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Associations between anthropometric indicators and refraction and ocular biometrics in a cross-sectional study of Chinese schoolchildren

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Complete List of Authors:	Ye, Sheng; School of Public Health, Tianjin Medical University Liu, Shengxin; School of Public Health, Tianjin Medical University Li, Wenlei; School of Public Health, Tianjin Medical University Wang, Qifan; School of Public Health, Tianjin Medical University Xi, Wei; School of Public Health, Tianjin Medical University Zhang , Xin; School of Public Health, Tianjin Medical University
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Manuscripts

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4 1 **Associations between anthropometric indicators and refraction and**
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7 2 **ocular biometrics in a cross-sectional study of Chinese schoolchildren**
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12 4 **Sheng Ye, Shengxin Liu, Wenlei Li, Qifan Wang, Wei Xi, and Xin Zhang**
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15 5 Department of Maternal, Child and Adolescent Health, School of Public Health, Tianjin
16
17 6 Medical University, Tianjin, China.
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20 7 SY and SL contributed equally to the work presented here and should therefore be regarded
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23 8 as equivalent authors.
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28 10 **Correspondence to**

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31 11 Prof. Xin Zhang, Department of Maternal, Child and Adolescent Health, School of Public
32
33 12 Health, Tianjin Medical University, No. 22 Qixiangtai Road, Tianjin 300070, China;
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36 13 zhangxin@tmu.edu.cn.
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42 15 **Synopsis**
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45 16 Development of refraction may be related to physical development during early adolescent
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47 17 growth. Future studies in endocrine traits, such as the sex hormones, could further provide
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50 18 new insights for the association between height and refraction.
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7 **22 ABSTRACT**8
9 **23 Objective** To identify associations between anthropometric indicators, including height,
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24 weight, and body mass index (BMI), and refraction and ocular biometrics in Chinese
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27 schoolchildren in Tianjin, China.28
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26 Design Cross-sectional study.**27 Participants** A total of 482 (86.1%) students (6 to 15 years old) were enrolled using a
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stratified, clustered, random sampling method in this study, with no recorded history of eye
or systemic pathologies.**30 Methodology** Height and weight were measured using standardized protocols. Ocular
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biometrics, such as axial length (AL), vitreous chamber depth (VCD), and corneal
curvature (CC), were measured by a low-coherence optical reflectometry device. The
AL/CC ratio was calculated. Cycloplegic refraction was measured using autorefraction.**34 Results** The overall prevalence of myopia was 71.16%. The mean refraction, height,
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weight and BMI were -1.48 ± 1.82 D, 140.79 ± 13.95 cm, 38.29 ± 10.86 kg, and $19.04 \pm$
 3.18 kg/m², respectively. Taller persons tended to have eyes with longer ALs ($+0.14$ mm
for each 10 cm difference in height, $P<0.05$), deeper VCDs ($+0.13$ mm, $P<0.05$), higher
AL/CC ratios ($+0.02$, $P<0.05$), and more negative refractions (-0.21 D, $P<0.05$) after
controlling for age, gender, parental myopia, family income, reading and writing distance,
and time spent outdoors. However, although weight was correlated with AL, central

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4 41 corneal thickness and VCD, students with different weights or BMIs showed similar
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7 42 refraction.

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9 43 **Conclusions** Height remained independently related to refraction and various ocular
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12 44 biometrics after adequately controlling covariates, which could support the idea that the
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15 45 development of refraction is related to physical development. Future work should focus on
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18 46 the effects of sex hormones on the association between height and refraction during early
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21 47 adolescent growth.

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23 48 **Keywords:** anthropometric indicators, refraction, ocular biometrics, schoolchildren
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28 50 **Strengths and limitations of this study**

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31 51 ● A stratified, clustered, random sampling strategy was applied to recruit participants,
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34 52 which could avoid the potential selection bias present in previous studies performed in
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37 53 specific population groups.
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39 54 ● Ocular biometrics were measured comprehensively and the covariates were controlled
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42 55 adequately, which allowed us to achieve a more detailed analysis.
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45 56 ● This study was cross-sectional design and could not allow an evaluation of causality.
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48 57 ● Puberty parameters were not available in our study, limiting the further research to
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51 58 explore the potential shared mechanism underlies both physical development during
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54 59 early adolescent growth and refractive status.

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61 **Introduction**

62 Myopia has reached almost epidemic proportions in the world, especially in certain areas
63 of East and Southeast Asia.¹ This condition is commonly viewed as etiologically
64 heterogeneous. Genetic and environmental risk factors have been shown to be involved in
65 its progression. The genetic basis of myopia has been supported by evidence indicating
66 high heritability values in twin studies² and a higher prevalence of myopia in children with
67 myopic parents.³ Excessive near work activities,^{4 5} limited time spent outdoors,^{6 7} and
68 intensive educational pressure^{8 9} all have been reported to promote the development of
69 myopia. In our effort to consider other factors, we noted that anthropometric indicators,
70 such as height, are thought to be associated with refraction, although no consensus has been
71 achieved regarding this issue.^{10 11}

72 Refractive status is determined by the balance of refractive power of the cornea and lens,
73 and the axial length (AL) of the eye (representing the combination of anterior chamber
74 depth (ACD), lens thickness (LT), and vitreous chamber depth (VCD)).¹² Myopia usually
75 arises in an eye that has become too long, particularly via the elongation of the vitreous
76 chamber. Several epidemiological studies have demonstrated that the changes in ocular
77 dimensions that occur in early life progress concomitant with physical development in
78 children,^{13 14} and the ages of cessation are also similar for increases in height and axial
79 elongation.¹³ Furthermore, genetic studies have confirmed that a common genetic pathway
80 underlies both height and AL,^{15 16} although no specific genetic variants have yet been

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4 81 identified. All of these clues suggest the existence of a shared mechanism that regulates
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7 82 the coordinated growth of body and eye size. It has been suggested that there may be a
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10 83 relationship between body stature and refraction. However, in contrast to the consensus
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12 84 regarding the significant associations between body stature and AL, the relationship
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15 85 between body stature and refraction remains controversial. Whereas many studies have
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17 86 reported that taller^{10 17-20} and heavier persons^{21 22} have an increased likelihood of having
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20 87 myopia, other studies have found no such association.²³⁻²⁸ The discrepancies among these
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23 88 findings may be due to differences in sample sizes, concept definitions or other
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26 89 methodological variations (e.g., height and weight obtained via self-reporting).

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28 90 In China, few studies have comprehensively measured ocular biometrics or further
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31 91 explored their associations with body stature. Wang et al.¹⁴ confirmed that there is a
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34 92 positive association between height and AL in 7- to 15-year-old schoolchildren based on
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37 93 longitudinal data obtained in Guangzhou, China. However, detailed information about the
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40 94 associations between body stature and refraction and other ocular biometrics was not
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43 95 available in that study. Additionally, myopia most commonly starts in young
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46 96 schoolchildren and progresses in early adolescence.²¹ It is most appropriate to study the
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49 97 effect of body growth on refractive development in young, growing students. Therefore, in
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52 98 the current survey, we explored the associations between anthropometric indicators,
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55 99 including height, weight, and body mass index (BMI), and both refraction and ocular
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57 100 biometrics in schoolchildren aged 6 to 15 years old in Tianjin, China.

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7 102 **METHODS**8
9 103 Participants were initially recruited using a stratified, clustered, random sampling method.10
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12 104 Two districts were randomly chosen from the 6 main urban districts in Tianjin in November13
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15 105 2016. Next, one school was randomly selected from each selected district. One class was16
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18 106 then randomly chosen from each grade level within the two selected schools. All students19
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21 107 in these selected classes were invited, but participation in this study was voluntary. After22
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24 108 the purposes and procedures of the study were explained to each student and their parents25
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27 109 in depth, written informed consent was collected. Students without parental consent and28
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30 110 students who had amblyopia, heterotropia, or any eye or systemic pathologies were31
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33 111 excluded. Finally, the study consisted of 482 (86.1% response rate) 6- to 15-year-old34
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36 112 students (264 boys, 218 girls) out of a total of 560 students who were initially invited.37
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39 113 Individuals who were included in the study were older (9.42 ± 2.09 vs 7.60 ± 2.38 years40
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42 114 old, $P < 0.01$) than those who were excluded (data not shown). There were no significant43
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45 115 differences in gender, parental myopia, monthly family income, reading and writing46
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48 116 distance, and time spent outdoors between the included and excluded individuals.49
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51 117 The study protocol was approved by the Ethics Committee of Tianjin Medical University52
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54 118 and performed in accordance with the tenets of the Declaration of Helsinki.55
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57 119 **Ocular examinations**58
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60 120 All included participants underwent a comprehensive eye examination, including

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4 121 measurements of intraocular pressure, a slit-lamp examination of the anterior and posterior
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6 122 segments, cycloplegic autorefractometry and ocular biometrics. The purpose of intraocular
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9 123 pressure measurement and the slit lamp examination was to exclude contraindications for
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12 124 mydriasis.

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15 125 Ocular biometrics, such as AL, central corneal thickness (CCT), ACD, LT, VCD, and
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17 126 corneal curvature (CC), were measured with a low-coherence optical reflectometry device
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20 127 (Lenstar LS900; Haag-Streit AG, 3098 Koeniz, Switzerland) in both eyes before pupil
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23 128 dilation. The AL/CC ratio, also commonly known as the axial length/corneal radius
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26 129 (AL/CR) ratio, was additionally calculated. Cycloplegia was then induced by administering
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29 130 two drops containing 0.5% tropicamide and 0.5% phenylephrine in a mixed eye agent to
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32 131 each eye at 0 and 5 minutes. At 25 minutes after the second instillation, participants with
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35 132 full cycloplegia underwent autorefractometry using an auto-kerato-refractor (Canon
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37 133 Autorefractor RK-F1, Tokyo, Japan), and 3 consecutive measurements were taken in both
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40 134 eyes. The mean value of 3 valid measurements was calculated for statistical analysis. All
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43 135 of the above instruments were calibrated before the ocular examination.

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45 136 The spherical equivalent refraction (SER) of each eye was then calculated as the
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48 137 spherical refraction + 1/2 of the cylindrical refraction using data obtained using the
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51 138 autorefractor. Myopia was defined as an SER of ≤ -0.5 diopters (D).

52 53 139 **Anthropometric measurements**

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56 140 Height and weight were obtained following specific standardized protocols. Height was

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4 141 determined with the subject standing barefoot on the floor of the height meter and recorded
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7 142 in centimeters (cm). Weight was measured without shoes and heavy coats on a calibrated
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10 143 electronic weighing scale and recorded in kilograms (kg). BMI was derived as
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12 144 weight/height² and recorded in kilograms per square meter (kg/m²).

145 **Questionnaire**

146 The parents of participants were asked to complete a questionnaire developed to collect
147 information on social-demographic characteristics and potential risk factors for school
148 myopia. Moreover, parents whose children were excluded from the study were also
149 required to finish the same questionnaire.

150 The basic characteristics of the participants included age (calculated as the date of
151 investigation minus the birth date of the child), gender (boy or girl), the monthly income
152 of the family (less than 4000 RMB, 4000-8000 RMB, 8000-10,000 RMB, 10,000-15,000
153 RMB, or more than 15,000 RMB), and the number of myopic parents (none, one parent,
154 or both parents). Near work related behaviors were ascertained with the question “What is
155 the distance between your child's eyes and a book when reading or writing?”, with answers
156 categorized as follows: <10 cm, 10-19 cm, 20-29 cm, and ≥30 cm. Time spent outdoors
157 was estimated by asking how many hours per day the child spent in outdoor activities
158 during weekdays and weekends separately. The average time spent outdoors was calculated
159 by the following formula: $[T_{\text{weekday}} (\text{hours spent on weekday}) \times 5 + T_{\text{weekend}} (\text{hours spent on}$
160 $\text{weekend}) \times 2] \div 7$.

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4 **161 Statistical analysis**
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7 162 Because refraction and ocular biometrics were highly correlated between the left and right
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9 163 eyes (the Pearson correlation coefficients (r) for refraction and AL were 0.90, $P<0.01$, and
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12 164 0.96, $P<0.01$, respectively), the data obtained from the right eye were chosen for analyses.

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15 165 Ocular biometrics were all normally distributed, as determined by P-P plots.
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17 166 T-tests were performed for quantitative variables and chi-square tests were performed
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20 167 for categorical variables to analyze the differences in basic characteristics between persons
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23 168 with and without myopia. Univariate associations between anthropometric indicators and
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26 169 refraction and ocular biometrics were identified. Simple linear regression models were
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29 170 constructed to assess the effects of height, weight, and BMI (as independent variables) on
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32 171 refraction and individual ocular biometrics (as dependent variables). Tests for linear trends
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35 172 were performed by entering the median value of each category of the anthropometric
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38 173 indicator based on quartiles as a continuous variable into the models. Multiple linear
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41 174 regression models were then fitted after adjusting, in turn, for age, gender, parental myopia,
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44 175 family income, reading and writing distance, and time spent outdoors. Collinearity
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47 176 diagnostics and a residual analysis were performed for all multiple linear regression models.
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50 177 We found that multicollinearity was absent among the independent variables used in each
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53 178 model, and the points in each residual plot were nearly homogeneously distributed on the
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56 179 two sides of the zero horizontal line, suggesting that these fitted models were appropriate.

57 180 Statistical analyses were performed using commercial statistical software (SPSS for
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4 181 Windows, version 20.0; IBM-SPSS, Chicago, Illinois, USA), and P values <0.05 were
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7 182 considered statistically significant.

8 9 183 **Patient and public involvement**

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12 184 Patients and the public were not involved in developing the research questionnaire,
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15 185 outcome measures and overall design of this study protocol.

16 17 18 19 20 187 **RESULTS**

21 22 23 188 **Characteristics of participants**

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26 189 Among the 482 included schoolchildren, the prevalence of myopia was 71.16% (343 of
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28 190 482; 95% CI, 67.01% to 75.10%). The mean SER, height, weight and BMI of all
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31 191 participants was -1.48 ± 1.82 D, 140.79 ± 13.95 cm, 38.29 ± 10.86 kg, and 19.04 ± 3.18
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34 192 kg/m^2 , respectively (Table 1). Participants with myopia were older ($P<0.01$), taller
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36 193 ($P<0.01$), heavier ($P<0.01$); were more likely to have myopic parents ($P<0.01$), a higher
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39 194 monthly family income ($P<0.05$), a closer reading and writing distance ($P<0.05$), and to
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42 195 spent less time outdoors ($P<0.05$); and had eyes with longer ALs ($P<0.01$), deep ACDs
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45 196 and VCDs ($P<0.01$), thinner LTs ($P<0.01$), and larger AL/CC ratios ($P<0.01$).

46 47 197 **Bivariate correlations between variables**

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50 198 Height was positively correlated with AL ($r= 0.50$, $P<0.01$), CCT ($r= 0.17$, $P<0.01$), ACD
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53 199 ($r= 0.29$, $P<0.01$), VCD ($r= 0.49$, $P<0.01$) and the AL/CC ratio ($r= 0.49$, $P<0.01$) and
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56 200 negatively correlated with SER ($r= -0.45$, $P<0.01$) and LT ($r= -0.24$, $P<0.01$), although

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4 201 these correlations were of low to moderate strength. However, there was no correlation
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7 202 between height and CC (Table 2). The correlation analysis of weight with refraction and
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10 203 individual ocular biometrics also produced similar results except that there was a positive
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12 204 correlation between weight and CC. BMI was positively correlated with AL, CCT, VCD
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15 205 and the AL/CC ratio and negatively correlated with SER but was not correlated with ACD,
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17 206 LT or CC.

207 **Linear trends in refraction and ocular biometrics changes by quartiles of body stature**

208 Taller and heavier persons tended to have eyes with longer ALs (P for trend, <0.01), thicker
209 CCTs (P for trend, <0.05), deeper ACDs (P for trend, <0.01), thinner LTs (P for trend,
210 <0.01), deeper VCDs (P for trend, <0.01), higher AL/CC ratios (P for trend, <0.01), and
211 more myopic refractions (P for trend, <0.01) (Table 3). In addition to ACD and LT, the
212 above tendencies were also observed among more obese schoolchildren (students with
213 higher BMIs).

214 **Linear regression analysis of the associations between anthropometric indicators and** 215 **refraction and ocular biometrics**

216 In model 1, we used the association between height and refraction as an example and found
217 that for each 10 cm increase in height, the SER was expected to decrease by 0.59 D ($P<0.01$)
218 without controlling for any covariates (Table 4). In the next two models, we controlled, in
219 turn, for age and gender or for age, gender, parental myopia, family income, reading and
220 writing distance and time spent outdoors, and found that the difference in SER declined by

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4 221 0.26 D ($P<0.01$) and 0.21 D ($P<0.05$) in each of these models, respectively. In general,
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7 222 taller persons tended to have eyes with longer ALs (+0.14 mm, $P<0.05$), deeper VCDs
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9 223 (+0.13 mm, $P<0.05$), greater AL/CC ratios (+0.02, $P<0.05$), and more negative refractions
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12 224 (-0.21 D, $P<0.05$). However, after we controlled for the same confounders described above,
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15 225 height was no longer related to CCT, ACD, or LT.

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17 226 Although weight was correlated with AL, CCT, and VCD in model 3, it was not
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20 227 associated with ACD, LT, the AL/CC ratio or refraction. For each 10 kg increase in weight,
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23 228 AL was 0.15 mm longer ($P<0.01$), CCT 4.44 μm thicker ($P<0.05$), and VCD 0.15 mm
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26 229 deeper ($P<0.01$). Nonetheless, BMI was not correlated with refraction or any individual
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29 230 ocular biometric in multiple linear regression models.

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32 33 34 232 **DISCUSSION**

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36 233 In this paper, we comprehensively measured ocular biometrics and then explored the
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39 234 associations between anthropometric indicators and refraction and ocular biometrics after
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42 235 adequately controlling covariates. We were therefore able to achieve a more detailed
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45 236 analysis than has been presented in previous studies. A stratified, clustered, random
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48 237 sampling strategy was applied to recruit participants, and this allowed us to avoid the
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51 238 potential selection bias present in previous studies performed in specific population groups,
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53 239 such as male conscripts.^{27 29}

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56 240 The current results are in almost complete agreement with those of Saw et al.,¹⁷ who

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4 241 showed that among 1449 Singaporean Chinese children aged 7-9 years old, taller persons
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7 242 were more likely to have eyes with longer ALs (+0.46 mm, $P<0.01$), deeper VCDs (+0.46
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10 243 mm, $P<0.01$), flatter corneas (+0.10 mm, $P<0.01$), greater AL/CC ratios (+0.02, $P=0.03$),
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12 244 and refractions that tended toward myopia (-0.47 D, $P<0.01$) after controlling for age,
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15 245 gender, parental myopia, and the number of books read per week. A birth cohort performed
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18 246 in Britain to examine the relationship between height growth trajectories and the
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21 247 development of myopia presented similar results.¹⁰ For each SD increase in height during
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24 248 the period the children aged from 2.5 to 10 years old, SER had become more negative by -
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26 249 0.075 D (95% CI, -0.112 to -0.039; $P<0.01$) and -0.081 D (95% CI, -0.129 to -0.034;
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29 250 $P<0.01$) when the children reached 11 and 15 years old, respectively. However, Huang et
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31 251 al.²⁸ reported that there was no statistically significant correlation between myopia shift
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34 252 and height changes among schoolchildren aged 7 to 9 years old in Taiwan, China.

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36 253 Although the association remains unclear, these results will help us to further explore
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39 254 the intricate relationship between the development of physical characteristics and
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42 255 refraction. A commonly proposed explanation for a potential association is that both higher
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45 256 height and myopia are independent consequences of better socioeconomic status, and there
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48 257 may therefore be no causal relationship between height and myopia.^{17 23} However, in this
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51 258 study, after we controlled for socioeconomic characteristics and myopia-related risk factors,
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54 259 height remained independently related to refraction and various ocular biometrics. Myopia
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56 260 most commonly develops during the period extending from childhood to early adolescence

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4 261 (from approximately 8 to 14 years old),³⁰ and this is also the period during which growth
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7 262 spurts occur;³¹ we therefore inferred that the development of refraction could be related to
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10 263 physical development during the early period of adolescent growth. The findings of the
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12 264 Singapore Cohort Study of Risk Factors for Myopia (SCORM) support this hypothesis.¹⁹
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15 265 The SCORM reported that boys and girls who experienced earlier peak height velocity also
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17 266 achieved earlier peak SER velocity (at a mean age of 10.1 vs 10.6 years old for boys,
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20 267 $P=0.01$, and 10.0 vs 10.6 years old for girls, $P=0.01$) and had an earlier age of onset of
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23 268 myopia (9.9 vs 10.4 years old for boys, $P=0.03$, and 9.7 vs 10.1 years old for girls, $P=0.04$).
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26 269 This could be a consequence of the sex hormone surge that occurs during early adolescence,
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29 270 especially during growth spurts. Moreover, sex hormone receptors are present in multiple
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32 271 regions of the human eye, including the iris, lens, and retina, and these receptors have been
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35 272 found to play roles in the development of various ocular diseases.³² Therefore, sex
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38 273 hormones may be a significant mediator of the association between height and refraction
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41 274 observed in our study. This hypothesis, if valid, suggests that the endocrine traits observed
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44 275 during childhood and adolescence could provide important clues for mechanistic studies
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47 276 aimed at exploring refractive development.

47 277 The relationships weight and BMI share with refraction are not as extensively studied as
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50 278 those with height, but also presented the inconclusive conclusions. Heavier and more obese
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53 279 Chinese children and adults in Singapore have been shown to have refractions that tend
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56 280 toward hyperopia.^{17 23} Heavier adults in rural Myanmar were also reported to have more

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4 281 positive refractions.²⁵ However, a twin study performed in Australia found that compared
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7 282 to females in the lowest quartile weight group, those in the highest weight quartile had a
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9 283 higher risk of myopia (OR: 1.79, $P=0.01$).²² Consistent with the results of a cross-sectional
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12 284 study performed in 19-year-old male conscripts in South Korea,²⁷ in our study, we found
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15 285 that weight and BMI had no effect on refraction. Inconsistencies in data regarding the
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18 286 relationships weight and height share with refraction (i.e., refractions were myopic only in
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21 287 taller children and not in heavier or more obese children) have been more difficult to
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24 288 explain. Some uncontrolled confounders, such as nutritional status, could lead to these
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27 289 differences. Nutritional status not only affects physical development but also influences
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30 290 the development of myopia.^{33 34} Therefore, in the future, a comprehensive dietary survey
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33 291 will be needed to determine whether nutritional status itself has any effect on the
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36 292 correlation between physical development and refractive development.

37 293 This study has several limitations that warrant consideration. First, information on
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40 294 putative myopia risk factors obtained from our questionnaire (e.g., the distance between
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43 295 the child's eyes and a book when reading or writing) was subjectively estimated by the
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46 296 parents. Although this method has been widely applied in previous studies, it can lead to
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49 297 recall bias. Differences between non-respondents and respondents may also have resulted
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52 298 in non-respondent bias given that a difference in age was identified between the individuals
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55 299 who were included in and excluded from this study. Second, all of the data collected in this
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58 300 study were cross-sectional and did not allow an evaluation of causality. Therefore, it

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4 301 remains uncertain whether the conclusions drawn from this study are applicable to
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7 302 longitudinal relationships. Furthermore, we could not analyze data regarding puberty
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10 303 parameters, such as the onset of pubic hair and voice break in boys and breast development
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12 304 and age at menarche in girls. A later age at menarche (older than 14 years old) has been
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15 305 found to be associated with a decreased risk of moderate and high myopia.³⁵ To determine
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17 306 whether physical development during early adolescent growth affects refractive status,
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20 307 these puberty parameters must be considered in future studies.

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23 308 In conclusion, we found that taller children tended to have eyes with longer ALs, deeper
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25 309 VCDs, higher AL/CC ratios and more myopic refractions after controlling for age, gender,
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28 310 parental myopia, family income, reading and writing distance, and time spent outdoors.
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31 311 The results of this study support the idea that the development of refraction is related to
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33 312 physical development during early adolescent growth. Further research is required to
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35 313 determine whether sex hormones during growth spurts could affect the association
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38 314 between height and refraction.

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53 319 Tianjin Medical University.

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4 321 SY, SL, WL and QW. Analysis and interpretation of the data: SY. Review and approval of
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7 322 the manuscript: SY, SL, WL, QW, WX and XZ.

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17 326 **Competing interests** None declared.

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20 327 **Patient consent** Obtained.

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23 328 **Ethics approval** Ethics Committee of Tianjin Medical University, China.

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26 329 **Provenance and peer review** Not commissioned; externally peer reviewed.

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28 330 **Data sharing statement** No additional data are available.

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Table 1 Summary of the characteristics of the participants.

	Total	Myopia	Nonmyopia	P Value
Age (years)	9.42 ± 2.09	9.88 ± 2.14	8.30 ± 1.45	<0.01
Male	264 (54.77)	187 (54.52)	77 (55.40)	0.86
Parental myopia*				<0.01
None	129 (28.48)	74 (23.13)	55 (41.35)	
One parent	188 (41.50)	134 (41.88)	54 (40.60)	
Both parents	136 (30.02)	112 (35.00)	24 (18.05)	
Monthly family income*				<0.05
<4000 RMB	41 (8.78)	27 (8.16)	14 (10.29)	
4000-8000 RMB	136 (29.12)	89 (26.89)	47 (34.56)	
8000-10,000 RMB	133 (28.48)	89 (26.89)	44 (32.35)	
10,000-15,000 RMB	91 (19.49)	73 (22.05)	18 (13.24)	
≥15,000 RMB	66 (14.13)	53 (16.01)	13 (9.56)	
Reading and writing distance*				<0.05
<10 cm	45 (9.62)	36 (10.81)	9 (6.67)	
10-20 cm	200 (42.74)	148 (44.44)	52 (38.52)	
20-30 cm	166 (35.47)	117 (35.14)	49 (36.30)	
≥30 cm	57 (12.18)	32 (9.61)	25 (18.52)	
Time spent outdoors (hours)	1.20 ± 0.70	1.16 ± 0.70	1.31 ± 0.69	<0.05
Height (cm)	140.79 ± 13.95	143.85 ± 14.17	133.22 ± 10.01	<0.01
Weight (kg)	38.29 ± 10.86	40.06 ± 11.05	33.92 ± 9.01	<0.01
BMI (kg/m ²)	19.04 ± 3.18	19.10 ± 3.14	18.89 ± 3.28	0.52
SER (D)	-1.48 ± 1.82	-2.20 ± 1.66	0.30 ± 0.54	<0.01
AL (mm)	23.81 ± 1.12	24.16 ± 1.07	22.95 ± 0.72	<0.01
CCT (μm)	547.65 ± 32.44	548.88 ± 33.32	544.63 ± 30.05	0.19

ACD (mm)	3.08 ± 0.26	3.14 ± 0.25	2.94 ± 0.23	<0.01
LT (mm)	3.47 ± 0.20	3.43 ± 0.20	3.55 ± 0.19	<0.01
VCD (mm)	17.27 ± 1.09	17.60 ± 1.05	16.46 ± 0.71	<0.01
CC (mm)	7.78 ± 0.26	7.78 ± 0.25	7.79 ± 0.26	0.84
AL/CC ratio	3.06 ± 0.13	3.11 ± 0.13	2.95 ± 0.07	<0.01

Data presented as means with standard deviation (SD) or as n (%).

*Numbers of individuals vary due to missing data.

Table 2 Bivariate correlations of body stature with refraction and ocular biometrics.

	Height (cm)	Weight (kg)	BMI (kg/m ²)
SER (D)	-0.45**	-0.39**	-0.11*
AL (mm)	0.50**	0.45**	0.15*
CCT (µm)	0.17**	0.19**	0.09*
ACD (mm)	0.29**	0.22**	0.03
LT (mm)	-0.24**	-0.19**	-0.04
VCD (mm)	0.49**	0.44**	0.16**
CC (mm)	0.07	0.10*	0.08
AL/CC ratio	0.49**	0.40**	0.10*

Data are the Pearson correlation coefficients.

*: $P < 0.05$.

** : $P < 0.01$.

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Table 3 Unadjusted mean values of refraction and ocular biometrics by quartiles of height, weight and BMI.

	Range	n	SER (D)	AL (mm)	CCT (μm)	ACD (mm)
<i>Height (cm)</i>						
1st quartile	100.0~130.0	127	$-0.48 \pm 1.13^\dagger$	23.09 ± 0.78	542.11 ± 30.93	2.97 ± 0.24
2nd quartile	130.1~140.0	136	-1.08 ± 1.46	23.58 ± 0.98	544.96 ± 32.69	3.05 ± 0.28
3rd quartile	140.1~150.7	99	-1.86 ± 1.80	24.15 ± 1.01	550.04 ± 32.31	3.16 ± 0.23
4th quartile	150.8~182.5	120	-2.68 ± 2.06	24.56 ± 1.14	554.58 ± 32.76	3.18 ± 0.22
<i>P</i> for trend‡			<i>P</i> <0.01	<i>P</i> <0.01	<i>P</i> <0.05	<i>P</i> <0.01
<i>Weight (kg)</i>						
1st quartile	20.0~30.0	129	-0.59 ± 1.19	23.19 ± 0.80	541.27 ± 32.75	3.02 ± 0.26
2nd quartile	30.1~36.1	112	-1.12 ± 1.30	23.58 ± 1.00	547.64 ± 31.34	3.04 ± 0.26
3rd quartile	36.2~45.0	128	-1.75 ± 1.92	24.02 ± 1.12	544.17 ± 31.56	3.12 ± 0.24
4th quartile	45.1~82.3	113	-2.54 ± 2.14	24.52 ± 1.12	558.92 ± 31.65	3.16 ± 0.24
<i>P</i> for trend			<i>P</i> <0.01	<i>P</i> <0.01	<i>P</i> <0.01	<i>P</i> <0.01
<i>BMI (kg/m²)</i>						
1st quartile	14.0~16.5	121	-1.19 ± 1.62	23.55 ± 1.05	543.79 ± 31.55	3.09 ± 0.25
2nd quartile	16.6~18.4	120	-1.39 ± 1.69	23.80 ± 1.14	545.79 ± 32.26	3.05 ± 0.28
3rd quartile	18.5~20.8	120	-1.59 ± 1.88	23.90 ± 1.12	547.12 ± 32.16	3.09 ± 0.25

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	Range	n	LT (mm)	VCD (mm)	CC (mm)	AL/CC ratio
<i>Height (cm)</i>						
4th quartile	20.9~30.6	121	-1.74 ± 2.05	24.00 ± 1.16	533.90 ± 33.26	3.11 ± 0.25
<i>P</i> for trend			<i>P</i> <0.05	<i>P</i> <0.01	<i>P</i> <0.05	<i>P</i> =0.32
<i>Weight (kg)</i>						
1st quartile	20.0~30.0	129	3.51 ± 0.20	16.64 ± 0.77	7.75 ± 0.25	2.99 ± 0.10
2nd quartile	30.1~36.1	112	3.49 ± 0.21	17.07 ± 0.97	7.78 ± 0.28	3.03 ± 0.11
3rd quartile	36.2~45.0	128	3.45 ± 0.21	17.46 ± 1.10	7.80 ± 0.24	3.08 ± 0.13
4th quartile	45.1~82.3	113	3.40 ± 0.19	17.95 ± 1.08	7.81 ± 0.25	3.14 ± 0.15
<i>P</i> for trend			<i>P</i> <0.01	<i>P</i> <0.01	<i>P</i> =0.08	<i>P</i> <0.01
<i>BMI (kg/m²)</i>						
1st quartile	14.0~16.5	121	3.45 ± 0.18	17.01 ± 1.05	7.73 ± 0.26	3.05 ± 0.12
2nd quartile	16.6~18.4	120	3.51 ± 0.23	17.23 ± 1.04	7.81 ± 0.26	3.05 ± 0.13

3rd quartile	18.5~20.8	120	3.46 ± 0.20	17.38 ± 1.11	7.81 ± 0.26	3.06 ± 0.14
4th quartile	20.9~30.6	121	3.44 ± 0.20	17.46 ± 1.13	7.79 ± 0.24	3.08 ± 0.14
<i>P</i> for trend			<i>P</i> =0.37	<i>P</i> <0.01	<i>P</i> =0.19	<i>P</i> <0.05

†Data are expressed as means ± SD.

‡Tests for linear trend is performed by entering the median value of each category of the anthropometric indicator as a continuous variable in the models.

Table 4 Multiple linear regression models of refraction and ocular biometry by height, weight, and BMI.

	Model 1	<i>P</i> Value	Model 2	<i>P</i> Value	Model 3	<i>P</i> Value
<i>Height (per 10cm)</i>						
SER (D)	-0.59 (-0.70, -0.49)†	<0.01	-0.26 (-0.45, -0.08)	<0.01	-0.21 (-0.40, -0.01)	<0.05
AL (mm)	0.40 (0.34, 0.47)	<0.01	0.18 (0.07, 0.29)	<0.01	0.14 (0.03, 0.26)	<0.05
CCT (µm)	4.03 (1.97, 6.08)	<0.01	2.43 (-1.29, 6.16)	0.20	3.41 (-0.76, 7.58)	0.11
ACD (mm)	0.05 (0.04, 0.07)	<0.01	0.02 (-0.01, 0.05)	0.17	0.02 (-0.02, 0.05)	0.34
LT (mm)	-0.04 (-0.05, -0.02)	<0.01	-0.01 (-0.03, 0.02)	0.57	-0.01 (-0.03, 0.02)	0.75
VCD (mm)	0.38 (0.32, 0.44)	<0.01	0.17 (0.06, 0.27)	<0.01	0.13 (0.02, 0.25)	<0.05
CC (mm)	0.01 (-0.01, 0.03)	0.13	0.01 (-0.02, 0.04)	0.41	0.01 (-0.03, 0.04)	0.81

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5	AL/CC ratio	0.05 (0.04, 0.06)	<0.01	0.02 (0.01, 0.03)	<0.01	0.02 (0.01, 0.03)	<0.05
6							
7	<i>Weight (per 10kg)</i>						
8							
9	SER (D)	-0.65 (-0.79, -0.51)	<0.01	-0.21 (-0.39, -0.03)	<0.05	-0.18 (-0.36, 0.01)	0.07
10							
11	AL (mm)	0.46 (0.38, 0.55)	<0.01	0.16 (0.05, 0.26)	<0.01	0.15 (0.04, 0.26)	<0.01
12							
13	CCT (μ m)	5.56 (2.93, 8.20)	<0.01	3.68 (0.06, 7.29)	<0.05	4.44 (0.42, 8.47)	<0.05
14							
15	ACD (mm)	0.05 (0.03, 0.07)	<0.01	-0.01 (-0.03, 0.02)	0.90	-0.01 (-0.03, 0.03)	0.87
16							
17	LT (mm)	-0.04 (-0.05, -0.02)	<0.01	0.01 (-0.02, 0.02)	0.95	0.01 (-0.02, 0.03)	0.96
18							
19	VCD (mm)	0.44 (0.36, 0.53)	<0.01	0.16 (0.06, 0.27)	<0.01	0.15 (0.04, 0.26)	<0.01
20							
21	CC (mm)	0.03 (0.01, 0.05)	<0.05	0.02 (-0.01, 0.05)	0.11	0.02 (-0.01, 0.05)	0.14
22							
23	AL/CC ratio	0.05 (0.04, 0.06)	<0.01	0.01 (-0.01, 0.02)	0.10	0.01 (-0.01, 0.02)	0.16
24							
25	<i>BMI (per 10kg/m²)</i>						
26							
27	SER (D)	-0.64 (-1.15, -0.13)	<0.05	-0.26 (-0.73, 0.20)	0.26	-0.27 (-0.74, 0.20)	0.25
28							
29	AL (mm)	0.53 (0.21, 0.84)	<0.01	0.20 (-0.07, 0.47)	0.15	0.23 (-0.05, 0.50)	0.10
30							
31	CCT (μ m)	9.50 (0.35, 18.65)	<0.05	6.37 (-2.79, 15.53)	0.17	7.19 (-2.87, 17.25)	0.16
32							
33	ACD (mm)	0.03 (-0.05, 0.10)	0.50	-0.03 (-0.10, 0.04)	0.46	-0.02 (-0.10, 0.05)	0.52
34							
35	LT (mm)	-0.02 (-0.08, 0.03)	0.42	0.01 (-0.05, 0.07)	0.79	0.01 (-0.06, 0.07)	0.86
36							
37	VCD (mm)	0.55 (0.24, 0.85)	<0.01	0.23 (-0.03, 0.50)	0.09	0.25 (-0.03, 0.52)	0.08
38							
39	CC (mm)	0.06 (-0.01, 0.14)	0.09	0.04 (-0.03, 0.11)	0.25	0.06 (-0.02, 0.14)	0.13
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AL/CC ratio	0.04 (0.01, 0.08)	<0.05	0.01 (-0.02, 0.04)	0.58	0.01 (-0.03, 0.04)	0.67
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†Each value represents a separate regression model, with height, weight, or BMI used as the independent variable, the refraction or individual ocular biometrics used as the dependent variable, either alone or with various confounders. Data in parentheses represents the 95% confidence interval.

Model 1 constructs based on crude data. In the next two models, we controlled, in turn, for age and gender or for age, gender, parental myopia, family income, reading and writing distance, and time spent outdoors.

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Associations between anthropometric indicators and both refraction and ocular biometrics in a cross-sectional study of Chinese schoolchildren

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4 1 **Associations between anthropometric indicators and both refraction**
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6 2 **and ocular biometrics in a cross-sectional study of Chinese**
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8 3 **schoolchildren**

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15 5 **Sheng Ye, Shengxin Liu, Wenlei Li, Qifan Wang, Wei Xi, and Xin Zhang**

16
17 6 Department of Maternal, Child and Adolescent Health, School of Public Health, Tianjin
18
19 7 Medical University, Tianjin, China.

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21
22
23 8 SY and SL contributed equally to the work presented here and should therefore be
24
25 9 regarded as equivalent authors.

26
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29
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31 10
32 11 **Correspondence to**

33
34 12 Prof. Xin Zhang, Department of Maternal, Child and Adolescent Health, School of
35
36 13 Public Health, Tianjin Medical University, No. 22 Qixiangtai Road, Tianjin 300070,
37
38 14 China; zhangxin@tmu.edu.cn.

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44 15
45 16 **Synopsis**

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47 17 The development of refraction may be related to physical development during early
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49 18 adolescent growth. The shared mechanism between body stature and refraction could
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51 19 shed new light on the etiology of myopia.

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4 22 **ABSTRACT**

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7 23 **Objective** To identify associations between anthropometric indicators, including height,
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9 24 weight, and body mass index (BMI), and both refraction and ocular biometrics in
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12 25 Chinese schoolchildren in Tianjin, China.

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14
15 26 **Design** Cross-sectional study.

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18 27 **Participants** A total of 482 (86.07%) students (6 to 15 years old) with no recorded
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20 28 history of ocular or systemic pathologies were enrolled in this study.

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23 29 **Methodology** Height and weight were measured using standardized protocols. Ocular
24
25 30 biometrics, such as axial length (AL), vitreous chamber depth (VCD), and corneal
26
27 31 curvature (CC), were measured by a low-coherence optical reflectometry device. The
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29 32 AL/CC ratio was calculated. Cycloplegic refraction was measured using autorefraction,
30
31 33 and spherical equivalent refraction (SER) was calculated. Myopia was defined as SER
32
33 34 ≤ -0.50 diopters (D). Multiple linear regression analysis was performed to explore the
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35 35 associations between anthropometric indicators and both refraction and ocular
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37 36 biometrics.

38
39 37 **Results** The overall prevalence of myopia was 71.16%. Overall, only height was
40
41 38 associated with AL, VCDs, AL/CC ratios, and refractions after controlling for age,
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43 39 gender, parental myopia, family income, reading and writing distance, and time spent
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45 40 outdoors. Furthermore, age-specific results demonstrated that both height and weight
46
47 41 were independently associated with refraction in only 6- to 8-year-old and 9- to 11-
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49 42 year-old participants. Especially from 9 to 11 years of age, higher heights in
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4 43 schoolchildren were associated with longer ALs (regression coefficient $b=+0.25$ for
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7 44 each 10 cm difference in height, $P<0.01$), deeper VCDs ($b=+0.23$, $P<0.01$), higher
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10 45 AL/CC ratios ($b=+0.04$, $P<0.01$), and more negative refractions ($b=-0.48$, $P<0.01$) in
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12 46 their eyes. The association pattern in weight was almost the same as that in height.

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14
15 47 **Conclusions** Height and weight remained independently related to refraction and
16
17 48 various ocular biometrics during the early period of adolescent growth after adequately
18
19
20 49 controlling for covariates, which could support the idea that a shared mechanism may
21
22
23 50 regulate the coordinated growth of body and eye size in children.

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25
26 51 **Keywords:** anthropometric indicators, refraction, ocular biometrics, schoolchildren
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31 53 **Strengths and limitations of this study**

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34 54 ● The study participants were schoolchildren ranging in age from 6 to 15 years old,
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36 55 a period when myopia commonly develops, which could allow us to study the
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39 56 association between body stature and refraction during development.
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42 57 ● The overall and age-specific associations between anthropometric indicators and
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44 58 both refraction and ocular biometrics were calculated in this study to help better
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47 59 clarify the coordinated growth of body and eye size.
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50 60 ● Ocular biometrics were measured comprehensively, and the covariates were
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53 61 adequately controlled, which allowed us to achieve a more detailed analysis.
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56 62 ● An evaluation of causality was not possible because this study had a cross-sectional
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59 63 design.
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65 Introduction

66 Myopia has reached almost epidemic proportions in the world, especially in certain
67 areas of East and Southeast Asia.¹ This condition is commonly viewed as etiologically
68 heterogeneous. Genetic and environmental risk factors are involved in its progression.
69 The genetic basis of myopia has been supported by evidence indicating high heritability
70 values in twin studies² and a higher prevalence of myopia in children with myopic
71 parents.³ Excessive near work activities,^{4,5} limited time spent outdoors,^{6,7} and intensive
72 educational pressure^{8,9} reportedly to promote the development of myopia. In our effort
73 to consider other factors, we noted that anthropometric indicators, such as height, are
74 thought to be associated with refraction, although no consensus has been achieved
75 regarding this issue.^{10,11}

76 Refractive status is determined by the balance of the refractive power of the cornea
77 and lens, and the axial length (AL) of the eye (representing the combination of anterior
78 chamber depth (ACD), lens thickness (LT), and vitreous chamber depth (VCD)).¹²
79 Myopia usually arises in an eye that has become too long, particularly via vitreous
80 chamber elongation. Several epidemiological studies have demonstrated that changes
81 in ocular dimensions that occur in early life progress concomitant with physical
82 development in children,^{13,14} and the ages of cessation are also similar for increases in
83 height and axial elongation.¹³ Furthermore, genetic studies have confirmed that a
84 common genetic pathway underlies both height and AL,^{15,16} although no specific

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4 85 genetic variants have yet been identified. All of these clues suggest a shared mechanism
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7 86 that regulates the coordinated growth of body and eye size. It has been suggested that
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10 87 there may be a relationship between body stature and refraction. However, in contrast
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12 88 to the consensus regarding the significant associations between body stature and AL,
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15 89 the relationship between body stature and refraction remains controversial. Although
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17 90 many studies have reported that taller^{10 17-20} and heavier persons^{21 22} have an increased
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20 91 likelihood of having myopia, other studies have found no such association.²³⁻²⁸ The
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23 92 discrepancies among these studies may be due to differences in sample sizes, concept
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26 93 definitions or other methodological variations (e.g., height and weight obtained via self-
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29 94 reporting).

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31 95 In China, few studies have comprehensively measured ocular biometrics or further
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34 96 explored their associations with body stature. Additionally, myopia most commonly
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37 97 starts in young schoolchildren and progresses in early adolescence.²¹ Therefore, it is
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40 98 most appropriate to study the effect of body growth on refractive development in young,
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43 99 growing students. In the current survey, we explored the associations between
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46 100 anthropometric indicators, including height, weight, and BMI, and both refraction and
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49 101 ocular biometrics in schoolchildren aged 6 to 15 years old in Tianjin, China.

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51 52 53 103 **METHODS**

54 55 104 **Recruitment**

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58 105 Participants were recruited based on the following strategies. Two districts were
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4 106 randomly chosen from the 6 main urban districts in Tianjin in November 2016. Next,
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7 107 one primary school and one junior high school were randomly selected from each
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10 108 selected district. Then, one class was randomly chosen from each grade level within the
11
12 109 two selected schools. All students in these selected classes were invited, but
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15 110 participation in this study was voluntary. After the purposes and procedures of the study
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17 111 were explained to each student and their parents in depth, written informed consent was
18
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20 112 collected. Students without parental consent and students who had amblyopia,
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23 113 heterotropia, or any ocular or systemic pathologies were excluded.

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25
26 114 The study protocol was approved by the Ethics Committee of Tianjin Medical
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28 115 University and performed in accordance with the tenets of the Declaration of Helsinki.

30 116 **Ocular examinations**

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34 117 All participants underwent a comprehensive eye examination, including measurements
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36 118 of intraocular pressure, a slit-lamp examination of the anterior and posterior segments,
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39 119 cycloplegic autorefractometry and ocular biometrics. The purpose of intraocular pressure
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41
42 120 measurement and slit-lamp examination was to exclude contraindications for mydriasis.

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44
45 121 Ocular biometrics, such as AL, central corneal thickness (CCT), ACD, LT, VCD,
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47 122 and corneal curvature (CC), were measured with a low-coherence optical reflectometry
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49
50 123 device (Lenstar LS900; Haag-Streit AG, 3098 Koeniz, Switzerland) in both eyes before
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52
53 124 pupil dilation. In addition, the AL/CC ratio, also commonly known as the axial
54
55 125 length/corneal radius (AL/CR) ratio, was calculated. Then, cycloplegia was induced by
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58 126 administering one drop containing 0.5% tropicamide and 0.5% phenylephrine in a
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4 127 mixed eye agent to each eye at 0 and 5 minutes. Twenty-five minutes after the second
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7 128 instillation, pupillary dilation and the pupillary light reflex were evaluated. Full
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10 129 cycloplegia was considered when the pupil diameter reached 6 mm or more and the
11
12 130 light reflex disappeared. A third drop was administered if full cycloplegia was not
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15 131 achieved. Then, participants with full cycloplegia underwent autorefractometry using an
16
17 132 auto-kerato-refractor (Canon Autorefractor RK-F1, Tokyo, Japan), and 3 consecutive
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19
20 133 measurements were taken in both eyes. The mean value of 3 valid measurements was
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23 134 calculated for statistical analysis. All of the above instruments were calibrated before
24
25
26 135 the ocular examination. All examinations were performed by board-certified
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29 136 ophthalmologists and certified optometrists.

31 137 **Definitions**

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33
34 138 The SER of each eye was calculated as the spherical refraction + 1/2 of the cylindrical
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36
37 139 refraction using data obtained using the autorefractor. Myopia was defined as an SER
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39
40 140 of ≤ -0.5 D.

41 141 **Anthropometric measurements**

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45 142 Height and weight were obtained following specific standardized protocols²⁹ and
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48 143 measured by community doctors on the students' campus. Height was determined with
49
50
51 144 the subject standing barefoot on the base of the height meter and recorded in centimeters
52
53
54 145 (cm). Weight was measured without shoes and heavy coats on a calibrated electronic
55
56
57 146 weighing scale and recorded in kilograms (kg). BMI was calculated as weight/height²
58
59
60 147 and recorded in kilograms per square meter (kg/m²).

148 **Questionnaire**

149 The parents of participants and those excluded were all asked to complete a
150 questionnaire developed to collect information on social-demographic characteristics
151 and potential risk factors for school myopia (supplementary Table 1).

152 The basic characteristics of the participants included age, gender, the monthly
153 income of the family, and the number of parents with myopia. Near-work-related
154 behaviors were ascertained with the question “What is the distance between your child's
155 eyes and a book when reading or writing?”, with answers categorized as follows: <10
156 cm, 10-19 cm, 20-29 cm, and ≥ 30 cm. Time spent outdoors was estimated by asking
157 how many hours per day the child spent on outdoor activities during weekdays and
158 weekends separately. The average time spent outdoors was calculated by the following
159 formula: $[T_{\text{weekday}} (\text{hours spent on weekdays}) \times 5 + T_{\text{weekend}} (\text{hours spent on weekends})$
160 $\times 2] \div 7$.

161 **Statistical analysis**

162 Because refraction and ocular biometrics were highly correlated between two eyes (the
163 Pearson correlation coefficients (r) for refraction and AL were 0.90, $P < 0.01$ and 0.96,
164 $P < 0.01$, respectively), the data obtained from the right eye were chosen for analyses.

165 Ocular biometrics were all normally distributed, as determined by P-P plots.

166 T-tests were performed for quantitative variables, and chi-square tests were
167 performed for categorical variables to analyze the differences in basic characteristics
168 between individuals with and without myopia. Univariate associations between

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4 169 anthropometric indicators and both refraction and ocular biometrics were identified.
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7 170 Simple linear regression models were constructed to assess the effects of height, weight,
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10 171 and BMI (as independent variables) on refraction and individual ocular biometrics (as
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12 172 dependent variables). Tests for linear trends were performed by entering the median
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15 173 value of each category of the anthropometric indicator based on quartiles as a
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18 174 continuous variable into the models. Multiple linear regression models were then fitted
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21 175 after adjusting, in turn, for age and gender or for age, gender, parental myopia,
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23 176 family income, reading and writing distance, and time spent outdoors. In addition, all
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26 177 participants were divided into the following age groups: 6 to 8 years old, 9 to 11 years
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28 178 old, and 12 to 15 years old. The results of age-specific associations of anthropometric
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31 179 indicators with both refraction and ocular biometrics after controlling for the above
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34 180 covariates were calculated. Collinearity diagnostics were performed, and
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37 181 multicollinearity was absent among the independent variables used in each model.

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39 182 Statistical analyses were performed using commercial statistical software (SPSS for
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42 183 Windows, version 20.0; IBM-SPSS, Chicago, Illinois, USA), and *P* values <0.05 were
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45 184 considered statistically significant.

46 47 185 **Patient and public involvement**

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50 186 Patients and the public were not involved in developing the research questionnaire,
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53 187 outcome measures or overall design of this study protocol.

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57 58 189 **RESULTS**

190 **Participant characteristics**

191 Among 560 students who were initially invited, a total of 482 participants ranging in
192 age from 6 to 15 years old were available for statistical analysis after excluding 70
193 students without parental consent, 5 students with heterotropia, and 3 students with
194 amblyopia. The response rate in this study was 86.07% (482 of 560). Individuals who
195 were included were older (9.42 ± 2.09 vs 7.60 ± 2.38 years old, $P < 0.01$) than those who
196 were excluded. There were no significant differences in gender, parental myopia,
197 monthly family income, reading and writing distance, and time spent outdoors between
198 included and excluded individuals.

199 The overall prevalence of myopia was 71.16% (343 of 482; 95% CI, 67.01% to
200 75.10%). The mean SER, height, weight and BMI of all participants was -1.48 ± 1.82
201 D, 140.79 ± 13.95 cm, 38.29 ± 10.86 kg, and 19.04 ± 3.18 kg/m², respectively (Table
202 1). Participants with myopia were older, taller, and heavier. These individuals were
203 more likely to have myopic parents, a higher monthly family income, a closer reading
204 and writing distance and to spend less time outdoors. Moreover, these participants had
205 eyes with longer ALs, deep ACDs and VCDs, thinner LTs, and larger AL/CC ratios (all
206 P values were less than 0.05).

207 **Bivariate correlations between variables**

208 Bivariate correlations of body stature with both refraction and ocular biometrics are
209 presented in Table 2, which was of low to moderate strength. For example, height was
210 positively correlated with AL ($r = 0.50$, $P < 0.01$), CCT ($r = 0.17$, $P < 0.01$), ACD ($r = 0.29$,

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4 211 $P<0.01$), VCD ($r=0.49$, $P<0.01$) and the AL/CC ratio ($r=0.49$, $P<0.01$) and negatively
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7 212 correlated with SER ($r=-0.45$, $P<0.01$) and LT ($r=-0.24$, $P<0.01$).

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9 213 **Linear trends in refraction and ocular biometrics changes by body stature**
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12 214 **quartiles**

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15 215 Taller and heavier individuals tended to have eyes with longer ALs, thicker CCTs,
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17 216 deeper ACDs, thinner LTs, deeper VCDs, higher AL/CC ratios, and more myopic
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20 217 refractions (all P values for trend were less than 0.05) (Table 3). In addition to ACD
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23 218 and LT, the above tendencies were also observed among more obese schoolchildren
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26 219 (students with higher BMIs).

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28 220 **Linear regression analysis of the associations between anthropometric indicators**
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31 221 **and both refraction and ocular biometrics**

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34 222 In model 1, we used the association between height and refraction as an example and
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36 223 found that for each 10 cm increase in height, the SER was expected to decrease by 0.59
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39 224 D ($P<0.01$) without controlling for any covariates (Table 4). In the next two models,
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42 225 we controlled, in turn, for age and gender or for age, gender, parental myopia, family
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45 226 income, reading and writing distance and time spent outdoors. The difference in SER
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48 227 declined by 0.26 D ($P<0.01$) and 0.21 D ($P<0.05$) in models 2 and 3, respectively. In
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50
51 228 general, higher heights were associated with longer ALs (+0.14 mm, $P<0.05$), deeper
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53 229 VCDs (+0.13 mm, $P<0.05$), greater AL/CC ratios (+0.02, $P<0.05$), and more negative
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55
56 230 refractions (-0.21 D, $P<0.05$) among 6- to 15-year-old participants. Nonetheless, weight
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59 231 and BMI were not correlated with refraction in our multiple linear regression models.
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4 232 Furthermore, the participants were categorized into the following age groups: 6 to 8
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7 233 years old (n=170), 9 to 11 years old (n=158), and 12 to 15 years old (n=154). After
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10 234 controlling for the above covariates, the age-specific associations were calculated
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12 235 (Table 5). Both height and weight remained independently associated with refraction
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15 236 in the age range from 6 to 8 years old and 9 to 11 years old. Particularly from 9 to 11
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17 237 years old, higher heights in schoolchildren were associated with longer ALs (+0.25 mm,
18
19 238 $P<0.01$), deeper VCDs (+0.23 mm, $P<0.01$), higher AL/CC ratios (+0.04, $P<0.01$), and
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22 239 more negative refractions (-0.48 D, $P<0.01$) in their eyes. Heavier weights were also
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25 240 associated with longer ALs (+0.29 mm, $P<0.01$), deeper VCDs (+0.29 mm, $P<0.01$),
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27 241 higher AL/CC ratios (+0.04, $P<0.01$), and more negative refractions (-0.48 D, $P<0.01$).
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30 242 However, from 12 to 15 years of age, no association was detected between body stature
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33 243 and refraction.
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39 245 **DISCUSSION**

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42 246 In this paper, we comprehensively measured ocular biometrics and then explored the
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44 247 overall and age-specific associations between anthropometric indicators and both
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47 248 refraction and ocular biometrics after adequately controlling for covariates among 6- to
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50 249 15-year-old schoolchildren. In China, few studies such as this one have been conducted.
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53 250 Wang et al.¹⁴ confirmed a positive association between height and AL in 7- to 15-year-
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56 251 old schoolchildren based on longitudinal data obtained in Guangzhou, China. However,
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59 252 detailed information about the associations between body stature and refraction and
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4 253 other ocular biometrics was not available in that study. Therefore, compared with
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7 254 previous studies,^{14 28} the present study achieved a more detailed analysis.

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9 255 The current results are in almost complete agreement with those of Saw et al.¹⁷ who
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12 256 showed that among 1449 Singaporean Chinese children aged 7-9 years old, taller
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15 257 individuals were more likely to have eyes with longer ALs (+0.46 mm, $P<0.01$), deeper
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18 258 VCDs (+0.46 mm, $P<0.01$), flatter corneas (+0.10 mm, $P<0.01$), greater AL/CC ratios
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21 259 (+0.02, $P=0.03$), and refractions that trended toward myopia (-0.47 D, $P<0.01$) after
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23 260 controlling for age, gender, parental myopia, and the number of books read per week.

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26 261 A birth cohort performed in Britain to examine the relationship between height growth
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29 262 trajectories and the development of myopia presented similar results.¹⁰ For each SD
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32 263 increase in height for children aged from 2.5 to 10 years old, SER became more
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35 264 negative by -0.075 D (95% CI, -0.112 to -0.039; $P<0.01$) and -0.081 D (95% CI, -0.129
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38 265 to -0.034; $P<0.01$) when the children reached 11 and 15 years old, respectively.
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41 266 However, Huang et al.²⁸ reported that no significant correlation between myopia shift
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44 267 and height changes among schoolchildren aged 7 to 9 years old in Taiwan, China.

45 268 Although the association remains unclear, these results will help us to further explore
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48 269 the intricate relationship between the development of physical characteristics and
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51 270 refraction. A commonly proposed explanation for this potential association is that both
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54 271 higher height and myopia are independent consequences of better socioeconomic status;
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57 272 therefore, there may be no causal relationship between height and myopia.^{17 23} However,
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60 273 in this study, after we controlled for socioeconomic characteristics and myopia-related

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4 274 risk factors, height remained independently related to refraction and various ocular
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7 275 biometrics. Myopia most commonly develops during the period from childhood to early
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10 276 adolescence (from approximately 8 to 14 years old),³⁰ and growth spurts also occur in
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12 277 this period.³¹ Therefore, we inferred that the development of refraction could be related
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15 278 to physical development during the early period of adolescent growth. The findings of
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17
18 279 the Singapore Cohort Study of Risk Factors for Myopia (SCORM) support this
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21 280 hypothesis.¹⁹ SCORM reported that boys and girls who experienced earlier peak height
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24 281 velocity also achieved earlier peak SER velocity (at a mean age of 10.1 vs 10.6 years
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26
27 282 old for boys, $P=0.01$, and 10.0 vs 10.6 years old for girls, $P=0.01$) and had an earlier
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29
30 283 age of onset of myopia (9.9 vs 10.4 years old for boys, $P=0.03$, and 9.7 vs 10.1 years
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32
33 284 old for girls, $P=0.04$). The exact biologic pathways underlying these associations are
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36 285 currently unknown. Some major systemic hormones, such as growth hormone, thymic
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39 286 hormone and insulin-like growth factors (IGFs), reportedly could regulate longitudinal
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42 287 bone growth during childhood, which are also involved in the development of
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45 288 experimental myopia.^{32 33} In addition, epidemiological studies reported that children
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48 289 with growth hormone deficiency have shorter body stature and ALs than usual.³⁴
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51 290 Growth hormone supplementation in these children could partially bring the stature and
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54 291 ALs back within the normal range.³⁵ Sex hormones may be another significant mediator
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57 292 during puberty,³⁶ but our age-specific results (no association was detected in 12- to 15-
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60 293 year-old participants) may not support this idea. Although these hormones were not
294 determined in this cross-sectional study, we believe that the shared mechanism between

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4 295 height and refraction may shed new light on the etiology of myopia and the efforts to
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7 296 explore the effect of endocrine traits observed during childhood and adolescence on
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10 297 body and eye size in the future studies.

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12 298 The relationships weight and BMI share with refraction are not as extensively studied
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15 299 as those with height, but the findings regarding these relationships are also inconclusive.
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18 300 Heavier and more obese Chinese children and adults in Singapore have refractions that
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21 301 trend toward hyperopia.^{17 23} Moreover, heavier adults in rural Myanmar reportedly have
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24 302 more positive refractions.²⁵ However, a cross-sectional study performed in 19-year-old
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27 303 male conscripts in South Korea found that weight and BMI had no effect on refraction.²⁷
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30 304 Consistent with the results of a twin study performed in Australia,²² in our study,
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33 305 heavier weights were associated with more negative refractions among participants
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36 306 aged 6 to 8 and 9 to 11 years old.

37 307 This study has several limitations that warrant consideration. First, information on
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40 308 putative myopia risk factors obtained from our questionnaire (e.g., the distance between
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43 309 the child's eyes and a book when reading or writing) was subjectively estimated by the
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46 310 parents. Although this method has been widely applied in previous studies,^{17 28} it can
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49 311 lead to recall bias. Second, the representativeness of the participants in this study may
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52 312 be affected to some extent because the participants were volunteers. Although there
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55 313 were no significant differences in nearly all basic characteristics between participants
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58 314 and those excluded, individuals who were included were older, which may have
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60 315 resulted in overestimation of the prevalence of myopia in our study. Third, all of the

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4 316 data collected in this study were cross-sectional in nature and do not allow an evaluation
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7 317 of causality. Therefore, whether the conclusions drawn from this study are applicable
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10 318 to longitudinal relationships remains uncertain. Despite these limitations, we believe
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12 319 that our study provides a valuable reference regarding the associations between
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15 320 anthropometric indicators and both refraction and ocular biometrics in Chinese
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18 321 schoolchildren aged 6 to 15 years old.

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20 322 In conclusion, both higher heights and heavier weights were associated with longer
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23 323 ALs, deeper VCDs, higher AL/CC ratios and more myopic refractions during the early
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26 324 period of adolescent growth after controlling for age, gender, parental myopia,
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29 325 family income, reading and writing distance, and time spent outdoors. The results of
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32 326 this study support the idea that a shared mechanism may regulate the coordinated
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35 327 growth of body and eye size in children.

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53 334 SY, SL, WL and QW. Analysis and interpretation of the data: SY. Review and approval
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56 335 of the manuscript: SY, SL, WL, QW, WX and XZ.

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9 339 **Competing interests** None declared.

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12 340 **Patient consent** Obtained.

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15 341 **Ethics approval** Ethics Committee of Tianjin Medical University, China.

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17 342 **Provenance and peer review** Not commissioned; externally peer reviewed.

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20 343 **Data sharing statement** No additional data are available.

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Table 1 Summary of the characteristics of the participants.

	Total	Myopia	Nonmyopia	<i>P</i> Value
Age (years)	9.42 ± 2.09	9.88 ± 2.14	8.30 ± 1.45	<0.01
Male	264 (54.77)	187 (54.52)	77 (55.40)	0.86
Female	218 (45.23)	156 (45.48)	62 (44.60)	0.86
Parental myopia*				<0.01
None	129 (28.48)	74 (23.13)	55 (41.35)	
One parent	188 (41.50)	134 (41.88)	54 (40.60)	
Both parents	136 (30.02)	112 (35.00)	24 (18.05)	
Monthly family income*				<0.05
<4000 RMB	41 (8.78)	27 (8.16)	14 (10.29)	
4000-8000 RMB	136 (29.12)	89 (26.89)	47 (34.56)	
8000-10,000 RMB	133 (28.48)	89 (26.89)	44 (32.35)	
10,000-15,000 RMB	91 (19.49)	73 (22.05)	18 (13.24)	
≥15,000 RMB	66 (14.13)	53 (16.01)	13 (9.56)	
Reading and writing distance*				<0.05
<10 cm	45 (9.62)	36 (10.81)	9 (6.67)	
10-20 cm	200 (42.74)	148 (44.44)	52 (38.52)	
20-30 cm	166 (35.47)	117 (35.14)	49 (36.30)	
≥30 cm	57 (12.18)	32 (9.61)	25 (18.52)	
Time spent outdoors (hours)	1.20 ± 0.70	1.16 ± 0.70	1.31 ± 0.69	<0.05
Height (cm)	140.79 ± 13.95	143.85 ± 14.17	133.22 ± 10.01	<0.01
Weight (kg)	38.29 ± 10.86	40.06 ± 11.05	33.92 ± 9.01	<0.01
BMI (kg/m ²)	19.04 ± 3.18	19.10 ± 3.14	18.89 ± 3.28	0.52
SER (D)	-1.48 ± 1.82	-2.20 ± 1.66	0.30 ± 0.54	<0.01
AL (mm)	23.81 ± 1.12	24.16 ± 1.07	22.95 ± 0.72	<0.01
CCT (μm)	547.65 ± 32.44	548.88 ± 33.32	544.63 ± 30.05	0.19
ACD (mm)	3.08 ± 0.26	3.14 ± 0.25	2.94 ± 0.23	<0.01

LT (mm)	3.47 ± 0.20	3.43 ± 0.20	3.55 ± 0.19	<0.01
VCD (mm)	17.27 ± 1.09	17.60 ± 1.05	16.46 ± 0.71	<0.01
CC (mm)	7.78 ± 0.26	7.78 ± 0.25	7.79 ± 0.26	0.84
AL/CC ratio	3.06 ± 0.13	3.11 ± 0.13	2.95 ± 0.07	<0.01

Data are presented as the means with standard deviation (SD) or as n (%).

*Numbers of individuals vary due to missing data.

Table 2 Bivariate correlations of body stature with refraction and ocular biometrics.

	Height (cm)	Weight (kg)	BMI (kg/m ²)
SER (D)	-0.45**	-0.39**	-0.11*
AL (mm)	0.50**	0.45**	0.15*
CCT (µm)	0.17**	0.19**	0.09*
ACD (mm)	0.29**	0.22**	0.03
LT (mm)	-0.24**	-0.19**	-0.04
VCD (mm)	0.49**	0.44**	0.16**
CC (mm)	0.07	0.10*	0.08
AL/CC ratio	0.49**	0.40**	0.10*

Data are the Pearson correlation coefficients.

*: $P < 0.05$.

** : $P < 0.01$.

Table 3 Unadjusted mean values of refraction and ocular biometrics by quartiles of height, weight and BMI.

	Range	n	SER (D)	AL (mm)	CCT (μm)	ACD (mm)
<i>Height (cm)</i>						
1st quartile	100.0~130.0	127	-0.48 \pm 1.13 [†]	23.09 \pm 0.78	542.11 \pm 30.93	2.97 \pm 0.24
2nd quartile	130.1~140.0	136	-1.08 \pm 1.46	23.58 \pm 0.98	544.96 \pm 32.69	3.05 \pm 0.28
3rd quartile	140.1~150.7	99	-1.86 \pm 1.80	24.15 \pm 1.01	550.04 \pm 32.31	3.16 \pm 0.23
4th quartile	150.8~182.5	120	-2.68 \pm 2.06	24.56 \pm 1.14	554.58 \pm 32.76	3.18 \pm 0.22
<i>P</i> for trend [‡]			<i>P</i> <0.01	<i>P</i> <0.01	<i>P</i> <0.05	<i>P</i> <0.01
<i>Weight (kg)</i>						
1st quartile	20.0~30.0	129	-0.59 \pm 1.19	23.19 \pm 0.80	541.27 \pm 32.75	3.02 \pm 0.26
2nd quartile	30.1~36.1	112	-1.12 \pm 1.30	23.58 \pm 1.00	547.64 \pm 31.34	3.04 \pm 0.26
3rd quartile	36.2~45.0	128	-1.75 \pm 1.92	24.02 \pm 1.12	544.17 \pm 31.56	3.12 \pm 0.24
4th quartile	45.1~82.3	113	-2.54 \pm 2.14	24.52 \pm 1.12	558.92 \pm 31.65	3.16 \pm 0.24
<i>P</i> for trend			<i>P</i> <0.01	<i>P</i> <0.01	<i>P</i> <0.01	<i>P</i> <0.01
<i>BMI (kg/m²)</i>						
1st quartile	14.0~16.5	121	-1.19 \pm 1.62	23.55 \pm 1.05	543.79 \pm 31.55	3.09 \pm 0.25
2nd quartile	16.6~18.4	120	-1.39 \pm 1.69	23.80 \pm 1.14	545.79 \pm 32.26	3.05 \pm 0.28

3rd quartile	18.5~20.8	120	-1.59 ± 1.88	23.90 ± 1.12	547.12 ± 32.16	3.09 ± 0.25
4th quartile	20.9~30.6	121	-1.74 ± 2.05	24.00 ± 1.16	533.90 ± 33.26	3.11 ± 0.25
<i>P</i> for trend			<i>P</i> <0.05	<i>P</i> <0.01	<i>P</i> <0.05	<i>P</i> =0.32
	Range	n	LT (mm)	VCD (mm)	CC (mm)	AL/CC ratio
<i>Height (cm)</i>						
1st quartile	100.0~130.0	127	3.55 ± 0.19	16.57 ± 0.74	7.75 ± 0.25	2.98 ± 0.09
2nd quartile	130.1~140.0	136	3.48 ± 0.23	17.07 ± 0.96	7.79 ± 0.27	3.03 ± 0.11
3rd quartile	140.1~150.7	99	3.42 ± 0.18	17.58 ± 0.99	7.81 ± 0.26	3.09 ± 0.13
4th quartile	150.8~182.5	120	3.41 ± 0.19	17.97 ± 1.12	7.78 ± 0.25	3.16 ± 0.14
<i>P</i> for trend			<i>P</i> <0.01	<i>P</i> <0.01	<i>P</i> =0.36	<i>P</i> <0.01
<i>Weight (kg)</i>						
1st quartile	20.0~30.0	129	3.51 ± 0.20	16.64 ± 0.77	7.75 ± 0.25	2.99 ± 0.10
2nd quartile	30.1~36.1	112	3.49 ± 0.21	17.07 ± 0.97	7.78 ± 0.28	3.03 ± 0.11
3rd quartile	36.2~45.0	128	3.45 ± 0.21	17.46 ± 1.10	7.80 ± 0.24	3.08 ± 0.13
4th quartile	45.1~82.3	113	3.40 ± 0.19	17.95 ± 1.08	7.81 ± 0.25	3.14 ± 0.15
<i>P</i> for trend			<i>P</i> <0.01	<i>P</i> <0.01	<i>P</i> =0.08	<i>P</i> <0.01
<i>BMI (kg/m²)</i>						

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1st quartile	14.0~16.5	121	3.45 ± 0.18	17.01 ± 1.05	7.73 ± 0.26	3.05 ± 0.12
2nd quartile	16.6~18.4	120	3.51 ± 0.23	17.23 ± 1.04	7.81 ± 0.26	3.05 ± 0.13
3rd quartile	18.5~20.8	120	3.46 ± 0.20	17.38 ± 1.11	7.81 ± 0.26	3.06 ± 0.14
4th quartile	20.9~30.6	121	3.44 ± 0.20	17.46 ± 1.13	7.79 ± 0.24	3.08 ± 0.14
<i>P</i> for trend			<i>P</i> =0.37	<i>P</i> <0.01	<i>P</i> =0.19	<i>P</i> <0.05

†Data are expressed as means ± SD.

‡Tests for linear trend is performed by entering the median value of each category of the anthropometric indicator as a continuous variable in the models.

Table 4 Multiple linear regression models of refraction and ocular biometry by height, weight, and BMI.

	Model 1	<i>P</i> Value	Model 2	<i>P</i> Value	Model 3	<i>P</i> Value
<i>Height (per 10 cm)</i>						
SER (D)	-0.59 (-0.70, -0.49)†	<0.01	-0.26 (-0.45, -0.08)	<0.01	-0.21 (-0.40, -0.01)	<0.05
AL (mm)	0.40 (0.34, 0.47)	<0.01	0.18 (0.07, 0.29)	<0.01	0.14 (0.03, 0.26)	<0.05
CCT (µm)	4.03 (1.97, 6.08)	<0.01	2.43 (-1.29, 6.16)	0.20	3.41 (-0.76, 7.58)	0.11
ACD (mm)	0.05 (0.04, 0.07)	<0.01	0.02 (-0.01, 0.05)	0.17	0.02 (-0.02, 0.05)	0.34

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5	LT (mm)	-0.04 (-0.05, -0.02)	<0.01	-0.01 (-0.03, 0.02)	0.57	-0.01 (-0.03, 0.02)	0.75
6							
7	VCD (mm)	0.38 (0.32, 0.44)	<0.01	0.17 (0.06, 0.27)	<0.01	0.13 (0.02, 0.25)	<0.05
8							
9	CC (mm)	0.01 (-0.01, 0.03)	0.13	0.01 (-0.02, 0.04)	0.41	0.01 (-0.03, 0.04)	0.81
10							
11	AL/CC ratio	0.05 (0.04, 0.06)	<0.01	0.02 (0.01, 0.03)	<0.01	0.02 (0.01, 0.03)	<0.05
12							
13	<i>Weight (per 10 kg)</i>						
14							
15	SER (D)	-0.65 (-0.79, -0.51)	<0.01	-0.21 (-0.39, -0.03)	<0.05	-0.18 (-0.36, 0.01)	0.07
16							
17	AL (mm)	0.46 (0.38, 0.55)	<0.01	0.16 (0.05, 0.26)	<0.01	0.15 (0.04, 0.26)	<0.01
18							
19	CCT (μm)	5.56 (2.93, 8.20)	<0.01	3.68 (0.06, 7.29)	<0.05	4.44 (0.42, 8.47)	<0.05
20							
21	ACD (mm)	0.05 (0.03, 0.07)	<0.01	-0.01 (-0.03, 0.02)	0.90	-0.01 (-0.03, 0.03)	0.87
22							
23	LT (mm)	-0.04 (-0.05, -0.02)	<0.01	0.01 (-0.02, 0.02)	0.95	0.01 (-0.02, 0.03)	0.96
24							
25	VCD (mm)	0.44 (0.36, 0.53)	<0.01	0.16 (0.06, 0.27)	<0.01	0.15 (0.04, 0.26)	<0.01
26							
27	CC (mm)	0.03 (0.01, 0.05)	<0.05	0.02 (-0.01, 0.05)	0.11	0.02 (-0.01, 0.05)	0.14
28							
29	AL/CC ratio	0.05 (0.04, 0.06)	<0.01	0.01 (-0.01, 0.02)	0.10	0.01 (-0.01, 0.02)	0.16
30							
31	<i>BMI (per 10 kg/m²)</i>						
32							
33	SER (D)	-0.64 (-1.15, -0.13)	<0.05	-0.26 (-0.73, 0.20)	0.26	-0.27 (-0.74, 0.20)	0.25
34							
35	AL (mm)	0.53 (0.21, 0.84)	<0.01	0.20 (-0.07, 0.47)	0.15	0.23 (-0.05, 0.50)	0.10
36							
37	CCT (μm)	9.50 (0.35, 18.65)	<0.05	6.37 (-2.79, 15.53)	0.17	7.19 (-2.87, 17.25)	0.16
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ACD (mm)	0.03 (-0.05, 0.10)	0.50	-0.03 (-0.10, 0.04)	0.46	-0.02 (-0.10, 0.05)	0.52
LT (mm)	-0.02 (-0.08, 0.03)	0.42	0.01 (-0.05, 0.07)	0.79	0.01 (-0.06, 0.07)	0.86
VCD (mm)	0.55 (0.24, 0.85)	<0.01	0.23 (-0.03, 0.50)	0.09	0.25 (-0.03, 0.52)	0.08
CC (mm)	0.06 (-0.01, 0.14)	0.09	0.04 (-0.03, 0.11)	0.25	0.06 (-0.02, 0.14)	0.13
AL/CC ratio	0.04 (0.01, 0.08)	<0.05	0.01 (-0.02, 0.04)	0.58	0.01 (-0.03, 0.04)	0.67

†Each value represents a separate regression model, with height, weight, or BMI used as the independent variable, the refraction or individual ocular biometrics used as the dependent variable, either alone or with various confounders. Data in parentheses represents the 95% confidence interval.

Model 1 constructs based on crude data. In the next two models, we controlled, in turn, for age and gender or for age, gender, parental myopia, family income, reading and writing distance, and time spent outdoors.

Table 5 Age-specific results of the associations of anthropometric indicators with both refraction and ocular biometrics.

	6-8 years old (n=170)	9-11 years old (n=158)	12-15 years old (n=154)
	<i>b</i>	<i>b</i>	<i>b</i>
<i>Height (per 10 cm)</i>			
SER (D)	-0.31 (-0.59, -0.03)*	-0.48 (-0.71, -0.24)**	0.35 (-0.52, 1.22)

AL (mm)	0.17 (-0.02, 0.35)	0.25 (0.11, 0.38)**	-0.25 (-0.69, 0.18)
CCT (μm)	2.01 (-5.59, 9.60)	0.77 (-3.82, 5.36)	10.49 (-5.41, 26.39)
ACD (mm)	0.04 (-0.02, 0.10)	0.03 (-0.01, 0.06)	-0.09 (-0.17, -0.01)
LT (mm)	-0.03 (-0.08, 0.02)	-0.01 (-0.04, 0.01)	0.07 (-0.02, 0.15)
VCD (mm)	0.18 (-0.004, 0.36)	0.23 (0.09, 0.36)**	-0.23 (-0.69, 0.23)
CC (mm)	-0.01 (-0.07, 0.05)	-0.01 (-0.05, 0.03)	0.01 (-0.09, 0.12)
AL/CC	0.03 (0.003, 0.05)*	0.04 (0.02, 0.05)**	-0.04 (-0.09, 0.02)
<i>Weight (per 10 kg)</i>			
SER (D)	-0.37 (-0.67, -0.07)*	-0.48 (-0.74, -0.23)**	0.39 (-0.23, 1.01)
AL (mm)	0.13 (-0.08, 0.33)	0.29 (0.15, 0.44)**	-0.09 (-0.41, 0.22)
CCT (μm)	1.43 (-6.93, 9.79)	3.00 (-1.99, 7.99)	10.83 (-0.38, 22.04)
ACD (mm)	-0.002 (-0.06, 0.06)	0.03 (-0.01, 0.07)	-0.06 (-0.11, 0.002)
LT (mm)	0.02 (-0.03, 0.08)	-0.03 (-0.06, 0.001)	0.02 (-0.05, 0.08)
VCD (mm)	0.11 (-0.09, 0.31)	0.29 (0.14, 0.44)**	-0.06 (-0.39, 0.28)
CC (mm)	0.02 (-0.05, 0.08)	0.003 (-0.04, 0.04)	0.04 (-0.04, 0.11)
AL/CC	0.01 (-0.01, 0.04)	0.04 (0.02, 0.06)**	-0.03 (-0.07, 0.01)
<i>BMI (per 10 kg/m²)</i>			

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SER (D)	-0.46 (-1.10, 0.17)	-0.63 (-1.38, 0.13)	0.96 (-1.02, 2.93)
AL (mm)	0.06 (-0.36, 0.48)	0.47 (0.05, 0.90)*	0.03 (-0.98, 1.03)
CCT (µm)	0.84 (-16.31, 17.99)	9.14 (-5.10, 23.37)	28.47 (-7.47, 64.41)
ACD (mm)	-0.07 (-0.19, 0.06)	0.04 (-0.07, 0.15)	-0.10 (-0.28, 0.09)
LT (mm)	0.10 (-0.01, 0.21)	-0.07 (-0.16, 0.01)	-0.03 (-0.23, 0.17)
VCD (mm)	0.01 (-0.40, 0.43)	0.51 (0.08, 0.93)*	0.15 (-0.91, 1.21)
CC (mm)	0.05 (-0.09, 0.19)	0.03 (-0.08, 0.14)	0.13 (-0.11, 0.37)
AL/CC	-0.01 (-0.06, 0.04)	0.05 (-0.003, 0.11)	-0.05 (-0.17, 0.08)

* $P < 0.05$; ** $P < 0.01$.

Each value represents a separate regression model with height, weight, or BMI used as the independent variable and the refraction or individual ocular biometrics used as the dependent variable. We controlled for gender, parental myopia, family income, reading and writing distance, and time spent outdoors. Data in parentheses represents the 95% confidence interval.

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For peer review only

Supplementary Table 1 Specific classification of some items in the questionnaire.

What day is your child's birthday?	_____ (yy/mm/dd)
What's your child's gender?	A. Male B. Female
What is the average monthly income of your family?	A. Less than 4000 RMB B. 4000-8000 RMB C. 8000-10,000 RMB D. 10,000-15,000 RMB E. More than 15,000 RMB
Does the child's mother wear glasses for myopia?	A. Yes B. No
Does the child's father wear glasses for myopia?	A. Yes B. No
What is the distance between your child's eyes and a book when reading or writing?	A. <10 cm B. 10-19 cm C. 20-29 cm D. ≥30 cm
How many hours per day dose the child spend on outdoor activities during weekdays?	_____ hours _____ minutes
How many hours per day dose the child spend on outdoor activities during weekends?	_____ hours _____ minutes

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	Page 2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	Page 2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Page 4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 5
Methods			
Study design	4	Present key elements of study design early in the paper	Page 6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	Page 6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Page 7-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Page 7-8
Bias	9	Describe any efforts to address potential sources of bias	Page 6-9
Study size	10	Explain how the study size was arrived at	Page 10
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Page 8-9
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	Page 8-9
		(b) Describe any methods used to examine subgroups and interactions	--
		(c) Explain how missing data were addressed	--
		(d) If applicable, describe analytical methods taking account of sampling strategy	--
		(e) Describe any sensitivity analyses	--
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Page 10
		(b) Give reasons for non-participation at each stage	Page 10
		(c) Consider use of a flow diagram	--
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Page 10
		(b) Indicate number of participants with missing data for each variable of interest	Page 10
Outcome data	15*	Report numbers of outcome events or summary measures	Page 10
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Page 10-12
		(b) Report category boundaries when continuous variables were categorized	Page 9
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	--
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	--
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Page 15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page 13-15
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 16

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Associations between anthropometric indicators and both refraction and ocular biometrics in a cross-sectional study of Chinese schoolchildren

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Manuscripts

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4 1 **Associations between anthropometric indicators and both refraction**
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7 2 **and ocular biometrics in a cross-sectional study of Chinese**
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9 3 **schoolchildren**

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15 5 **Sheng Ye¹, Shengxin Liu¹, Wenlei Li¹, Qifan Wang¹, Wei Xi¹, and Xin Zhang¹**
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20 7 **Author affiliation**

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22
23 8 1. Department of Maternal, Child and Adolescent Health, School of Public Health,
24
25 9 Tianjin Medical University, No. 22 Qixiangtai Road, Tianjin 300070, China.

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28 10 SY and SL contributed equally to the work presented here and should therefore be
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31 11 regarded as equivalent authors.

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36 13 **Correspondence to**

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39 14 Prof. Xin Zhang; zhangxin@tmu.edu.cn.
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4 15 **ABSTRACT**

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7 16 **Objective** To identify associations between anthropometric indicators (height, weight,
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10 17 and body mass index (BMI)) and both refraction and ocular biometrics in Chinese
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12 18 schoolchildren in Tianjin, China.

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15 19 **Design** Cross-sectional study.

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18 20 **Participants** A total of 482 (86.07%) students (6 to 15 years old) with no history of
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20 21 ocular or systemic pathologies were enrolled in this study.

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22 22 **Methodology** Height and weight were measured using standardized protocols. Ocular
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24 23 biometrics (axial length (AL), vitreous chamber depth (VCD), and corneal curvature
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26 24 (CC)) were measured by a low-coherence optical reflectometry device. Cycloplegic
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28 25 refraction was measured using autorefraction. The AL/CC ratio and spherical
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30 26 equivalent refraction (SER) were calculated. Myopia was defined as $SER \leq -0.50$
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32 27 diopters (D). Multiple linear regression analysis was performed to explore the
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34 28 associations between anthropometric indicators (height, weight and BMI) and both
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36 29 refraction and ocular biometrics.

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39 30 **Results** The overall prevalence of myopia was 71.16%. Overall, only height was
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41 31 associated with ALs, VCDs, AL/CC ratios, and refractions after controlling for age,
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43 32 gender, parental myopia, family income, reading and writing distance, and time spent
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45 33 outdoors. Furthermore, age-specific results demonstrated that height and weight were
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47 34 independently associated with refraction in 6- to 8-year-old and 9- to 11-year-old
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49 35 participants. Higher heights in schoolchildren were associated with longer ALs
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4 36 (regression coefficient $b=+0.25$ for each 10 cm difference in height, $P<0.01$), deeper
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7 37 VCDs ($b=+0.23$, $P<0.01$), higher AL/CC ratios ($b=+0.04$, $P<0.01$), and more negative
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10 38 refractions ($b=-0.48$, $P<0.01$). Heavier weights were also associated with longer ALs
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12 39 (+0.29 mm, $P<0.01$), deeper VCDs (+0.29 mm, $P<0.01$), higher AL/CC ratios (+0.04,
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15 40 $P<0.01$), and more negative refractions (-0.48 D, $P<0.01$).

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17 41 **Conclusions** Height and weight remained independently related to refraction and
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20 42 various ocular biometrics during the early adolescent growth period after adequately
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23 43 controlling for covariates, which could support the idea that a shared mechanism may
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26 44 regulate the coordinated growth of body and eye size in children.

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28 45 **Keywords:** anthropometric indicators, refraction, ocular biometrics, schoolchildren
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32 33 34 47 **Strengths and limitations of this study**

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36 48 ● The study participants were schoolchildren ranging in age from 6 to 15 years old,
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39 49 a period when myopia commonly develops, which could allow us to study the
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42 50 association between body stature and refraction during development.
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45 51 ● The overall and age-specific associations between anthropometric indicators and
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48 52 both refraction and ocular biometrics were calculated in this study to help better
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51 53 clarify the coordinated growth of body and eye size.
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53 54 ● Ocular biometrics were measured comprehensively, and the covariates were
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55 55 adequately controlled, which allowed us to achieve a more detailed analysis.
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58 56 ● An evaluation of causality was not possible because this study had a cross-sectional
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9 59 **Introduction**
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12 60 Myopia has reached almost epidemic proportions in the world, especially in certain
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14 61 areas of East and Southeast Asia.¹ This condition is commonly viewed as etiologically
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16 62 heterogeneous. Genetic and environmental risk factors are involved in its progression.
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18 63 The genetic basis of myopia has been supported by evidence indicating high heritability
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20 64 values in twin studies² and a higher prevalence of myopia in children with myopic
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22 65 parents.³ Excessive near work activities,^{4,5} limited time spent outdoors,^{6,7} and intensive
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24 66 educational pressure^{8,9} reportedly to promote the development of myopia. In our effort
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26 67 to consider other factors, we noted that anthropometric indicators, such as height, are
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28 68 thought to be associated with refraction, although no consensus has been achieved
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30 69 regarding this issue.^{10,11}
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39 70 Refractive status is determined by the balance of the refractive power of the cornea
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41 71 and lens, and the axial length (AL) of the eye (representing the combination of anterior
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43 72 chamber depth (ACD), lens thickness (LT), and vitreous chamber depth (VCD)).¹²
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45 73 Myopia usually arises in an eye that has become too long, particularly via vitreous
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47 74 chamber elongation. Several epidemiological studies have demonstrated that changes
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49 75 in ocular dimensions that occur in early life progress concomitant with physical
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51 76 development in children,^{13,14} and the ages of cessation are also similar for increases in
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53 77 height and axial elongation.¹³ Furthermore, genetic studies have confirmed that a
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4 78 common genetic pathway underlies both height and AL,^{15 16} although no specific
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7 79 genetic variants have yet been identified. All of these clues suggest a shared mechanism
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10 80 that regulates the coordinated growth of body and eye size. It has been suggested that
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12 81 there may be a relationship between body stature and refraction. However, in contrast
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15 82 to the consensus regarding the significant associations between body stature and AL,
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18 83 the relationship between body stature and refraction remains controversial. Although
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20 84 many studies have reported that taller^{10 17-20} and heavier persons^{21 22} have an increased
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23 85 likelihood of having myopia, other studies have found no such association.²³⁻²⁸ The
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26 86 discrepancies among these studies may be due to differences in sample sizes, concept
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29 87 definitions or other methodological variations (e.g., height and weight obtained via self-
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31 88 reporting).

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34 89 In China, few studies have comprehensively measured ocular biometrics or further
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37 90 explored their associations with body stature. Additionally, myopia most commonly
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40 91 starts in young schoolchildren and progresses in early adolescence.²¹ Therefore, it is
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43 92 most appropriate to study the effect of body growth on refractive development in young,
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46 93 growing students. In the current survey, we explored the associations between
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49 94 anthropometric indicators, including height, weight, and BMI, and both refraction and
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51 95 ocular biometrics in schoolchildren aged 6 to 15 years old in Tianjin, China.

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54 55 97 **METHODS**

56 57 58 98 **Recruitment**

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4 99 Participants were recruited based on the following strategies. Two districts were
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7 100 randomly chosen from the 6 main urban districts in Tianjin in November 2016. Next,
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10 101 one primary school and one junior high school were randomly selected from each
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12 102 selected district. Then, one class was randomly chosen from each grade level within the
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15 103 two selected schools. All students in these selected classes were invited, but
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18 104 participation in this study was voluntary. After the purposes and procedures of the study
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21 105 were explained to each student and their parents in depth, written informed consent was
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24 106 collected. Students without parental consent and students who had amblyopia,
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27 107 heterotropia, or any ocular or systemic pathologies were excluded.

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29 108 The study protocol was approved by the Ethics Committee of Tianjin Medical
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32 109 University and performed in accordance with the tenets of the Declaration of Helsinki.

33 34 110 **Ocular examinations**

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37 111 All participants underwent a comprehensive eye examination, including measurements
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40 112 of intraocular pressure, a slit-lamp examination of the anterior and posterior segments,
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43 113 cycloplegic autorefraction and ocular biometrics. The purpose of intraocular pressure
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46 114 measurement and slit-lamp examination was to exclude contraindications for mydriasis.

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48 115 Ocular biometrics, such as AL, central corneal thickness (CCT), ACD, LT, VCD,
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51 116 and corneal curvature (CC), were measured with a low-coherence optical reflectometry
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54 117 device (Lenstar LS900; Haag-Streit AG, 3098 Koeniz, Switzerland) in both eyes before
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57 118 pupil dilation. In addition, the AL/CC ratio, also commonly known as the axial
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60 119 length/corneal radius (AL/CR) ratio, was calculated. Then, cycloplegia was induced by

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4 120 administering one drop containing 0.5% tropicamide and 0.5% phenylephrine in a
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7 121 mixed eye agent to each eye at 0 and 5 minutes. Twenty-five minutes after the second
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9 122 instillation, pupillary dilation and the pupillary light reflex were evaluated. Full
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12 123 cycloplegia was considered when the pupil diameter reached 6 mm or more and the
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15 124 light reflex disappeared. A third drop was administered if full cycloplegia was not
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18 125 achieved. Then, participants with full cycloplegia underwent autorefraction using an
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21 126 auto-kerato-refractor (Canon Autorefractor RK-F1, Tokyo, Japan), and 3 consecutive
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23 127 measurements were taken in both eyes. The mean value of 3 valid measurements was
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26 128 calculated for statistical analysis. All of the above instruments were calibrated before
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29 129 the ocular examination. All examinations were performed by board-certified
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31 130 ophthalmologists and certified optometrists.

131 **Definitions**

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36 132 The SER of each eye was calculated as the spherical refraction + 1/2 of the cylindrical
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39 133 refraction using data obtained using the autorefractor. Myopia was defined as an SER
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42 134 of ≤ -0.5 D.

135 **Anthropometric measurements**

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47 136 Height and weight were obtained following specific standardized protocols²⁹ and
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50 137 measured by community doctors on the students' campus. Height was determined with
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53 138 the subject standing barefoot on the base of the height meter and recorded in centimeters
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56 139 (cm). Weight was measured without shoes and heavy coats on a calibrated electronic
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59 140 weighing scale and recorded in kilograms (kg). BMI was calculated as weight/height²
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4 141 and recorded in kilograms per square meter (kg/m²).
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7 142 **Questionnaire**
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9 143 The parents of participants and those excluded were all asked to complete a
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12 144 questionnaire developed to collect information on social-demographic characteristics
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15 145 and potential risk factors for school myopia (supplementary Table 1).
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17 146 The basic characteristics of the participants included age, gender, the monthly
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20 147 income of the family, and the number of parents with myopia. Near-work-related
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23 148 behaviors were ascertained with the question “What is the distance between your child's
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26 149 eyes and a book when reading or writing?”, with answers categorized as follows: <10
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28 150 cm, 10-19 cm, 20-29 cm, and ≥30 cm. Time spent outdoors was estimated by asking
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31 151 how many hours per day the child spent on outdoor activities during weekdays and
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34 152 weekends separately. The average time spent outdoors was calculated by the following
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37 153 formula: [T_{weekday} (hours spent on weekdays) \times 5 + T_{weekend} (hours spent on weekends)
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39 154 \times 2] \div 7.
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42 155 **Statistical analysis**
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45 156 Because refraction and ocular biometrics were highly correlated between two eyes (the
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47 157 Pearson correlation coefficients (r) for refraction, AL, CCT, ACD, LT, VCD, CC and
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50 158 AL/CC ratio were 0.90, 0.96, 0.89, 0.93, 0.93, 0.95, 0.97 and 0.95, respectively, and all
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53 159 P values were lower than 0.01), the data obtained from the right eye were chosen for
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56 160 analyses. Ocular biometrics were all normally distributed, as determined by P-P plots.
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58 161 T-tests were performed for quantitative variables, and chi-square tests were
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4 162 performed for categorical variables to analyze the differences in basic characteristics
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6 163 between individuals with and without myopia. Univariate associations between
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9 164 anthropometric indicators and both refraction and ocular biometrics were identified.
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12 165 Simple linear regression models were constructed to assess the effects of height, weight,
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14 166 and BMI (as independent variables) on refraction and individual ocular biometrics (as
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17 167 dependent variables). Tests for linear trends were performed by entering the median
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20 168 value of each category of the anthropometric indicator based on quartiles as a
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23 169 continuous variable into the models. Multiple linear regression models were then fitted
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26 170 after adjusting, in turn, for age and gender or for age, gender, parental myopia,
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29 171 family income, reading and writing distance, and time spent outdoors. In addition, all
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32 172 participants were divided into the following age groups: 6 to 8 years old, 9 to 11 years
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35 173 old, and 12 to 15 years old. The results of age-specific associations of anthropometric
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38 174 indicators with both refraction and ocular biometrics after controlling for the above
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41 175 covariates were calculated. Collinearity diagnostics were performed, and
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44 176 multicollinearity was absent among the independent variables used in each model.

45 177 Statistical analyses were performed using commercial statistical software (SPSS for
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48 178 Windows, version 20.0; IBM-SPSS, Chicago, Illinois, USA), and *P* values <0.05 were
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51 179 considered statistically significant.

52 180 **Patient and public involvement**

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55 181 Patients and the public were not involved in developing the research questionnaire,
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58 182 outcome measures or overall design of this study protocol.
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7 184 **RESULTS**

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9 185 **Participant characteristics**

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12 186 Among 560 students who were initially invited, a total of 482 participants ranging in
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15 187 age from 6 to 15 years old were available for statistical analysis after excluding 70
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18 188 students without parental consent, 5 students with heterotropia, and 3 students with
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21 189 amblyopia. The response rate in this study was 86.07% (482 of 560). Individuals who
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24 190 were included were older (9.42 ± 2.09 vs 7.60 ± 2.38 years old, $P < 0.01$) than those who
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27 191 were excluded. There were no significant differences in gender, parental myopia,
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29 192 monthly family income, reading and writing distance, and time spent outdoors between
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31 193 included and excluded individuals.

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34 194 The overall prevalence of myopia was 71.16% (343 of 482; 95% CI, 67.01% to
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37 195 75.10%). The mean SER, height, weight and BMI of all participants was -1.48 ± 1.82
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40 196 D, 140.79 ± 13.95 cm, 38.29 ± 10.86 kg, and 19.04 ± 3.18 kg/m², respectively (Table
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43 197 1). Participants with myopia were older, taller, and heavier. These individuals were
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46 198 more likely to have myopic parents, a higher monthly family income, a closer reading
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49 199 and writing distance and to spend less time outdoors. Moreover, these participants had
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52 200 eyes with longer ALs, deep ACDs and VCDs, thinner LTs, and larger AL/CC ratios (all
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55 201 P values were less than 0.05).

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57 202 **Bivariate correlations between variables**

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59 203 Bivariate correlations of body stature with both refraction and ocular biometrics are
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4 204 presented in Table 2, which was of low to moderate strength. For example, height was
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6
7 205 positively correlated with AL ($r=0.50$, $P<0.01$), CCT ($r=0.17$, $P<0.01$), ACD ($r=0.29$,
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9 206 $P<0.01$), VCD ($r=0.49$, $P<0.01$) and the AL/CC ratio ($r=0.49$, $P<0.01$) and negatively
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11
12 207 correlated with SER ($r=-0.45$, $P<0.01$) and LT ($r=-0.24$, $P<0.01$).

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15 208 **Linear trends in refraction and ocular biometrics changes by body stature**
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17 209 **quartiles**

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20 210 Taller and heavier individuals tended to have eyes with longer ALs, thicker CCTs,
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23 211 deeper ACDs, thinner LTs, deeper VCDs, higher AL/CC ratios, and more myopic
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26 212 refractions (all P values for trend were less than 0.05) (Table 3). In addition to ACD
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29 213 and LT, the above tendencies were also observed among more obese schoolchildren
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31 214 (students with higher BMIs).

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34 215 **Linear regression analysis of the associations between anthropometric indicators**
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36 216 **and both refraction and ocular biometrics**

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39 217 In model 1, we used the association between height and refraction as an example and
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42 218 found that for each 10 cm increase in height, the SER was expected to decrease by 0.59
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45 219 D ($P<0.01$) without controlling for any covariates (Table 4). In the next two models,
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48 220 we controlled, in turn, for age and gender or for age, gender, parental myopia, family
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51 221 income, reading and writing distance and time spent outdoors. The difference in SER
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54 222 declined by 0.26 D ($P<0.01$) and 0.21 D ($P<0.05$) in models 2 and 3, respectively. In
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57 223 general, higher heights were associated with longer ALs (+0.14 mm, $P<0.05$), deeper
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59 224 VCDs (+0.13 mm, $P<0.05$), greater AL/CC ratios (+0.02, $P<0.05$), and more negative
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4 225 refractions (-0.21 D, $P<0.05$) among 6- to 15-year-old participants. Nonetheless, weight
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7 226 and BMI were not correlated with refraction in our multiple linear regression models.
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9 227 Furthermore, the participants were categorized into the following age groups: 6 to 8
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12 228 years old ($n=170$), 9 to 11 years old ($n=158$), and 12 to 15 years old ($n=154$). After
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15 229 controlling for the above covariates, the age-specific associations were calculated
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18 230 (Table 5). Both height and weight remained independently associated with refraction
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21 231 in the age range from 6 to 8 years old and 9 to 11 years old. Particularly from 9 to 11
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23 232 years old, higher heights in schoolchildren were associated with longer ALs ($+0.25$ mm,
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25 233 $P<0.01$), deeper VCDs ($+0.23$ mm, $P<0.01$), higher AL/CC ratios ($+0.04$, $P<0.01$), and
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28 234 more negative refractions (-0.48 D, $P<0.01$) in their eyes. Heavier weights were also
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31 235 associated with longer ALs ($+0.29$ mm, $P<0.01$), deeper VCDs ($+0.29$ mm, $P<0.01$),
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34 236 higher AL/CC ratios ($+0.04$, $P<0.01$), and more negative refractions (-0.48 D, $P<0.01$).
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37 237 However, from 12 to 15 years of age, no association was detected between body stature
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39 238 and refraction.
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43 44 240 **DISCUSSION**

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47 241 In this paper, we comprehensively measured ocular biometrics and then explored the
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50 242 overall and age-specific associations between anthropometric indicators and both
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53 243 refraction and ocular biometrics after adequately controlling for covariates among 6- to
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56 244 15-year-old schoolchildren. In China, few studies such as this one have been conducted.
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59 245 Wang et al.¹⁴ confirmed a positive association between height and AL in 7- to 15-year-
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4 246 old schoolchildren based on longitudinal data obtained in Guangzhou, China. However,
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7 247 detailed information about the associations between body stature and refraction and
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10 248 other ocular biometrics was not available in that study. Therefore, compared with
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12 249 previous studies,^{14 28} the present study achieved a more detailed analysis.

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15 250 The current results are in almost complete agreement with those of Saw et al.¹⁷ who
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17 251 showed that among 1449 Singaporean Chinese children aged 7-9 years old, taller
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20 252 individuals were more likely to have eyes with longer ALs (+0.46 mm, $P<0.01$), deeper
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23 253 VCDs (+0.46 mm, $P<0.01$), flatter corneas (+0.10 mm, $P<0.01$), greater AL/CC ratios
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26 254 (+0.02, $P=0.03$), and refractions that trended toward myopia (-0.47 D, $P<0.01$) after
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29 255 controlling for age, gender, parental myopia, and the number of books read per week.
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31 256 A birth cohort performed in Britain to examine the relationship between height growth
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34 257 trajectories and the development of myopia presented similar results.¹⁰ For each SD
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37 258 increase in height for children aged from 2.5 to 10 years old, SER became more
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40 259 negative by -0.075 D (95% CI, -0.112 to -0.039; $P<0.01$) and -0.081 D (95% CI, -0.129
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43 260 to -0.034; $P<0.01$) when the children reached 11 and 15 years old, respectively.
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46 261 However, Huang et al.²⁸ reported that no significant correlation between myopia shift
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49 262 and height changes among schoolchildren aged 7 to 9 years old in Taiwan, China.

50 263 Although the association remains unclear, these results will help us to further explore
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53 264 the intricate relationship between the development of physical characteristics and
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56 265 refraction. A commonly proposed explanation for this potential association is that both
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59 266 higher height and myopia are independent consequences of better socioeconomic status;
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4 267 therefore, there may be no causal relationship between height and myopia.^{17 23} However,
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7 268 in this study, after we controlled for socioeconomic characteristics and myopia-related
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10 269 risk factors, height remained independently related to refraction and various ocular
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12 270 biometrics. Myopia most commonly develops during the period from childhood to early
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15 271 adolescence (from approximately 8 to 14 years old),³⁰ and growth spurts also occur in
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18 272 this period.³¹ The early period of adolescence is mainly characterized by growth spurts
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21 273 and the onset of sexual development, which lasts for approximately 2 or 3 years.³² The
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24 274 age range of early adolescence is approximately 8 to 11 years old. Therefore, we
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27 275 inferred that the development of refraction could be related to physical development
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30 276 during the early period of adolescent growth. The findings of the Singapore Cohort
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33 277 Study of Risk Factors for Myopia (SCORM) support this hypothesis.¹⁹ SCORM
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36 278 reported that boys and girls who experienced earlier peak height velocity also achieved
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39 279 earlier peak SER velocity (at a mean age of 10.1 vs 10.6 years old for boys, $P=0.01$,
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42 280 and 10.0 vs 10.6 years old for girls, $P=0.01$) and had an earlier age of onset of myopia
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45 281 (9.9 vs 10.4 years old for boys, $P=0.03$, and 9.7 vs 10.1 years old for girls, $P=0.04$).
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48 282 The exact biologic pathways underlying these associations are currently unknown.
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51 283 Some major systemic hormones, such as growth hormone, thymic hormone and insulin-
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54 284 like growth factors (IGFs), reportedly could regulate longitudinal bone growth during
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57 285 childhood, which are also involved in the development of experimental myopia.^{33 34} In
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60 286 addition, epidemiological studies reported that children with growth hormone
287 deficiency have shorter body stature and ALs than usual.³⁵ Growth hormone

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4 288 supplementation in these children could partially bring the stature and ALs back within
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7 289 the normal range.³⁶ Sex hormones may be another significant mediator during
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10 290 puberty,³⁷ but our age-specific results (no association was detected in 12- to 15-year-
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13 291 old participants) may not support this idea. Although these hormones were not
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16 292 determined in this cross-sectional study, we believe that the shared mechanism between
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19 293 height and refraction may shed new light on the etiology of myopia and the efforts to
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22 294 explore the effect of endocrine traits observed during childhood and adolescence on
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25 295 body and eye size in the future studies.

26 296 The relationships weight and BMI share with refraction are not as extensively studied
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29 297 as those with height, but the findings regarding these relationships are also inconclusive.
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32 298 Heavier and more obese Chinese children and adults in Singapore have refractions that
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35 299 trend toward hyperopia.^{17 23} Moreover, heavier adults in rural Myanmar reportedly have
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38 300 more positive refractions.²⁵ However, a cross-sectional study performed in 19-year-old
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41 301 male conscripts in South Korea found that weight and BMI had no effect on refraction.²⁷
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44 302 Consistent with the results of a twin study performed in Australia,²² in our study,
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47 303 heavier weights were associated with more negative refractions among participants
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50 304 aged 6 to 8 and 9 to 11 years old.

51 305 This study has several limitations that warrant consideration. First, information on
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54 306 putative myopia risk factors obtained from our questionnaire (e.g., the distance between
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57 307 the child's eyes and a book when reading or writing) was subjectively estimated by the
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60 308 parents. Although this method has been widely applied in previous studies,^{17 28} it can

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4 309 lead to recall bias. Second, the representativeness of the participants in this study may
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7 310 be affected to some extent because the participants were volunteers. Although there
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10 311 were no significant differences in nearly all basic characteristics between participants
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12 312 and those excluded, individuals who were included were older, which may have
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15 313 resulted in overestimation of the prevalence of myopia in our study. Third, all of the
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17 314 data collected in this study were cross-sectional in nature and do not allow an evaluation
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20 315 of causality. Therefore, whether the conclusions drawn from this study are applicable
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23 316 to longitudinal relationships remains uncertain. Additionally, the significant correlation
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26 317 observed in our study needs to be interpreted carefully because of the small sample size.
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29 318 It is important to avoid making strong conclusions about these associations, regardless
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32 319 of whether the results were positive. A larger sample size study is needed in the future
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35 320 to validate our conclusions. Despite these limitations, we believe that our study
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38 321 provides a valuable reference regarding the associations between anthropometric
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41 322 indicators and both refraction and ocular biometrics in Chinese schoolchildren aged 6
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44 323 to 15 years old.

45 324 In conclusion, both higher heights and heavier weights were associated with longer
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48 325 ALs, deeper VCDs, higher AL/CC ratios and more myopic refractions during the early
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51 326 period of adolescent growth after controlling for age, gender, parental myopia,
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54 327 family income, reading and writing distance, and time spent outdoors. The results of
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56
57 328 this study support the idea that a shared mechanism may regulate the coordinated
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60 329 growth of body and eye size in children.

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13 334 Health of Tianjin Medical University.

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19 336 SY, SL, WL and QW. Analysis and interpretation of the data: SY. Review and approval
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21 337 of the manuscript: SY, SL, WL, QW, WX and XZ.

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24
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33 341 **Competing interests:** None declared.

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36 342 **Patient consent:** Obtained.

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39 343 **Ethics approval:** Ethics Committee of Tianjin Medical University, China.

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42 344 **Provenance and peer review:** Not commissioned; externally peer reviewed.

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45 345 **Data sharing statement:** No additional data are available.

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Table 1 Summary of the characteristics of the participants.

	Total	Myopia	Nonmyopia	<i>P</i> Value
Age (years)	9.42 ± 2.09	9.88 ± 2.14	8.30 ± 1.45	<0.01
Male	264 (54.77)	187 (54.52)	77 (55.40)	0.86
Female	218 (45.23)	156 (45.48)	62 (44.60)	0.86
Parental myopia*				<0.01
None	129 (28.48)	74 (23.13)	55 (41.35)	
One parent	188 (41.50)	134 (41.88)	54 (40.60)	
Both parents	136 (30.02)	112 (35.00)	24 (18.05)	
Monthly family income*				<0.05
<4000 RMB	41 (8.78)	27 (8.16)	14 (10.29)	
4000-8000 RMB	136 (29.12)	89 (26.89)	47 (34.56)	
8000-10,000 RMB	133 (28.48)	89 (26.89)	44 (32.35)	
10,000-15,000 RMB	91 (19.49)	73 (22.05)	18 (13.24)	
≥15,000 RMB	66 (14.13)	53 (16.01)	13 (9.56)	
Reading and writing distance*				<0.05
<10 cm	45 (9.62)	36 (10.81)	9 (6.67)	
10-20 cm	200 (42.74)	148 (44.44)	52 (38.52)	
20-30 cm	166 (35.47)	117 (35.14)	49 (36.30)	
≥30 cm	57 (12.18)	32 (9.61)	25 (18.52)	
Time spent outdoors (hours)	1.20 ± 0.70	1.16 ± 0.70	1.31 ± 0.69	<0.05
Height (cm)	140.79 ± 13.95	143.85 ± 14.17	133.22 ± 10.01	<0.01
Weight (kg)	38.29 ± 10.86	40.06 ± 11.05	33.92 ± 9.01	<0.01
BMI (kg/m ²)	19.04 ± 3.18	19.10 ± 3.14	18.89 ± 3.28	0.52
SER (D)	-1.48 ± 1.82	-2.20 ± 1.66	0.30 ± 0.54	<0.01
AL (mm)	23.81 ± 1.12	24.16 ± 1.07	22.95 ± 0.72	<0.01
CCT (μm)	547.65 ± 32.44	548.88 ± 33.32	544.63 ± 30.05	0.19
ACD (mm)	3.08 ± 0.26	3.14 ± 0.25	2.94 ± 0.23	<0.01

LT (mm)	3.47 ± 0.20	3.43 ± 0.20	3.55 ± 0.19	<0.01
VCD (mm)	17.27 ± 1.09	17.60 ± 1.05	16.46 ± 0.71	<0.01
CC (mm)	7.78 ± 0.26	7.78 ± 0.25	7.79 ± 0.26	0.84
AL/CC ratio	3.06 ± 0.13	3.11 ± 0.13	2.95 ± 0.07	<0.01

Data are presented as the means with standard deviation (SD) or as n (%).

*Numbers of individuals vary due to missing data.

Table 2 Bivariate correlations of body stature with refraction and ocular biometrics.

	Height (cm)	Weight (kg)	BMI (kg/m ²)
SER (D)	-0.45**	-0.39**	-0.11*
AL (mm)	0.50**	0.45**	0.15*
CCT (µm)	0.17**	0.19**	0.09*
ACD (mm)	0.29**	0.22**	0.03
LT (mm)	-0.24**	-0.19**	-0.04
VCD (mm)	0.49**	0.44**	0.16**
CC (mm)	0.07	0.10*	0.08
AL/CC ratio	0.49**	0.40**	0.10*

Data are the Pearson correlation coefficients.

*: $P < 0.05$.

** : $P < 0.01$.

Table 3 Unadjusted mean values of refraction and ocular biometrics by quartiles of height, weight and BMI.

	Range	n	SER (D)	AL (mm)	CCT (μm)	ACD (mm)
<i>Height (cm)</i>						
1st quartile	100.0~130.0	127	$-0.48 \pm 1.13^\dagger$	23.09 ± 0.78	542.11 ± 30.93	2.97 ± 0.24
2nd quartile	130.1~140.0	136	-1.08 ± 1.46	23.58 ± 0.98	544.96 ± 32.69	3.05 ± 0.28
3rd quartile	140.1~150.7	99	-1.86 ± 1.80	24.15 ± 1.01	550.04 ± 32.31	3.16 ± 0.23
4th quartile	150.8~182.5	120	-2.68 ± 2.06	24.56 ± 1.14	554.58 ± 32.76	3.18 ± 0.22
<i>P</i> for trend‡			<i>P</i> <0.01	<i>P</i> <0.01	<i>P</i> <0.05	<i>P</i> <0.01
<i>Weight (kg)</i>						
1st quartile	20.0~30.0	129	-0.59 ± 1.19	23.19 ± 0.80	541.27 ± 32.75	3.02 ± 0.26
2nd quartile	30.1~36.1	112	-1.12 ± 1.30	23.58 ± 1.00	547.64 ± 31.34	3.04 ± 0.26
3rd quartile	36.2~45.0	128	-1.75 ± 1.92	24.02 ± 1.12	544.17 ± 31.56	3.12 ± 0.24
4th quartile	45.1~82.3	113	-2.54 ± 2.14	24.52 ± 1.12	558.92 ± 31.65	3.16 ± 0.24
<i>P</i> for trend			<i>P</i> <0.01	<i>P</i> <0.01	<i>P</i> <0.01	<i>P</i> <0.01
<i>BMI (kg/m²)</i>						
1st quartile	14.0~16.5	121	-1.19 ± 1.62	23.55 ± 1.05	543.79 ± 31.55	3.09 ± 0.25
2nd quartile	16.6~18.4	120	-1.39 ± 1.69	23.80 ± 1.14	545.79 ± 32.26	3.05 ± 0.28

3rd quartile	18.5~20.8	120	-1.59 ± 1.88	23.90 ± 1.12	547.12 ± 32.16	3.09 ± 0.25
4th quartile	20.9~30.6	121	-1.74 ± 2.05	24.00 ± 1.16	533.90 ± 33.26	3.11 ± 0.25
<i>P</i> for trend			<i>P</i> <0.05	<i>P</i> <0.01	<i>P</i> <0.05	<i>P</i> =0.32
	Range	n	LT (mm)	VCD (mm)	CC (mm)	AL/CC ratio
<i>Height (cm)</i>						
1st quartile	100.0~130.0	127	3.55 ± 0.19	16.57 ± 0.74	7.75 ± 0.25	2.98 ± 0.09
2nd quartile	130.1~140.0	136	3.48 ± 0.23	17.07 ± 0.96	7.79 ± 0.27	3.03 ± 0.11
3rd quartile	140.1~150.7	99	3.42 ± 0.18	17.58 ± 0.99	7.81 ± 0.26	3.09 ± 0.13
4th quartile	150.8~182.5	120	3.41 ± 0.19	17.97 ± 1.12	7.78 ± 0.25	3.16 ± 0.14
<i>P</i> for trend			<i>P</i> <0.01	<i>P</i> <0.01	<i>P</i> =0.36	<i>P</i> <0.01
<i>Weight (kg)</i>						
1st quartile	20.0~30.0	129	3.51 ± 0.20	16.64 ± 0.77	7.75 ± 0.25	2.99 ± 0.10
2nd quartile	30.1~36.1	112	3.49 ± 0.21	17.07 ± 0.97	7.78 ± 0.28	3.03 ± 0.11
3rd quartile	36.2~45.0	128	3.45 ± 0.21	17.46 ± 1.10	7.80 ± 0.24	3.08 ± 0.13
4th quartile	45.1~82.3	113	3.40 ± 0.19	17.95 ± 1.08	7.81 ± 0.25	3.14 ± 0.15
<i>P</i> for trend			<i>P</i> <0.01	<i>P</i> <0.01	<i>P</i> =0.08	<i>P</i> <0.01
<i>BMI (kg/m²)</i>						

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1st quartile	14.0~16.5	121	3.45 ± 0.18	17.01 ± 1.05	7.73 ± 0.26	3.05 ± 0.12
2nd quartile	16.6~18.4	120	3.51 ± 0.23	17.23 ± 1.04	7.81 ± 0.26	3.05 ± 0.13
3rd quartile	18.5~20.8	120	3.46 ± 0.20	17.38 ± 1.11	7.81 ± 0.26	3.06 ± 0.14
4th quartile	20.9~30.6	121	3.44 ± 0.20	17.46 ± 1.13	7.79 ± 0.24	3.08 ± 0.14
<i>P</i> for trend			<i>P</i> =0.37	<i>P</i> <0.01	<i>P</i> =0.19	<i>P</i> <0.05

†Data are expressed as means ± SD.

‡Tests for linear trend is performed by entering the median value of each category of the anthropometric indicator as a continuous variable in the models.

Table 4 Multiple linear regression models of refraction and ocular biometry by height, weight, and BMI.

	Model 1	<i>P</i> Value	Model 2	<i>P</i> Value	Model 3	<i>P</i> Value
<i>Height (per 10 cm)</i>						
SER (D)	-0.59 (-0.70, -0.49)†	<0.01	-0.26 (-0.45, -0.08)	<0.01	-0.21 (-0.40, -0.01)	<0.05
AL (mm)	0.40 (0.34, 0.47)	<0.01	0.18 (0.07, 0.29)	<0.01	0.14 (0.03, 0.26)	<0.05
CCT (µm)	4.03 (1.97, 6.08)	<0.01	2.43 (-1.29, 6.16)	0.20	3.41 (-0.76, 7.58)	0.11
ACD (mm)	0.05 (0.04, 0.07)	<0.01	0.02 (-0.01, 0.05)	0.17	0.02 (-0.02, 0.05)	0.34

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5	LT (mm)	-0.04 (-0.05, -0.02)	<0.01	-0.01 (-0.03, 0.02)	0.57	-0.01 (-0.03, 0.02)	0.75
6							
7	VCD (mm)	0.38 (0.32, 0.44)	<0.01	0.17 (0.06, 0.27)	<0.01	0.13 (0.02, 0.25)	<0.05
8							
9	CC (mm)	0.01 (-0.01, 0.03)	0.13	0.01 (-0.02, 0.04)	0.41	0.01 (-0.03, 0.04)	0.81
10							
11	AL/CC ratio	0.05 (0.04, 0.06)	<0.01	0.02 (0.01, 0.03)	<0.01	0.02 (0.01, 0.03)	<0.05
12							
13	<i>Weight (per 10 kg)</i>						
14							
15	SER (D)	-0.65 (-0.79, -0.51)	<0.01	-0.21 (-0.39, -0.03)	<0.05	-0.18 (-0.36, 0.01)	0.07
16							
17	AL (mm)	0.46 (0.38, 0.55)	<0.01	0.16 (0.05, 0.26)	<0.01	0.15 (0.04, 0.26)	<0.01
18							
19	CCT (μm)	5.56 (2.93, 8.20)	<0.01	3.68 (0.06, 7.29)	<0.05	4.44 (0.42, 8.47)	<0.05
20							
21	ACD (mm)	0.05 (0.03, 0.07)	<0.01	-0.01 (-0.03, 0.02)	0.90	-0.01 (-0.03, 0.03)	0.87
22							
23	LT (mm)	-0.04 (-0.05, -0.02)	<0.01	0.01 (-0.02, 0.02)	0.95	0.01 (-0.02, 0.03)	0.96
24							
25	VCD (mm)	0.44 (0.36, 0.53)	<0.01	0.16 (0.06, 0.27)	<0.01	0.15 (0.04, 0.26)	<0.01
26							
27	CC (mm)	0.03 (0.01, 0.05)	<0.05	0.02 (-0.01, 0.05)	0.11	0.02 (-0.01, 0.05)	0.14
28							
29	AL/CC ratio	0.05 (0.04, 0.06)	<0.01	0.01 (-0.01, 0.02)	0.10	0.01 (-0.01, 0.02)	0.16
30							
31	<i>BMI (per 10 kg/m²)</i>						
32							
33	SER (D)	-0.64 (-1.15, -0.13)	<0.05	-0.26 (-0.73, 0.20)	0.26	-0.27 (-0.74, 0.20)	0.25
34							
35	AL (mm)	0.53 (0.21, 0.84)	<0.01	0.20 (-0.07, 0.47)	0.15	0.23 (-0.05, 0.50)	0.10
36							
37	CCT (μm)	9.50 (0.35, 18.65)	<0.05	6.37 (-2.79, 15.53)	0.17	7.19 (-2.87, 17.25)	0.16
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ACD (mm)	0.03 (-0.05, 0.10)	0.50	-0.03 (-0.10, 0.04)	0.46	-0.02 (-0.10, 0.05)	0.52
LT (mm)	-0.02 (-0.08, 0.03)	0.42	0.01 (-0.05, 0.07)	0.79	0.01 (-0.06, 0.07)	0.86
VCD (mm)	0.55 (0.24, 0.85)	<0.01	0.23 (-0.03, 0.50)	0.09	0.25 (-0.03, 0.52)	0.08
CC (mm)	0.06 (-0.01, 0.14)	0.09	0.04 (-0.03, 0.11)	0.25	0.06 (-0.02, 0.14)	0.13
AL/CC ratio	0.04 (0.01, 0.08)	<0.05	0.01 (-0.02, 0.04)	0.58	0.01 (-0.03, 0.04)	0.67

†Each value represents a separate regression model, with height, weight, or BMI used as the independent variable, the refraction or individual ocular biometrics used as the dependent variable, either alone or with various confounders. Data in parentheses represents the 95% confidence interval.

Model 1 constructs based on crude data. In the next two models, we controlled, in turn, for age and gender or for age, gender, parental myopia, family income, reading and writing distance, and time spent outdoors.

Table 5 Age-specific results of the associations of anthropometric indicators with both refraction and ocular biometrics.

	6-8 years old (n=170)	9-11 years old (n=158)	12-15 years old (n=154)
	<i>b</i>	<i>b</i>	<i>b</i>
<i>Height (per 10 cm)</i>			
SER (D)	-0.31 (-0.59, -0.03)*	-0.48 (-0.71, -0.24)**	0.35 (-0.52, 1.22)

AL (mm)	0.17 (-0.02, 0.35)	0.25 (0.11, 0.38)**	-0.25 (-0.69, 0.18)
CCT (μm)	2.01 (-5.59, 9.60)	0.77 (-3.82, 5.36)	10.49 (-5.41, 26.39)
ACD (mm)	0.04 (-0.02, 0.10)	0.03 (-0.01, 0.06)	-0.09 (-0.17, -0.01)
LT (mm)	-0.03 (-0.08, 0.02)	-0.01 (-0.04, 0.01)	0.07 (-0.02, 0.15)
VCD (mm)	0.18 (-0.004, 0.36)	0.23 (0.09, 0.36)**	-0.23 (-0.69, 0.23)
CC (mm)	-0.01 (-0.07, 0.05)	-0.01 (-0.05, 0.03)	0.01 (-0.09, 0.12)
AL/CC	0.03 (0.003, 0.05)*	0.04 (0.02, 0.05)**	-0.04 (-0.09, 0.02)
<i>Weight (per 10 kg)</i>			
SER (D)	-0.37 (-0.67, -0.07)*	-0.48 (-0.74, -0.23)**	0.39 (-0.23, 1.01)
AL (mm)	0.13 (-0.08, 0.33)	0.29 (0.15, 0.44)**	-0.09 (-0.41, 0.22)
CCT (μm)	1.43 (-6.93, 9.79)	3.00 (-1.99, 7.99)	10.83 (-0.38, 22.04)
ACD (mm)	-0.002 (-0.06, 0.06)	0.03 (-0.01, 0.07)	-0.06 (-0.11, 0.002)
LT (mm)	0.02 (-0.03, 0.08)	-0.03 (-0.06, 0.001)	0.02 (-0.05, 0.08)
VCD (mm)	0.11 (-0.09, 0.31)	0.29 (0.14, 0.44)**	-0.06 (-0.39, 0.28)
CC (mm)	0.02 (-0.05, 0.08)	0.003 (-0.04, 0.04)	0.04 (-0.04, 0.11)
AL/CC	0.01 (-0.01, 0.04)	0.04 (0.02, 0.06)**	-0.03 (-0.07, 0.01)
<i>BMI (per 10 kg/m²)</i>			

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SER (D)	-0.46 (-1.10, 0.17)	-0.63 (-1.38, 0.13)	0.96 (-1.02, 2.93)
AL (mm)	0.06 (-0.36, 0.48)	0.47 (0.05, 0.90)*	0.03 (-0.98, 1.03)
CCT (µm)	0.84 (-16.31, 17.99)	9.14 (-5.10, 23.37)	28.47 (-7.47, 64.41)
ACD (mm)	-0.07 (-0.19, 0.06)	0.04 (-0.07, 0.15)	-0.10 (-0.28, 0.09)
LT (mm)	0.10 (-0.01, 0.21)	-0.07 (-0.16, 0.01)	-0.03 (-0.23, 0.17)
VCD (mm)	0.01 (-0.40, 0.43)	0.51 (0.08, 0.93)*	0.15 (-0.91, 1.21)
CC (mm)	0.05 (-0.09, 0.19)	0.03 (-0.08, 0.14)	0.13 (-0.11, 0.37)
AL/CC	-0.01 (-0.06, 0.04)	0.05 (-0.003, 0.11)	-0.05 (-0.17, 0.08)

* $P < 0.05$; ** $P < 0.01$.

Each value represents a separate regression model with height, weight, or BMI used as the independent variable and the refraction or individual ocular biometrics used as the dependent variable. We controlled for gender, parental myopia, family income, reading and writing distance, and time spent outdoors. Data in parentheses represents the 95% confidence interval.

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Supplementary Table 1 Specific classification of some items in the questionnaire.

What day is your child's birthday?	_____ (yy/mm/dd)
What's your child's gender?	A. Male B. Female
What is the average monthly income of your family?	A. Less than 4000 RMB B. 4000-8000 RMB C. 8000-10,000 RMB D. 10,000-15,000 RMB E. More than 15,000 RMB
Does the child's mother wear glasses for myopia?	A. Yes B. No
Does the child's father wear glasses for myopia?	A. Yes B. No
What is the distance between your child's eyes and a book when reading or writing?	A. <10 cm B. 10-19 cm C. 20-29 cm D. ≥30 cm
How many hours per day dose the child spend on outdoor activities during weekdays?	_____ hours _____ minutes
How many hours per day dose the child spend on outdoor activities during weekends?	_____ hours _____ minutes

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	Page 2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	Page 2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Page 4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 5
Methods			
Study design	4	Present key elements of study design early in the paper	Page 6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	Page 6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Page 7-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Page 7-8
Bias	9	Describe any efforts to address potential sources of bias	Page 6-9
Study size	10	Explain how the study size was arrived at	Page 10
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Page 8-9
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	Page 8-9
		(b) Describe any methods used to examine subgroups and interactions	--
		(c) Explain how missing data were addressed	--
		(d) If applicable, describe analytical methods taking account of sampling strategy	--
		(e) Describe any sensitivity analyses	--
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Page 10
		(b) Give reasons for non-participation at each stage	Page 10
		(c) Consider use of a flow diagram	--
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Page 10
		(b) Indicate number of participants with missing data for each variable of interest	Page 10
Outcome data	15*	Report numbers of outcome events or summary measures	Page 10
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Page 10-12
		(b) Report category boundaries when continuous variables were categorized	Page 9
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	--
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	--
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Page 15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page 13-15
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 16

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.