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Socioeconomic mechanisms of myopia boom in China: a nationwide cross-sectional study

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ABSTRACT

Objectives To assess the association between socioeconomic development and the myopia boom in China.

Design Nationwide cross-sectional study.

Setting We used data from the China Family Panel Study (CFPS 2010), and the Chinese National Survey on Students' Constitution and Health (CNSSCH 2010).

Participants Participants included 33 600 individuals and 14 226 families from the CFPS 2010, and 86 199 students aged 7–12 years from the CNSSCH 2010.

Measures The main measure was students' visual impairment (defined as Snellen visual acuity ≤20/25 (0.8) in the worse eye) rate of each province (or municipality or autonomous region); other measures included the Gini coefficient of property, logarithm of average property, Gini coefficient of education, average education duration and return-to-education rate of each province (or municipality or autonomous region). The visual impairment rate was calculated using students' data, aged 7–12 years, from the CNSSCH 2010. The Gini coefficient of property and logarithm of average property were calculated using the families' data from the CFPS 2010; the Gini coefficient of education, average education duration and return-to-education rate were calculated using individuals' data aged 18–44 years from the CFPS 2010.

Results The urban environment (coefficient: 0.209; p<0.001), Gini coefficient of property (coefficient: 1.979; p=0.005), logarithm of average property (coefficient: 0.114; p<0.001), average education duration (coefficient: 0.041; p<0.001) and return-to-education rate (coefficient: 0.195; p<0.001) were positively associated with the logit function of visual impairment rate.

Conclusions Economic development may promote an increased desire to pursue wealth. Regarding high return to education and a fairly competitive education system, individuals are likely to pursue wealth through education, which is associated with a heavier education burden and higher prevalence rates of myopia.

Strengths and limitations of this study

- ► The data were obtained from two nationwide investigations, which used unified and standardised methodologies.
- ► The current study explored the socioeconomic mechanism causing prevalence of myopia in China from a meso-level perspective.
- ► This study used data collected in 2010, which were the most up to date available; subsequent economic developments may influence findings.
- ► The socioeconomic indicators were calculated using available data, which may not facilitate comparisons with other studies adopting alternative index calculations.

INTRODUCTION

Worldwide, the prevalence of myopia has grown rapidly in recent decades.[1] In China, the myopia boom has become an important public health issue. The prevalence of visual impairment (VI) in Chinese students, caused mainly by myopia, increased by nearly 2.5-fold in the past 30 years.[2] Currently, the prevalence of myopia is more than 80% among university students in China.[3] Uncorrected myopia is not only among the leading causes of VI and blindness, but if it progresses to high or pathological myopia,[4] it can also lead to blinding diseases such as retinal detachment, cataract, glaucoma and myopic retinopathy.[5] A high prevalence of myopia has also been observed in other parts of East Asia, such as Singapore, South Korea, Japan, Hong Kong and Taiwan.[6–10] For these reasons, there is a rise in research to investigate the reasons for the myopia boom.

Intensive education is a widely acknowledged risk factor for myopia.[11–15] More years spent in education are closely associated with the rising prevalence of myopia.[11–13] Additionally, children studying at schools, with heavy educational pressure, characterised by long class hours, lots of homework, different kinds of remedial classes and intense competition for examinations, are at an elevated risk of myopia.[14 15] Hence, policies to reduce the educational burden, such as reducing school hours, homework and school-based examinations, were proposed and implemented in regions with a high prevalence of myopia, including China, Singapore and other East Asian regions.[16–18]

However, after years of educational reforms, study pressure and myopia prevalence has not reduced.[2 19 20] Despite the burden-reduction policies implemented for more than 20 years in China, there has been a corresponding growth in private supplementary tutoring, with 47% participation rate in urban students.[21] Although hours spent studying in school have shortened, hours of after-school tutoring classes have been alternatively increased, and it has had no significant influence on the total educational burden. Meanwhile, the prevalence of myopia has increased in the past two decades in China.[2 19 20] The situation is similar in other East Asian areas, such as Singapore, South Korea, Hong Kong and Taiwan.[22–24] Therefore, in addition to studying education-related factors, it is vital to study socioeconomic factors, which are on the upstream of the causal chain of myopia, to understand the epidemics of myopia and to present new solutions.[13 25]

To date, a limited number of studies have concentrated on the socioeconomic factors of myopia, and its mechanisms remain elusive.[2 26 27] Economic development has been reported to be closely associated with the prevalence of myopia. In China, areas with high economic development have shown further epidemics of myopia.[2 27] A previous study analysed the VI rate in young Chinese and the economic development and found that the prevalence of myopia was highly correlated with the VI rate; if the provincial gross domestic product (GDP) doubled, the VI rate increased by 20% in that province.[2] It was assumed that with economic development, behaviour and lifestyle changes lead to increased indoor activities. This could be the reason for the high prevalence of myopia.[2] However, a number of highly developed countries, such as Australia and the USA, showed relatively low prevalence of myopia.[13 28] These findings suggest that the extent of economic development cannot fully explain the regional variation in the prevalence of myopia. Further studies are needed to explore how economic development affects the prevalence of myopia.

In the current study, we presented a socioeconomic hypothesis for the myopia boom in China based on the principles of development economics, educational economics and social medicine, which increased the property gap among different classes of society,[29] motivating individuals to purchase property. In a society with a high return to education and fair access to education, families may invest heavily in their children's education to achieve higher incomes in the future,[30 31] thereby improving family property and social class. However, investments in education and high expectations can extend children's study time and shorten the outdoor time, a factor associated with a remarkable increase in myopia.[32 33]

To verify this hypothesis, we analysed the relationship among residents' property equity, educational equity, return to education and VI rate using data from two nationwide investigations in 2010 in China.

MATERIALS AND METHODS

Data sources and Main Measures

The socioeconomic indicators (Gini coefficient of property, logarithm of average property, Gini coefficient of education, average duration of education and return to education) used in the present study were all derived from the China Family Panel Studies published in 2010 (CFPS 2010).[34] The CFPS 2010 covers 25 provinces (or municipalities or autonomous regions) in China except for Hong Kong, Macau, Taiwan, Xinjiang, Tibet, Qinghai, Inner Mongolia, Ningxia and Hainan; therefore, CFPS 2010 represents 95% of China's population and could be regarded as a national sample.

The main measure was the students' VI (defined as Snellen visual acuity (VA) ≤20/25 (0.8) in the worse eye) rate of each province (or municipality or autonomous region); other measures included the Gini coefficient of property, logarithm of average property, Gini coefficient of education, average education duration and return-to-education rate of each province (or municipality or autonomous region).

The VI rate used in the presenting study was derived from the Chinese National Survey on Students' Constitution and Health in 2010 (CNSSCH 2010),[35] including 86 199 subjects aged 7–12 years. The survey participants were selected from 30 provinces and municipalities in China except for Tibet. In the present study, the Pearson correlation coefficient between the VI rate and the prevalence rate of myopia was 0.92 (p<0.001) (online supplemental material S1).

The detailed process of the VA test has been previously described in the CNSSCH.[2 19 35] Unaided distance VA was measured by qualified optometrists for both eyes using a retroilluminated logMAR chart with tumbling E optotypes (Precision Vision) in rooms with illumination of approximately 500 lx. The VA measurement was performed using a uniform protocol throughout the surveys, beginning at a distance of 5 m, with the fourth line from the bottom (Snellen 20/20). VA of the eye was determined using the lowest line read correctly. Present VA, best-corrected VA and cycloplegic refraction were not measured because of limited resources.

VI was defined as unaided distance VA ≤0.8 (Snellen 20/25) in the worse eye. In the present study, we used the vision impairment rates of primary school pupils in 25 provinces and municipalities expressed in CNSSCH 2010, which could be matched with the economic data presented in CFPS 2010.

The Gini coefficient of property and logarithm of average property were calculated using the families' data from the CFPS 2010, while the Gini coefficient of education, average education duration and return-to-education rate were calculated using the data of individuals aged 18–44 years from the CFPS 2010. The methods used to calculate the socioeconomic indicators in our study were as follows:

Gini coefficient of property

The Gini coefficient of property was calculated using the household data presented in CFPS 2010 with the following formulas:

Net asset per household=family's net assets/family population

Entire family weight=family population×average household weight

Family weighted net assets=net asset per household×entire family weight

After sorting the net assets per household from small to large, the entire family weights and family weighted net assets were accumulated line by line to achieve the cumulative family weights and cumulative weighted net assets in each region. For each line, the share of family weight (denoted as 'X') and the share of family net assets (denoted as 'Y') were calculated as follows:

X=entire family weight/cumulative family weights

Y=family weighted net assets/cumulative weighted net assets

Then, the Lorenz curve was drawn, and the Gini coefficient of the property was calculated.

Average property

Using the household data presented in CFPS 2010, the cumulative family weights and cumulative weighted net assets in each region were obtained. The average property was calculated from the cumulative weighted net assets divided by cumulative family weights.

Gini coefficient of education

The Gini coefficient of education was calculated using the formulas presented in the CFPS 2010. Individuals aged between 18 and 44 years who had successfully completed their studies were included in this study.

Individuals' weighted duration of education=individuals' duration of education×individuals' weight

After sorting the individuals' weighted duration of education from small to large, the individuals' weight and weighted duration of education was accumulated line by line to achieve the cumulative individual weights and cumulative weighted duration of education in each region. For each line, the share of individuals' weight (denoted as 'X') and the share of individuals' duration of education (denoted as 'Y') were calculated as follows:

X=individuals' weight/cumulative individuals' weights

Y=individuals' weighted duration of education/cumulative weighted duration of education

Subsequently, the Lorenz curve was plotted, and the Gini coefficient of education was calculated accordingly.

Average education duration

Using the adults' data presented in CFPS 2010, individuals aged 18–44 years who had successfully completed the studies were included. The cumulative individual weights and cumulative weighted duration of education in each region were determined. The average duration of education was calculated by dividing the cumulative weighted duration of education by the cumulative weight of individuals.

Return to education

Return to education was calculated using the adults' data presented in the CFPS 2010. Individuals aged between 18 and 44 years who had successfully completed the study were included. Unmarried adults' actual income was used as personal income (denoted as 'income'), while married adults' average actual income of the couple was used as personal income (denoted as 'Income'). The working years (denoted as 'Wy') were calculated as follows:

Wy=age–years of education–6

Then, the Mincerian model was estimated in each region:

$\mathrm{Ln(Income)}=\alpha+\beta1\times\text{years of education}+\beta2\times Wy+\beta2\times Wy^2$

β1 was the estimated value of return to education.

STATISTICAL ANALYSIS

The mean±SD of the Gini coefficients of property, logarithm of the average property, Gini coefficients of education, average duration of education, and return to education of the 25 sampling units were calculated for urban and rural subareas. Additionally, Student's t-test was used to determine statistical significance in the above-mentioned indicators between urban and rural areas. Locally weighted scatterplot smoothing (LOESS) was used for univariate analysis to explore the association between the above-mentioned indicators and VI rate. LOESS regression is a non-parametric technique that uses local weighted regression to fit a smooth curve. LOESS curves can reveal trends and cycles in data that might be difficult to model with a parametric curve.

Ordinary least squares (OLS) was applied to estimate the unknown parameters in the linear regression model, the dependent variable was the logit function of the VI rate, and the independent variables were the Gini coefficient of property, logarithm of the average property, Gini coefficient of education, average duration of education and return to education. Although regression coefficients of each independent variable were estimated, collinearity was also examined using the variance inflation factor (VIF). If any VIF was greater than 10, the collinearity could not be ignored, and the principal component regression would be used in lieu of OLS. The data were analysed using SAS software (V.9.4; SAS Institute), and the figures were plotted using Excel 2016 software (Microsoft Corporation, Redmond, Washington, USA).

PATIENT AND PUBLIC INVOLVEMENT

Our study did not involve any human participation or public involvement, since all data were obtained from the public data CFPS 2010, and the report of CNSSCH 2010.

Table 1 Overview of visual impairment rates and socioeconomic indicators

Urban/rural	Sample size*	Indicator	Mean	SD	P value of the difference between urban and rural
Urban	25	Visual impairment rate (%)	0.49	0.07	<0.01
		Gini coefficient of property	0.55	0.06	0.15
		Logarithms of the average property	11.40	0.68	<0.01
		Gini coefficient of education	0.20	0.06	<0.01
		Average educational duration (years)	10.21	1.42	<0.01
		Educational returns†	0.40	0.23	<0.01
Rural	23	Visual impairment rate (%)	0.34	0.10	
		Gini coefficient of property	0.52	0.08	
		Logarithms of the average property	10.39	0.45	
		Gini coefficient of education	0.28	0.09	
		Average educational duration (years)	7.27	1.21	
		Educational returns†	0.19	0.25	

*CFPS covers 25 provinces (or municipalities or autonomous regions) in China. In 23 provinces, the investigation was conducted in the urban areas and rural areas, respectively. However, in Beijing and Shanghai, the investigation was conducted only in the urban areas. Therefore, in the sum, 25 urban areas and 23 rural areas were included.
†Educational returns were calculated through the Mincerian model.
CFPS, China Family Panel Study.

RESULTS

Characteristics of the socioeconomic status and VI rate

This study included survey data collected from 23 provinces (urban and rural areas) and 2 municipalities. Participants included 33 600 individuals and 14 226 families from the CFPS 2010, and 86 199 students aged 7–12 years from the CNSSCH 2010. Detailed information about the socioeconomic status of the residents in the sample is summarised in online supplemental material S2.

Table 1 shows the VI rates and socioeconomic indicators of the different areas in China. The VI rates of the primary school students were found to be 49.19%±7.04% for urban areas, and 33.45%±9.58% for rural areas. The results of the Gini coefficient of property, logarithm of the average property, Gini coefficient of education, the average duration of education and return to education are presented in table 1. The results of the Student's t-test showed significant differences in all indicators, except for the Gini coefficient of property, between urban and rural areas. The results indicated that urban areas in China have higher VI rate (p<0.001), higher average property (p<0.001), fairer education system (p<0.001), longer duration of education (p<0.001) and higher return to education (p=0.003).

Associations between the socioeconomic status and VI rate

Table 2 shows the correlations between the socioeconomic indicators and the VI rate. The results showed that the VI rate positively correlated with the Gini coefficient of property (p=0.023), logarithm of the average property (p<0.001), average duration of education (p<0.001) and return to education (p=0.022), while it negatively correlated with the Gini coefficient of education (p=0.006). Additionally, it should be noted that the average duration of education positively correlated with the logarithm of

Table 2 Correlations between the socioeconomical Indicators and the visual impairment rate

	Visual impairment rate	Gini coefficient of property	Logarithms of the average property	Gini coefficient of education	Average educational duration	Educational return*
Visual impairment rate	1	0.326*	0.530***	–0.391**	0.544***	0.330*
Gini coefficient of property		1	0.126	0.090	0.077	0.014
Logarithms of the average property			1	–0.582***	0.861***	0.320*
Gini coefficient of education				1	–0.809***	–0.231
Average educational duration					1	0.425**
Educational return						1

*P<0.05; **p<0.01; ***p<0.001.
*Educational return was calculated through the Mincerian model.

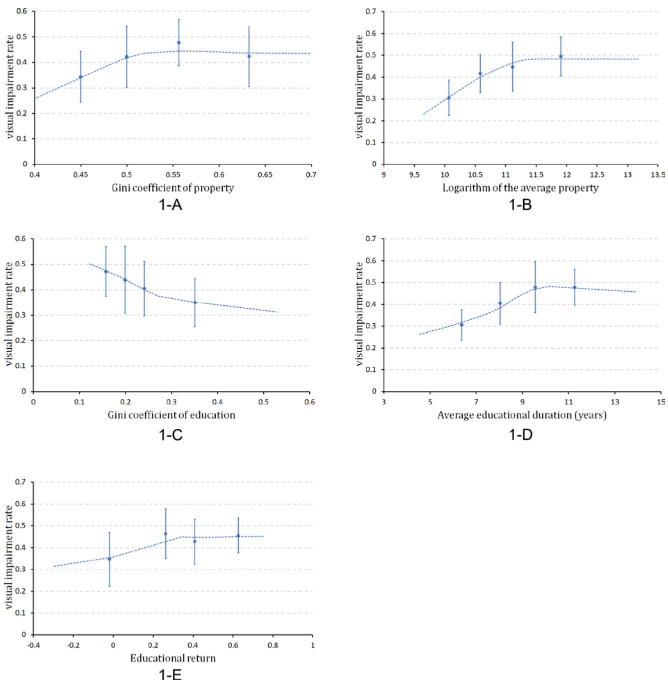

Figure 1 The relationship between the visual impairment rate and socioeconomic indicators. We equally divided the records into four subgroups, respectively, in each panel, according to the value of the corresponding socioeconomic indicator from the minimum to the maximum. The blue dot represented the means of the corresponding socioeconomic indicator and the visual impairment rate of each subgroup, and the solid blue line represented the SD of the visual impairment rate. The blue dotted line was the fitting result of the LOESS regression. (A) It could be found that before the sharp peak of the Gini coefficient of property, the visual impairment rate continued to rise; however, after the peaks, the rate was essentially stable. (B) It could be found that before the sharp peak of the logarithm of the average property, the visual impairment rate continued to rise; however, after the peaks, the rate was essentially stable. (C) It could be found that before the sharp peak of the Gini coefficient of education, the visual impairment rate continued to decrease; however, after the peaks, the rate was gradually becoming stable. (D) It could be found that before the sharp peak of the average educational duration, the visual impairment rate continued to rise; however, after the peaks, the rate was essentially stable. (E) It could be found that before the sharp peak of the educational return, the visual impairment rate continued to rise; however, after the peaks, the rate was essentially stable. LOESS, locally weighted scatterplot smoothing.

the average property ($p<0.001$) and return to education ($p=0.003$), while it negatively correlated with the Gini coefficient of education ($p<0.001$).

Additionally, the LOESS regressions were used to explore the forms of the associations between the VI rate and the socioeconomic indicators mentioned above (figure 1). The results revealed that before the sharp peaks, the VI rate continued to rise or fall; however, after the peaks, the rates were essentially stable.

Socioeconomic status and VI rate models

Table 3 displays the results of the OLS and principal component regression. According to the OLS results, collinearity could not be ignored (table 3), hence, principal component regression was used. The feature vectors are shown in online supplemental material S3. The results of the principal component regression are presented in table 3. Results indicated that VI rate was higher in the urban areas, in areas with larger property gaps, higher average property, longer average duration of education and higher rates of return to education.

DISCUSSION

The present study showed that VI rates are higher in areas with higher residents' property, larger property gaps, fairer educational opportunities and higher returns to education. Although the prevalence rate of myopia could be slightly different from the VI rate in Chinese children and adults, myopia comprised dominant proportion of VI based on uncorrected VA,[36,37] and the VI rate was highly correlated with the prevalence of myopia.[2,19,20] This is the first study linking economic development and education systems to explain the prevalence of myopia and demonstrate the association of poverty gap, rate of return to education and education equity with VI.

The results of the present study indicate an association between socioeconomic factors and the prevalence of myopia in China. Economic development aggravates the property gap, promoting the willingness to pursue wealth and improving social status. Regarding high return to education and a fairly competitive education system, different individuals may pursue wealth through education, leading to heavier education burden and longer education years, increasing near work time and decreasing outdoor time, and finally, leading to the epidemic of myopia. In return, a higher level of education may promote economic development, which may exacerbate the process. The reason why the Gini coefficient of education was irrelevant to the VI rate, maybe because the Gini coefficients of education of the sampling units were low and variability of the independent variable (Gini coefficients of education) was not satisfactory.

The current study could, in part, explain the current epidemic of myopia in China. In China, the annual increase of GDP rate has still remained at about 6%–10% in recent decades,[38] with the property gap (Gini coefficient of property) equal to 0.549 in urban and 0.519 in rural areas. The Central People's Government of China put great emphasis on educational reforms, including the resurrection of the national college entrance examination to ensure a fair selection process of talents and popularisation of the 9-year compulsory education to assist different groups of students, such as those living in poverty, ethnic minorities and girls in having equal opportunities for basic education. These reforms may markedly increase education equity, with a Gini coefficient of education equal to 0.198 in urban areas and 0.279

Table 3 Results of OLS and principal component regression

	OLS regression		Principal component regression	
Indicator	β coefficient*	VIF	β coefficient*	VIF
Intercept	−2.148 (1.207)	0	−3.104 (0.513)***	0.531
Urban (reference: rural)	0.604 (0.170)**	2.602	0.209 (0.034)***	0.035
Gini coefficient of property	1.569 (0.778)	1.122	1.979 (0.673)**	0.687
Logarithms of the average property	0.182 (0.151)	4.723	0.114 (0.019)***	0.024
Negative Gini coefficient of education	1.686 (1.305)	4.058	0.351 (0.255)	0.345
Average educational duration	−0.117 (0.097)	12.948	0.041 (0.008)***	0.009
Educational return†	0.256 (0.240)	1.358	0.195 (0.033)***	0.216

*P<0.05; **p<0.01; ***p<0.001.
*The numbers outside the brackets are means, while the numbers in the brackets are SEs.
†Educational return was calculated through the Mincerian model.
OLS, ordinary least squares; VIF, variance inflation factor.

in rural areas. The return to education is high in China. Previous studies showed that the Mincerian in China increased from 3.6% in 1988 to 12.2% in 1993.[39] In the present study, the Mincerian was 40.4% in urban areas and 19.1% in rural areas, meaning that with 1 extra year of education, income increased by 40.4% in urban areas and by 19.1% in rural areas. Under this socioeconomic background, numerous individuals and families were willing to seek property and improve their social status through investment in education. Consequently, the VI rate, mainly caused by myopia, continuously increased from 1985 to 2010, as reported in the CNSSCH.[19]

Similar situations can be found in other countries. For example, although Singapore is a developed country with a high economic level, the property gap is still relatively large with a Gini coefficient of property within 0.45.[40] Additionally, the rates of return to education remained remarkable, equal to 13.4% and 13.1% for the Mincerian in 1974 and 1998, respectively.[39] These results may explain the prevalence of myopia in Singapore. Contrarily, Australia is also a developed country with a high economic level; however, the Gini coefficient of property was 30.5% in 2006, which was relatively low in the world, indicating a relatively small property gap.[41] Meanwhile, the rate of return to education remained relatively low at 8% in 1989 and 8.3% in 2010.[39 42] These data validate our hypothesis and explain the low prevalence of myopia in Australia.[28]

After the Second World War, the prevalence of myopia increased in both Germany and Japan,[8 43] which was probably associated with rapid economic development after the war. However, in recent years, the prevalence of myopia in Germany has noticeably reduced compared with that in Japan, which could be associated with the increased social welfare and decreased return to education as regulated by the German government. The Mincerian in West Germany was 12.6% in 1977 and 4.9% in 1987.[39] Contrastingly, the income gap remained high in Japan,[44] and Mincerian increased from 6.5% in 1975 to 13.2% in 1988,[39] which could be associated with the high prevalence of myopia in Japan.

The strength of the present study is that the data were obtained from two nationwide investigations, which used unified and standardised methodologies to validate the results. The current study explored the socioeconomic mechanisms causing the prevalence of myopia in China from a meso-level perspective. Our study provides a detailed explanation for the myopia boom in China, a finding helpful to other developing countries in controlling myopia prevalence due to the process of rapid economic development.

The present study has several limitations. First, the study used data from 2010, as it was the most recent data that we could access, for both VI rate and socioeconomic data. Second, the Gini coefficient of property, Gini coefficient of education, average property, average duration of education and returns to education were all calculated using the available data, making it difficult to compare then with the indexes calculated by other studies, because of the differences in the included samples and methods of calculation. For instance, to calculate the rate of returns to education, some studies used Heckman's method, while others used the OLS method, which cannot be compared directly. Third, the present results are based on data from China.

Although present study findings may explain the prevalence of myopia in other countries, such as Singapore, Australia, Japan and Germany, they might not explain the increasing myopia prevalence worldwide since different countries have different social, economic and education systems. Additionally, the present study has a cross-sectional design, not a longitudinal design, and therefore we cannot establish a causal relationship between VI and socioeconomic conditions. Hence, the present study could only explain the association between economic development, education and VI, mainly due to myopia in China.

Based on the results of the present study, our suggestions for controlling the prevalence of myopia are as follows: (1) reforming the talent selection system to make it more diversified, not just using written test scores as the only form, but also paying attention to other aspects of personal performance, such as sports and arts; (2) improving the training and evaluation system of vocational education so that manual and technical skilled workers/labourers can obtain more educational returns, social respect and recognition in the country.

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Competing interests None declared.

Patient consent for publication Not required.

Ethics approval All data were obtained from the public data China Family Panel Study (CFPS 2010), and the report of Chinese National Survey on Students' Constitution and Health (CNSSCH 2010). Therefore, the need for ethical approval and consent to participate was waived off.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. Data may be obtained from a third party and are not publicly available. The data used in this paper were from the China Family Panel Study, and the Chinese National Survey on Students' Constitution and Health. The meso-level socioeconomic indicators have been displayed in the supplemental material.

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