

# The return on investment for the prevention and treatment of childhood and adolescent overweight and obesity in China: a modelling study

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## Summary

**Background** The rapid increase in child and adolescent overweight and obesity (OAO) in China has a significant health and economic impact. This study undertook an investment case analysis to evaluate the health and economic impacts of child and adolescent OAO in China and the potential health and economic returns from implementing specific policies and interventions.

**Methods** The analysis estimates the reduction in mortality and morbidity from implementing a set of evidence-based interventions across China between 2025 and 2092 using a deterministic Markov cohort model. Modelled interventions were identified by literature review and expert recommendation and include fiscal and regulatory policies, eHealth breastfeeding promotion, school-based interventions, and nutritional counselling by physicians. The study applies a societal costing perspective to model the economic impact on healthcare cost savings, wages, and productivity during adulthood. By projecting and comparing the costs between a status quo scenario and an intervention scenario, the study estimates the return on investment (ROI) for interventions separately and in combination.

**Findings** Without intervention China will experience 3.3 billion disability-adjusted life years (DALYs) due its current levels of child and adolescent OAO and a lifetime economic impact of CNY 218 trillion (USD 31.6 trillion), or a lifetime CNY 2.5 million loss per affected child or adolescent (USD 350 thousand). National implementation of all five interventions would avert 179.4 million DALYs and result in CNY 13.1 trillion of benefits over the model cohort's lifetime. Implementing fiscal and regulatory policies had the strongest ROI, with benefits accruing at least 10 years after implementation. Scaling up China's current school-based interventions offers China significant health and economic gains, however, the ROI is lower than other modelled interventions.

**Interpretation** Effective prevention and treatment of child and adolescent OAO is critical to China's health and economic development. Multiple interventions offer a comprehensive approach to address the various factors that increase risk of child and adolescent OAO. Nonetheless, fiscal and regulatory policies offer the strongest health and economic gains.

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## 摘要

**背景** 儿童超重肥胖的迅速增长对中国的健康和经济产生了深远的影响。本研究旨在通过投资案例分析来探讨中国儿童超重肥胖带来的健康及经济影响，并评估实施特定政策与干预措施可能带来的健康和经济效益。

**方法** 采用确定性Markov队列模型，预测2025-2092年间在中国实施基于循证的几项干预措施后，对相关疾病的发病率和死亡率的影响。纳入模型的5项干预措施是基于文献综述研究和专家建议确定的，包括对含糖饮料征收20%的税收、限制向儿童销售不健康食品、通过手机短信传播母乳喂养知识、以学校为基础的儿童肥胖干预及医生提

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营养咨询。本研究从社会成本视角模拟了对成年期医疗成本的节约、工资以及劳动生产力的经济影响。通过预测和比较采取干预措施和不采取干预措施的经济成本，估计了上述5种干预措施单独或组合使用的投资回报率。

**结果** 基于目前儿童超重肥胖现状，如果不采取任何干预措施，2025-2092年间，中国将面临33亿残疾调整生命年(DALYs)的损失、218万亿元人民币(约31.6万亿美元)的经济损失、平均每个受影响的儿童将面临250万元人民币(约35万美元)的经济损失。如果在中国全面实施上述5项干预措施，预计能够减少1.794亿DALYs的损失，并带来13.1万亿元的经济收益。其中，对含糖饮料征收20%税收和限制向儿童销售不健康食品两项干预措施的投资回报率最高，预计在实施后的10年内开始显现经济效益。实施以学校为基础的儿童肥胖干预能够带来显著的健康和经济收益，然而，其投资回报率低于其他4项干预措施。

**解读** 有效预防和治疗儿童超重肥胖对中国的健康和经济发展至关重要。多项干预措施将针对超重肥胖的多种危险因素提供综合和全面的解决方案。然而，在所有的干预措施中，对含糖饮料征税和限制向儿童销售不健康食品两项干预措施能带来最大的健康和经济效益。

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**Editor note:** This translation in Chinese was submitted by the authors and we reproduce it as supplied. It has not been peer reviewed. Our editorial processes have only been applied to the original abstract in English, which should serve as reference for this manuscript.

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**Keywords:** China; Child health; Adolescent health; Overweight; Obesity; Investment case; Economic evaluation; Health policy

### Research in context

#### Evidence before this study

We searched PubMed, Google Scholar and China Knowledge Infrastructure (CNKI) using the term “investment case” or “cost benefit” in combination with “China” or “obesity” or “child” or “adolescent” for original publications between January 1, 2013 and March 1, 2023. Economic evaluations of child and adolescent overweight and obesity interventions in China overwhelmingly focus on the cost effectiveness or cost-benefit of specific school-based interventions. Moreover, scant examples of overweight and obesity investment case analyses focused on children and adolescents are available globally.

#### Added value of this study

We believe this to be the first investment case on child and adolescent overweight and obesity in China. Our study estimates the reduction in mortality and morbidity as well as the economic return on investment from implementing a diverse set of evidence-based child and adolescent overweight

and obesity interventions across China between 2025 and 2092. The results illustrate the significant health and economic impacts from child and adolescent overweight and obesity in an upper-middle income country. It quantifies the potential health and economic gains from scaling existing interventions and implementing novel fiscal and regulatory interventions in China.

#### Implications of all the available evidence

The findings demonstrate the critical need to invest in addressing child and adolescent overweight and obesity in China. The study illustrates that a comprehensive strategy to address multiple risk factors for child and adolescent overweight and obesity offers the strongest lifetime health benefits and a strong return on investment to the country. Furthermore, an investment case analysis of child and adolescent overweight and obesity interventions offers a robust tool to support health policy prioritization.

### Introduction

Globally, the economic impact of overweight and obesity (OAO) was estimated at 2.19% of global gross domestic product (GDP) in 2019.<sup>1</sup> As childhood and adolescent OAO is a strong predictor of adult obesity and has a long-term impact on health outcomes, educational attainment and labour productivity, taking early action is critical to mitigating the economic and health consequences associated with obesity.<sup>2</sup>

In parallel to the rapid economic growth over recent decades, China has additionally undergone an epidemiological transition from diseases associated with undernutrition to a rapid increase in the prevalence of diseases associated with unhealthy diet and sedentary lifestyles.<sup>3</sup> Whereas OAO prevalence among children and adolescents aged 0–19 years in China was substantially below the global average in 2000 (8.8%), a remarkable 400% increase occurred over the next two

decades to an estimated 37.9% in 2020, surpassing other Western Pacific countries and upper-middle-income countries.<sup>1,4</sup> Nearly two out of five children and adolescents in China are affected by OAO and if the current trend continues, by 2030 this will encompass 60% of China's children and adolescents.<sup>1,4</sup>

In recent years China has developed a number of national policies and interventions to address this trend. Historically, these interventions focused on school-based nutrition and physical activity programs.<sup>5</sup> For example, in 2008, the Bureau of Disease Prevention and Control National Health Commission revised the Guidelines for the Prevention and Control of Overweight and Obesity Among School Aged Children and Adolescents in China.<sup>5</sup> Infant nutrition has also been a focus with nutrition assessment and dietary guidance before and during pregnancy. While not initially implemented as an obesity control and prevention policy, in the 1990s China began implementing the 'Baby-friendly hospital initiative' (BFHI) to promote exclusive breastfeeding, which is now known to reduce the risk of OAO later in life as is considered by nutrition researchers as a 'double-duty' intervention.<sup>6–8</sup>

Important limitations to China's current child and adolescent obesity prevention strategy have previously been highlighted, including the absence of interventions that have been shown to be effective at reducing exposure to risk factors associated with OAO in various countries.<sup>9–13</sup> These include, for example, taxation and restrictions on the marketing of unhealthy food and drinks to children and adolescents.<sup>5</sup> Additionally, there are limited guidelines for addressing child and adolescent OAO in primary care settings.<sup>5</sup>

In 2021, revised 'Guidelines for the Prevention and Control of Overweight and Obesity Among School Aged Children and Adolescents in China' were issued, and in 2020, a national government implementation plan to prevent and reduce of obesity in children and adolescents set a target to reduce the annual growth of child and adolescent OAO by 70% by 2030.<sup>14</sup>

While there have been economic evaluations of child and adolescent OAO interventions in China, they focus on the cost effectiveness or cost-benefit of specific school-based interventions.<sup>15–17</sup> Middle-income countries are also still underrepresented in global cost-of-illness evaluations of childhood and adolescent OAO.<sup>18</sup> This investment case analysis aims to estimate the health and economic impacts of child and adolescent OAO and identify which policies and interventions targeting different components of the obesogenic environment can produce the largest health and economic returns for China.

## Methods

### Model overview

This investment case model is an Excel-based deterministic Markov cohort model assesses the health and

economic impact of interventions to prevent and reduce child and adolescent OAO, applying an adapted methodology drawing from two economic models. The Assessing Cost-Effectiveness in Obesity (ACE-Obesity) model examines impacts on future mortality, and the Early Prevention of Obesity in Childhood (EPOCH) model, which also includes healthcare costs and productivity loss, assesses the cost-effectiveness of child and adolescent OAO prevention interventions.<sup>19–22</sup> This investment case model builds upon these models by estimating the economic cost-of-illness attributable to child and adolescent OAO while estimating the economic and health return on investment (ROI) associated with interventions to prevent and treat child and adolescent OAO.<sup>23,24</sup>

The model assesses the health impacts of OAO among children and adolescents in China. Using a societal cost perspective, it estimates the reduction in mortality and morbidity from implementing evidence-based interventions and the resulting economic impact in terms of healthcare cost savings, and impacts on wages and productivity during adulthood, including from education.<sup>25</sup> The model cohort includes children and adolescents aged 0–19 in 2025 and estimates impacts from 2025 to 2092. In 2092, the mean age of the cohort will be 77 years—the current life expectancy in China. 2025 was selected as the base year assuming to allow time to prepare the programs and policies. The model assumes that the interventions' full effects are realized one year after implementation.

### BMI and overweight and obesity prevalence

The model utilizes the global standard cut off points for OAO. In adults, overweight is defined as a body mass index (BMI, calculated as weight in kilograms divided by the square of height in meters) of 25 to <30 and obesity is defined as a BMI of 30 and above.<sup>26</sup> For children aged 5–19, overweight is defined as a BMI-for-age above one standard deviation of the World Health Organization (WHO) Growth Reference median for children of the same age and sex, and obesity as a BMI-for-age above two standard deviations of the median.<sup>27</sup> For children under five years, overweight is weight-for-height greater than two standard deviations above the median, and obesity is weight-for-height greater than three standard deviations above the median.<sup>27</sup>

The analysis assumes that current trends in mortality, morbidity, and risk factors in China remain unchanged and project future mean BMI and OAO prevalence, disaggregated by age and sex. For children aged 0–19 years in 2025 in China (the model cohort) we project future BMI for every year from age 5–19 and then five-year increments from age 20 onward.<sup>19,28</sup> We use single-year age groups because the relationship between BMI and OAO is more variable during childhood and adolescence and stabilizes in adulthood, for

which we use five-year age groups. To project the mean BMI by age and year we used cohort and age effects on BMI of children, adolescents, and adults in China estimated using multiple linear regression to analyse historical BMI data for China from the NCD-Risk Factor Collaboration.<sup>19,28</sup> Mean BMI is then used to model the prevalence of OAO based on the historical relationship between BMI and OAO changes through the life cycle.

#### *Health consequences*

We estimated the health consequences in terms of years of life lost (YLLs), years lived with disability (YLDs), and disability-adjusted life-years (DALYs) during the cohort's lifetime. We used projections of all-cause mortality rate from the United Nations Population Division,<sup>29</sup> and cause-specific mortality rates for 2000–2019 from the Global Burden of Disease to project the future mortality rate and YLLs, by cause, sex, and age, in the status quo scenario.<sup>30</sup> For the intervention scenario we estimated the reduction in YLLs and YLDs using the potential impact fraction (PIF) calculated for each obesity-attributable disease. The PIF is the proportional change in mortality or morbidity attributable to a change in exposure to a risk factor. The reduction in DALYs is the sum of the reduction in YLLs and YLDs. Health results were disaggregated by sex.

#### *Economic consequences*

We estimated the baseline economic impact of children and adolescents who are affected by OAO as a combination of obesity-attributable healthcare costs during child and adulthood, and the impact obesity has on their future labour productivity. Child and adolescent OAO are associated with a lower level of educational attainment,<sup>31–33</sup> which in turn results in lower lifetime wages earned.<sup>34,35</sup> Although obesity is associated with lower work productivity in terms of absenteeism and presenteeism,<sup>25,36</sup> data on productivity loss from illnesses in China is currently unavailable. To estimate the productivity loss due to obesity-related absenteeism and presenteeism we used a systematic review of peer-reviewed studies to provide average inpatient and outpatient consultations by the population with obesity,<sup>37</sup> absenteeism days, and presenteeism rate (see [Supplementary Materials](#) for further details).<sup>1</sup>

The value of life lost is calculated using 1) the number of years of life lost as a result of child and adolescent OAO attributable mortality and 2) gross domestic product (GDP) per capita.<sup>38</sup> GDP per capita is used as a proxy for the economic value of a life year to capture economic losses from premature mortality.<sup>38</sup> Using GDP per capita as a proxy for value of a year of life (compared to wages or the value of a statistical life year) offers a more equitable approach to valuing each individual's economic contribution across the life course regardless of their employment status.<sup>39</sup>

#### **Intervention selection**

Taking account of China's efforts to expand the scope of child and adolescent OAO interventions, several steps were followed to identify effective, cost-effective, and nationally relevant interventions. Firstly, we undertook systematic literature reviews of interventions to prevent and reduce child and adolescent obesity in China, as well as in other countries worldwide, to identify their effectiveness and cost-effectiveness (see [Supplementary Materials, Supplementary Figures S1–S4 and Table S1](#)). We reviewed the WHO guidelines on child obesity<sup>40</sup> and interviewed individuals with relevant expertise in child and adolescent obesity from government and academia in China to gain insight into which interventions may be most valuable and relevant. Finally, we convened an expert advisory group comprised of academic experts on child and adolescent OAO in China to guide the prioritization of a set of cost-effective, nationally relevant interventions.

Based on the evidence collected, the following five priority interventions were selected. [Table 1](#) describes the baseline level of national coverage for each intervention if it were to remain as it is at present (status quo) as well as target national coverage levels for the five interventions to achieve impact. Intervention coverage levels were first identified through a targeted search of peer-reviewed literature and grey literature and was finalized through the expert advisory group's consensus. Each intervention focuses on a unique age group as specified by the intervention literature.

The baseline coverage for the tax on SSBs, eHealth breastfeeding promotion, restrictions on marketing unhealthy foods to children, and physician nutrition counselling were set at 0%. We used a baseline coverage of 5% for the combined intervention to strengthen school-based interventions. Although components of the combined school-based interventions have been piloted in urban settings, these interventions are not actively implemented nationally.<sup>5,17,44,45</sup> As a fiscal policy, the target coverage is for the SSB tax is 100% as it would be nationally implemented. The target coverage for nutrition counselling by physicians is 40% of the target population based on guidance for screening and physician training from China's 2017 National Basic Public Health Service Specification (Third Edition) and the *Healthy China Action Plan (2019–2030)*. The target coverage level for all other interventions was set at 80% as an implementation goal. The default target coverage level of 80% for non-fiscal interventions that was not the nutrition counselling program was selected as it recognizes that implementation may be incremental and full implementation may not be an appropriate initial target.

1. *20% excise taxation on Sugar Sweetened Beverages (SSBs)*—The tax is calculated using a tiered tax approach with both ad valorem and specific tax on sugar content. For example, soda and carbonated

Intervention	Intervention target population	China baseline (%)	Modelled target (%)
20% excise tax on sugar sweetened beverages (SSBs) <sup>41</sup>	General population of children and adolescents	0	100
e-Health breastfeeding promotion through text messages to pregnant women <sup>42,a</sup>	Pregnant women	0	80
Restrictions on marketing unhealthy foods to children and adolescents <sup>43</sup>	Children and adolescents aged 2–18 years	0	80
Combined school interventions			
Primary school interventions <sup>17,a</sup>	School children aged 6–11 years	5	80
School-based social marketing campaign <sup>11</sup>	School children and adolescents aged 6–17 years	5	80
Nutrition counselling by physicians <sup>43</sup>	Children and adolescents affected by OAO aged 0–19 years	0	40

<sup>a</sup>Indicates intervention has previously been implemented in China.

**Table 1: Current status of national interventions in China and target goals.**

drinks have a higher ad valorem rate than fruit and vegetable juice, or beverage concentrates. Additionally, specific tax rates are adjusted based on sugar content, with a range from less than 6 grams to the highest amount of more than 18 grams. For example, an SSB with more than 6 grams per 100 mL will be levied by a higher tax rate than those with a lower sugar concentration. The 20% excise tax is based on WHO recommendations and the specific sugar content tax implemented by Thailand in 2017, the closest regionally comparative tax model.<sup>41,46</sup>

2. *e-Health breastfeeding promotion*—Breastfeeding promotion information is disseminated to pregnant women via text messages during their third trimester of pregnancy; within three days post-delivery; and periodically at one, three, six, and nine months after delivery. Information content is based on the WHO “Ten Steps for the Successful Promotion of Breastfeeding.”
3. *Restrictions on marketing unhealthy foods to children and adolescents*—Restrict advertising for unhealthy foods and beverages in all forms of commercial communications, across all channels, including digital media, for children and adolescents 2–18 years old (The investment case does not evaluate the impact of restrictions on marketing infant formula due to lack of cost-effectiveness data).
4. *Combined school-based interventions*—A comprehensive combined intervention of two components. The primary-school intervention includes: 1) nutrition education, including information for parents, and classes for students, parents, teachers, and health workers; 2) school cafeteria lunch menus periodically assessed by advisors and provided specific recommendations for improvement, and 3) physical activity sessions based on the “Happy 10 Minutes” program in which teachers lead a 10-min moderate intensity exercise session for students twice during the school day. An accompanying social marketing campaign would be concurrently implemented across all primary and

secondary schools alongside the structured school programs to help students put behaviours into practice, using behavioural messaging to encourage and support physical activity and improved dietary practices.

5. *Nutrition counselling by physicians*—Nutrition counselling for children and adolescents from ages 0–19 affected by OAO by physicians in a primary care setting. Younger children’s parents or caregivers who would receive and implement the physician’s advice.

Additionally, as financial resources for investing in all the interventions may be limited, the investment case explores the impact of two unique packages of the aforementioned interventions based on national policy priorities as advised by the expert advisory group.

Package 1—SSB tax and unhealthy food marketing restrictions. While these national policy approaches are not currently in place in China, these interventions typically have lower long-term implementation costs.

Package 2—Marketing restrictions, e-Health breastfeeding promotion, and the combined school-based interventions. This broad package offers ‘double-duty’ actions that address the common factors responsible for different forms of malnutrition (undernutrition, OAO, and micronutrient deficiencies). Although breastfeeding promotion and school-based interventions already exist, these would be strengthened and fully scaled up.

#### *Intervention cost and target population*

Intervention costs were estimated using unit cost data for China. Where China-specific data was unavailable, global costs were applied. The costs of fiscal interventions and strengthening the restrictions on marketing unhealthy foods include costs for planning and development, operations, administration, and monitoring. We did not include revenue from SSB taxation in our estimate of the intervention cost. Changes to sales of unhealthy food and the impact on GDP and tax revenue are not evaluated as the costing takes a societal

approach, rather than taking the cost of a specific provider into account.

Cost for the supplementary social marketing campaign in schools includes program organization costs, training teachers and food service staff, extra teaching and staff time, and additional curricular activities, such as brochures and books. Cost for the e-Health breastfeeding promotion includes message development, management, and text message fees. Cost for primary school-based interventions includes school implementation labour, materials, training, communications, transportation and accommodation, and monitoring.

We modelled the costs of the SSB tax and physician counselling for ages 0–19 years, and the cost of social marketing in schools for ages 6–17. Primary school interventions included children aged 6–11 years and e-Health breastfeeding promotion to mothers of children 0–9 months old. Restrictions on marketing unhealthy foods encompassed children and adolescents between ages 2–18. Costs and benefits were reported in CNY 2020 and discounted at 3% per year, the standard discount rate for global health economic evaluations.<sup>38,47,48</sup>

Fig. 1 summarizes the methodology for estimating

health and economic impact and data sources for the data inputs.

#### Economic outcome indicator

The investment case uses a ROI analysis as an indicator of intervention efficiency. The ROI (or benefit-cost ratio) is calculated by dividing the total economic value gained from the interventions by their implementation cost. The ROI analysis compares implementation cost to all economic benefits—averted mortality (YLLs), healthcare costs averted, and wages and productivity gained.

#### Sensitivity analysis

Additional analyses were conducted to test the sensitivity of the results to changes in our assumptions. First, a 95% confidence interval (95% CI) for the ROI estimates was derived by utilizing the upper and lower limits of the intervention effect size reported in the literature. Second, as there is a growing discussion around using a higher discount rate middle-income countries to illustrate a preference for receiving benefits earlier, sensitivity analysis applies a higher discount rate of 5% to estimate the ROI.<sup>49</sup> Third, sensitivity analyses conducted consider how the changes in national

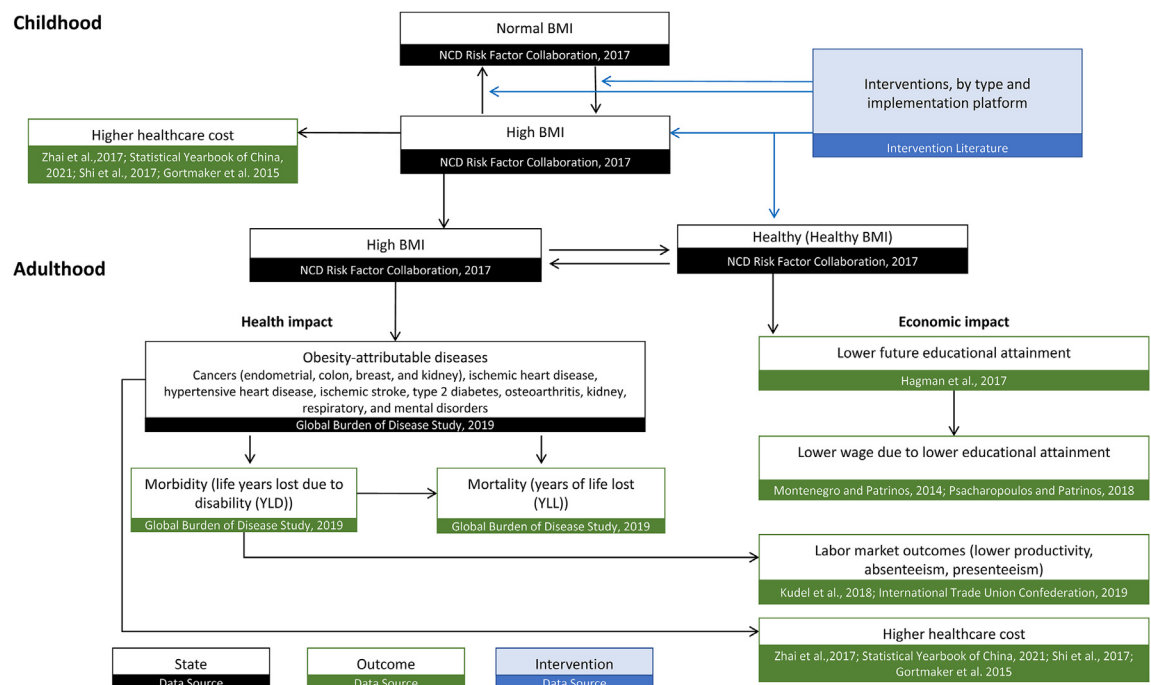


Fig. 1: Investment case model for estimating China's health and economic burden attributable to childhood and adolescent overweight and obesity. Text in black refers to a health state; text in green refers to outcomes; text in blue refers to interventions.

income (GDP per capita) impacted the value of these changes in mortality or life expectancy. Using the *Lancet Commission on Investing in Health* (CIH)'s global GDP multiplier (1.6) and East Asian and Pacific (2.2) GDP multipliers developed based on life year valuation estimates from life expectancy changes between 2000 and 2011, the analyses estimated an upper bound to the economic value of premature mortality.<sup>39,50</sup> Fourth, we doubled the time for the full effects of the interventions to be realized from one to two years following implementation. Fifth, assuming each intervention does not achieve its full effect size, we conducted sensitivity analyses examining the ROI results if each intervention achieved 80% effectiveness or only realized 80% effectiveness two years after implementation. Finally, a sensitivity analysis varied the impact of childhood obesity on educational attainment such that obesity in childhood has been associated with a 43% lower likelihood of not completing 12 or more years of education.<sup>51</sup>

### Ethics committee approval

The study was approved by both the RTI International Institutional Review Board (STUDY00021812), and the Peking University Biomedical Ethics Committee (IRB00001052-22019) as non-human subjects research exempt from full review.

### Roles of funding source

UNICEF China staff members (SC and AN) are co-authors and contributed to the conceptualization, writing-review & editing, and funding acquisition of the manuscript.

## Results

### Status quo scenario

Without further intervention, approximately 3.3 billion disability-adjusted life years (DALYs) would occur due to child and adolescent OAO in China between 2025 and 2092. The majority of DALYs would occur among girls (75%) due to their lifetime risk of additional obesity-attributable conditions that boys do not experience (e.g., ovarian, and uterine cancers). In terms of economic value, CNY 211.4 trillion would not be realized between 2025 and 2092 due to mortality resulting from child and adolescent OAO within the model cohort (Table 2).

Between 2025 and 2092—the average lifetime of the cohort children and adolescents—the direct national healthcare cost attributable to child and adolescent OAO would cost China CNY 261 billion. Between 2025 and 2092 the total wages lost and productivity loss attributable to child and adolescent OAO by the model cohort is CNY 1.8 trillion and CNY 4.6 trillion, respectively. The value of life lost over the cohort's lifetime is equivalent to CNY 211.4 trillion. Based on current OAO trends, the

	Total lifetime cost (CNY billions)	Average lifetime cost per child with obesity (CNY)
<b>Direct healthcare costs</b>		
During childhood	21	558
During adulthood	240	6470
<b>Total direct healthcare costs</b>	<b>261</b>	<b>7029</b>
<b>Indirect costs</b>		
Loss in lifetime wages	1798	48,513
Productivity loss	4572	49,924
Value of Life Lost	211,420	2,308,521
<b>Total indirect costs</b>	<b>217,790</b>	<b>2,406,958</b>
<b>Total direct plus indirect cost</b>	<b>218,051</b>	<b>2,413,986</b>

**Table 2: Lifetime national direct and indirect costs attributable to child and adolescent overweight and obesity, 2025–2092.**

health and economic impacts of child and adolescent OAO total CNY 218.1 trillion over the lifetime of the cohort, or nearly twice China's annual GDP in 2021 (Table 2). The average annual health and economic burden is equivalent to three percent of China's annual GDP.<sup>52</sup>

### Intervention scenario

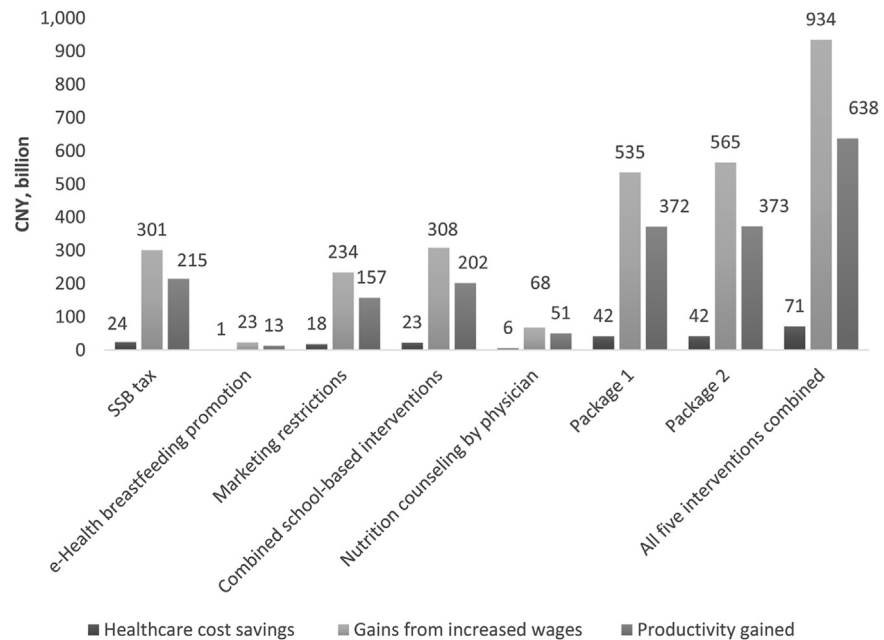
By implementing the new or strengthened interventions in the model China can achieve significant health and economic gains. Table 3 shows the health improvements (in DALYs) that may be achieved by implementing the five interventions and the intervention packages during the model cohort's lifetime.

Fig. 2 illustrates the national economic gains from lifetime healthcare savings and gains in wages and productivity. Combining all the modelled interventions offers reductions in CNY 71.2 billion of healthcare expenditure, CNY 637.6 billion of production losses averted, and CNY 934.3 billion in wage gains.

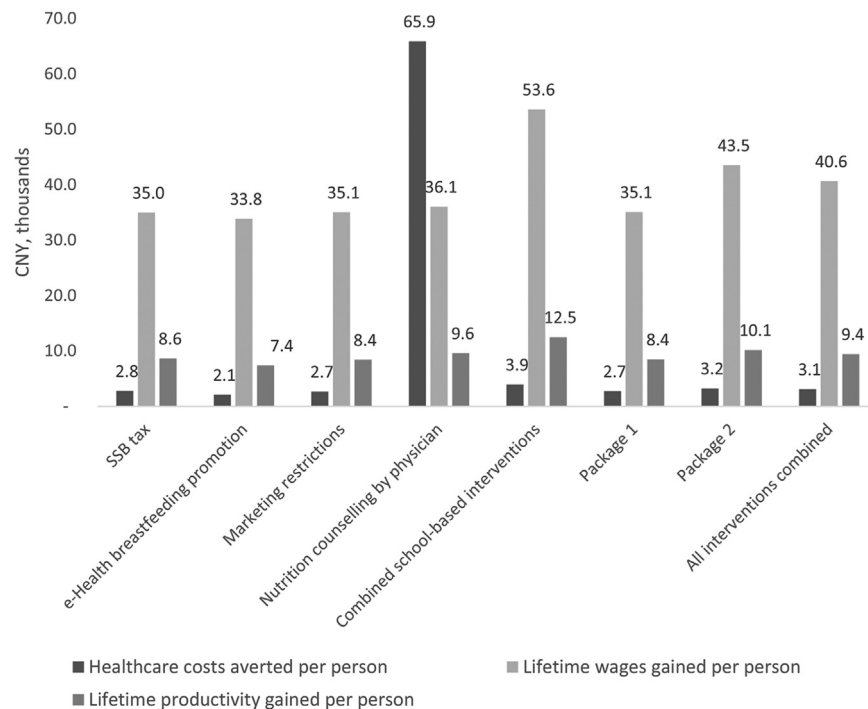
Fig. 3 shows these same gains per person terms using UN population projections.<sup>29</sup> Healthcare costs averted result from reduced prevalence of child and

	Lifetime reduction in DALYs (millions)
20% excise tax on sugar sweetened beverages (SSBs)	59.8
Combined school-based interventions	59.0
Restrictions on marketing unhealthy foods to children and adolescents	45.8
Nutrition counselling by physicians	11.3
e-Health breastfeeding promotion through text messages to pregnant women	3.5
Package 1: SSB tax and marketing restrictions	105.6
Package 2: Marketing restrictions, e-Health breastfeeding promotion, combined school-based interventions	108.3
<b>All five interventions combined</b>	<b>179.4</b>

**Table 3: National impact of interventions on DALY reductions during the lifetime of the model cohort.**



**Fig. 2: Total national lifetime healthcare savings and gains in wages and productivity, 2025–2092 (CNY, billions 2020).** Intervention 'Package 1' includes fiscal and regulatory policies including the SSB tax and marketing restriction interventions. Intervention 'Package 2' includes marketing restrictions, e-Health breastfeeding promotion, and combined school-based interventions.



**Fig. 3: National per person healthcare savings and gains in wages and productivity, 2025–2092 (CNY, thousands 2020).** Intervention 'Package 1' includes fiscal and regulatory policies including the SSB tax and marketing restriction interventions. Intervention 'Package 2' includes marketing restrictions, e-Health breastfeeding promotion, and combined school-based interventions.

adolescent OAO as fewer individuals seek treatment for overweight- and obesity-attributable diseases. Productivity gains result from fewer individuals missing work (absenteeism) or experiencing reduced productivity while at work (presenteeism) resulting from overweight- and obesity-attributable diseases. Finally, as more individuals achieve tertiary education, there are wage gains associated with higher educational achievement.

The lifetime benefits per child or adolescent who is prevented from having or continuing to be affected by OAO because of the interventions ranges from CNY 44,893 per infant whose mother receives e-Health breastfeeding promotion messaging to CNY 130,649 per child that receives nutrition counselling from physicians (Table 4). Implementing all five interventions would result in benefits of CNY 177,745 per child and adolescent nationally. As the model follows the lifetime of a cohort aged 0–19 in 2025, interventions that begin early in life and reach a wider age group are likely to have a more benefits per child or adolescent. For example, the e-Health breastfeeding promotion total benefits derive only from those aged 0 in the model cohort in 2025, whereas the combined school-based intervention includes total benefits among those aged 6–11 years in 2025 (primary school intervention) and the social marketing campaign reaches those aged 6–17 years old in 2025. In terms of lifetime wages and productivity per person, the largest gains from an individual intervention would be from the combined school-based interventions (CNY 66,074; Fig. 3).

Table 5 provides the cost of implementing the five interventions from 2025 to 2044 over the course of the model cohort's child and adolescence nationally. Of the five interventions, the marketing restriction is the least expensive to implement with a total national cost of CNY 245 million including planning, operations, administration, and monitoring. In contrast, implementing the combined program to strengthen school-based

interventions would be most expensive, with a total cost of CNY 142 billion, including costs for labour, materials, training, transportation, and monitoring. Similarly, Package 1—including marketing restrictions and the SSB tax has a lower implementation cost than Package 2—including school-based interventions, marketing restrictions, and the e-Health breastfeeding promotion. Implementing all five interventions nationally would cost a total of CNY 146 billion.

Table 6 shows the national return on investment (ROI) of the five selected interventions individually and in combination over a time horizon of 30 years, 50 years, and 66 years. The ROI for implementing all five interventions implemented in combination increases over the time horizons, with a positive ROI achieved within a 30-year period, increasing exponentially over a lifetime. Both the SSB taxation and restrictions on marketing unhealthy foods not only achieve positive ROIs over a 10-year period (109:1 and 98:1, respectively), but they also have significantly higher ROIs over the course of a lifetime compared to the other interventions. The combined program to strengthen school-based interventions yield significantly lower ROIs than implementing other interventions across a lifetime.

Table 7 provides the ROI results from sensitivity analyses, which apply a 5% discount rate; consider the potential gains in health or life expectancy in the absence of mortality attributable to child and adolescent overweight obesity; or assume the interventions only reach 80% effectiveness two years after implementation. See Supplementary Tables S3–S6 for additional analyses.

## Discussion

This study found that the health and economic impacts of child and adolescent OAO over a lifetime are equivalent to two times China's annual GDP in 2021. This provides a strong rationale for intensifying investment

	Healthcare costs averted (CNY billions)	Gains from increased wages (CNY billions)	Productivity gained from averted work absenteeism and presenteeism (CNY billions)	Economic value of life years gained (YLLs only) (CNY billions)	Total benefits (CNY billions)	Total benefits per person (CNY)
20% excise tax on sugar sweetened beverages (SSBs)	24	301	215	3970	4510	89,768
e-Health breastfeeding promotion through text messages to pregnant women	1	23	13	145	183	44,893
Restrictions on marketing unhealthy foods to children and adolescents	18	234	157	2845	3254	77,173
Combined school-based interventions	23	308	202	3618	4150	109,521
Nutrition counselling by physicians	6	68	51	834	958	130,649
Package 1: SSB tax and marketing restrictions	42	535	372	6816	7764	120,684
Package 2: Marketing restrictions, e-Health breastfeeding; combined school-based interventions	42	565	373	6608	7587	129,050
All five interventions combined	71	934	638	11,412	13,055	177,745

Table 4: National economic gains resulting from the five interventions, 2025–2092 (CNY 2020).

Implementation cost	China (CNY, millions)
Marketing restrictions	245
SSB tax	399
e-Health breastfeeding promotion	1051
Nutrition counselling by physicians	1419
Combined school-based interventions	142,628
Package 1: SSB tax and marketing restrictions	644
Package 2: Marketing restrictions, e-Health breastfeeding, combined school-based interventions	143,924
<b>All five interventions combined</b>	<b>145,742</b>

**Table 5: Cost of implementing child and adolescent overweight and obesity interventions nationally, 2025–2044 (CNY 2020).**

in effective interventions to prevent and reduce child and adolescent OAO. Additional to the significant health benefits that these interventions offer, they offer substantial economic benefits to the country and yield a high return on investment within 30 years of implementation. The analysis estimated the costs and benefits—in health and economic terms—of fully implementing five national-level interventions identified as effective at preventing and reducing child and adolescent OAO and appropriate to the social, political, and economic context in China. Combining all five interventions would offer a comprehensive strategy for addressing the breadth of factors that increase risk for child and adolescent OAO. The CNY 13.1 trillion of benefits associated with implementing all five interventions nationally is the equivalent of four years of China's annual government domestic health expenditure.<sup>52</sup>

Selective intervention packages also showed a strong reduction in the health and economic burden associated with child and adolescent OAO. A package including marketing restrictions, e-Health breastfeeding promotion, and school-based interventions offer a reduction in 108.3 million disability-adjusted life years and a lifetime ROI of 52:1. Since China already has a foundation of

school and breastfeeding interventions, these may be strengthened to enhance reach and impact. Nonetheless the new investments in fiscal or regulatory policy offered the strongest return on investment with 12,059 CNY returned for every CNY invested over a lifetime due to their low long-term implementation costs and effectiveness related to reducing the risk of child and adolescent OAO.

Awareness and interest in addressing the growing prevalence of child and adolescent OAO in China has increased in recent years, manifesting in national strategies and media interest.<sup>53,54</sup> Yet the national strategies have predominantly focused upon school-based interventions. This analysis indicates that diversifying China's toolbox of policies and programs to address a wider number of the influences that have been shown to significantly augment the risk factors for OAO will be critical to slowing the current trend and mitigating the associated economic burden.<sup>55</sup> National policies that address China's obesogenic environment—excise taxes on sugar sweetened beverages and restricting marketing of unhealthy foods to children and adolescents—offer the greatest potential for impact. This was also found to be the case in a national investment case conducted in Mexico, another upper-middle-income country.<sup>23</sup> Further research to identify capacity development needs and to build stakeholder coalitions at national and subnational levels can valuably support implementation planning.

China has a sizeable population of children and adolescents affected by OAO,<sup>56,57</sup> thus effective treatment options are needed. By establishing nutrition counselling by primary care physicians, the country can better support children and adolescents' health needs. The intervention showed positive economic and health benefits within a thirty-year period. Research has identified limitations in the services and quality of care available within the Chinese primary care system,<sup>58</sup> however, there have been initiatives to improve primary care infrastructure and utilization, such as the

	Return on investment (ROI)			
	Over 10 years (95% CI)	Over 30 years (95% CI)	Over 50 years (95% CI)	Over lifetime (95% CI)
Restrictions on marketing unhealthy foods to children and adolescents	98 (6 to 189)	1358 (100 to 2617)	4942 (365 to 9519)	13,266 (982 to 25,551)
20% excise tax on sugar sweetened beverages (SSBs)	109 (100 to 118)	1188 (1087 to 1283)	4316 (3496 to 4667)	11,317 (10,330 to 12,243)
Nutrition counselling by physicians	5 (5 to 5)	73 (71 to 74)	259 (253 to 266)	674 (658 to 691)
e-Health breastfeeding promotion through text messages to pregnant women	-1 (-1 to -1)	14 (1 to 28.1)	61 (5 to 117)	173 (16 to 330)
Combined school-based intervention	-1 (-1 to -1)	2 (0 to 5)	10 (2 to 20)	28 (6 to 57)
Package 1: SSB tax and marketing restrictions	105 (64 to 145)	1253 (711 to 1791)	4554 (2582 to 6515)	12,059 (6768 to 17,313)
Package 2: Marketing restrictions, e-Health breastfeeding; combined school-based interventions	-1 (-1 to -1)	4 (0 to 10)	19 (2 to 37)	52 (8 to 102)
<b>All five interventions combined</b>	<b>0 (-1 to 0)</b>	<b>8 (4 to 13)</b>	<b>33 (16 to 20)</b>	<b>89 (4 to 141)</b>

**Table 6: National return on investment (ROI) of selected child and adolescent obesity and obesity interventions over a 10-year, 30-year, 50-year, and lifetime time horizon (95% CI).**

	ROI with a 5% discount rate		ROI using the East Asia and Pacific GDP multiplier		ROI achieves 80% effectiveness after two years	
	Over 30 years	Over lifetime	Over 30 years	Over lifetime	Over 30 years	Over lifetime
Restrictions on marketing unhealthy foods to children and adolescents	1030	11,522	1887	27,188	967	9564
20% excise tax on sugar sweetened beverages (SSBs)	910	9911	1674	23,272	857	8290
Nutrition counselling by physicians	56	598	101	1379	54	509
e-Health breastfeeding promotion through text messages to pregnant women	9	124	18	338	11	138
Combined school-based intervention	1	24	3	59	1	16
Package 1: SSB tax and marketing restrictions	955	10,525	1755	24,764	899	8775
Package 2: Marketing restrictions, e-Health breastfeeding; combined school-based interventions	3	43	6	107	2	33
<b>All five interventions combined</b>	<b>6</b>	<b>75</b>	<b>12</b>	<b>183</b>	<b>5</b>	<b>60</b>

Table 7: National return on investment (ROI) of selected child and adolescent obesity and obesity interventions over a 30-year and lifetime time horizon.

family physician registration policy in 2018 and the Healthy China 2030 plan.<sup>58,59</sup> Moreover, clinical guidelines for managing OAO among children and adolescents were recently published,<sup>60</sup> providing a springboard for capacity development among physicians and harnessing their expertise to proactively guide young people and their families.

This study found that increased national investment to scale up what may be seen as more familiar or ‘traditional’ school interventions for healthy eating and physical activity, alongside the new approach of social marketing—to encourage and support healthy behaviours using behavioural messaging, offered the second greatest total benefits over a lifetime. Yet this comes with the caveat that implementation costs reduce this combined intervention’s potential return on investment compared to other interventions.

An important point manifest in the results is that the disease burden attributable to child and adolescent OAO manifests over an individual’s lifetime and so there can be some lag time before benefits are most tangible. Thus, the full package of five interventions, particularly the individual e-Health breastfeeding promotion intervention and the combined school-based interventions have a negative ROI after a 10-year period, whereas the return on investment by 30 years is significant. As such, long-term investment will be key to reducing China’s health and economic burden attributable to child and adolescent OAO.

We understand that this is the first study to estimate the return on investment for addressing child and adolescent OAO through multiple interventions in China.<sup>16</sup> Nonetheless, the modelling analysis is based upon a set of assumptions that are important to note along with the limitations they may present. First, China-specific data was used where available, however, at times supplementary global data, including intervention effect sizes, was needed to fill gaps. Due to the paucity of systemic reviews of child and adolescent obesity interventions, effect sizes were derived from a comprehensive English-language and Chinese-language

literature review of global and Chinese intervention literature to identify relevant intervention literature. As intervention effect sizes were derived from literature available, with the exception of the SSB tax intervention’s effect size that differs based on sex and age,<sup>41</sup> the model assumes each intervention’s effect is the same across its target population and does not differentiate between gender, regions, and economic conditions within China. Second, we assume that current obesity trends in China will continue without additional efforts to control the risks.

Due to limited data availability, we only modelled the impact of exclusive breastfeeding for the first six months of life and did not model the benefit that may derive from breastfeeding and optimal infant and young child feeding during the first two years of a child’s life. Nor did we model the various additional benefits of breastfeeding beyond child OAO prevention, such as reduced childhood undernutrition, micronutrient deficiencies, and infections; improved childhood cognitive outcomes; or maternal reduction in obesity, some cancers, and diabetes.<sup>61,62</sup> Additional productivity losses from caregiver absenteeism associated with child and adolescent OAO school absences was not included in the analysis. The scope was limited to one form of malnutrition—obesity, and did not model the benefits related to preventing other forms of malnutrition.<sup>63</sup> As several of the modelled interventions, such as breastfeeding promotion and marketing restrictions, address multiple forms of malnutrition (undernutrition, micronutrient deficiencies, and OAO)<sup>8</sup> we would expect to see further benefits.<sup>64</sup> While this national investment case examined the return on investment by investing in childhood and adolescent OAO interventions at a national-scale, local investment in piloting these or similar interventions may be heterogenous. As such, the intervention baseline and target coverage levels may vary from those modelled. This partial equilibrium model aims to provide a foundation to develop a general equilibrium childhood obesity model that accounts for all dynamic changes in the economy. The analysis applied a societal

cost perspective, which offers insight into the interventions' impact on the wider population by including all costs to, and health effects within society as a whole (regardless of who paid or who was affected).<sup>47,65</sup> Thus, financial losses to implementing bodies were not estimated because from a whole of society perspective these represent transfers of resources, rather than net gains or losses.<sup>47</sup>

This analysis offers evidence for a robust policy response to the child and adolescent OAO epidemic in China. The five interventions are cost-effective in delivering better health for children and adolescents in China and the results demonstrate the economic benefits of implementing effective new interventions and strengthening existing efforts.

#### Contributors

GM supervised and contributed the writing-review & editing of the manuscript. CLM contributed to the manuscript's investigation, writing-original draft, writing-review & editing, visualization, and project administration. AJM conceptualized and supervised the manuscript and contributed to its methodology and writing-review & editing. SC contributed to the conceptualization, writing-review & editing, and funding acquisition of the manuscript. AN contributed to the conceptualization, writing-review & editing, and funding acquisition of the manuscript. MZ contributed to investigation, data curation, writing-review & editing, and project administration. DW contributed to the formal analysis, writing-review & editing, and the manuscript's visualization. YW, ZY, HW, LZ, and RN all contributed to the review and editing of the manuscript.

#### Data sharing statement

The datasets used and/or analysed for the study are available in publicly accessible databases including the World Bank's World Development Indicators (<https://datatopics.worldbank.org/world-development-indicators/>), the International Labour Organization's ILOSTAT database (<https://ilostat.ilo.org/>), NCD Risk Factor Collaboration (<https://ncdrisc.org/data-downloads.html>), Global Burden of Disease Study (<https://www.healthdata.org/gbd>), China Statistical Yearbook (<http://www.stats.gov.cn/english/Statisticaldata/yearbook/>), and the UN World Population Prospects (<https://population.un.org/wpp/>). Derived data supporting the findings of this study are available from the corresponding author upon request.

#### Declaration of interests

DCW reports a grant/contract from the World Bank. The rest of the authors declare no competing interests.

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#### Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.lanwpc.2023.100977>.

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