

Secular Trends of Ascariasis Infestation and Nutritional Status in Chinese Children From 2000 to 2014: Evidence From 4 Successive National Surveys

Yanhui Dong,¹ Zhiyong Zou,¹ Peijin Hu,¹ Bin Dong,¹ Zhenghe Wang,¹ Zhaogeng Yang,¹ Bo Wen,¹ Yinghua Ma,¹ Yi Song,¹ Jun Ma¹ and Patrick W.C. Lau²

¹Institute of Child and Adolescent Health, School of Public Health, Peking University, Beijing, China; ²Department of Sport and Physical Education, Hong Kong Baptist University, Kowloon Tong, Hong Kong, China

Background. This study aimed to assess secular trends and epidemiological status of ascariasis infestations and to explore its effects on the nutritional transition among Chinese children from 2000 to 2014.

Methods. Data were collected from 69 435 Chinese children aged 7-year-olds and 9-year-olds in 4 successive cross-sectional surveys of Chinese National Survey on Students' Constitution and Health. Ascariasis infestation was defined by using the Kato-Katz method. Nutritional status was classified into stunting, thinness, overweight, and obesity by WHO definition.

Results. From 2000 to 2014, the ascariasis infestation rates decreased from 9.1% to 1.7%, the stunting and thinness prevalence decreased from 4.3% and 13.8% to 0.7% and 7.1%, while the overweight and obesity prevalence increased from 3.6% and 2.1% to 9.8% and 9.1%, respectively. Compared to children in the ascariasis noninfestation group, those infected with ascariasis had a worse nutritional status. Yet, the disparity in nutritional status between 2 groups disappeared over time. Provinces with a higher gross domestic product per capita simultaneously had lower ascariasis infestation rates, lower stunting and thinness prevalence, and higher overweight and obesity prevalence.

Conclusions. The retardation effects caused by ascariasis infestation on nutritional status in Chinese children seemed to be offset by the rapid economic development and nutritional transition over time; nevertheless, multiple prevention and control measures are still needed and should be continuously strengthened.

Keywords. ascariasis; children; nutritional status; obesity; overweight; stunting; thinness.

Ascariasis is considered one of the most common intestinal helminthiasis diseases worldwide and has infected more than 1 billion people globally [1, 2], but it is also one of the most neglected tropical diseases around the world as currently defined by the World Health Organization (WHO) [3, 4]. Ascariasis infestations are exceptionally high in developing countries, particularly in those with a tropical climate and poor sanitation and hygiene [5].

School-aged children are particularly more susceptible to parasitic infestations, including ascariasis, than any other age group [6, 7]. In developing countries, 12% of the global disease burden caused by intestinal helminths are estimated to occur in children aged 5–14 years old [8]. Heavy gastrointestinal infestation caused by ascariasis can lead to malabsorption, diarrhea,

anemia, and malnutrition [1, 3, 9]. Ascariasis infestations in children also may impair growth, cause intellectual retardation, or affect cognitive development and academic achievements [10, 11]. Established mechanisms explain adverse effects caused by ascariasis infestations through decreasing food intake and nutrient absorption, increasing metabolic requirements, and directing nutrient losses [12].

Large numbers of ascariasis infestations are transmitted via the fecal-oral route where parasitic eggs are excreted into the environment in the stools of infected cases [13]. Therefore, ascariasis infestations are preventable. Improved standards of personal hygiene, the development of an effective sewage system, and waste water treatment have contributed to a reduction of environmental contamination and consequently have lowered the spread of ascariasis infestations [14–16]. China's rapid development in recent years has led to significant improvements in infrastructure and living conditions. At the same time, a large improvement in the nutritional status of children was made in past decades [17]. In this context, scant studies have reported the secular trends in ascariasis infestations and its effects on the nutritional status changes in Chinese children.

Hence, recent data were used from the Chinese National Survey on Students' Constitution and Health (CNSSCH, 2014), as well as earlier data from previous surveys (CNSSCH, 2000,

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Correspondence: Y. Ma or Y. Song (Institute of Child and Adolescent Health, School of Public Health, Peking University, 38 Xueyuan Road, Haidian District, Beijing, China, 100191 (yinghuama@bjmu.edu.cn; songyi@bjmu.edu.cn).

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2005 and 2010), which are a series of successive cross-sectional surveys with representative children in China. The 2 objectives of the present study were as follows: (1) assess secular trends and epidemiological status of ascariasis infestations among Chinese children from 2000–14 and (2) explore the effects of ascariasis infestations on the nutritional transition in the context of different economic development levels.

METHODS

Study Design and Subjects

Data were obtained from the 4 CNSSCH in 2000, 2005, 2010 and 2014, the largest nationally representative successive survey of school-aged children in China, which was designed to investigate their health status. The CNSSCH was first conducted in 1985, and it used the same sampling and investigation procedure in 2000, 2005, 2010 and 2014 [18, 19]. Briefly, 31 national mainland provinces were included in the surveys, excluding Hong Kong, Macao, and Taiwan. Data from Hong Kong, Macao, and Taiwan are not available, because the CNSSCH did not cover these regions. Data were collected from the Han ethnicity group in all provinces, except Tibet where the Han ethnic group is a minority. In each province, 3 socioeconomic status groups or prefecture-level cities (ie, upper, moderate, and low) were selected randomly in 1985 and then the subsequent surveys applied the same sampling framework. In each prefecture-level city within a province, all rural primary schools were selected randomly, yielding equal number participants in both boys and girls aged 7 and 9 years in each survey year. All selected participants were listed in the investigation after meeting the inclusion criteria and obtaining informed consent from both the students and their parents. Participants were eligible for this study if they and their parents had lived in the local areas for longer than 1 year. All eligible participants underwent a medical examination before data collection to ensure that they had no other overt physical or mental disorders. Finally, our sample for these analyses included 69 435 Chinese children aged 7 and 9 years (17 949 in 2000, 19 047 in 2005, 16 844 in 2010, and 15 703 in 2014); 3673 participants with missing data on ascariasis eggs testing and refusal to the participant of ascariasis eggs collection were excluded. The surveys were conducted according to the Declaration of Helsinki guidelines and were performed under the leadership of 6 ministries within China, including the Ministry of Education, General Administration of Sport, Ministry of Health, State Ethnic Affairs Commission, Ministry of Science and Technology, and Ministry of Finance. This study was approved by the Medical Research Ethics Committee of Peking University Health Science Center (IRB00001052-18002).

Ascaris Eggs Collection and Testing

All eligible participants were required to conserve about 10 grams of feces within 24 hours and place in a small flask

with a lid under the guidance of their parents and teachers. Professionally trained testing personnel used the Kato-Katz method to examine the ascariasis eggs. Ascariasis infestation was defined as fertilized, unfertilized, and deproteinized eggs after using microscopic examination and identification with other helminth eggs [20]. Based on the requirement of ethics and privacy principles, the school principals, teachers, and parents were suggested to take necessary measures for all students infected with ascariasis in the hospitals.

Measures and Definition for Nutritional Status

Height (cm) and weight (kg) were measured to the nearest 0.1 cm and 0.1 kg with a portable wall-mounted stadiometer and standardized scale using the mean values of the 3 measurements. Measurements were conducted by a team of trained field professionals who were required to pass a training course in anthropometric measurements. Participants were required to wear light clothing only and stand straight, barefoot, and at ease while being measured. All measurement instruments were calibrated before use and standardized instruments were used for the measurements at all survey sites.

We analyzed the CNSSCH data for 4 outcomes: stunting, thinness, overweight, and obesity, which were defined by WHO standards and classifications, in children aged 7 and 9 years [21]. Standard application of thinness, overweight, and obesity were defined based on body mass index (BMI), which was calculated as body weight (kg) divided by height (m) squared (kg/m^2). Then, a Z score was calculated as the child's BMI minus the median BMI. Finally, divide the standard deviation (SD) for that child's age and sex in the WHO reference population [22]. Similar calculations were done to establish Z scores for height (for stunting as less than -2 SD for height Z scores) thinness was defined as less than -2 SD for BMI Z scores. BMI Z scores of more than 1 and 2 SD were classified as overweight and obesity, respectively.

Ascertainment of GDP per Capita

A socioeconomic indicator of GDP (gross domestic product) per capita was included at provincial level in each survey year from 2000–14, which were collected in the statistical yearbook of China and Subnational of National Bureau of Statistics of China [23]. GDP per capita was stratified based upon the quartiles of the 30 provinces in each survey year according to the following distribution: Q1 (lower quartile), Q2 (middle-lower quartile), Q3 (middle-upper quartile), and Q4 (upper quartile).

Statistical Analysis

To assess the epidemiological characteristic of the ascariasis infestation rates, the trends and geographical distribution of ascariasis infestation rates were summarized in each survey year from 2000 to 2014. The geographical distribution of ascariasis infestation rates were compared among the provinces (excluding

Hong Kong, Macau, Tibet, and Taiwan) in each survey year using Spmap in Stata (College Station, TX). All participants were divided into 2 groups: ascariasis infestation or noninfestation. The distributions of nutritional status of continuous variables including height, weight, and BMI were compared between these 2 groups in each year using kernel densities, which are nonparametric, smoothing graphs independent of bin width when compared with histograms. The prevalence of nutritional status of categorical variables including stunting, thinness, overweight and obesity were compared between these 2 groups in each year using chi-squared tests. Logistic regression was used to estimate the risks of each categorical nutritional outcome in the ascariasis infestation group versus the noninfestation group using odds ratio (OR) adjusted for age, sex, province, and inner-provincial economic status in each survey year. Scatter plots and fitted lines were conducted to assess the nutritional transition and association between ascariasis infestation rates and the nutritional status prevalence over time from 2000–14 using different weighted quartile provinces based on GDP per capita. All analyses were performed using Stata 12.0 software. Two-sided *P* values less than 0.05 were considered significant.

RESULTS

The Characteristics of the Study Sample

As shown in Table S1, a total of 69 435 Chinese children aged 7 and 9 years participated in this study. The distributions for sex and age among the 4 survey years were quite similar. The average height, weight, and BMI, as well as overweight and obesity prevalence dramatically increased from 2000 to 2014. The infestation rates of ascariasis, stunting, and thinness prevalence steadily decreased from 2000 to 2014.

Epidemiological Characteristics of the Ascariasis Infestation Rates

Figure 1 demonstrated that both boys and girls witnessed the same downward trends in ascariasis infestation rates from 2000 to 2014 (boys from 9.4% to 1.8%, girls from 8.7 to 1.6%) without

statistical significant difference between boys and girls in each survey year. Children aged 7 years had a significantly higher infestation rate of ascariasis than those aged 9 years from 2000 to 2010 ($P \leq 0.001$), but this age disparity narrowed over time until to 2014 with no statistical significant difference ($P = .759$) (Table S2). Geographically, higher ascariasis infestation rates could be found in the western and southwestern provinces (including Guizhou, Sichuan, Qinghai, and Hunan province) with similar distributions in 2000 and 2005. The rate of change, however, also was higher in the western provinces where larger decreases in ascariasis infestation rates were demonstrated. For example, Guizhou, Shannxi, Hunan, and Sichuan registered the largest decrease of 27.5, 24.8, 24.0 and 8.9 percent from 2000 to 2014 (Figure 2).

Ascariasis Infestation and Nutritional Status

Figure 3 shows the changes in the mean height, weight, and BMI between the ascariasis infestation group and the noninfestation group from 2000 to 2014. A lower mean height and weight was seen in ascariasis infestation group than the noninfestation group in 2000, 2005, and 2010, but this disparity narrowed down in 2014 with no significant difference between the 2 groups. However, no obvious difference was found in the mean BMI between 2 groups in each survey year.

Figure 4 shows the changes in the prevalence of stunting, thinness, overweight, and obesity between the ascariasis infestation group and the noninfestation group from 2000 to 2014. Along with the steady decrease in the stunting and thinness prevalence and the increase in overweight and obesity in both groups over time from 2000 to 2010, the ascariasis infestation group had a higher prevalence of stunting and thinness and a lower prevalence of overweight and obesity in each survey year. However, the statistically significant difference in the prevalence of stunting and thinness versus overweight and obesity gradually diminished over time. For example, there was a statistically significant higher prevalence of stunting in the ascariasis

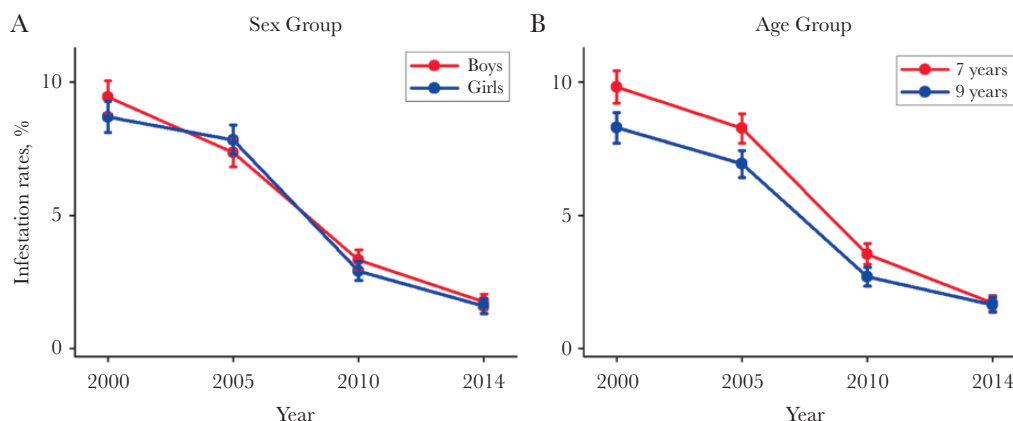


Figure 1. The trends of ascariasis infestation rates from 2000 to 2014 in children of both sexes and in 2 age groups.

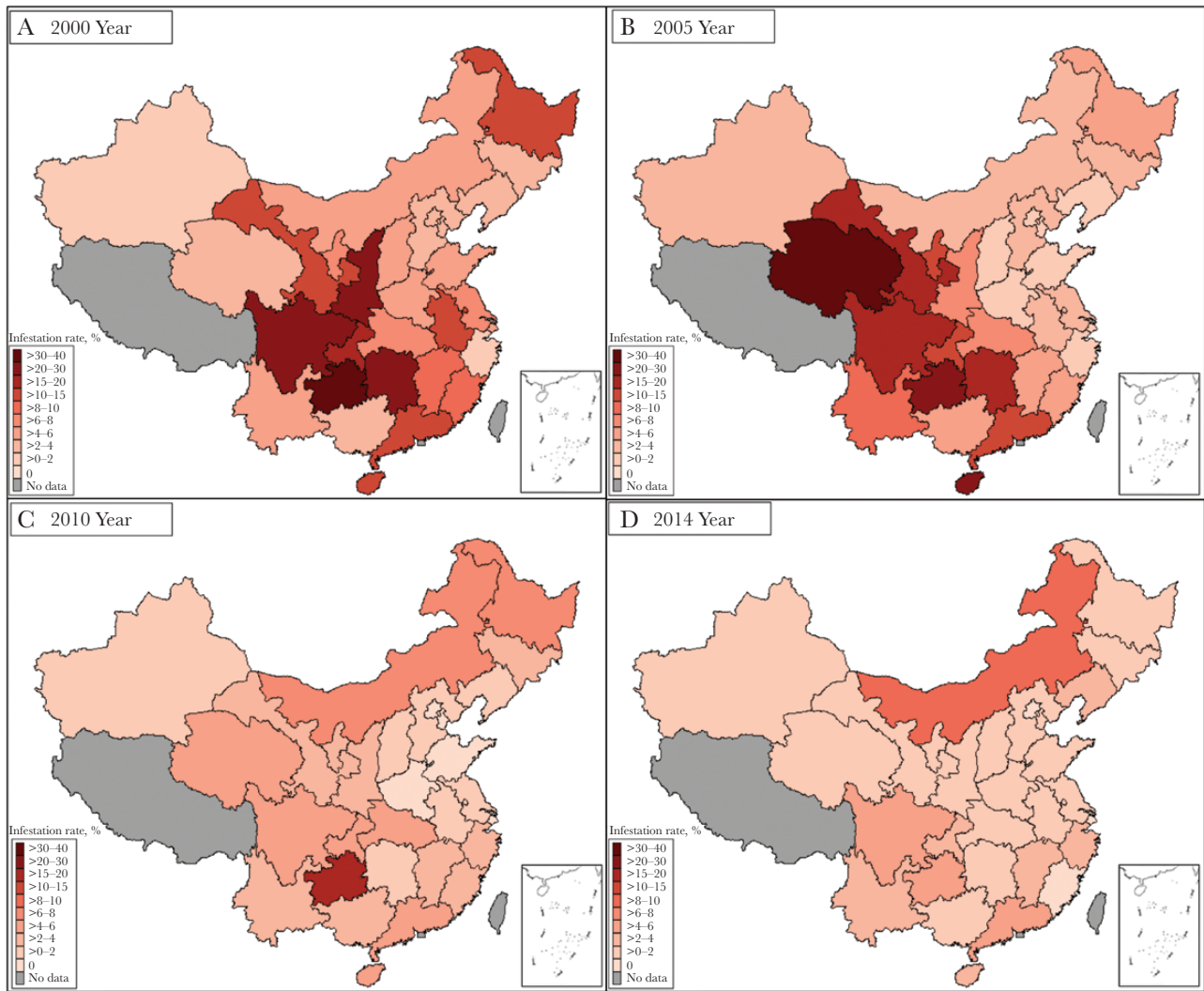


Figure 2. The trends of ascariasis infestation rates at provincial levels from 2000 to 2014 in Chinese children.

infestation group than in the noninfestation group (7.7% vs 4.0%, $P < .001$) in 2000, but the difference disappeared in 2014 (0.8% vs 0.7%, $P = .854$) (Table S3).

After adjusting for some confounders, apart from thinness, the ascariasis infestation group had higher risk of stunting and lower risk of overweight and obesity in early survey years in both boys and girls compared to the noninfestation group ($P < .05$). However, the risk differences between these 2 groups were not significant in 2014 (Table 1).

The Transition of Ascariasis Infestation and Nutritional Status With Increase in GDP per Capital

As shown in Figure 5, the decrease in ascariasis infestation seemed to follow the nutritional status transition, including the decrease in stunting and thinness and the increase in overweight and obesity over time, particularly in the infestation group with a rapid shift speed (Figure S1). As a whole, all provinces in quartile 4 with a higher GDP per capita seemed to have a lower

ascariasis infestation rate, a lower stunting and thinness prevalence, and a higher overweight and obesity prevalence simultaneously. For example, ascariasis infestation has become almost undetectable in Beijing in quartile 4 in 2014 (0.0%), where the lowest prevalence of stunting and thinness (0.0% and 6.5%) and the highest prevalence of overweight and obesity (13.5% and 22.3%) also were shown.

DISCUSSION

These national representative data of Chinese children shows that the ascariasis infestation rates dropped dramatically from 2000 to 2014, particularly in those less-developed western provinces. The ascariasis infestation had a serious impact on the nutritional status of children, but this effect seems to have waned and dissipated over time. Along with the rapid socioeconomic development and nutritional transition from malnutrition to overnutrition in Chinese children, the retardation effect of

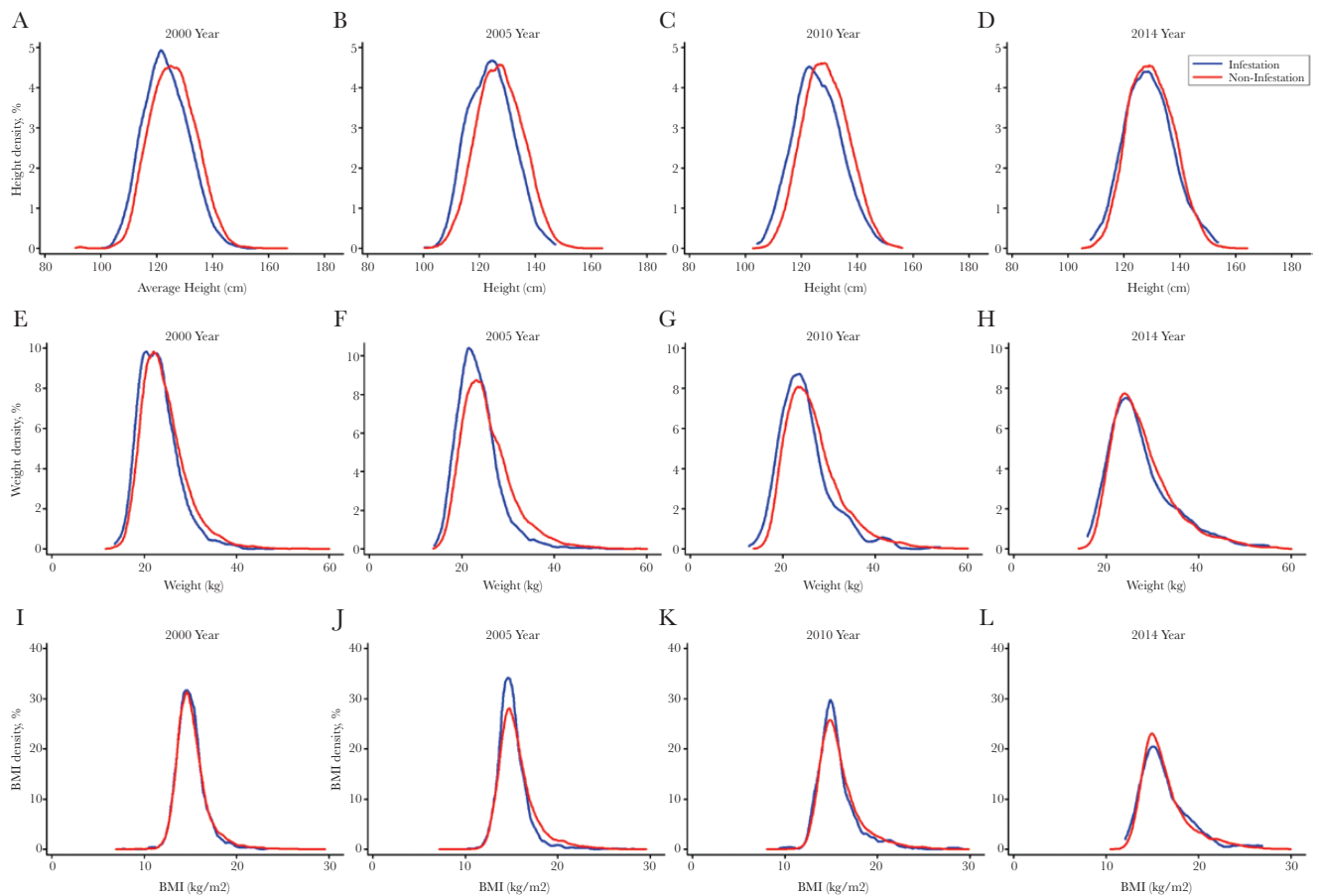


Figure 3. Comparison of height, weight, and body mass index distribution shifts in time from 2000 to 2014 between the ascariasis infestation group (blue lines) and the noninfestation group (red lines) among Chinese children.

nutritional status caused by ascariasis infestation has been minimal. Up to our best knowledge, this is the first study to assess the epidemiological situation of ascariasis infestation and its effects on nutritional status in the context of different economic development regions of Chinese children.

Ascariasis infestation was one of the neglected intestinal pathogenic parasites diseases and remains one of the major health problems of the contemporary world [3]. The majority of victims were children in developing countries where there is soil and water contamination, a limited number of households with access to safe drinking water sources, a large number of asymptomatic carriers, low standards of hygiene, and lack of health care, all of which results in the spread of orally-transmitted infestations [24–26]. China, a developing country with rapid economic development, has passed the era of high levels of ascariasis infestation, and also has also made important efforts in the control of parasitic diseases. For example, China’s Ministry of Health issued a national policy, the “National Investigation and Control Program on the Main Parasitic Diseases,” aimed to prevent and control the nation’s main parasitic diseases [27, 28]. During the period from 2005 to 2014, integrated measures were implemented to control the national parasitic diseases,

including standardized human body and animal deworming drug coverage, health education to improve awareness rates and health behavior formation, harmless sanitary toilets, and knowledge and skills training for medical personnel, particularly in rural areas [28]. In addition, these measures have been continuously strengthened and will be continued through Chinese multisectoral cooperation during the next cycle from 2016 to 2020 [29]. Other policies, such as the “rural water and toilet facilities improvement” policy, have been carried out for many years, driven by special departments set up in 1991 [30]. Such multifaceted policy campaigns might be the key for improving children’s health and controlling the ascariasis infestation in China, especially in rural areas. Some developing countries also have implemented some parasitic control measures, such as a mass deworming campaign with a single-dose chemotherapy in Afghan children, but such efforts did not seem to have effective results[26]. Thus, China’s comprehensive parasite control efforts have produced good results, which also provides a good reference for other developing countries.

Ascariasis infestation and malnutrition always occur together among children in a country or region, particularly in poor areas [10]. Ascariasis infestation in children may impair nutritional

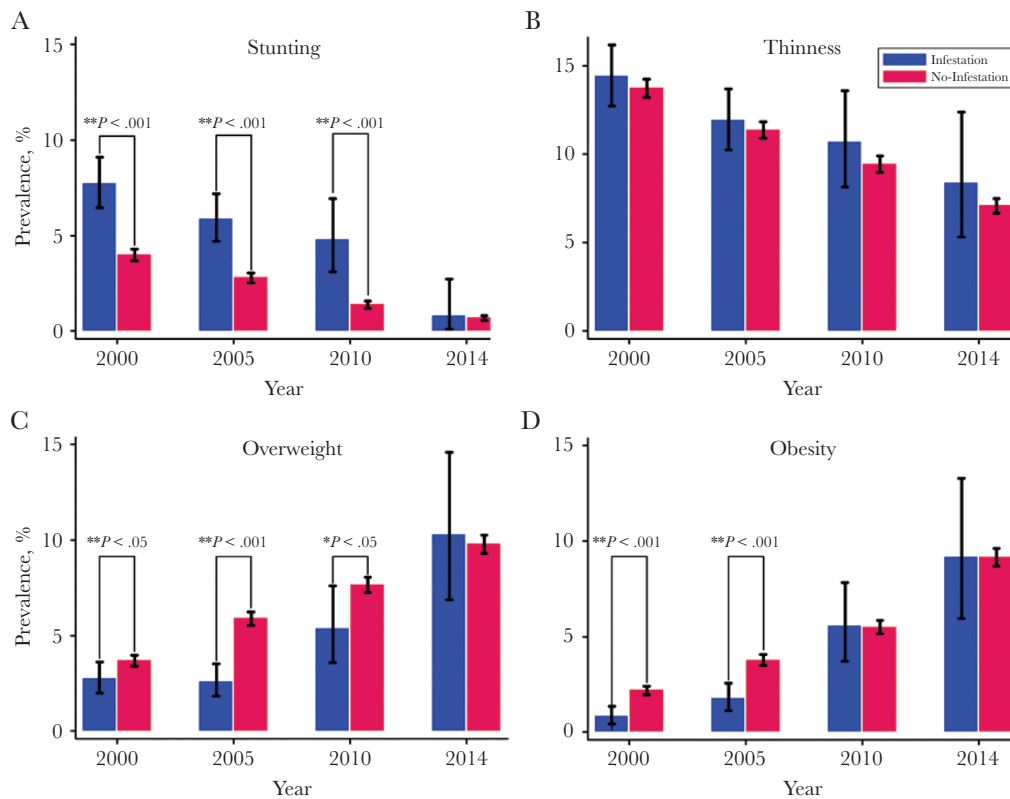


Figure 4. Comparison of the prevalence of malnutrition (stunting and thinness) and overnutrition (overweight and obesity) between the ascariasis infestation group (blue bars) and the noninfestation group (red bars) in each survey year from 2000 to 2014 among Chinese children.

status, but the adverse effects have diminished along with the economic development. During the study period, China has undergone rapid nutritional transition with a dramatic decrease

in malnutrition and an explosive increase in overnutrition. In the early stages of the transition, the impaired effect of ascariasis infestation kept an independent evidence factor with the

Table 1. The Adjusted Odds Ratio for Nutritional Outcomes of Children Infected With Ascariasis Versus Noninfestation in Both Boys and Girls^a

Nutritional Status	Total		Boys		Girls	
	Adjusted OR	P values	Adjusted OR	P values	Adjusted OR	P values
Stunting						
2000	1.97(1.63,2.38)	<.001	2.09(1.61,2.73)	<.001	1.85(1.41,2.43)	<.001
2005	1.45(1.13,1.85)	.003	1.17(0.80,1.71)	.429	1.71(1.24,2.35)	.001
2010	2.43(1.58,3.75)	.000	3.32(1.90,5.80)	.000	1.63(0.81,3.29)	.170
2014	1.00(0.24,4.08)	.996	1.03(0.14,7.54)	.979	0.94(0.13,6.92)	.954
Thinness						
2000	0.99(0.87,1.12)	.835	0.93(0.78,1.11)	.413	1.05(0.88,1.26)	.577
2005	0.89(0.75,1.06)	.187	1.15(0.91,1.45)	.233	0.69(0.54,0.89)	.005
2010	1.05(0.79,1.40)	.725	1.18(0.81,1.71)	.393	0.91(0.59,1.41)	.679
2014	1.23(0.79,1.91)	.360	0.63(0.27,1.43)	.267	1.90(1.11,3.24)	.019
Overweight						
2000	0.83(0.68,1.03)	.085	0.67(0.50,0.90)	.008	1.07(0.80,1.44)	.642
2005	0.54(0.38,0.75)	<.001	0.52(0.33,0.82)	.005	0.56(0.34,0.93)	.024
2010	0.82(0.56,1.21)	.314	0.84(0.52,1.38)	.497	0.77(0.41,1.47)	.433
2014	1.06(0.71,1.58)	.786	0.83(0.47,1.48)	.526	1.41(0.80,2.47)	.238
Obesity						
2000	0.58(0.43,0.79)	<.001	0.64(0.44,0.92)	.017	0.47(0.27,0.83)	.009
2005	0.67(0.45,1.01)	.059	0.83(0.52,1.34)	.448	0.44(0.19,0.99)	.047
2010	1.33(0.91,1.96)	.144	1.52(0.95,2.43)	.083	1.05(0.53,2.08)	.887
2014	1.08(0.71,1.65)	.714	0.92(0.53,1.62)	.784	1.36(0.72,2.56)	.341

^aOR values were adjusted for age, sex, province, and inner-provincial economic status.

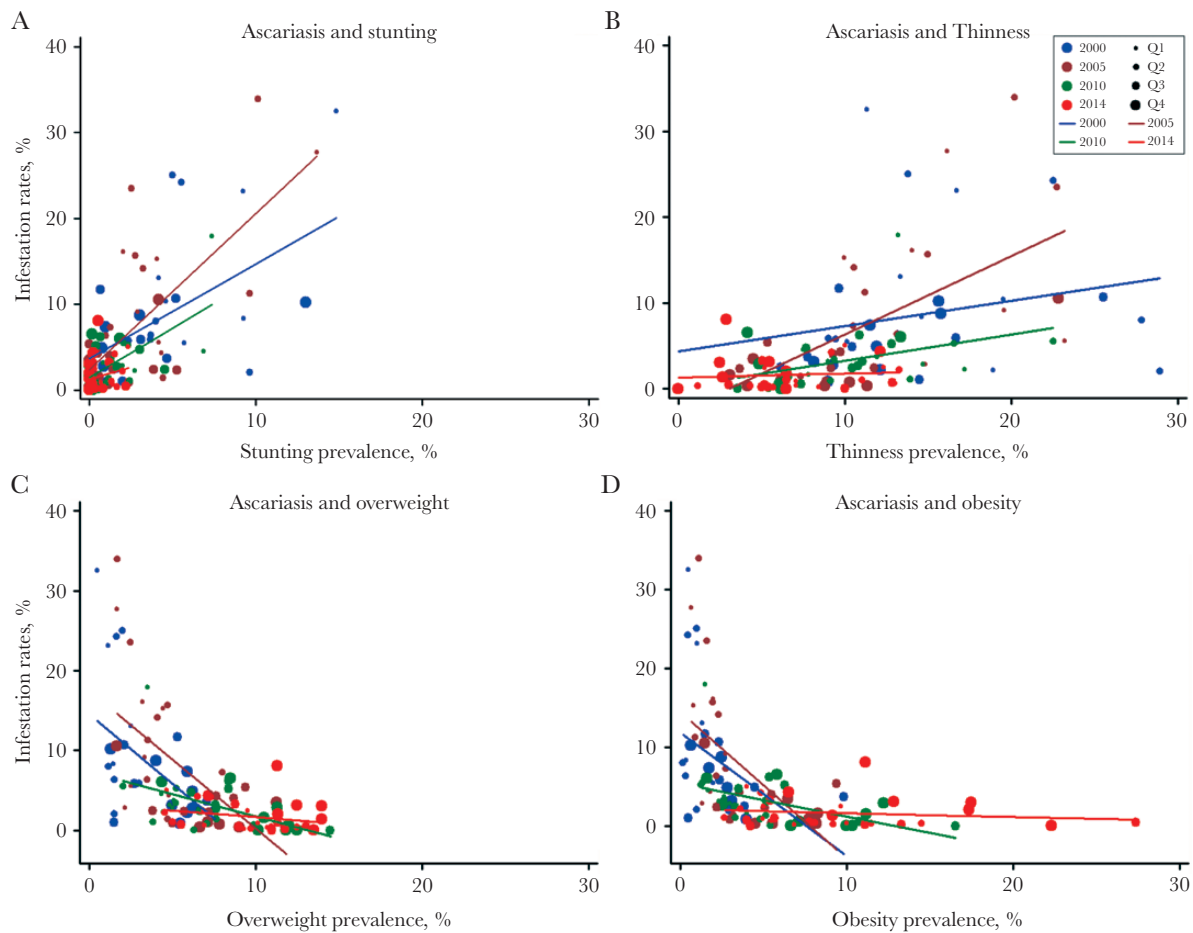


Figure 5. The correlations between ascariasis infestation and nutritional status (stunting [A], thinness [B], overweight [C], and obesity [D]) from 2000 to 2014. Note: Each point represented a province in China and a total of 30 provinces were included in the analyses (except for Hongkong, Macao, Taiwan, and Tibet). Points and fitted lines of different colors represent the provinces in different years (blue for 2000, maroon for 2005, green for 2010, and red for 2014). Points with different sizes represented provinces in different quartiles of economic status in the survey years based on the GDP (gross domestic product) per capita (the smallest point for 1st Q with low GDP per capita; next to the smallest point for 2nd Q with low-middle GDP per capita; next to the largest point for 3rd Q with upper-middle GDP per capita; the smallest point for 4th Q with the highest GDP per capita among 30 provinces in the corresponding survey year).

nutritional status of children, but the effect might have been gradually supplemented by many other factors (such as the diverse food oversupply, physical inactivity, stress, and other environmental factors, which were also the reasons for the nutrition improvements and obesity explosion in China) [31]. Based on our findings, the nutritional retardation of children caused by ascariasis and other parasitic infestation is more serious in current developing countries, which was supported by our stratified analysis of different economic level (GDP per capita) provinces. Chinese underdeveloped provinces still faced high rates of ascariasis infestation, high prevalence of malnutrition, and low levels of overnutrition. However, they also followed the developed provinces with a relatively large decrease in ascariasis infestation rates and rapid nutritional transition from malnutrition to overnutrition over time. Thus, more increased efforts and multiple investments on health to improve nutrition, water, sanitation, and hygiene were needed in developing countries

[32, 33], which can offset the ascariasis infestation's impact on nutrition in children.

Our study has some potential implications. The epidemiological features of ascariasis infestation and its associations with nutritional transitions were comprehensively assessed, which provided evidence to prevent nutritional retardation through prevention and treatment of ascariasis infestation among children, particularly in Chinese rural areas and other developing countries. A recent study found that isolated measures in improving water, sanitation, and hygiene in rural Zimbabwe did not reduce stunting, anemia, and diarrhea in infant and young children [34]. New evidence showed that rapid economic development followed by multiple improvement measures could effectively counteract the adverse effects of ascariasis infestation on nutritional status in children. The combined various measures taken in China in the past decade have provided a significant reference for other developing

countries in the control of ascariasis and other parasites and for nutrition improvement. However, our findings also suggested new and serious challenges. Currently, food diversity and the shift in dietary patterns' changes in favor of fresh food increased the risks of various parasitic diseases. In addition, the rural economy and the poor health literacy of people in underdeveloped areas are also an important factor hindering the prevention and control of parasites in China and other developing countries. Therefore, ascariasis infestation should not be ignored, and its prevention and control measures should be further strengthened, especially for vulnerable children populations.

This study has notable strengths that derive from its comprehensive evaluation of ascariasis infestation and nutritional status, the large sample size across China's multiple provinces, and repeated comparable surveys across a 14-year period spanning major economic development. Several limitations should be noted. Firstly, only children aged 7 and 9 years were included in the present study, which might result in a partial estimation of child ascariasis infestation. However, it could provide important evidence for early health education for sanitation and hygiene to prevent ascariasis in children in school settings. Secondly, some factors in terms of schools, families, and individuals, such as drinking water facilities and sanitation in schools and homes and dietary habits at family and individual levels were not included in the survey, which may limit the extrapolation of the conclusions.

In summary, ascariasis infestation has dropped significantly in Chinese children, and its retardation effects of nutritional status were gradually offset over time with the rapid development of economic development and nutritional transition from malnutrition to overnutrition in China. Great improvements of ascariasis infestation and nutritional status were made in economically developed provinces in China. However, this situation remains serious in economically underdeveloped areas characterized by the high ascariasis infestation rates and poor nutritional status. Thus, the sustained multiple control measures of ascariasis and other parasites, such as standardized coverage of deworming agents, health education, farming practice improvements, and personal and food hygiene, should be strengthened further, particularly in rural and underdeveloped regions.

Supplementary Data

Supplementary materials are available at *Open Forum Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

Acknowledgments

Y.D. conceptualized and designed the study, completed the statistical analysis, drafted the initial manuscript, and reviewed and revised the manuscript. Y.M. J.M., and Y.S. contributed to the conceptualization and design

of the study, supervised the data collection, performed the statistical analyses and initial drafting of the manuscript, and reviewed and revised the manuscript; Z.Z., P.H., and B.D. contributed to the conceptualization and design of the study and reviewed and revised the manuscript; Z.W., Z.Y., B.W., and P.W.C.L. assisted with the statistical analyses and reviewed the manuscript. We would like to acknowledge the support from all of the team members and the student participants, teachers, parents, and local education and health staffs in the programs.

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Potential conflicts of interest. Other than the acknowledged funding sources, all authors have no further reported conflicts of interest. All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Conflicts that the editors consider relevant to the content of the manuscript have been disclosed.

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