High-Precision Identification and Prediction of Spatiotemporal Evolution Patterns of Overweight Among Under-Five Children in China: Postprint

Authors: Zhang Xiyu, Li Ye, Wu Qunhong, Li Jida, Hu Yu

Date: 2022-10-17T00:00:00+00:00

Abstract

Background The normalization of overweight problems among young children has undermined future population quality to some extent, posing significant risks to the sustainable development of China' s human health capital stock.

Objective To scientifically understand the spatiotemporal evolution patterns and future trends of overweight rates among children under five years old in China, and to implement precise intervention measures for controlling the development of childhood overweight phenomena and improving regional government governance effectiveness.

Methods Based on high-resolution 5km$×$5km grid data of overweight rates among children under five years old in China from 2000 to 2019, this paper respectively employed the Theil-Sen median, Mann-Kendall test, and Hurst exponent to characterize the spatiotemporal evolution patterns and development trends of overweight rates among Chinese children under five on a per-pixel basis.

Results The overweight rate among children under five showed a significant increase in 60.59% of regions, with the proportion of increasing trends in central and eastern regions being much higher than in the western region; 25.33% of regions exhibited no significant change in overweight rate evolution trends, yet spatially were scattered in patches across parts of various provinces, such as the middle reaches of the Yangtze River urban agglomeration; 14.08% of regions displayed a significant decreasing evolution trend, concentrated in parts of Xinjiang, Qinghai, Sichuan, and Yunnan in western China, as well as local areas of Tianjin and Shandong in eastern China. Additionally, according to the Hurst exponent, 84.87% of the study area demonstrated persistent or trend-strengthening patterns.

Conclusion This study found that the overweight rate among children under five in China exhibits obvious spatial differentiation characteristics and has a synergistic "U-shaped" relationship with regional development overall, linking together a multi-stage development overweight problem complex of "stunting-overweight decline period" - "overweight phenomenon plateau period" - "overnutrition-overweight rise period" . Aiming at the social problem of childhood overweight derived from the coupling of multiple factors, the research results provide scientific support and policy reference for the government to formulate region-specific policies, construct a three-tier linked governance network of "government policy regulation-social concept permeation-family health management" , and scientifically and precisely solve childhood overweight problems.

Full Text

Preamble

High-precision identification and prediction of spatio-temporal evolutionary patterns of overweight among children under five in China– Multidimensional synergistic governance strategies based on regional development

Xiyu Zhang[1], Ye Li[1]*, Qunhong Wu[2], Jida Li[2], Yu Hu[2]

Funding: National Natural Science Foundation of China project "Research on the poverty reduction effect of medical insurance in the post-poverty alleviation era: Spatial-temporal differentiation patterns, vulnerability identification, and collaborative governance" (Grant No. 72174047); National Natural Science Foundation of China project (Grant No. 71874045); Heilongjiang Provincial Natural Science Foundation project "Panoramic tracking and vulnerable target research on health poverty in Heilongjiang Province from the perspective of spatial poverty reduction" (LH2021G015)

1. Research Centre for Health Policy and Hospital Management, School of Health Management, Harbin Medical University, Harbin, 150081, China
2. Department of Social Medicine, School of Health Management, Harbin Medical University, Harbin, 150081, China

*Corresponding author: Ye Li, Professor, Doctoral supervisor; Email: liye8459@163.com

---

Abstract

Background: The phenomenon of overweight among young children has, to a certain extent, compromised future population quality and poses significant risks to the sustainable development of China' s human health capital stock.

Objective: To scientifically understand the spatio-temporal evolution patterns and future trends of overweight rates among children under five in China, enabling precise interventions to control the development of childhood overweight and improve regional governance effectiveness.

Methods: Based on high-precision 5km$×$5km grid data on overweight prevalence among children under five in China from 2000–2019, this study employed the Theil-Sen median, Mann-Kendall test, and Hurst index to characterize spatio-temporal evolution patterns and development trends pixel by pixel.

Results: Significant increases in overweight rates among children under five were observed in 60.59% of regions, with the proportion of increasing trends substantially higher in central and eastern China than in western regions. 25.33% of regions showed non-significant changes in overweight rates, yet these were spatially scattered in patchy distributions across various provinces, such as the middle reaches of the Yangtze River urban agglomeration. 14.08% of regions exhibited significantly decreasing trends, concentrated in parts of Xinjiang, Qinghai, Sichuan, and Yunnan in western China, as well as localized areas in Tianjin and Shandong in eastern China. Additionally, according to the Hurst index, 84.87% of the study area demonstrated persistent or trend-enhancing patterns.

Conclusion: This study reveals significant spatial differentiation in overweight rates among children under five in China, with a synergistic U-shaped association with regional development overall, linking together a multi-stage problem cluster of overweight across "declining stage of stunting-overweight," "stabilization stage," and "rising stage of overweight from overnutrition." Addressing overweight in young children as a social problem derived from coupled multidimensional factors, our findings provide scientific support and policy references for government formulation of region-specific policies, construction of a three-level governance network of "government policy regulation—social concept penetration—family health management," and scientifically precise solutions to childhood overweight.

Keywords: children under five; overweight; spatio-temporal evolution patterns; trend analysis; health geography; China

---

Stunting, wasting, overweight, and underweight are commonly used to measure the degree and patterns of individual nutritional intake. However, approximately half of all countries globally had made no progress in improving child overweight by 2020, with the situation still deteriorating in many regions. Early attention to overweight among young children may be an effective pathway to mitigating future childhood overweight. Researchers worldwide have conducted surveys on childhood overweight rates, finding that an overweight or obese child at age 4.5 has a fivefold probability of developing obesity by age 12. Modifiable influencing factors such as diet and physical activity can be substantially improved during early childhood. As a critical period for establishing healthy dietary behavior patterns and maintaining healthy growth trajectories, children

under five can be regarded as a strategic population for chronic disease prevention.

Currently, countries including Iran, Brazil, India, Ethiopia, and China have conducted national and regional surveys on overweight rates among children under five and explored their determinants. Additionally, some scholars have conducted trend studies on overweight rates among children under five in specific regions. Although many are review studies based on existing literature, some have performed trend analysis using long-term tracking data. Notably, a fifteen-year empirical study in Peru found that urban overweight rates among children under five experienced a long-term decline, gradually stabilizing after 2005.

China' s overweight problem among children under five is particularly severe, with affected children reaching 6.964 million—the highest in the world. Indonesia, ranking second, has less than half this number. Furthermore, China accounted for 16.8% of the global total of overweight children under five in 2012, a figure that rose to 17.9% by 2020. Therefore, analyzing the development trends of childhood overweight in China is necessary to provide theoretical guidance for alleviating this burden. Some scholars have explored trends in overweight rates among Chinese children under five between 1989–2014, with some literature further highlighting distinct spatial differentiation characteristics underlying these trends. However, existing research on the spatio-temporal diagnosis of childhood overweight in China suffers from limitations including outdated time series, low spatial precision, and insufficient attention to young children.

Based on these gaps, this study employs high-precision grid data on overweight rates among children under five from the Institute for Health Metrics and Evaluation (IHME) to characterize spatio-temporal evolution patterns across China from 2000–2019 pixel by pixel (the minimum raster unit). By capturing evolution characteristics, we predict future change directions, providing early warnings and evidence-based support for local governments to scientifically govern childhood overweight. This work holds important applied value and strategic significance for controlling overweight phenomena among Chinese children under five, reducing future national disease burden, and implementing precise interventions to improve regional governance effectiveness.

1.1 Data Sources

The overweight rate among children under five is defined as the proportion of children under five whose weight-for-height exceeds two standard deviations of the WHO growth reference standard. China' s data on overweight rates among children under five were obtained from IHME' s global 5km$\times$5km grid estimation dataset covering 105 low- and middle-income countries. This dataset' s geographic estimates are based on 420 household surveys from sample countries. The Chinese grid data estimations draw from four surveys: the China Family Dynamics Survey 2016 from the China Population and Development Research

Center; the China Health and Nutrition Survey 1989–2011 from the Carolina Population Center at the University of North Carolina at Chapel Hill and the National Institute for Nutrition and Health; the Secular Trends in Growth and Nutritional Outcomes of Children under Five Years Old in Xiamen; and the China National Nutrition Survey 2002 from the Health Statistics Information Center of the Ministry of Health. The results essentially cover all provinces in mainland China (data for Hong Kong, Macau, and Taiwan are missing due to limitations in the original data). Detailed descriptions of the dataset' s spatio-temporal estimation process are available in previous literature and are not reiterated here.

1.2.1 Multi-year Raster Mean

ArcGIS 10.4 was used to calculate multi-year means for each pixel across the raster data series using the following formula:

$$\bar{X}_n = \frac{\sum_{i=2000}^{2019} x_i}{n}$$

where x_i represents the time series data of overweight rates among children under five for the same pixel.

1.2.2 Theil-Sen Median

The Theil-Sen median method was applied to calculate trends in the overweight prevalence grid for Chinese children under five. This robust non-parametric statistical method offers high computational efficiency and is insensitive to outliers and measurement errors, having been previously applied in trend analysis of long-term time series data in astronomy and hydrology. This study uses the method to estimate overall trends in overweight rates among children under five over the past 20 years, with the data unit being the minimum raster unit—the pixel. A positive Theil-Sen median (β) generally indicates an increasing trend in overweight rates, while a negative value suggests a decreasing trend. The calculation process for β is as follows:

$$\beta = \text{median}\left(\frac{x_j - x_i}{j - i}\right), \forall j > i$$

where x_j and x_i represent the time series data of overweight rates among children under five for the same pixel.

1.2.3 Mann-Kendall Test

The Mann-Kendall test serves as an important non-parametric test that does not require specific sample distributions and is minimally disturbed by outliers, commonly used to validate Theil-Sen median results. In this study, the Mann-Kendall test is employed as a critical technical pathway to determine the significance of trend estimates from the previous step, enabling secondary classification of varying degrees of increasing and decreasing trends.

The Mann-Kendall test statistic S is calculated as:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}(x_j - x_i)$$

where

$$\operatorname{sgn}(x) = \begin{cases} 1 & \text{if } x > 0 \\ 0 & \text{if } x = 0 \\ -1 & \text{if } x < 0 \end{cases}$$

The expected value of S is zero, with variance:

$$\sigma^2 = \frac{n(n-1)(2n+5) - \sum_{j=1}^{p} t_j(t_j-1)(2t_j+5)}{18}$$

where p is the number of tied groups in the dataset and t_j is the number of data points in the j-th tied group. S approximately follows a normal distribution, thus enabling the Z transformation:

$$Z = \begin{cases} \frac{S-1}{\sigma} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{\sigma} & \text{if } S < 0 \end{cases}$$

1.2.4 Hurst Index

The Hurst index reflects temporal autocorrelation, particularly capturing hidden long-term trends (long-term memory) within sequences. It describes characteristics of biased random walks (fractional Brownian motion) and was first proposed by hydrologist Hurst. Building on previous applications of the Hurst index in plant disease incidence studies, this study extends its use to explore development patterns in human disease prevalence, estimating future development patterns of overweight rates among Chinese children under five based on long-term trends. However, since childhood overweight may be influenced by cultural and dietary

habits exhibiting short-term correlations, direct Hurst index estimation could introduce bias. Therefore, before formal Hurst index calculation, this study generates corresponding residual sequences based on first-order autoregressive equations to eliminate interference from linear dependencies.

$$X_t = a + bX_{t-1} + \varepsilon_t$$

where X_t represents the overweight prevalence value for a given raster in year t, a is the constant term, and ε_t is the residual term.

The detailed calculation process for the Hurst index of the residual sequence is as follows:

If the residual sequence in this study is defined as $OVERWEIGHT_t$, $t = 1, 2, \ldots, n$, then for positive integer τ, the mean sequence of this time series is defined as:

$$\overline{OVERWEIGHT}_\tau = \frac{1}{\tau}\sum_{t=1}^{\tau} OVERWEIGHT_t, \quad \tau = 1, 2, \ldots, n$$

The cumulative deviation sequence is defined as:

$$X(t,\tau) = \sum_{t=1}^{\tau}(OVERWEIGHT_t - \overline{OVERWEIGHT}_\tau)$$

The range sequence is defined as:

$$R_\tau = \max X(t,\tau) - \min X(t,\tau), \quad \text{where } \tau = 1, 2, \ldots, n; 1 \le t \le \tau$$

The standard deviation sequence is defined as:

$$S_\tau = \sqrt{\frac{1}{\tau}\sum_{t=1}^{\tau}(OVERWEIGHT_t - \overline{OVERWEIGHT}_\tau)^2}, \quad \text{where } \tau = 1, 2, \ldots, n$$

Thus, the Hurst index is defined as:

$$\frac{R_\tau}{S_\tau} = (c\tau)^H$$

where H is the Hurst index and c is a scaling parameter. H can be estimated through least squares fitting in double-logarithmic coordinates $\ln(R_\tau/S_\tau), \ln(\tau)$. Generally, when H equals exactly 0.5, current conditions are considered not to

affect the future, with overweight prevalence deviations from trend levels following a random walk. When $0 < H < 0.5$, the series exhibits anti-persistence; conversely, when $0.5 < H < 1$, it shows enhanced memory with persistence or trend strengthening.

ArcGIS 10.4 was used to extract raster data on overweight rates among children under five in mainland China and generate first-order autoregressive residual sequences, with further trend analysis and prediction conducted using R 4.1.0. Theil-Sen median calculations and MK tests were implemented using the `sen.slope` function from the R package *trend*, while Hurst index calculations relied on R packages *terra* and *reservoir*.

2.1 Spatial Patterns of Overweight Among Children Under Five in China, 2000–2019

To better observe spatial patterns of overweight rates across regions during the 20-year period, multi-year average overweight rates were calculated pixel by pixel (excluding null values), yielding [Figure 1: see original paper]. Overall, overweight among children under five in China over the past two decades was most prevalent in most areas of Shandong and Hunan provinces, as well as localized regions in Fujian, Guangdong, Hainan, Beijing, and Tianjin. Notably, Hunan province showed the most widespread problem, with a provincial average overweight rate of 29.42% over the 20-year period.

2.2 Characterizing Evolution Patterns of Overweight Among Children Under Five in China, 2000–2019

Based on the coupling of Theil-Sen median and Mann-Kendall test results, evolution trends over the past 20 years were categorized as: significantly decreasing (99% confidence), significantly decreasing (95% confidence), non-significant change (95% confidence), significantly increasing (95% confidence), and significantly increasing (99% confidence), illustrated in [Figure 2: see original paper]. Concurrently, based on equal-area projection of raster data, area statistics for these evolution trends were compiled in (null value areas excluded).

From the evolution trends of overweight rates over the past 20 years, the vast majority of regions (60.59%) showed significant increases. The proportion of regions with increasing trends was substantially higher in the relatively developed central and eastern regions compared to the less developed western regions. 25.33% of regions exhibited non-significant changes in overweight rates, yet these were spatially scattered in patchy distributions across various provinces, such as the middle reaches of the Yangtze River urban agglomeration. This further demonstrates the heterogeneity in spatio-temporal evolution of overweight rates among Chinese children under five, where coarse geographic boundary divisions

may obscure actual change trends. Additionally, 14.08% of regions showed significantly decreasing trends, concentrated in parts of Xinjiang, Qinghai, Sichuan, and Yunnan in western China, as well as localized areas in Tianjin and Shandong in eastern China.

2.3 Predicting Future Deviation Trends in Overweight Prevalence Among Children Under Five in China

Based on Hurst index results from first-order autoregressive residual sequences, future deviation trends from original levels were predicted for each pixel, with regional areas and proportions calculated through geometric statistics from the previous step, yielding [Figure 3: see original paper] and . Future trend changes were classified into three categories: anti-persistence (0<H<0.5), random walk (H=0.5), and persistence (0.5<H<1). We found that 84.87% of regions will exhibit persistence or trend enhancement in the future, covering most of the study area. Where original overweight prevalence was above trend levels, even greater prevalence may occur in the future; where original prevalence was below trend levels, even lower prevalence may result.

---

3 Discussion

Based on high-precision grid data on overweight rates among children under five in China from 2000–2019, this study identified evolution patterns of childhood overweight across the country and predicted future deviation trends from original levels, pinpointing priority areas for addressing overweight among children under five within China' s uneven economic development landscape, thereby promoting future population quality improvement and disease burden control. The main conclusions are as follows:

3.1 Evolution Patterns of Overweight Among Children Under Five in China: Significant Spatial Differentiation

According to Theil-Sen median and MK test results, overweight rates among children under five have maintained increasing trends across most regions of China over the past two decades, with this phenomenon more prevalent in the more developed central and eastern regions. Previous literature indicates that over the past decade, China has experienced faster growth in childhood overweight from dietary and lifestyle changes than any other country, with increased consumption of fried foods, animal-source foods, snacks, and sedentary time playing important roles.

Notably, this study also detected decreasing trends in overweight rates among children under five in both eastern and western China. For some better-developed regions, particularly the Bohai Rim economic belt including Tianjin

and Shandong, recent declining trends align with previous literature. Further research suggests this trend may reverse in the next age group. Additionally, in western China, surrounding Qinghai province, localized areas in Xinjiang, Qinghai, Sichuan, and Yunnan also showed some degree of decline. Previous research indicates that childhood overweight in relatively underdeveloped areas may essentially be stunting—a form of "pseudo-overweight" —reflecting how social structure and cultural factors affect young children' s health through dietary habits and behavior patterns.

Studies have identified inappropriate dietary choices in impoverished rural Chinese households, such as reduced purchase of high-quality, high-cost protein foods like animal-source products. This phenomenon, influenced by low education levels, is more common in left-behind households centered on grandparents. Additionally, insufficient physical activity is considered a potential risk factor for stunting among young children in impoverished households. Furthermore, ethnic minority dietary habits and behavior patterns are also potential risk factors for stunting-overweight, particularly given the concentration of ethnic minorities in the aforementioned four western provinces. Fortunately, the declining overweight rates in parts of these four western provinces may reflect mitigation of childhood stunting problems in this region alongside regional development over the past two decades.

3.2 "U-shaped" Three-stage Development Model for Young Childhood Overweight: Where Do We Go From Here?

Overall, China' s young childhood overweight problem shows a U-shaped relationship with regional development. When regional development levels are low, the apparent deficiency in residents' economic status and education permeates the core vulnerability of family nutrition, childcare concepts, and health literacy, ultimately inducing overweight problems caused by stunting. During early economic development, as families increase attention and investment in nutrition, dietary structure, and physical activity for young children, relatively healthy weight is maintained. When regions continue rapid development, residents experience extreme material abundance with continuously fractured and transcendent cultural ecology and lifestyles, bringing negative impacts. High-calorie diets and sedentary behavior—"diseases of affluence"—become mainstream lifestyle patterns for young children, and overweight from overnutrition begins to increase. The Middle East has become a typical example of this final stage over recent decades, where rapid modernization and urbanization have reduced children' s physical activity levels and increased high-calorie intake, continuously raising obesity and overweight prevalence.

From the Hurst index results, in most regions, without further effective intervention, future development of overweight prevalence among children under five may maintain or even strengthen increasing trends under this U-shaped three-stage model. For regions with higher development levels, this could create substantial hidden dangers. These results further reveal concerns that previous poli-

cies addressing young childhood overweight lacked a collaborative governance perspective and precise intervention. Notably, as China achieved comprehensive elimination of absolute poverty in 2020, future childhood overweight problems will concentrate in relatively poor households, where "diseases of affluence" are more likely to occur.

According to intervention protocols from WHO and Mexico's National Academy of Medicine, feasible solutions include "incorporating health into curricula, providing nutritious meals, and promoting physical activity through school programs," "regulating child food marketing to avoid promoting any form of unhealthy beverages and foods," "front-of-package labeling systems that promote healthy food choices and influence industry behavior and product formulation," and "economic incentives to promote healthy food consumption and taxes to discourage unhealthy beverage and food consumption." While we endorse these macro-level regulatory approaches, we argue that simultaneous social interventions should be based on regional economic and cultural ecology, further strengthening the penetration and implantation of childcare concepts regarding dietary health and physical activity to truly achieve primary prevention of young childhood overweight.

3.3 Young Childhood Overweight as a Complex Spatio-temporal Specific Problem Driven by Multidimensional Factors: Region-specific Policy Formulation and Multi-level Collaborative Governance Network Construction

Young childhood overweight is a social problem derived from coupled multidimensional factors. Beyond regional development as the primary driver, multiple factor drivers dominated by sociocultural factors should not be ignored. China' s young childhood overweight problem exhibits significant spatial heterogeneity and is not driven by a single factor. Based on regional development trends, profiling characteristics of overweight children include dietary choice dediversification, daily dietary fat centralization, physical activity deficiency, and comprehensive dietary behavior patterns driven by ethnic customs—all critical entry points for blocking and intervention in the next stage, requiring combined improvement through government macro-regulation, social cultural guidance, and family health literacy enhancement.

Based on these findings, this paper proposes several policy considerations for mitigating and controlling childhood overweight in China against the backdrop of sustained economic development, illustrated in [Figure 4: see original paper]:

Formulate multi-stage precise interventions based on inherent regional differences in economy, culture, and health: The key to preventing adolescent and adult overweight or obesity lies in the first year of life. Therefore, intervention from the perspective of young children themselves or their families is most efficient. From a regional policy formulation standpoint, scientifically determining the stage and type of overweight problems based on regional de-

velopment status and young children' s health conditions will be the primary step. The core of addressing young childhood overweight will shift under different stage-specific problem orientations. For the "stunting-overweight decline stage," feasible solutions should identify and supplement nutrient deficiencies in young children based on local dietary habits, with particular attention to vulnerable groups such as poor and low socioeconomic status populations. For the "overweight stabilization stage" to "overnutrition-overweight rising stage," intervention focus should shift to relatively poor populations in urban areas, emphasizing dietary and behavioral patterns of young children in these families. Approaches may include investing in family health education programs and exercise facilities, implementing small-scale "junk food taxes," and subsidizing "healthy food benefits" to promote healthy diets and lifestyles among the general population. This proposition is cost-effective, particularly for jointly controlling future health costs for residents and public fiscal costs.

Construct a three-level collaborative governance network of "government policy regulation–social concept penetration–family health management" from a collaborative governance perspective: As a social problem derived from coupled multidimensional factors, young childhood overweight concerns the human capital lifeline of national development, the cost burden of social operation, and the quality and well-being of family growth, requiring coordinated attention from the state, society, and families. The government employs broad policy instruments to regulate and govern unhealthy commercial behaviors and cultural inputs at the macro level, helping establish health literacy awareness among the entire population–especially health protection measures for young children not yet in education–through national health plans and multiple policy and legislative pathways. Simultaneously, for relatively poor regions and families, multi-faceted support and assistance focusing on economic aid should be strengthened. The overall social ecology of healthy diets, reasonable nutrition, healthy lifestyles, and physical activity should be shaped through social guidance and penetration to improve overall health literacy and block young childhood overweight. Family education has long been considered an efficient solution. The external emergence of health awareness and social atmosphere ultimately internalizes into family-based health management units for comprehensive management of young children' s integrated dietary behavior patterns. This policy-driven, society-guided, family-management approach advances the prevention threshold for childhood overweight and further reduces the severity of future problems.

3.4 Limitations

This study has several limitations. First, factors such as dietary habits and popular culture may cause short-term correlations in overweight rates among children under five. Although this study employed first-order autoregressive residual sequences to avoid certain linear dependencies, the Hurst index cannot

exclude influences of some endogenous factors on local overweight rates, and the relatively short time series may limit Hurst index accuracy, requiring cautious interpretation of conclusions. Second, due to the extremely high precision of overweight rate data, complete matching with corresponding economic geography data is difficult, so exploration of causes behind spatio-temporal evolution patterns of childhood overweight in China could not incorporate relevant indicators and was primarily based on literature conclusions and logical inference. Finally, since the minimum unit in this study' s data is 5km$\times$5km rather than independent administrative units, and the target population is young children, existing literature evidence is relatively weak, though this also demonstrates the innovative nature of this study.

Author Contributions: Xiyu Zhang managed data, conducted formal analysis, developed methodology, and wrote the original draft. Ye Li acquired funding, conceived the study, and reviewed and edited the manuscript. Qunhong Wu reviewed and edited the manuscript. Jida Li and Yu Hu performed validation and visualization.

Conflict of Interest: The authors declare no conflict of interest.

References

[1] Organization W H. Levels and trends in child malnutrition: UNICEF/WHO/The World Bank Group joint child malnutrition estimates: key findings of the 2020 edition[A]. In: Levels and trends in child malnutrition: UNICEF/WHO/The World Bank Group joint child malnutrition estimates: key findings of the 2020 edition[M]. 2020.

[2] Wijnhoven T M A, Van Raaij J M A, Spinelli A, et al. WHO European Childhood Obesity Surveillance Initiative 2008: weight, height and body mass index in 6-9-year-old children[J]. Pediatric obesity, 2013, 8(2): 79-97.

[3] Organization W H. Report of the commission on ending childhood obesity[M]. World Health Organization, 2016.

[4] Black R E, Victora C G, Walker S P, et al. Maternal and child undernutrition and overweight in low-income and middle-income countries[J]. The lancet, 2013, 382(9890): 427-451.

[5] Hernández B, Peterson K, Sobol A, et al. Overweight in 12-49 year-old women and children under 5 years of age in Mexico[J]. Salud Publica de Mexico, 1996, 38(3): 178-188.

[6] Whitaker R C, Wright J A, Pepe M S, et al. Predicting Obesity in Young Adulthood from Childhood and Parental Obesity[J]. New England Journal of Medicine, 1997, 337(13): 869-873.

[7] Benton D. Role of parents in the determination of the food preferences of children and the development of obesity[J]. International journal of obesity, 2004, 28(7): 858-869.

[8] McGuire S. Institute of Medicine (IOM) early childhood obesity prevention policies. Washington, DC: the National Academies Press; 2011[J]. Advances in Nutrition, 2012, 3(1): 56-57.

[9] Olstad D L, McCargar L. Prevention of overweight and obesity in children under the age of 6 years[J]. Applied Physiology, Nutrition, and Metabolism, 2009, 34(4): 551-570.

[10] Cole T J. Children grow and horses race: is the adiposity rebound a critical period for later obesity?[J]. BMC pediatrics, 2004, 4(1): 1-7.

[11] Ventura A K, Mennella J A. Innate and learned preferences for sweet taste during childhood[J]. Current Opinion in Clinical Nutrition & Metabolic Care, 2011, 14(4): 379-384.

[12] Wardle J, Cooke L. Genetic and environmental determinants of children' s food preferences[J]. British Journal of Nutrition, 2008, 99(S1): S15-S21.

[13] Harris G. Development of taste and food preferences in children[J]. Current Opinion in Clinical Nutrition & Metabolic Care, LWW, 2008, 11(3): 315-319.

[14] Mennella J A, Jagnow C P, Beauchamp G K. Prenatal and postnatal flavor learning by human infants[J]. Pediatrics, 2001, 107(6): e88-e88.

[15] Moreira M de A, Cabral P C, Ferreira H da S, et al. Overweight and associated factors in children from northeasten Brazil[J]. Jornal de Pediatria, 2012, 88: 347-352.

[16] Salehiniya H, Yazdani K, Barekati H, et al. The Prevalence of overweight and obesity in children under 5 years in tehran, iran, in 2012: a population-based study[J]. Research in cardiovascular medicine, 2016, 5(1).

[17] Chakraborty P, Anderson A K. Predictors of overweight in children under 5 years of age in India[J]. Curr Res J Soc Sci, 2010, 2: 138-146.

[18] Weldearegay H G, Gebrehiwot T G, Abrha M W, et al. Overweight and obesity among children under five in Ethiopia: further analysis of 2016 national demographic health survey: a case control study[J]. BMC research notes, 2019, 12(1): 1-6.

[19] Zhang Y-Q, Li H, Wu H-H, et al. Stunting, wasting, overweight and their coexistence among children under 7 years in the context of the social rapidly developing: Findings from a population-based survey in nine cities of China in 2016[J]. PloS one, 2021, 16(1): e0245455.

[20] Chen Y, Zhang Y, Kong Z, et al. The prevalence of overweight and obesity in children and adolescents in China[J]. Chinese Journal of Disease Control & Prevention, 2017(09 vo 21): 866-869+878.

[21] Wang S, Dong Y, Wang Z, et al. Trends in the prevalence of overweight and obesity among 7- to 18-year-old students in China, 1985-2014[J]. Chinese Journal of Preventive Medicine, 2017(04 vo 51): 300-305.

[22] Deng S, Liu Y, Zhang J, et al. Prevalence and risk factors of overweight/obesity among urban school children in five cities[J]. Chinese Journal of Public Health, 2017(09 vo 33): 1327-1331.

[23] Yu D, Ju L, Li S, et al. Provincial prevalence of overweight and obesity among 0-5 years old children in China in 2013[J]. Journal of hygiene research, 2020(02 vo 49): 190-194.

[24] Guo Z, Feng Z, Wang W, et al. Epidemiological characteristics and intervention strategies of overweight and obesity among Chinese school-age children[J]. Chinese Journal of School Health, 2021(11 vo 42): 1747-1750.

[25] Ma S, Zhang Y, Yang L, et al. Analysis on the trend of overweight and obesity of children and adolescents in 9 provinces of China from 1991 to 2015[J]. Chinese Journal of Preventive Medicine, 2020(02): 133-134-135-136-137-138.

[26] Yuan J, Jin B, Si S, et al. Analysis of overweight and obesity trends among Chinese children aged 6 to 15 years from 2009 to 2019[J]. Chinese Journal of Pediatrics, 2021(11 vo 59): 935-941.

[27] Abarca-Gómez L, Abdeen Z A, Hamid Z A, et al. Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128·9 million children, adolescents, and adults[J]. The lancet, 2017, 390(10113): 2627-2642.

[28] Wang Y, Lobstein T I M. Worldwide trends in childhood overweight and obesity[J]. International journal of pediatric obesity, 2006, 1(1): 11-25.

[29] Cattaneo A, Monasta L, Stamatakis E, et al. Overweight and obesity in infants and pre-school children in the European Union: a review of existing data[J]. Obesity reviews, 2010, 11(5): 389-398.

[30] Loret de Mola C, Quispe R, Valle G A, et al. Nutritional transition in children under five years and women of reproductive age: a 15-years trend analysis in Peru[J]. PloS one, 2014, 9(3): e92550.

[31] Xiao Y, Qiao Y, Pan L, et al. Trends in the prevalence of overweight and obesity among Chinese preschool children from 2006 to 2014[J]. PloS one, 2015, 10(8): e0134466.

[32] Luo J, Hu F B. Time trends of obesity in pre-school children in China from 1989 to 1997[J]. International journal of obesity, Nature Publishing Group, 2002, 26(4): 553-558.

[33] Chen J, Chen W, Zeng G, et al. Secular trends in growth and nutritional outcomes of children under five years old in Xiamen, China[J]. International Journal of Environmental Research and Public Health, 2016, 13(11): 1104.

[34] Lyu Y, Ouyang F, Ye X Y, et al. Trends in overweight and obesity among rural preschool children in southeast China from 1998 to 2005[J]. Public health, 2013, 127(12): 1082-1089.

[35] Wang F, Yao Y, Yang Q. Cohort study on thin, overweight and obesity of preschool children among 7 cities in China[J]. Chinese Journal of Disease Control & Prevention, 2019(05 vo 23): 522-526.

[36] Wang F, Jin X, Jiang J, et al. Situation and effecting factors of preschool children among several cities in China[J]. Chinese Journal of Child Health Care, 2017(04 vo 25): 346-349.

[37] Jia P, Xue H, Zhang J, et al. Time trend and demographic and geographic disparities in childhood obesity prevalence in China—evidence from twenty years of longitudinal data[J]. International journal of environmental research and public health, 2017, 14(4): 369.

[38] Institute for Health Metrics and Evaluation (IHME). Global Under-5 Overweight Prevalence Geospatial Estimates 2000-2019. Seattle, United States of America: Institute for Health Metrics and Evaluation (IHME)[J]. 2020.

[39] Mapping local patterns of childhood overweight and wasting in low-and middle-income countries between 2000 and 2017[J]. Nature medicine, 2020, 26(5): 750-759.

[40] Hurst H E. Long-term storage capacity of reservoirs[J]. Transactions of the American society of civil engineers, 1951, 116(1): 770-799.

[41] Xu X, Chen X. Analyzing the Non-linearity of Chinese Rice Major Diseases Progress Curves Using R/S Method[J]. System Sciences and Comprehensive Studies in Agriculture, 2011(01 vo 27): 72-77.

[42] He Z, He J. Remote Sensing on Spatio-temporal Evolution of Vegetation Cover in the Yellow River Basin during 1982-2013[J]. Transactions of the Chinese Society for Agricultural Machinery, 2017(02 vo 48): 179-185.

[43] Pohlert T, Pohlert M T, Kendall S. Package 'trend'[J]. Title non-parametric trend tests and change-point detection, 2016.

[44] Hijmans R J, Bivand R, Forner K, et al. Package 'terra' [J]. 2022.

[45] Turner S W, Galelli S. Water supply sensitivity to climate change: An R package for implementing reservoir storage analysis in global and regional impact studies[J]. Environmental Modelling & Software, 2016, 76: 13-19.

[46] Li Y, Mao F. China' s Regional Economic Growth and Economic Structure Changes: 1978-2016[J]. Economist, 2019, 2(2): 55-65.

[47] Gordon-Larsen P, Wang H, Popkin B M. Overweight dynamics in Chinese children and adults[J]. Obesity Reviews, 2014, 15: 37-48.

[48] Xiao Y. The prevalence and related factor analysis of overweight and obesity among Chinese preschool children aged from 3 to 6 years in Tianjin[D]. Tianjin:

Tianjin Medical University, 2016.

[49] Wang X, Höjer B, Guo S, et al. Stunting and 'overweight' in the WHO Child Growth Standards–malnutrition among children in a poor area of China[J]. Public health nutrition, 2009, 12(11): 1991–1998.

[50] Zong X-N, Li H. Physical growth of children and adolescents in China over the past 35 years[J]. Bulletin of the World Health Organization, 2014, 92: 555–564.

[51] Yang Q, Yuan T, Yang L, et al. Household food insecurity, dietary diversity, stunting, and anaemia among left-behind children in poor rural areas of China[J]. International journal of environmental research and public health, 2019, 16(23): 4778.

[52] Wei Q W, Zhang J X, Scherpbier R W, et al. High prevalence of developmental delay among children under three years of age in poverty-stricken areas of China[J]. Public health, 2015, 129(12): 1610–1617.

[53] Mirmiran P, Sherafat Kazemzadeh R, Jalali Farahani S, et al. Childhood obesity in the Middle East: a review[J]. EMHJ-Eastern Mediterranean Health Journal, 16 (9), 1009-1017, 2010, 2010.

[54] Organization W H. Global strategy on diet, physical activity and health[J]. World Health Organization, 2004.

[55] Brownell K D, Kersh R, Ludwig D S, et al. Personal responsibility and obesity: a constructive approach to a controversial issue[J]. Health affairs, 2010, 29(3): 379–387.

[56] Rivera J A, Hernandez M, Aguilar C, et al. Obesity in Mexico. Recommendations for state policy[J]. Mexico City (Mexico): Academia Nacional de Medicina [National Academy of Medicine.], 2012: 145–65.

[57] Mozaffarian D, Afshin A, Benowitz N L, et al. Population approaches to improve diet, physical activity, and smoking habits: a scientific statement from the American Heart Association[J]. Circulation, 2012, 126(12): 1514–1563.

[58] Wang J L, Wang N R. National epidemiological study on obesity children aged 0–18 years in Chongqing urban area[J]. Chin J Child Health Care, 2008, 16: 55–57.

[59] Qin X, Pan J. The medical cost attributable to obesity and overweight in China: Estimation based on longitudinal surveys[J]. Health economics, 2016, 25(10): 1291–1311.

[60] JA M N, SS G V, JE C B, et al. Effectiveness of educational interventions conducted in latin america for the prevention of overweight and obesity in scholar children from 6-17 years old; a systematic review[J]. Nutricion Hospitalaria, 2014, 31(1): 102–114.

Note: Figure translations are in progress. See original paper for figures.