

Distribution and Trends in Corneal Thickness Parameters in a Large Population-Based Multicenter Study of Young Chinese Adults

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PURPOSE. The purpose of this study was to characterize corneal thickness from multiple regions and determine accurate reference values in young adults for diagnosis and treatment.

METHODS. This cross-sectional observational study was conducted from January 2008 through October 2016 using examiner-blinded clinical measurements and included 37,375 healthy eyes from young adults who exhibited normal corneal morphology, had no history of eye surgery or trauma, had stopped wearing soft contact lenses for ≥ 2 weeks (rigid contact lenses for ≥ 4 weeks), and had undergone topographies of both eyes on same day. Keratoconus and subclinical keratoconus were excluded. This multicenter study was conducted in four provinces of China: Tianjin, Shandong, Hubei, and Xinjiang.

RESULTS. Central corneal, corneal vertex, and thinnest corneal thicknesses were higher in eyes from Hubei than other provinces. The left eye was thicker than the right in patients from Shandong, Tianjin, and Hubei, but not Xinjiang. Overall corneal thickness was higher in eyes from Hubei than from other provinces. Changing trend of the whole-cornea thickness in eyes from Xinjiang differed from eyes from other provinces. Trends in maximum and minimum axial for change of corneal thickness were similar between eyes from Hubei and Xinjiang and between Shandong and Tianjin.

CONCLUSIONS. Corneal thickness differs among eyes from different regions. Corneal thickness parameters are influenced by ethnicity and geographical location, as increasing proximity to the equator was related to increasing corneal thickness. Design of refractive surgery and diagnosis of related diseases in patients of a certain area should be based on reference values from its population.

Keywords: corneal thickness, multicenter study, pentacam

As the most anterior tissue of the eyeball, the cornea is important in maintaining the integrity of eye function and structure. Corneal thickness is one of the most important indicators of visual health, which can be used to evaluate the function of the endothelium and the effects of various drugs on the cornea; further, corneal thickness may give aid in evaluation and measurement of IOP. Corneal thickness has also been reported as an independent risk factor for glaucoma.^{1,2} With the fairly recent development of corneal refractive surgery, corneal parameters, typically represented by corneal thickness, have become highly important in the design of refractive surgery and the diagnosis of early keratoconus; corneal thickness evaluation also serves to effectively reduce the incidence of postoperatively keratoconus.³

Increased attention on corneal thickness has resulted in its characterization in a large number of reports from a variety of countries and regions.⁴⁻⁷ Because of differences in geography,

ethnicity, and other factors, there is wide variation within these data; therefore, reference values of corneal thickness-related parameters should not be used indistinctly and should be sensitive to differences within each population.

China contains the largest population in the world, within the fourth-largest country (by landmass) in the world. Combined, these characteristics compel a meaningful study of corneal thickness-related parameters specifically in a Chinese population. However, previous relevant studies have been limited to a single city or single region within China⁷⁻⁹; thus, they cannot accurately assess corneal thickness of the entire Chinese population. Therefore, we explored the normal range of corneal thickness in young Chinese adults through a multicenter study that recorded and analyzed corneal thickness-related parameters in a young adult Chinese population.





FIGURE 1. Geographical distribution of the four provinces in China that were included in this study. *Red coordinates* indicate the location of the four research centers where data were collected.

MATERIALS AND METHODS

Study Subjects

This cross-sectional study was carried out in four medical centers in different regions of China: Tianjin Eye Hospital, Shandong province; Jinan Mingshui Eye Hospital, Hubei province; Wuhan General Hospital of Guangzhou Military Command of PLA, Xinjiang province; and The First Affiliated Hospital of Xinjiang Medical University (Fig. 1 shows locations of provinces and research centers included in this study). The content of this study conforms to ethical standards of the Declaration of Helsinki, and informed consent was signed by all enrolled patients.

Anterior segment examination data were collected from January 2008 through October 2016. Using an initial set of >48,000 samples, screening was performed according to inclusion criteria. (1) According to the latest United Nations WHO GBD2000 on the division of human age, adults 18 to 44 years old were identified as young people; these were included in the study group.¹⁰ (2) Patients who exhibited normal corneal morphology, had no corneal macula, had no history of eye surgery or trauma, and had stopped wearing soft contact lenses for ≥ 2 weeks or rigid contact lenses for ≥ 4 weeks. (3) Patients must have had corneal topographies of both eyes recorded on the same day. Patients with keratoconus, suspected keratoconus, or subclinical keratoconus were excluded from the study (diagnosis based on global consensus¹¹ and the ABCD Grading System¹² for keratoconus).

Clinical Examinations

An examiner-blinded method was used to measure each subject, by using Pentacam (3D anterior segment analysis and diagnostic system; OCULUS, Wetzlar, Germany). All four research centers used the same type of machine (Pentacam HR) to conduct tests and perform data collection for subjects. All equipment was calibrated by engineers from

the same company, at 3-month intervals. The calibration tool is a standard simulated eye with fixed thickness, curvature, and grayscale parameters. When using the optical principle to measure the simulated eye, the device records the standard parameters of the simulated eye to its digital signal processor, ensuring that the precision of the instrument is maintained.

Using the natural pupil state in a darkroom, the mandible was placed in the mandibular pad; subjects were asked to keep their eyes open and to watch the circles in the blue-ribbon indicator after blinking twice. The tester (a member of the research team) used the joystick to aim and focus with the screen cue. To avoid detection bias, the automatic measuring system release mode was selected: when the instrument detected the pupil center, the edge, and the clear corneal apex, automatic measurement began. According to quality specification (QS) requirements, the instrument only displays the test results of "OK" to the tester.

Statistical Analysis

Data were analyzed by SAS9.4 statistical software (SAS Institute, Cary, NC, USA). Quantitative data are described using mean \pm SD or median (Q1 to Q3); the Kruskal-Wallis test was used to compare among at least three groups; the Wilcoxon rank-sum test was used to compare between two groups; and Spearman rank correlation analysis was used to test for trends. $P < 0.05$ indicated statistical significance.

RESULTS

This study included 37,375 healthy eyes preparing for corneal refractive surgery in patients whose age was between 18 and 44 years; mean patient age was 25.00 (range, 20.00 to 31.00) years; and patients were residents from four provinces of China: Shandong, Tianjin, Hubei, and Xinjiang.

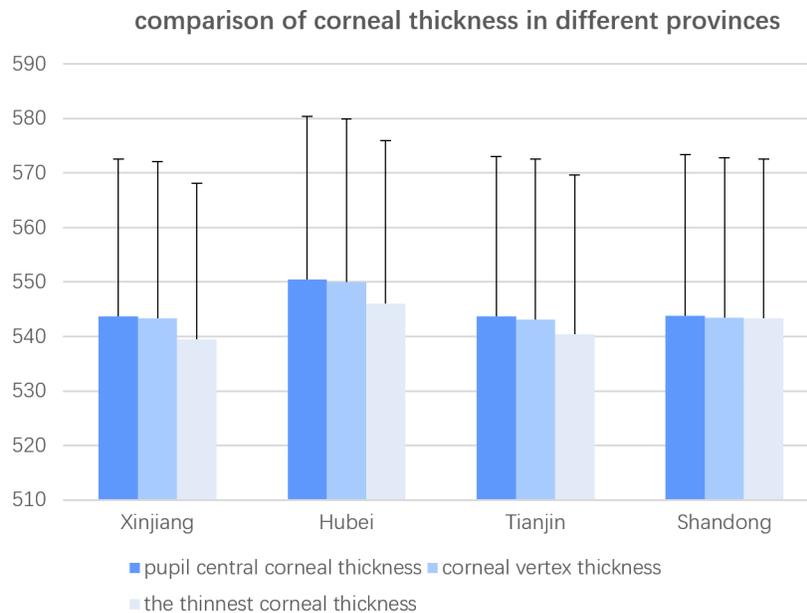


FIGURE 2. Bar graph showing comparison of corneal thickness-related parameters in eyes from different provinces in China (µm).

Corneal Thickness

In this study, we conducted a statistical analysis of the following variables in samples from all four included provinces: central corneal thickness, corneal vertex thickness, and thinnest corneal thickness. Figure 2 and Table 1 show significant differences between regions in central corneal thickness, corneal vertex thickness, and thinnest corneal thickness ($P < 0.0001$). Notably, all three parameters were significantly higher in eyes from Hubei relative to eyes from other areas.

We also compared corneal thickness between right and left eyes within each region. As shown in Table 2 and Figure 3, central corneal thickness (Pupil Center Pachy), corneal vertex thickness (Corneal Vertex Pachy), and thinnest corneal thickness (Thinnest Locat Pachy) were significantly different between right and left eyes from Shandong ($P < 0.0001$), Tianjin ($P < 0.0001$), and Hubei ($P < 0.05$); in these three provinces, the thickness of the left eye was greater than the

thickness of the right eye. However, there was no significant difference between right and left eyes from Xinjiang.

Corneal Thickness Spatial Profile

Concentric circles are made with the thinnest point of the cornea as the center, and the circumference average thickness is calculated across different diameters. A corneal thickness spatial profile (CTSP) of 0 mm indicates the location of the thinnest point of the cornea.

We analyzed CTSP from 0 to 10 mm in diameter (Table 3; Fig. 4) and found statistically significant differences in CTSP at all diameters among the four regions ($P < 0.0001$).

At all measured diameters, the corneal thickness of eyes from Hubei province was significantly higher than the corneal thickness of eyes from the other three areas. Notably, at 6, 8, and 10 mm in diameter, the corneal thickness of eyes from Xinjiang was significantly higher than the corneal thickness of eyes from Shandong and Tianjin (Fig. 4).

TABLE 1. Comparison of Corneal Thickness-Related Parameters in Eyes From Different Provinces of China

Province	N (Missing)	Mean ± SD	Median (Q1–Q3)	χ^2	P
Central corneal thickness (µm)					
Shandong	16,999 (7)	543.85 ± 29.53	543.00 (524–563)	108.087	<0.0001
Tianjin	16,770 (0)	543.64 ± 29.43	543.00 (524–563)		
Hubei*	2514 (0)	550.45 ± 29.98	550.00 (529–570)		
Xinjiang	1085 (0)	543.67 ± 28.84	543.00 (525–562)		
Corneal vertex thickness (µm)					
Shandong	17,002 (4)	543.47 ± 29.30	543.00 (523.00–563.00)	107.630	<0.0001
Tianjin	16,761 (9)	543.15 ± 29.37	542.00 (523.00–562.00)		
Hubei*	2514 (0)	549.97 ± 29.96	549.00 (529.00–570.00)		
Xinjiang	1085 (0)	543.29 ± 28.82	543.00 (524.00–562.00)		
Thinnest corneal thickness (µm)					
Shandong	17,002 (4)	543.35 ± 29.17	540.00 (520.00–559.00)	80.992	<0.0001
Tianjin	16,761 (9)	540.42 ± 29.23	539.00 (520.00–560.00)		
Hubei*	2514 (0)	546.08 ± 29.85	545.00 (525.00–566.00)		
Xinjiang	1085 (0)	539.46 ± 28.69	539.00 (521.00–557.00)		

Wilcoxon rank sum test.

* Significantly different from all other provinces.

TABLE 2. Comparison of Corneal Thickness-Related Parameter Variables Between Right and Left Eyes Within Patients From Different Provinces

Variable	Left Eye			Right Eye			Z	P
	N (Missing)	Mean ± SD	Median (Q1–Q3)	N (Missing)	Mean ± SD	Median (Q1–Q3)		
Shandong								
Pupil Center Pachy	8190 (2)	545.08 ± 29.29	544.00 (525.00–564.00)	8809 (1)	542.70 ± 29.37	542.00 (522.00–562.00)	5.162	<0.0001
Corneal Vertex Pachy	8192 (0)	544.67 ± 29.23	544.00 (525.00–564.00)	8810 (0)	542.36 ± 29.33	542.00 (522.00–562.00)	5.009	<0.0001
Thinnest Locat Pachy	8192 (0)	541.40 ± 29.03	541.00 (521.00–560.00)	8810 (0)	539.36 ± 29.26	539.00 (519.00–558.00)	4.489	<0.0001
Tianjin								
Pupil Center Pachy	7925 (0)	545.18 ± 29.31	544.00 (525.00–564.00)	8845 (0)	542.27 ± 29.47	541.00 (522.00–561.00)	6.182	<0.0001
Corneal Vertex Pachy	7921 (4)	544.67 ± 29.25	544.00 (525.00–564.00)	8840 (5)	541.78 ± 29.41	541.00 (522.00–561.00)	6.157	<0.0001
Thinnest Locat Pachy	7921 (4)	541.69 ± 29.10	540.00 (522.00–561.00)	8840 (5)	539.28 ± 29.30	538.00 (519.00–559.00)	5.147	<0.0001
Hubei								
Pupil Center Pachy	1182 (0)	552.33 ± 30.00	552.00 (531.00–572.00)	1332 (0)	548.77 ± 29.86	548.00 (527.00–568.50)	2.881	0.004
Corneal Vertex Pachy	1182 (0)	551.79 ± 29.97	551.00 (531.00–572.00)	1332 (0)	548.35 ± 29.87	548.00 (527.00–568.00)	2.798	0.005
Thinnest Locat Pachy	1182 (0)	547.97 ± 29.73	547.00 (528.00–568.00)	1332 (0)	544.40 ± 29.87	544.00 (523.00–565.00)	2.950	0.003
Xinjiang								
Pupil Center Pachy	539 (0)	544.54 ± 29.54	544.00 (525.00–563.00)	546 (0)	542.81 ± 28.15	542.00 (525.00–561.00)	0.883	0.377
Corneal Vertex Pachy	539 (0)	544.12 ± 29.55	543.00 (524.00–563.00)	546 (0)	542.47 ± 28.09	542.00 (525.00–560.00)	0.827	0.408
Thinnest Locat Pachy	539 (0)	540.42 ± 29.28	540.00 (521.00–559.00)	546 (0)	538.51 ± 28.10	537.00 (519.00–556.00)	1.016	0.310

Percentage of Cornea Thickness Increase

Percentage thickness increase (PTI) is obtained by beginning with the thinnest point of the cornea as the center and then forming 22 concentric circles whose size increases by 0.4 mm per circle; the final calculation measures average thickness by increasing the ratio of the circle under each diameter.

We analyzed PTI from 0 to 10 mm in diameter (Table 4) and found statistically significant differences in PTI at all diameters among the four regions ($P < 0.0001$). At all measured diameters, the PTI of eyes from Xinjiang was significantly higher than the PTI of eyes from other provinces; the PTI of eyes from Hubei was also significantly higher than the PTI of eyes from Shandong and Tianjin.

We also performed a test of trends in PTI within each province. As shown in Figure 5, there was a positive correlation between PTI and corneal diameter in all four provinces ($P < 0.0001$); notably, PTI gradually increased with increasing corneal diameter in all provinces. Importantly, the growth trend of PTI is similar across provinces.

In addition, we analyzed the maximum and minimum axial PTI in each province. Figure 6 and Table 5 show statistically significant differences in the maximum and minimum axial PTI in each region ($P < 0.0001$); the maximum and minimum axial PTI measurements exhibited similar trends between Hubei and Xinjiang and between Shandong and Tianjin.

DISCUSSION

Corneal thickness and corneal thickness-related parameters are important indicators for the assessment and diagnosis of ocular diseases. These parameters are closely inspected for use in corneal refractive surgery, glaucoma diagnosis and treatment, refractive examination, IOP, and other related examinations. Particularly in corneal refractive surgery patients, corneal thickness and its related parameters are important for preoperative screening of keratoconus, for perisurgical evaluation of the correct ablation profile, and for suitable design of the cutting range to maintain postsurgical corneal morphologic stability. Many studies suggest that excessive corneal cutting is an important factor in corneal ectasia. The width and depth of refractive surgery and the residual thickness of the stroma clearly affect the biomechanics of the cornea.¹³ The rate of corneal protrusion after refractive surgery in patients with suspected keratoconus is higher than the rate of corneal protrusion in patients with normal recovery.¹⁴ Thus, correct assessment of corneal thickness-related parameters is crucial to successful corneal refractive surgery.

Normal reference values are an important basis for clinical judgment during patient examinations. The diagnostic criteria for many diseases are based on differences between the clinical observations and normal reference values. For example, the diagnostic criterion for keratoconus uses a diagnostic standard that is established using the lowest 1% and the highest 99% of corneal thickness-related parameters in the normal population.¹⁵ However, most diagnostic instruments are produced in Europe and America and thus using normal reference values from European and American populations. However, China is a country of vast territory, with a large population and various nationalities that exhibit racial differences in relation to corneal thickness among different regions and races.^{16–18} Therefore, it may not be effective to evaluate the Chinese population using normal values from Europeans and Americans. Therefore, we studied corneal thickness-related parameters in a large population of young Chinese adults.

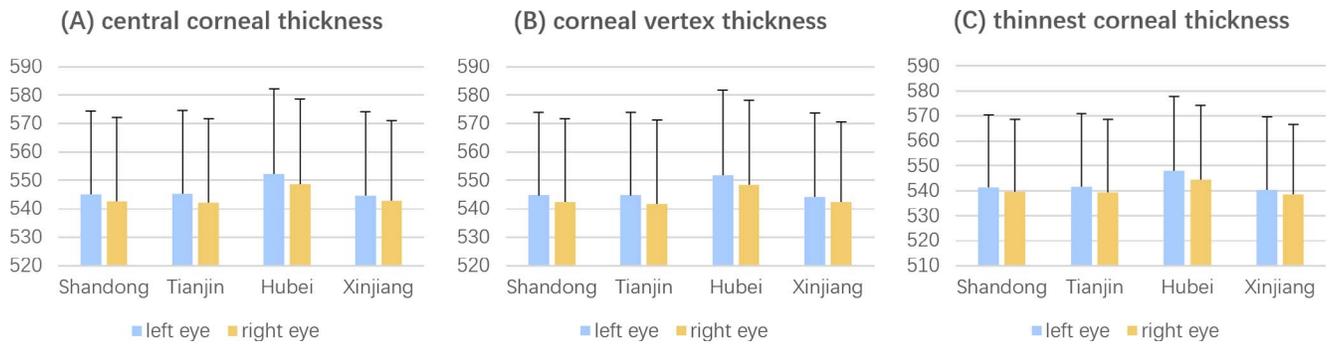


FIGURE 3. Comparison of corneal thickness-related parameters between right and left eyes within patients from different provinces. **(A)** Comparison of central corneal thickness between right and left eyes. **(B)** Comparison of corneal vertex thickness between right and left eyes. **(C)** Comparison of thinnest corneal thickness between right and left eyes.

In our study, the central corneal thickness, corneal vertex thickness, and thinnest corneal thickness of eyes from Hubei province were significantly higher than those same parameters in eyes from the other three provinces. Hubei province is in south China in the subtropical zone; meanwhile, Shandong, Tianjin, and Xinjiang are all in north China, in the warm temperate zone. Therefore, we speculate that the central corneal thickness, corneal vertex thickness, and thinnest corneal thickness may be affected by the intensity of sunlight: increased sun intensity may lead to a thicker cornea. Other studies have shown that (from north to south), the central corneal thickness was 521.0 μm in Japanese,¹⁹ 530.9 μm in

Koreans,²⁰ 535.6 μm in Chinese living in Handan (a city in north China),²¹ 541.5 μm in Chinese living in Liwan (a city in south China),⁸ and 552.3 μm in Singaporean Chinese.²² Although these studies used sample sizes of a few hundred or few thousand subjects, the trend of these previous data supports our speculation that a more equatorial latitude is associated with increased central corneal thickness, perhaps because of the increased intensity of sunlight and increased exposure to ultraviolet light.²³

We found that the thickness of the left eye was greater than the thickness of the right eye in multiple measures: central corneal thickness, corneal vertex thickness, and thinnest

TABLE 3. Comparison of CTSP in Eyes From Different Provinces

Province	N (Missing)	Mean ± SD	Median (Q1–Q3)	χ^2	P
CTSP at 0 mm diameter (μm)					
Shandong	16,999 (7)	540.37 ± 29.17	540.00 (520.00–559.00)	80.697	<0.0001
Tianjin	16,767 (3)	540.46 ± 29.24	539.00 (521.00–560.00)		
Hubei*	2514 (0)	546.10 ± 29.85	545.00 (525.00–566.00)		
Xinjiang	1085 (0)	539.49 ± 28.70	539.00 (521.00–557.00)		
CTSP at 2 mm diameter (μm)					
Shandong	16,999 (7)	548.73 ± 29.48	548.00 (528.00–568.00)	104.810	<0.0001
Tianjin	16,767 (3)	548.70 ± 29.56	548.00 (529.00–568.00)		
Hubei*	2514 (0)	555.32 ± 30.13	554.00 (534.00–575.00)		
Xinjiang	1085 (0)	548.65 ± 29.06	548.00 (529.00–567.00)		
CTSP at 4 mm diameter (μm)					
Shandong	17,002 (4)	576.19 ± 31.53	576.00 (555.00–596.00)	145.688	<0.0001
Tianjin	16,768 (2)	576.18 ± 31.07	575.00 (555.00–596.00)		
Hubei*	2514 (0)	584.32 ± 31.33	583.00 (563.00–605.00)		
Xinjiang	1085 (0)	577.55 ± 30.32	577.00 (558.00–597.00)		
CTSP at 6 mm diameter (μm)					
Shandong	17,002 (4)	626.54 ± 33.99	626.00 (604.00–648.00)	169.425	<0.0001
Tianjin	16,767 (3)	626.87 ± 33.55	626.00 (605.00–649.00)		
Hubei*	2514 (0)	636.08 ± 33.76	635.00 (613.00–659.00)		
Xinjiang†	1085 (0)	628.83 ± 32.74	628.00 (608.00–650.00)		
CTSP at 8 mm diameter (μm)					
Shandong	16,999 (7)	704.98 ± 36.76	705.00 (680.00–729.00)	270.038	<0.0001
Tianjin	16,762 (8)	705.10 ± 36.92	705.00 (680.00–729.00)		
Hubei*	2511 (3)	717.85 ± 37.30	718.00 (691.00–742.00)		
Xinjiang†	1085 (0)	709.95 ± 36.66	710.00 (685.00–734.00)		
CTSP at 10 mm diameter (μm)					
Shandong	14,439 (2567)	812.50 ± 43.78	811.00 (783.00–841.00)	133.884	<0.0001
Tianjin	14,993 (1777)	810.64 ± 43.65	810.00 (781.00–839.00)		
Hubei*	1719 (795)	823.40 ± 43.10	822.00 (794.00–852.00)		
Xinjiang†	698 (387)	817.41 ± 45.15	817.00 (785.00–848.00)		

Wilcoxon rank sum test.

* Significantly different from all other provinces.

† Significantly different from Shandong and Tianjin.

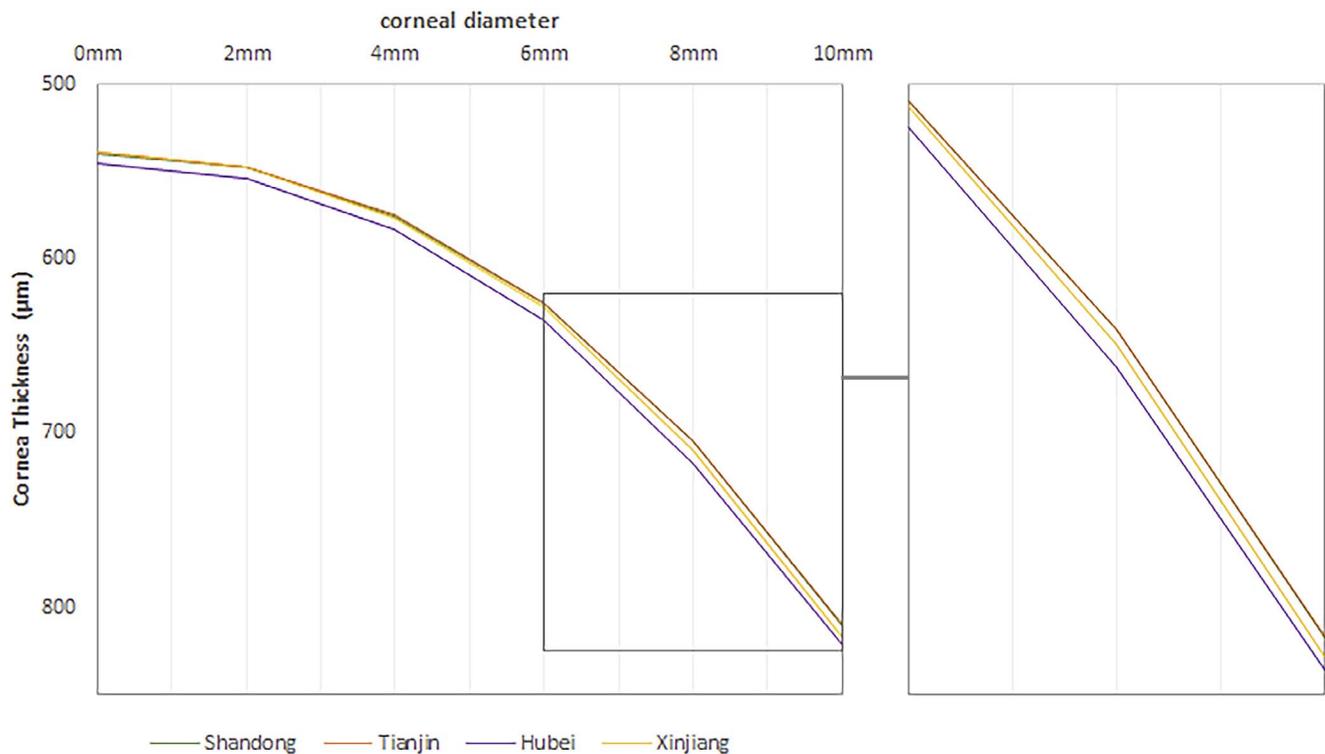


FIGURE 4. Trend of change in CTSP in different provinces. Corneal thickness in eyes from Hubei was significantly higher than corneal thickness in eyes from the other three areas. At 6, 8, and 10 mm in diameter, corneal thickness in eyes from Xinjiang was significantly higher than corneal thickness in eyes from Shandong and Tianjin.

corneal thickness. Right and left eyes from Shandong, Tianjin, and Hubei were statistically significantly different. However, there was no significant difference between any right-eye values and left-eye values in eyes from Xinjiang. According to prior reports, the difference in corneal thickness between left and right eyes is different across different study populations: Altinok et al.²⁴ reported no significant difference between right and left eye central corneal thickness values in a Turkish population; similar results were reported by Wriedt and

Wengert²⁵ in a study of Northwestern American Indians/Alaskan Natives. However, Durkinc et al.¹⁷ reported a significant difference between right-eye and left-eye central corneal thickness values in Aboriginal and Caucasian participants, where central corneal thickness in the right eye was thinner than central corneal thickness in the left. Pedersen et al.²⁶ reported that the thickness of the cornea in the right eye was thinner than in the left in low myopic people; they speculated that the difference may be due to the angle κ . In our study, there were more residents from the Uygur ethnic group in Xinjiang, which is quite different from nationality of residents of the other three provinces, most of whom have reported Han nationality. Anthropologic studies suggest that Han Chinese may represent the Mongolian race and that the Uygur people are descended from both Mongolia and the Caucasus region. These different ethnicities vary widely in their gene expression; therefore, further studies are needed to determine whether differences in corneal thickness between right and left eyes are related to specific ethnic backgrounds.

We analyzed two additional corneal thickness-related parameters, CTSP and PTI, which can describe corneal morphology. We found that the eyes from the Xinjiang population exhibit multiple significant differences compared with eyes from the other three provinces, both in CTSP and in PTI. Notably, Hubei and Xinjiang are inland provinces, whereas Shandong and Tianjin are coastal provinces, with corresponding differences in climate and humidity; consistent with these geographical similarities, maximum and minimum axial PTI exhibited similar trends between Hubei and Xinjiang, whereas similar trends were observed between Shandong and Tianjin. These results indicate that regional and racial differences may influence corneal morphologic differences. Some similar research reports also thought the difference in race and regional climate (area elevation, relative humidity, living and

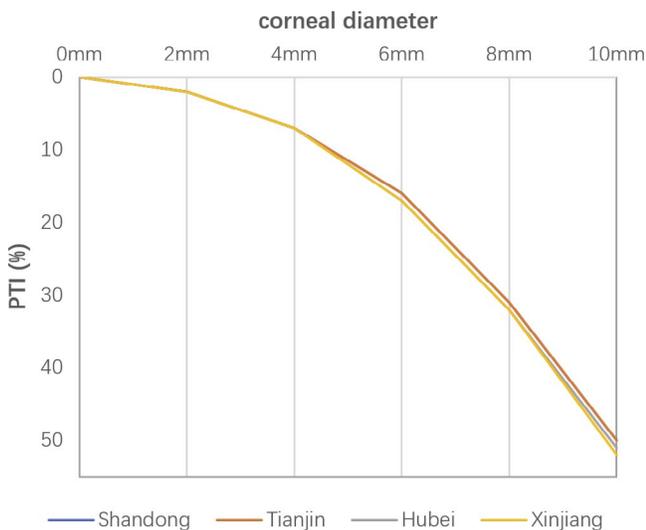


FIGURE 5. Trend line chart of PTI in eyes from different provinces. The growth trend of PTI is similar across provinces, and all PTI measurements increased with increases in corneal diameter.

TABLE 4. Comparison of PTI in Eyes From Different Provinces

Province	N (Missing)	Mean ± SD	Median (Q1–Q3)	χ^2	P
PTI at 0 mm diameter (%)					
Shandong	16997 (9)	0.00 ± 0.00	0.00 (0.00–0.00)	0.000	1.0000
Tianjin	16764 (6)	0.00 ± 0.00	0.00 (0.00–0.00)		
Hubei	2512 (2)	0.00 ± 0.00	0.00 (0.00–0.00)		
Xinjiang	1085	0.00 ± 0.00	0.00 (0.00–0.00)		
PTI at 2 mm diameter (%)					
Shandong	16,997 (9)	1.58 ± 0.49	2.00 (1.00–2.00)	750.809	<0.0001
Tianjin	16,764 (6)	1.55 ± 0.50	2.00 (1.00–2.00)		
Hubei*	2514 (0)	1.79 ± 0.41	2.00 (2.00–2.00)		
Xinjiang†	1085 (0)	1.80 ± 0.41	2.00 (2.00–2.00)		
PTI at 4 mm diameter (%)					
Shandong	16,997 (9)	6.65 ± 0.86	7.00 (6.00–7.00)	664.119	<0.0001
Tianjin	16,766 (4)	6.62 ± 0.83	7.00 (6.00–7.00)		
Hubei*	2514 (0)	7.01 ± 0.85	7.00 (6.00–8.00)		
Xinjiang†	1085 (0)	7.05 ± 0.83	7.00 (7.00–8.00)		
PTI at 6 mm diameter (%)					
Shandong	16,997 (9)	15.98 ± 1.79	16.00 (15.00–17.00)	279.964	<0.0001
Tianjin	16,766 (4)	16.02 ± 1.76	16.00 (15.00–17.00)		
Hubei*	2514 (0)	16.49 ± 1.76	17.00 (15.00–18.00)		
Xinjiang†	1085 (0)	16.58 ± 1.71	17.00 (15.00–18.00)		
PTI at 8 mm diameter (%)					
Shandong	16,997 (9)	30.52 ± 3.34	31.00 (28.00–33.00)	306.763	<0.0001
Tianjin	16,762 (8)	30.52 ± 3.28	31.00 (28.00–33.00)		
Hubei*	2511 (3)	31.53 ± 3.39	32.00 (29.00–34.00)		
Xinjiang†	1085 (0)	31.65 ± 3.36	32.00 (29.00–34.00)		
PTI at 10 mm diameter (%)					
Shandong	14,437 (2569)	50.57 ± 6.26	50.00 (46.00–55.00)	91.979	<0.0001
Tianjin	14,993 (1777)	50.21 ± 6.17	50.00 (46.00–54.00)		
Hubei*	1719 (795)	51.32 ± 6.59	51.00 (47.00–56.00)		
Xinjiang†	698 (387)	51.92 ± 6.75	52.00 (48.00–56.00)		

Wilcoxon rank sum test.

* Significantly different from all other provinces.

† Significantly different from Tianjin and Shandong.

eating habits, etc.) may be the main cause of the difference in the biological parameters of the eyes in different regions.^{27–29}

A limitation of our study is that we did not study the corneal thickness of eyes with different diopters or compare eyes between male and female sexes; previous studies have shown

that corneal thickness is independent of diopter and sex: there was no significant difference in central corneal thickness between emmetropic and ametropic eyes,³⁰ among eyes with different diopters,^{31,32} or between men and women.²³ Based on these prior research results, we expect that our data should

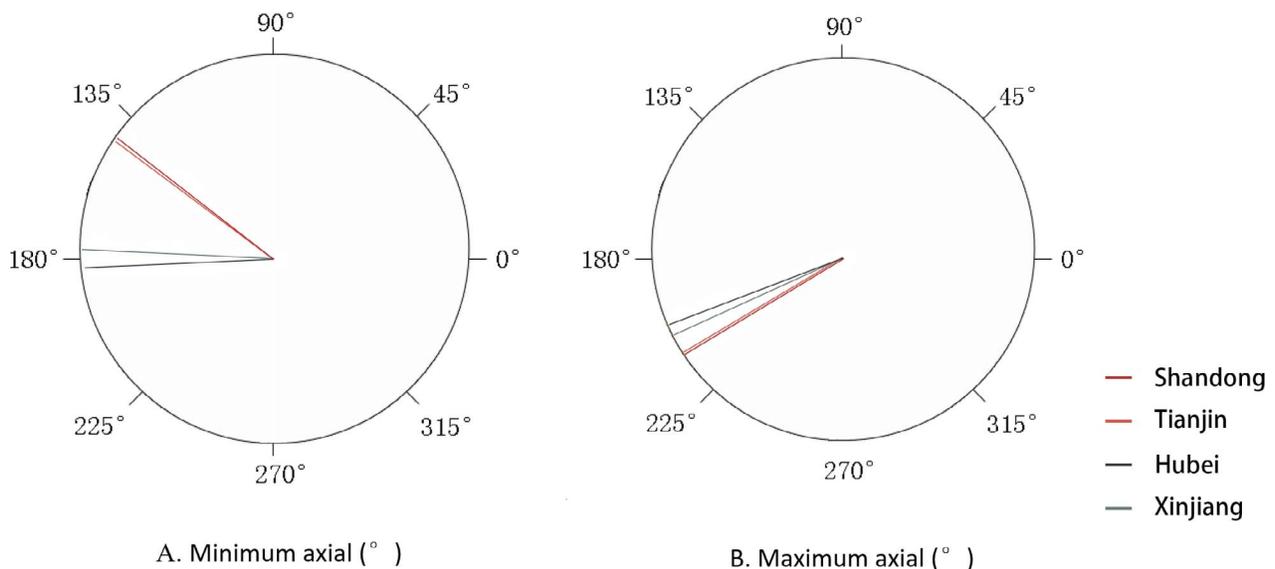


FIGURE 6. Sketch map of the axial PTI in eyes from different provinces. (A) Minimum axial PTI. (B) Maximum axial PTI.

TABLE 5. Comparison of Axial PTI in Eyes From Different Provinces

Province	N (Missing)	Mean \pm SD	Median (Q1–Q3)	χ^2	P
Minimum axial (°)					
Shandong*	16,999 (7)	142.87 \pm 111.70	157.00 (23.00–188.00)	336.22	<0.0001
Tianjin*	16,767 (3)	143.16 \pm 104.53	157.00 (34.00–188.00)		
Hubei†	2514 (0)	182.63 \pm 125.63	180.00 (38.00–334.00)		
Xinjiang†	1085 (0)	177.10 \pm 123.81	176.00 (38.00–330.00)		
Maximum axial (°)					
Shandong*	16,997 (9)	210.93 \pm 86.98	255.00 (105.00–277.00)	37.63	<0.0001
Tianjin*	16,767 (3)	210.59 \pm 90.99	259.00 (101.00–277.00)		
Hubei†	2514 (0)	200.93 \pm 85.77	230.50 (105.00–277.00)		
Xinjiang†	1085 (0)	204.39 \pm 88.06	240.00 (105.00–274.00)		

Wilcoxon rank sum test.

* Similarity between Shandong and Tianjin.

† Similarity between Hubei and Xinjiang.

effectively represent the normal values of corneal thickness-related parameters in young Chinese adults, because the Chinese population is a group with its own distinctive characteristics.

Possessing normal values for corneal thickness-related parameters in the Chinese population will aid in accurate diagnoses of early keratoconus, suspected keratoconus, and other diseases. With the rapid increase in number of eyes that have undergone corneal refractive surgery in China, it is important to perform an accurate and effective preoperative evaluation of the biological properties of the cornea; this allows design of a more reasonable form of corneal cutting, which then aids in more accurate diagnosis of keratoconus and serves to reduce the incidence of corneal ectasia after corneal tissue ablation. We will refine our investigations of cornea-related indicators in future large population studies, which should aid in improving the accuracy of the diagnosis and surgical treatment of corneal and ocular diseases.

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