Distribution and associations of intraocular pressure in 7- and 12-year-old Chinese children: The Anyang Childhood Eye Study

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Abstract

Purpose

To report the intraocular pressure (IOP) and its association with myopia and other factors in 7 and 12-year-old Chinese children.

Methods

All children participating in the Anyang Childhood Eye Study underwent non-contact tonometry as well as measurement of central corneal thickness (CCT), axial length, cycloplegic auto-refraction, blood pressure, height and weight. A questionnaire was used to collect other relevant information. Univariable and multivariable analysis were performed to determine the associations of IOP.

Results

A total of 2760 7-year-old children (95.4%) and 2198 12-year-old children (97.0%) were included. The mean IOP was 13.5 ± 3.1 mmHg in the younger cohort and 15.8 ± 3.5 mmHg in the older cohort (P < 0.0001). On multivariable analysis, higher IOP in the younger cohort was associated with female gender (standardized regression coefficient [SRC], 0.11, P < 0.0001), increasing central corneal thickness (SRC, 0.39, P < 0.0001), myopia (SRC, 0.05, P = 0.03), deep anterior chamber (SRC, 0.07, P < 0.01), smaller waist (SRC, 0.07, P < 0.01) and increasing mean arterial pressure (SRC, 0.13, P < 0.0001). In the older cohort, higher IOP was again associated with female gender (SRC, 0.16, P < 0.0001), increasing central corneal thickness (SRC, 0.43, P < 0.0001), deep anterior chamber (SRC, 0.09, P < 0.01), higher body mass index (SRC, 0.07, P = 0.04) and with increasing mean arterial pressure (SRC, 0.09, P = 0.01), age at which reading commenced (SRC, 0.10, P < 0.01) and birth method (SRC, 0.09, P = 0.01), but not with myopia (SRC, 0.09, P = 0.20).
Conclusion
In Chinese children, higher IOP was associated with female gender, older age, thicker central cornea, deeper anterior chamber and higher mean arterial pressure. Higher body mass index, younger age at commencement of reading and being born of a caesarean section was also associated with higher IOP in adolescence.

Introduction
Intraocular pressure (IOP) is an important characteristic of eye growth.[1] Compared to adults, there is a relative paucity of information, especially population based data on the association of intraocular pressure (IOP) with myopia and other factors in children. Refs IOP has been reported to be associated with factors such as central corneal thickness (CCT), refractive error as well as systemic factors including age, sex, ethnicity, blood pressure and prematurity [2–11]. However, other reports have not found any associations between IOP and refractive error [12–15], age [9,13,15,16], ethnicity [17], sex [5,9,13,15,18,19] or even CCT [17]. These conflicting results may be due to measurement methods, sample sizes, age ranges, ethnic diversity as well as interactions between these and ocular factors [2,9,20].

Myopic eyes have been reported to have a higher IOP than non-myopic eyes and it has been hypothesized that a higher IOP may affect the development of myopia in children [4,21,22]. Other reports have not supported an association between IOP and refractive error/axial length [12,13,23] or change in these parameters on follow-up [5].

The purpose of this study is to report the IOP and its associations, including myopia in a large population based sample of Chinese children.

Materials and methods
The Anyang Childhood Eye Study (ACES) is a school-based cohort study that aims to report the prevalence, incidence and progression of myopia in two cohorts (grade 1 and grade 7) Chinese students in the urban areas of Anyang, Henan Province, Central China. Details of the methodology have been reported previously [24–26]. The grade.

7 students were recruited from October 2011 to December 2011. The ACES adhered to the Declaration of Helsinki and was approved by the ethics committee of Beijing Tongren Hospital, Capital Medical University. Each student was asked for verbal assent and informed written consent was obtained from at least one parent. The authors had access to information that could identify individual participants during or after data collection.

IOP was recorded with a non-contact tonometer (Havitz, HNT-7000) in both eyes. Three measurements were obtained for each eye, and the mean value was recorded. CCT measurements were obtained with the iVue 100 (Optovue Inc, Fremont, California, USA) [27–29]. The measurements were made as recommended by the manufacturer: the children fixated on an internal light in the machine for the few seconds required to generate automatic measurements [28]. Ocular biometric parameters were measured using IOL Master (Carl Zeiss, Meditec AG Jena, Germany); the average of five measurements was averaged.

Cycloplegic autorefraction was performed using an autorefractor (HRK-7000A, HUVITZ, South Korea). Cycloplegia was achieved by instilling 2 drops of 1% cyclopentolate (Alcon) and 1 drop of Mydrin P (Santen, Japan) at 5-minute intervals preceded by a single drop of topical anesthetic agent (Alcaine, Alcon). A third drop of cyclopentolate was administrated if the pupillary light reflex was still present and / or the pupil size was < 6.0 mm. Three auto-refraction
readings were taken and the average was recorded. Emmetropia, myopia and hyperopia were defined as the cycloplegic spherical equivalent (SE) of +1.0 D to -0.5 D, < -0.5 D and ≥+1.0D, respectively.

Data on number of myopic parents (0, 1 2), birth length, birth weight, birth method (normal or caesarean), gestational week, smoking during pregnancy (yes or no), living with smoker during pregnancy (yes or no), doing Chinese eye exercise (yes or no), age at commencement of reading, maximum time spent on continuous reading at one session, distance between face and book when reading and writing, headache during near work (yes or no), books read per week, time spent on near work and outdoors, lights on while sleeping at night (yes or no), parents smoking status (yes or no), water intake per day, frequency for drinking tea or coffee, favorite beverage, and age of myopia onset were obtained using questionnaires that have been published elsewhere [24].

**Statistical analysis**

As the IOP of right and left eyes were highly correlated (Pearson’s correlation coefficient $r = 0.8$), only the data from right eyes were used for analysis. Refractive error was analyzed as spherical equivalent (SE), calculated as sphere plus half cylinder. Statistical analysis was performed using Statistical Analysis System Software (version 9.1.3, SAS Institute, Inc., Cary, NC, USA) and values were reported as mean ± standard deviation. Independent t-test was performed to evaluate the differences in baseline characteristics of the two groups of children. Univariable regression analysis was performed to assess the associations between IOP and ocular and general parameters. This was followed by multivariable regression analysis using the variables that had a P value less than 0.1 in univariable analysis or had any factor with biological plausibility. P ≤0.05 was considered to be statistically significant.

**Results**

Data was available for 2760 of the 2893 grade 1 students (95.4%) and 2198 of the 2267 grade 7 students (97.0%) examined (Table 1) [24]. Some students or their parents refused to undergo the measurement of IOP. The mean age of grade 1 and 7 children was 7.1 and 12.7 years, respectively. The older cohort had a higher IOP (15.8 mm Hg vs. 13.5 mm Hg, P <0.01), longer axial length (24.1 mm vs. 22.7 mm, P <0.01), higher myopia (-1.5 D vs. +0.9 D, P <0.01), deeper anterior chambers (3.6 mm vs. 2.9 mm, P <0.01), higher proportions of non-myopic parents, higher blood pressure and higher anthropometric parameters than the 7-year-olds. In both cohorts the IOP was marginally higher in girls than in boys and in myopes compared to emmetropes or hyperopes.

The results of univariable regression analysis in the two groups are shown in Table 2. In the younger group of children, IOP was significantly associated with gender, number of myopic parents, systolic pressure, diastolic pressure, mean arterial pressure, time outdoors, CCT, spherical equivalent, axial length, anterior chamber depth. In the older group IOP was also associated with age, gender number of myopic parents, birth method, systolic pressure, diastolic pressure, mean arterial pressure, CCT, spherical equivalent, axial length and anterior chamber depth. It was also associated with the age at which they started reading and hours spent sleeping.

The results of multivariable regression analysis are shown in Table 3. In grade 1 children a higher IOP was associated with female gender, thicker CCT, deeper anterior chamber, higher mean arterial pressure, higher myopia and smaller waist size. In the grade 7 children it was also associated with female gender, thicker CCT, deeper anterior chamber, higher mean
arterial pressure but also with higher body mass index, younger age at onset of reading and birth method of caesarean (normal labour as reference).

### Discussion

In this large sample of Chinese children, we found that the grade 7 children had a higher IOP (2.3 mmHg) compared to those in grade 1. In both groups, a higher IOP was associated with being girls, thicker central cornea, deeper anterior chamber and higher blood pressure. In young children, higher IOP was also associated with more myopia and smaller waist. In older children, higher IOP was also associated with younger age of independent reading and caesarean.

The IOP in children of different ethnicities (and adult Chinese) are shown in Table 4. The mean IOP in our study was similar to that of children from Japan [30], Czechoslovakia [31], Malaysia [32] and Singapore (including Chinese, Malays and Indians) [13,33], but was lower than that reported in Turks (16.7 and 17.5 mm Hg) [34,35], USA (black children, 19.3 mm Hg; White children, 17.7 mm Hg) [16], UK (16.7 mm Hg) [36], as well as children from Eastern China (17.6 mm Hg) [37]. While some of these differences could be related to the measurement methods, structural differences between different racial groups also likely play a role. Interestingly the mean IOP in our grade 7 children was similar to that of adult Chinese reported from Northern China [38,39], Southern China [40,41], and Singapore [42]. The measurement technique was not uniform, but the data suggest that adult levels of IOP could be achieved by about 12 years of age. If confirmed baseline measurements at a younger age may be useful to identify true change in IOP unrelated to age.

The COMET study reported a slightly higher IOP (0.66 mm Hg) in boys compared to girls [5]. Three years later the findings were reversed, with IOP lower by 0.57 mm Hg in boys [2].

### Table 1. Baseline characteristics of grade 1 (n = 2760) and grade 7 (n = 2198) children.

|                     | Young group | Older group | \( P \) |
|---------------------|-------------|-------------|--------|
| **Age (y)**         | 7.1±0.4     | 12.7±0.5    | <0.01  |
| **Gender (female, %)** | 1154(41.8) | 1072(48.8)  | <0.01  |
| **SE (D)**          | 0.9±0.9     | -1.5±2.0    | <0.01  |
| **Axial length (mm)** | 22.7±0.7   | 24.1±1.0    | <0.01  |
| **Anterior Chamber depth (mm)** | 2.9±0.2     | 3.6±0.3     | <0.01  |
| **Intraocular pressure (mmHg)** | 13.5±3.1 | 15.8±3.5     | <0.01  |
| **Boys**            | 13.3±3.0    | 15.5±3.4    |         |
| **Girls**           | 13.8±3.2    | 16.2±3.5    |         |
| **Hyperopia**       | 13.3±3.0    | 14.3±3.3    |         |
| **Emmetropia**      | 13.7±3.1    | 15.3±3.3    |         |
| **Myopia**          | 14.0±3.1    | 16.2±3.5    |         |
| **Central corneal thickness (um)** | 540±31      | 538±34      | 0.07    |
| **Parental myopia (n, (%))** | None | 1307 (60.3) | 1282 (69.7) | <0.01  |
|                     | Either | 666 (30.7) | 440 (23.9) |
|                     | Both   | 194 (9.0)  | 117 (6.4)  |
| **Systolic blood pressure (mmHg)** | 97.3±10.2 | 105.5±11.6 | <0.01  |
| **Diastolic blood pressure (mmHg)** | 58.3±9.4   | 66.1±9.8   | <0.01  |
| **Mean arterial pressure (mmHg)** | 71.3±9.0   | 79.2±9.4   | <0.01  |
| **Height (m)**      | 123.5±5.5  | 155.0±7.3  | <0.01  |
| **Weight (kg)**     | 24.6±4.8   | 47.7±10.9  | <0.01  |
| **BMI (kg/m2)**     | 16.1±2.4   | 19.8±3.7   | <0.01  |

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Table 2. Associations of IOP on univariable regression.

| Parameters                                      | Grade 1 Children | Grade 7 Children |
|------------------------------------------------|------------------|------------------|
| **General Parameters**                         |                  |                  |
| Age                                            | 0.21             | 0.05             |
| Gender#                                        | < .0001          | < .0001          |
| Number of myopic parents†                      | 0.0089           | 0.002            |
| Height                                         | 0.27             | 0.01             |
| Weight                                         | 0.99             | < .0001          |
| Waist                                          | 0.047            | 0.06             |
| BMI                                            | 0.57             | 0.0004           |
| Birth length                                    | 0.09             | 0.44             |
| Birth weight                                    | 0.10             | 0.57             |
| Birth method**                                  | 0.047            | 0.0003           |
| Gestational weeks                              | 0.02             | 0.41             |
| Smoking during pregnancy*                      | 0.85             | 0.67             |
| Living with smoker during pregnancy*           | 0.27             | 0.98             |
| Doing Chinese eye exercise*                    | 0.56             | 0.82             |
| Systolic pressure                              | < .0001          | < .0001          |
| Diastolic pressure                             | < .0001          | 0.0009           |
| Mean arterial pressure                         | < .0001          | < .0001          |
| Age at commencement of reading                 | 0.99             | 0.003            |
| Maximum time spent reading continuously         | 0.26             | 0.13             |
| Distance between face and book when reading /writing | 0.37             | 0.17             |
| Headache during near work*                     | 0.53             | 0.47             |
| Books read per week                            | 0.11             | 0.62             |
| Time spent on near work                        | 0.09             | 0.43             |
| Time spent outdoors                            | 0.03             | 0.80             |
| Time spent sleeping                            | 0.0497           | 0.02             |
| Lights on while sleeping at night*             | 0.75             | 0.84             |
| Parents smoking status*                        | 0.17             | 0.008            |
| Water intake per day                           | 0.60             | 0.04             |
| Frequency for drinking tea                     | 0.74             | 0.59             |
| Favorite beverage                              | 0.94             | 0.17             |
| Frequency for drinking coffee                  | 0.25             | 0.87             |
| **Ocular Parameters**                          |                  |                  |
| Central corneal thickness                      | < .0001          | < .0001          |
| Spherical equivalent                           | < .0001          | < .0001          |
| Axial length                                    | 0.03             | < .0001          |
| Anterior chamber depth                         | 0.01             | 0.0001           |
| Dominant eye                                   | 0.08             | 0.03             |
| Age of myopia onset                            | 0.42             | 0.09             |

# male as reference
† 0 as reference
**Normal labour as reference
* Answer ‘no’ as reference

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We report lower IOP in boys compared to girls, but the differences were small, 0.5 mmHg in the 7-year-olds and 0.7 mmHg in the 12-year-olds. While gender was identified as a factor associated with IOP on multivariable regression, the differences are small and probably insignificant.

The CCT was similar in both groups and showed a positive association with IOP (an increase of 4~5 mm Hg in IOP for every 100 μm in CCT), consistent with most previous reports [9,16,43]. Central corneal thickness has been previously reported to be greater in children with ocular hypertension than in controls.

In our study, IOP was higher in myopic eyes than in emmetropic or hyperopic eyes. While the absolute difference was small in grade 1 children, this increased to 1 mmHg in grade 2.

### Table 3. Associations of IOP on multivariable regression analysis.

| Parameters                          | Grade 1 Children |                      | P value | Grade 7 Children |                      | P value |
|-------------------------------------|------------------|----------------------|---------|------------------|----------------------|---------|
|                                     | Parameter estimate | Standardized regression coefficient |         | Parameter estimate | Standardized regression coefficient |         |
| Gender                              | 0.68828          | 0.11038              | <.0001  | 1.15001          | 0.16014              | <.0001  |
| Central corneal thickness           | 0.03934          | 0.39056              | <.0001  | 0.04598          | 0.42841              | <.0001  |
| Anterior chamber depth              | 0.87725          | 0.06798              | 0.0055  | 1.32966          | 0.09160              | 0.0078  |
| Mean arterial pressure              | 0.04460          | 0.13181              | <.0001  | 0.03472          | 0.08854              | 0.0107  |
| Spherical equivalent                | -0.17213         | -0.05227             | 0.0276  |                  |                      |         |
| Waist                               | -0.03562         | -0.07103             | 0.0018  |                  |                      |         |
| Body mass index (BMI)               |                  |                      |         |                  |                      |         |
| Age at commencement of reading      |                  |                      |         |                  |                      |         |
| Birth method*                       |                  |                      |         |                  |                      |         |

* Normal labour as reference

We report lower IOP in boys compared to girls, but the differences were small, 0.5 mmHg in the 7-year-olds and 0.7 mmHg in the 12-year-olds. While gender was identified as a factor associated with IOP on multivariable regression, the differences are small and probably insignificant.

The CCT was similar in both groups and showed a positive association with IOP (an increase of 4~5 mm Hg in IOP for every 100 μm in CCT), consistent with most previous reports [9,16,43]. Central corneal thickness has been previously reported to be greater in children with ocular hypertension than in controls.

In our study, IOP was higher in myopic eyes than in emmetropic or hyperopic eyes. While the absolute difference was small in grade 1 children, this increased to 1 mmHg in grade 2.

### Table 4. Mean intraocular pressure (IOP) obtained in children of different ethnicities and adult Chinese.

| Study                          | Ethnicity                      | Age (years) | Method                                | Mean±SD          |
|--------------------------------|--------------------------------|-------------|---------------------------------------|------------------|
| Li et al. (current study)      | Northern Chinese              | 7.1±0.4     | Non-contact tonometry                  | 13.5±3.1         |
| Jiang et al.[37]               | Eastern Chinese               | 4–18        | Non-contact tonometry                  | 17.6±2.7         |
| Hikoya et al.[30]              | Japanese                      | 8 months–18 | Tono-Pen                              | 13.9±2.4         |
| Muir et al.[45]                | Black                         | 5–17        | Goldman applanation and Tono-Pen       | 19.3±6.0         |
| Yiidrim et al.[36]             | Turkish                       | 10.1±1.6    | Noncontact tonometry                   | 16.7±2.7         |
| Sahin et al.[34]               | Turkish                       | 7–12        | Tono-Pen                              | 17.4±2.7         |
| Osmera et al.[31]              | Czech                         | 7–17        | Goldman applanation Tonometry         | 14.5±2.6         |
| Lee et al.[13]                 | Singaporean Chinese           | 9–11        | Non-contact tonometry                  | 16.6±2.7         |
| Doughty et al.[36]             | White                         | 5–15        | Non-contact tonometry                  | 16.7±2.9         |
| Lim et al. [33]                | Singaporean (Chinese, Malays and Indians) | 13.97±0.9 | Ocular Response Analyzer | 15.1±2.84 |
| Heiday et al. [32]             | Malay                          | 12.27±2.76  | Non-contact tonometry                  | 15.6±3.05        |
| Zhao et al.[38]                | Northern Chinese              | 50+         | Perkins                               | 13.5±2.2         |
| Xu et al.[46]                  | Northern Chinese              | 40+         | Non-contact tonometry                  | 16.1±3.4         |
| He et al.[40]                  | Southern Chinese              | 50+         | Tonopen                               | 15.2±3.1         |
| Lin et al.[41]                 | Southern Chinese              | 65+         | Non-contact tonometry                  | 12.9±3.1         |
| Foster et al.[42]              | Singaporean Chinese           | 40+         | Goldman applanation Tonometry         | 15.3              |

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children and may suggest a trend. A significant negative association between IOP and spherical equivalent was found in univariable analysis in both groups of children. On multivariable regression this association persisted only in the younger children. IOP was positively associated with deeper anterior chamber in both groups of children (about 1 mm Hg/mm).

We also found that children with who started reading earlier in life had a higher IOP. This supports other reports that time spent indoors reading or writing was associated with a higher IOP [37]. The same study also reported an association between higher IOP and longer axial length [37], which is similar to our findings of deeper anterior chamber and higher IOP. These results confirm that a higher IOP is associated with higher myopia and relevant ocular parameters but its role as a causative factor remains unclear.

Higher IOP was associated with higher mean arterial pressure in both young and older children: a 10 mm Hg increase in mean arterial pressure was associated with about a 0.4 mm Hg increase in IOP. This is similar to what has been reported in adult Chinese, Foster et al [42] found that a 10 mm Hg increase in blood pressure was associated with 0.3 mm Hg in IOP.

Birth by caesarean section was found to be associated with higher IOP compared with normal labour. While this could be chance finding, it is possible that children delivered by caesarean section are more likely to be premature and myopic, and have higher IOP via that association. We do accept that some factors may be significant by chance alone.

The strengths of the present study are the population based large sample size, two groups of children with different mean age and multiple well documented factors included for analysis and the high rate of participation. There are several limitations too. Firstly, a non-contact tonometer rather than the Goldmann tonometer was used to measure IOP. The non-contact tonometer was selected because it is quick, easy to use on children with a lower risk of disease transmission and has been used in other studies in children. Next, the two groups covered two different age groups with no children in between; this limits extrapolation of the effect of age on IOP. Also, as it involved a different cohort, the effect of age is actually counterfactual: ideally we should follow the same cohort to detect this change.

In summary, in grade 1 and grade 7 Chinese children, IOP was associated with gender, age, central corneal thickness, anterior chamber depth and blood pressure. Follow up of these two cohorts to further assess these associations and the role of IOP in the development of myopia is planned.

Supporting information
S1 Table. The underlying participant-level data.
(XLS)

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**References**

1. Biglan AW (2006) Glaucoma in children: are we making progress? J AAPOS 10: 7–21. https://doi.org/10.1016/j.aaapos.2005.10.001 PMID: 16527674

2. Manny RE, Mitchell GL, Cotter SA, Jones-Jordan LA, Kleinstein RN, Mutti DO, et al. (2011) Intraocular pressure, ethnicity, and refractive error. Optom Vis Sci 88: 1445–1453. https://doi.org/10.1097/OPX.0b013e18230f559 PMID: 21946783

3. Youn DH, Yu YS, Park IW (1990) Intraocular pressure and axial length in children. Korean J Ophthalmol 4: 26–29. https://doi.org/10.3341/kjo.1990.4.1.26 PMID: 22142404

4. Quinn GE, Berlin JA, Young TL, Ziyalan S, Stone RA (1995) Association of intraocular pressure and myopia in children. Ophthalmology 102: 180–185. PMID: 7862404

5. Manny RE, Deng L, Crossnoe C, Gwiazda J (2008) IOP, myopic progression and axial length in a COMET subgroup. Optom Vis Sci 85: 97–105. https://doi.org/10.1097/OPX.0b013e3181622633 PMID: 18296926

6. Nomura H, Ando F, Nino N, Shimokata H, Miyake Y (2004) The relationship between intraocular pressure and refractive error adjusting for age and central corneal thickness. Ophthalmic Physiol Opt 24: 41–45. PMID: 14687200

7. Tong L, Saw SM, Siak JK, Gazzard G, Tan D (2004) Corneal thickness determination and correlates in Singaporean schoolchildren. Invest Ophthalmol Vis Sci 45: 4004–4009. https://doi.org/10.1167/iovs.04-0121 PMID: 15505049

8. Bhan A, Browning AC, Shah S, Hamilton R, Dave D, Dua HS (2002) Effect of corneal thickness on intraocular pressure measurements with the pneumotonometer, Goldmann applanation tonometer, and Tono-Pen. Invest Ophthalmol Vis Sci 43: 1389–1392. PMID: 11980851

9. Shimmyo M, Ross AJ, Moy A, Mostafavi R (2003) Intraocular pressure, Goldmann applanation tension, corneal thickness, and corneal curvature in Caucasians, Asians, Hispanics, and African Americans. Am J Ophthalmol 136: 603–613. PMID: 14516799

10. Recep OF, Hasiripi H, Cagil N, Sarikatipoglu H (2001) Relation between corneal thickness and intraocular pressure measurement by noncontact and applanation tonometry. J Cataract Refract Surg 27: 1787–1791. PMID: 11709252

11. Uva MG, Reibaldi M, Longo A, Avitable T, Gagliano C, Scillo D, et al. (2011) Intraocular pressure and central corneal thickness in premature and full-term newborns. J AAPOS 15: 367–369. https://doi.org/10.1016/j.aaapos.2011.04.004 PMID: 21816643

12. Goss DA, Caffey TW (1999) Clinical findings before the onset of myopia in youth: 5. Intraocular pressure. Optom Vis Sci 76: 286–291. PMID: 10375243

13. Lee AJ, Saw SM, Gazzard G, Cheng A, Tan DT (2004) Intraocular pressure associations with refractive error and axial length in children. Br J Ophthalmol 88: 5–7. PMID: 14693759

14. Lee SM, Edwards MH (2000) Intraocular pressure in anisometropic children. Optom Vis Sci 77: 675–679. PMID: 11147738

15. Puell-Marin MC, Romero-Martin M, Dominguez-Carmona M (1997) Intraocular pressure in 528 university students: effect of refractive error. J Am Optom Assoc 68: 657–662. PMID: 9354058

16. Muir KW, Duncan L, Enyedi LB, Friedman SF (2006) Central corneal thickness in children: Racial differences (black vs. white) and correlation with measured intraocular pressure. J Glaucoma 15: 520–523. https://doi.org/10.1097/01.jgl.0000212280.78044.45 PMID: 17106365
17. Haider KM, Mickler C, Oliver D, Moya FJ, Cruz OA, Davitt BV (2008) Age and racial variation in central corneal thickness of preschool and school-aged children. J Pediatr Ophthalmol Strabismus 45: 227–233. PMID: 18705620

18. Sihota R, Tuli D, Dada T, Gupta V, Sachdeva MM (2006) Distribution and determinants of intraocular pressure in a normal pediatric population. J Pediatr Ophthalmol Strabismus 43: 14–18; quiz 36–17. PMID: 16491720

19. Akinci A, Cetinkaya E, Aycan Z, Oner O (2007) Relationship between intraocular pressure and obesity in children. J Glaucoma 16: 627–630. https://doi.org/10.1097/IJG.0b013e318057528a PMID: 18091182

20. Tomlinson A, Phillips CI (1970) Applanation tension and axial length of the eyeball. Br J Ophthalmol 54: 548–553. PMID: 5458678

21. Edwards MH, Brown B (1993) Intraocular pressure in a selected sample of myopic and nonmyopic Chinese children. Optom Vis Sci 70: 15–17. PMID: 8430003

22. Jensen H (1992) Myopia progression in young school children and intraocular pressure. Doc Ophthalmol 82: 249–255. PMID: 1303861

23. Edwards MH, Brown B (1996) IOP in myopic children: the relationship between increases in IOP and the development of myopia. Ophthalmic Physiol Opt 16: 243–246. PMID: 8977891

24. Li SM, Liu LR, Li SY, Ji YZ, Fu J, Wang Y, et al. (2013) Design, methodology and baseline data of a school-based cohort study in central China: the Anyang Childhood Eye Study. Ophthalmic Epidemiol 20: 348–359. https://doi.org/10.3109/09286586.2013.842596 PMID: 24160405

25. Li SM, Li SY, Kang MT, Zhou Y, Liu LR, Li H, et al. (2015) Near work related parameters and myopia in Chinese children: the Anyang Childhood Eye Study. PLoS One 10: e0134514. https://doi.org/10.1371/journal.pone.0134514 PMID: 26244865

26. Atchison DA, Li SM, Li H, Li SY, Liu LR, Kang MT, et al. (2015) Relative peripheral hyperopia does not predict development and progression of myopia in children. Invest Ophthalm Vis Sci 56: 6162–6170. https://doi.org/10.1167/iosvs.15-17200 PMID: 26397463

27. Li SM, Wang N, Zhou Y, Li SY, Kang MT, Liu LR, et al. (2015) Paraxial schematic eye models for 7- and 14-year-old Chinese children. Invest Ophthalm Vis Sci 56: 3577–3583. https://doi.org/10.1167/iosvs.15-16428 PMID: 26047044

28. Zhu BD, Li SM, Li H, Liu LR, Wang Y, Yang Z, et al. (2013) Retinal nerve fiber layer thickness in a population of 12-year-old children in central China measured by iVue-100 spectral-domain optical coherence tomography: the Anyang Childhood Eye Study. Invest Ophthalm Vis Sci 54: 8104–8111. https://doi.org/10.1016/j.ijjo.2013.11-1958 PMID: 24150754

29. Li SM, Li SY, Kang MT, Zhou YH, Li H, Liu LR, et al. (2015) Distribution of ocular biometry in 7- and 14-year-old Chinese children. Optom Vis Sci 92: 566–572. https://doi.org/10.1097/OPX.0000000000000570 PMID: 25875684

30. Hikoya A, Sato M, Tsuzuki K, Koide YM, Asaoka R, Hotta Y (2009) Central corneal thickness in Japanese children. Jpn J Ophthalmol 53: 7–11. https://doi.org/10.1007/s10384-008-0619-6 PMID: 19184302

31. Osmera J, Filous A, Hlozanek M (2009) Central corneal thickness, intraocular pressure and their correlation in a healthy Czech children aged 7–17 years. Cesk Slov Oftalmol 65: 19–23. PMID: 19366033

32. Heidary F, Gharebaghi R, Wan Hitam WH, Naing NN, Wan-Arfah N, Shatriah I (2011) Central corneal thickness and intraocular pressure in Malay children. PLoS One 6: e25208. https://doi.org/10.1371/journal.pone.0025208 PMID: 21998644

33. Lim L, Cheung N, Gazzard G, Chan YH, Wong TY, Saw SM (2009) Corneal biomechanical properties and retinal vascular caliber in children. Invest Ophthalm Vis Sci 50: 121–125. https://doi.org/10.1167/iosvs.08-2352 PMID: 18775868

34. Sahin A, Basmak H, Yildirim N (2008) The influence of central corneal thickness and corneal curvature on intraocular pressure measured by tono-pen and rebound tonometer in children. J Glaucoma 17: 57–61. https://doi.org/10.1097/IJG.0b013e31806ab336 PMID: 18303387

35. Yildirim N, Sahin A, Basmak H, Bal C (2007) Effect of central corneal thickness and radius of the corneal curvature on intraocular pressure measured with the Tono-Pen and noncontact tonometer in healthy schoolchildren. J Pediatr Ophthalmol Strabismus 44: 216–222. PMID: 17694826

36. Doughty MJ, Laiquzzaman M, Muller A, Oblak E, Button NF (2002) Central corneal thickness in European (white) individuals, especially children and the elderly, and assessment of its possible importance in clinical measures of intra-ocular pressure. Ophthalmic Physiol Opt 22: 491–504. PMID: 12477013

37. Jiang WJ, Wu JF, Hu YY, Wu H, Sun W, Lu TL, et al. (2014) Intraocular pressure and associated factors in children: the Shandong children eye study. Invest Ophthalm Vis Sci 55: 4128–4134. https://doi.org/10.1167/iosvs.14-14244 PMID: 24876285
38. Zhao J, Sui R, Jia L, Ellwein LB (2002) [Prevalence of glaucoma and normal intraocular pressure among adults aged 50 years or above in Shunyi county of Beijing]. Zhonghua Yan Ke Za Zhi 38: 335–339. PMID: 12139808

39. Xu L, Wang Y, Wang S, Wang Y, Jonas JB (2007) High myopia and glaucoma susceptibility the Beijing Eye Study. Ophthalmology 114: 216–220. https://doi.org/10.1016/j.ophtha.2006.06.050 PMID: 17123613

40. He M, Foster PJ, Ge J, Huang W, Zheng Y, Friedman DS, et al. (2006) Prevalence and clinical characteristics of glaucoma in adult Chinese: a population-based study in Liwan District, Guangzhou. Invest Ophthalmol Vis Sci 47: 2782–2788. https://doi.org/10.1167/iovs.06-0051 PMID: 16799014

41. Lin HY, Hsu WM, Chou P, Liu CJ, Chou JC, Tsai SY, et al. (2005) Intraocular pressure measured with a noncontact tonometer in an elderly Chinese population: the Shihpai Eye Study. Arch Ophthalmol 123: 381–386. https://doi.org/10.1001/archopht.123.3.381 PMID: 15767482

42. Foster PJ, Machin D, Wong TY, Nge TP, Kirwan JF, Johnson GJ, et al. (2003) Determinants of intraocular pressure and its association with glaucomatous optic neuropathy in Chinese Singaporeans: the Tanjong Pagar Study. Invest Ophthalmol Vis Sci 44: 3885–3891. PMID: 12939305

43. Doughty MJ, Zaman ML (2000) Human corneal thickness and its impact on intraocular pressure measures: a review and meta-analysis approach. Surv Ophthalmol 44: 367–408. PMID: 10734239

44. Muir KW, Jin J, Freedman SF (2004) Central corneal thickness and its relationship to intraocular pressure in children. Ophthalmology 111: 2220–2223. https://doi.org/10.1016/j.ophtha.2004.06.020 PMID: 15582077

45. Xu L, Li J, Zheng Y, Cui T, Zhu J, Ma K, et al. (2005) Intraocular pressure in Northern China in an urban and rural population: the Beijing eye study. Am J Ophthalmol 140: 913–915. https://doi.org/10.1016/j.ajo.2005.04.050 PMID: 16310472