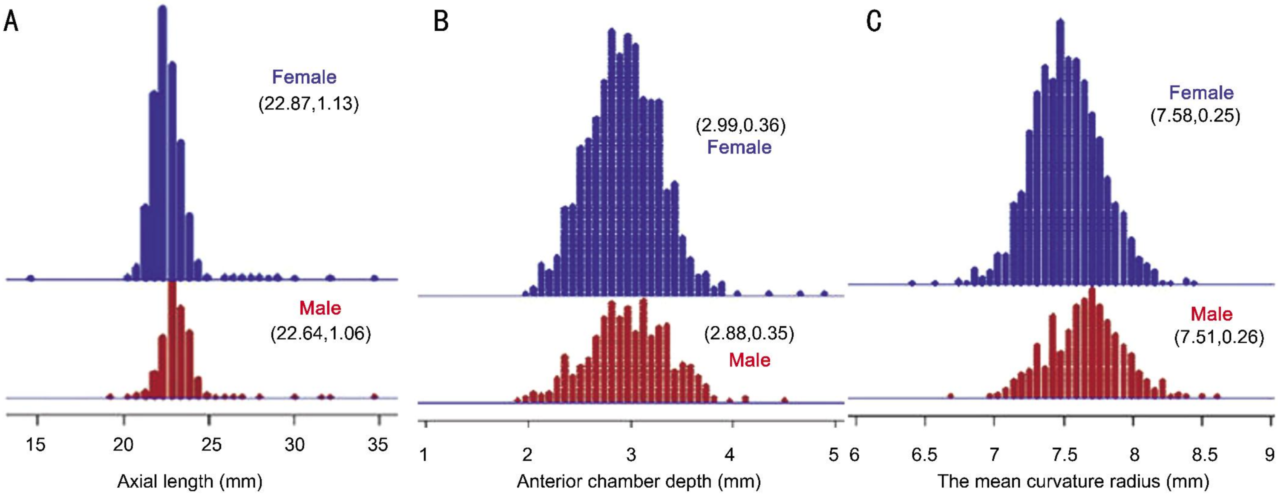

Figure 1 Distribution of parameters by sex groups ($\overline{x} \pm s$) A: AL; B: ACD; C: MCR.

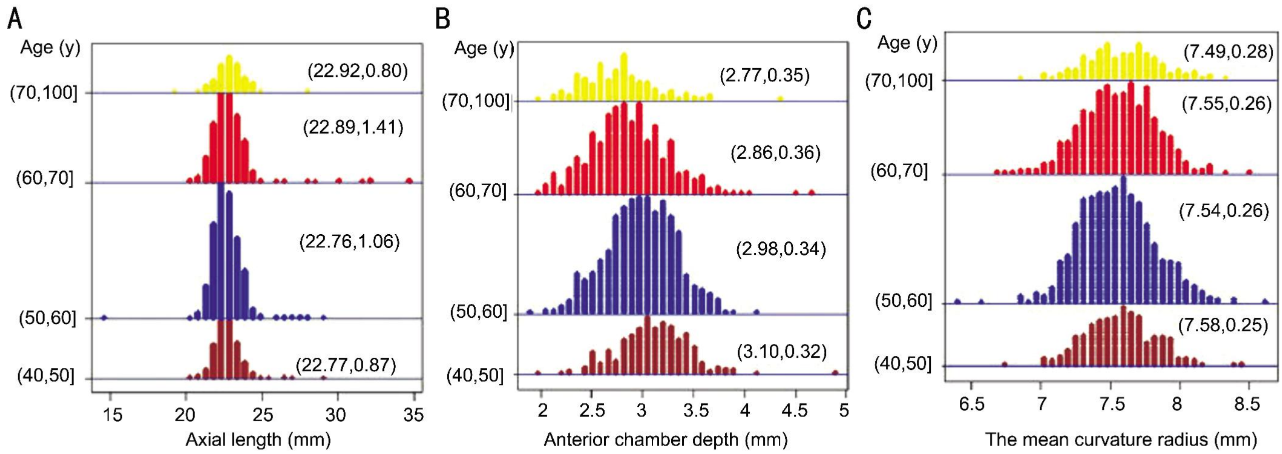

Figure 2 Distribution of parameters by age groups ($\overline{x} \pm s$) A: AL; B: ACD; C: MCR.

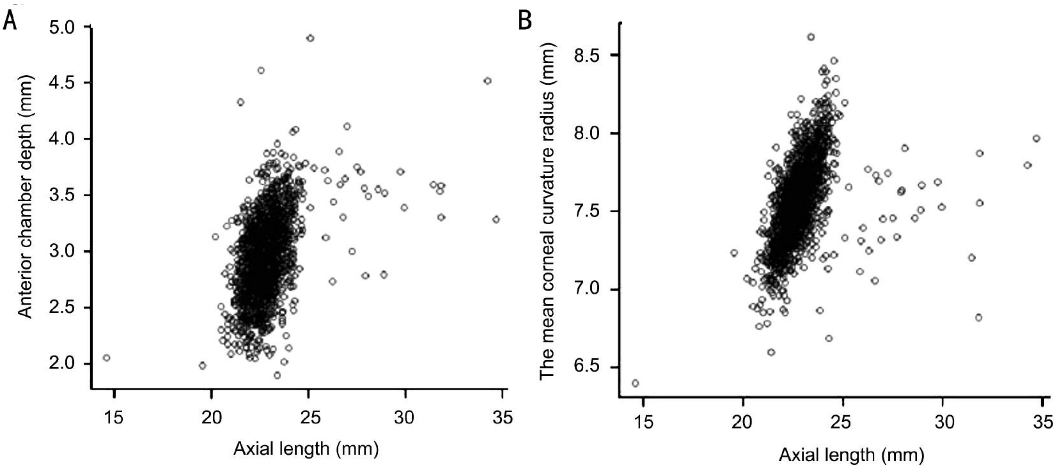

Figure 3 Association among parameters A: Association between AL and ACD; B: Association between AL and MCR.

population (22.80 mm) was lower compared with the Handan Eye Study [1] (*n*=5723) of northern Chinese rural adults aged 30+ (22.9 mm), lower compared with the Beijing eye study[2] of northern Chinese adults (*n*=3159) aged 50 to 93y (23.25 mm), lower compared with the Liwan eye study[3] of southern Chinese adults (*n*=1360) aged 50+ (23.3 mm) and the Tanjong Pagar Survey [4] (*n*=1717) of Singapore Chinese adults aged 40 to 81y (23.2 mm), also lower than Hong Kong Chinese[9]. Compared with other race, AL in our population is lower than westerner (23.65 mm[10]), however, in Cheng *et al*'s study [11], the mean AL is longer in Chinese compared with non-Chinese but this difference was not significant in multivariate analysis.

We compare only across elder population because the influence by lens opacity is minimal in this age group. The difference in AL may be explained by a lower degree of urbanization in rural central China and subsequently a lower rate of axial myopia. Different age and sex distributions may also cause some bias. Participants in our study are elder and with lower education and less near-work activities, thus shorter ALs is predictable. Thirdly, the other data were measured by A-scan or anterior segment optical coherence tomography (AS-OCT) while ours measured by IOL-master, although researches had shown that immersion ultrasound, PCI, and low coherence reflectometry provided comparable ocular biometry measurements[12].

In our study, older adults tended to have shorter ALs. This has also been observed in most of related studies [2-6]. Decreasing ALs with age could attribute to either a cohort effect (*i.e.* with older generations have shorter ALs because of poorer nutrition, general health, or other unknown factors than younger generations) or to an actual reduction in AL with increasing age. No cohort study was done to clarify this problem yet.

Casson *et al* [6] pointed out that the incidence of primary angle-closed glaucoma doubles when the ocular AL decreases every 1 mm, from which we can conclude that people in central China, especially the elderly, more inclined to the progress of primary closed-angle glaucoma. Also, our study shows that an increase in height or weight was significantly associated with longer AL, even after controlling for sex and age. Similar findings were described in the Tanjong Pagar Survey [4] and the Reykjavik Eye Study [13]. It indicated that myopia appears to be more common in taller and heavier persons.

Axial Chamber Depth Distribution and Its Related Factors ACD is an important reference parameter in anterior segmental parameter, which commonly was the distance from the posterior surface of the cornea to the anterior vertex of the crystalline lens exposed by the pupil, along the eye's optical axis.

The ACD in our population (2.96 mm) was deeper compared with the Handan Eye Study [1] (*n*=5723) of Chinese rural adults aged 30+ (2.93 mm), deeper compared with the Tanjong Pagar Survey[4] (*n*=1717) of Chinese adults aged 40 to 81y (2.90 mm), but much shorter than westerner (3.10 mm, *n* =1335) [10]. The reason may lie in different measuring devices, ACD measured by ultrasound was found to be significantly shorter than that by noncontact measuring systems (2.58 mm *vs* 2.94 mm [14]), and all the above study as comparison used ultrasound thus a lower result was predictable. On the other hand, this is consistent with the higher incidence of primary angle-closed glaucoma of Chinese compared with westerner. The smaller anterior chamber width contributes to more crowded anterior chambers, thus higher risk of angle closure. The more anteriorly located lens under a less vaulted cornea in Chinese compared with non-Chinese [15] may account for the higher risk of angle closure in this subpopulation.

Our studies had revealed that ACD becomes shallower with age increasing, which coincides with previous results. The correlation of ACD with age confirmed further that the incidence of primary angle closure glaucoma increased with age, especially in Asian elderly population. Numerous studies [16,17] using ultrasound [18], Scheimpflug photography, PCI, time-domain OCT and magnetic resonance imaging (MRI) have shown that the lens thickness increases over age. The findings have shown that the increasing lens thickness may serve as an important factor causing the reduction of ACD over age[19].

ACD is found to have no linear correlation with height and weight. The Tanjong Pagar Survey [20] found that taller persons tended to have longer deeper ACDs, which was supposed to be the compensatory effect for the taller with a longer AL to maintain emmetropia, but it did not identify whether ACD and height are independent related or associated with ocular axial.

Our analysis showed that ACD correlated positively with AL. But another research [21] has proved that the strongest determinants of ACD were lens vault (LV) and posterior corneal arc length (PCAL). LV and PCAL explained 76.8% of the variability in ACD. When information about LV and PCAL were available, AL was a poor determinant of ACD. Tan *et al* [22] and Nongpiur *et al*'s[23] study also support that LV was the determining factor for shallow ACD.

Either the central ACD less than 2.5 mm or the peripheral ACD smaller than 20 degree has been regard as shallow ACD, which is a cardinal risk factor for PACG. Measurement of axial ACD has been used in population screening for angle closure[24]. When ACD is between 2.1-2.3 mm, the PACG prevalence was 25% in China; when ACD is between 1.5-2.1 mm, the prevalence was 53.5%; when ACD is less than 1.5 mm, the prevalence was 100%[25]. Although there are other factors having influence on ACD, such as lens thickness and refraction, shallow ACD is still regarded as the strongest predictor of PACG [26], which may provide reliable data and basis for prevention of glaucoma. In this research, we choose 2.5 mm to be the dividing point. The prevalence of shallow ACD in our analysis is 10.1%, while another data [27] showed the prevalence of PACG in China is 1.4%, this means quite a number of shallow-ACD people will not develop to PACG ultimately. We suppose that there is still a lot follow-up work to figure out which groups of shallow ACD are more inclined to get PACG.

The Mean Corneal Curvature Distribution and Its Related Factors The mean K_1, K_2, and MCR in our study is respectively 7.49 mm, 7.63 mm, 7.56 mm.

Table 2 AL and its corresponding K_1, K_2, MCR

AL (mm)	Eyes	K_1	K_2	MCR
20≤AL<21	18	7.13	7.04	7.09
21≤AL<22	288	7.38	7.23	7.31
22≤AL<23	786	7.59	7.46	7.52
23≤AL<24	511	7.79	7.65	7.72
24≤AL<25	88	7.97	7.81	7.89
25≤AL≤34.7	30	7.70	7.37	7.53
Total	1721	7.63	7.48	7.56

AL:Axial length; MCR: Mean corneal curvature radius; K_1: Vertical corneal curvature radius; K_2: Horizontal corneal curvature radius.

The MCR in our population (7.56 mm) was lower compared with the Handan Eye Study [1] (n=5723) of Chinese rural adults aged 30+ (7.62 mm)and lower compared with the Liwan eye study[3] of Chinese adults (n=1360) aged 50+(7.8 mm), lower compared with the Germany eye center (7.69 mm[28]), which indicate that central rural Chinese may have more curved cornea.

As K_1 increased and K_2 decreased with age, the radio K_1/K_2 increased with age. Most researchers suggest that the reason is that as age increases, astigmatism with rule changes into astigmatism against rule [29]. MCRs also decrease as the age increase, in accord with the previous study.

It is reported that Myopia has a higher prevalence among Asians compared with Western population and a higher prevalence of myopia among elderly Asians, demonstrating a bimodal distribution [30]. It will cause refractive errors when loss of coordination such as AL and corneal radius of curvature. Understanding the interrelationship between refraction and ocular biometry may help to explain the trends and patterns of refractive errors observed in different populations and ethnicities. To evaluate the relationship between AL and MCR in Chinese people, statistical analysis was done on increase of MCR per 1 mm increase in AL. We can see from Table 2, with AL increasing from 20 mm to 25 mm, MCR also gradually increased from 7.09 mm to 7.89 mm, MCR will increase averagely 0.15 mm per 1 mm increase in AL. As the eye ball is approximately sphere, and cornea is in the horizontal surface of the front of the ocular axial, it is inferred: AL is basically proportional to MCR.

MCR had no linear correlation with height and weight. However, as I noted before, AL correlated positively with height and weight. Therefore, we may suppose that eyes have a self-correcting mechanism to maintain emmetropia. In addition, we analyzed the AL/MCR ratio, which is considered to be the most important parameter and the best predictor of the refractive state of the human eye and is usually close to 3.0 in emmetropic eyes [31]. The mean AL/MCR ratio in our study was 3.02, and the ratio had no significant correlation with gender, height or weight, but correlated with age and ACD.

In conclusion, for the first time we reported biometry data of the ocular biometry in a large population of adults in rural central China, which could be a powerful supplement for the database of Chinese population. In combination with previous study in other regions of China, we can see the people in central rural China have lower AL, more curved cornea. Besides, elder people have longer AL but shallower ACD, which indicates a higher prevalence of PACG. The only drawback of our study is a mismatching of male and female subjects number, but we have tried to eliminate the error by separate analysis of male and female when we compare among different age groups.

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