Comprehensive systematic review and meta-analysis of risk factors for childhood obesity in China and future intervention strategies

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Summary

Background Childhood obesity is a critical public health concern in China. This study identified the key determinants of childhood obesity in China and provided recommendations for future intervention strategies.

Methods We conducted a comprehensive systematic review and meta-analysis to identify multiple-level determinants of childhood obesity in China and calculated the population-attributable risk percentage (PAR%) for each modifiable determinant. We also conducted expert consultations using the Socio-ecological Model to gain insights into the causes of obesity. Additionally, we reviewed current Chinese policies on childhood obesity intervention and compared them with the priorities identified in the meta-analysis and expert consultation to pinpoint policy gaps.

Findings Our meta-analysis, incorporating 419 studies, identified 33 risk factors for childhood obesity. At the individual-level, we identified 11 key contributors including early-life risk factors such as maternal pre-pregnancy overweight/obesity (PAR%: 16.7%), breastfeeding duration of less than six months (14.1%), cesarean section delivery (11.1%), excessive gestational weight gain (10.5%), high birth weight (4.2%), and gestational diabetes mellitus (3.6%), and 13 behavioral factors during childhood such as sugar sweetened beverage consumption (16.4%), insufficient sleep (15.0%), rapid eating speed (14.7%), less than 2 h of physical activity per day (6.3%), and over 2 h of daily screen time (5.6%). We also identified six prominent family-level factors such as maternal overweight/obesity (24.3%) and paternal overweight/obesity (23.5%). Expert consultation highlighted genetic factors, and prioritized actionable risk factors, particularly dietary, expanding on the meta-analysis findings. Finally, policy review revealed that existing Chinese policies inadequately addressed these determinants, especially at the macro and structural levels.

Interpretation This study highlights the importance of targeting high-risk populations and addressing detrimental behavioral factors, especially on early-life influences. However, real-world impacts require a comprehensive approach that goes beyond individual factors. More future effective intervention efforts are needed.

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Keywords: Children; Adolescents; Obesity; Risk factors; Policy; Meta-analysis; Expert consultations

Research in context

Evidence before this study

Childhood obesity is a critical public health crisis, particularly in China, demanding urgent actions. Despite efforts by the Chinese Government to curb obesity through national policies and health initiatives issued over the past ten years, these measures have not effectively controlled the obesity epidemic. The development of childhood obesity in China is shaped by a complex interplay of lifestyle and environmental factors, but the precise impact and relative importance of these determinants remain unclear. To address this knowledge gap, we conducted a comprehensive systematic review and meta-analysis, searching databases including PubMed, Scopus, Web of Science, Wanfang, Weipu, and China National Knowledge Infrastructure from Jan 1, 2014, to June 8, 2024. Our search strategy incorporated terms such as "Infant", "Child", "Adolescent", "Overweight", "Obesity", "Macrosomia", "Large for gestational age", and "China", focusing on both English and Chinese publications. We included cross-sectional, cohort, and case–control studies reporting on obesogenic factors. To complement and validate the meta-analysis, we consulted experts within China to identify and prioritize key determinants of childhood obesity. Simultaneously, we reviewed policies from the State Council and relevant ministries to evaluate existing prevention and control strategies.

Added value of this study

This study is the first comprehensive review and meta-analysis to map out multi-level determinants of childhood obesity in China, identifying 33 significant individual-, family-, school-, and societal-level risk factors. By calculating population-attributable risk percentages, we quantified the impact of modifiable determinants, thereby offering a novel framework for prioritizing interventions. At the individual-level, we identified six key early-life risk factors including excessive gestational weight gain, breastfeeding duration less than six months, maternal pre-pregnancy overweight/obesity, cesarean section, high birth weight (birth weight >4000 g), and gestational diabetes mellitus, and five key modifiable behaviors during childhood including insufficient sleep, rapid eating speed, excessive sugar-sweetened beverages consumption, low physical activity, and extensive screen time. Family-level risk factors included parental overweight/obesity and urban residency as emerging notable factors. While the meta-analysis identified a broad spectrum of obesity's determinants, expert insights prioritized actionable risk factors, offering targeted intervention strategies. Both approaches highlighted a lack of evidence regarding macro-level influences, such as policy impacts. Furthermore, our policy review revealed several areas needing improvement, including weak enforcement mechanisms, an overemphasis on individual responsibility, a need for enhanced multisectoral collaboration, inadequate focus on early-life risk factors, and challenges in ineffective public health communication. We made recommendations for future actions.

Implications of all the available evidence

This study highlights the urgent need of adopting a holistic approach to obesity prevention that considers both individual and systemic factors. It provides a roadmap for policymakers to formulate an integrated, government-led policy framework to effectively combat the childhood obesity epidemic and enhance the health and well-being of future generations in China.

Introduction

Childhood obesity represents one of the most urgent public health challenges, with its global prevalence soaring over the past four decades.[1] The World Obesity Federation projected a rise in childhood obesity worldwide from 175 million in 2020 to 310 million by 2030.[2] This trend is particularly alarming in China, where the prevalence of overweight and obesity may increase from 19% among school-aged children and 10.4% among preschoolers in 2020 to 31.8% and 15.6% by 2030, respectively.[3–5] Early-onset obesity not only heightens the risk of chronic conditions,[6,7] but also imposes a substantial economic burden on the healthcare system in China.[8] Despite national efforts to address this issue,[4,9] progress has been limited, highlighting the need for a deeper understanding of the primary drivers of childhood obesity to inform more effective interventions and policies.[4]

Obesity results from a complex interplay of biological, behavioral, and environmental factors.[10–15] The Social-Ecological Model (SEM) offers a robust framework for understanding these multifaceted causes, emphasizing the broader societal, cultural, economic, and environmental contexts in which children live.[16]

While previous studies have often focused on single obesogenic factors, meta-analyses[17–19] and large observational studies[20–23] from other countries highlighted the significant roles of home and built environment, along with individual behaviors, in shaping global childhood obesity trends. Given China's unique socioeconomic transitions, socio-cultural landscape, and child growth patterns, a comprehensive context-specific exploration of childhood obesity determinants is essential.[24,25] This necessity was echoed by a recent Lancet series on Childhood Obesity in China, which highlighted an urgent need to identify and quantify the major contributors across different developmental stages.[26]

Existing meta-analyses on childhood obesity in China have limitations, including small sample sizes, limited geographic and age coverage, and a focus on individual- and family-level determinants.[27,28] Thus, a socio-ecological approach is essential to capture broader interconnections.[29] While meta-analyses offer valuable insights into obesity, they are constrained by the original study, which primarily focuses on individual and immediate environmental factors, making them less equipped to evaluate meso- or macro-level determinants, such as taxation policies or healthcare reforms.[30] Therefore, our study incorporated expert consultations to provide a broader, policy-relevant perspective. In addition, the adequacy of related policies in China remains unclear. By synthesizing policy analysis, meta-analysis evidence, and expert insights, our study identifies gaps and proposes actionable recommendations to enhance real-world applicability. This approach ensures the rigor and policy relevance of our findings.

This study aims to: 1) perform a systematic review and meta-analysis, supplemented by population-attributable risk percentages (PAR%), to pinpoint key determinants at population-level of obesity among Chinese children; 2) engage experts to validate quantitative findings and gain qualitative insights into societal-and policy-level drivers, ensuring a comprehensive understanding of the major risk factors; and 3) propose recommendations for future efforts. The conceptual framework for our study is depicted in Fig. 1.

Methods

Information search strategy and selection criteria

This systematic review and meta-analysis adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and was pre-registered with PROSPERO (CRD42024568590). We conducted a comprehensive literature search for studies published between January 2014 and June 2024, using PubMed, Scopus, and Web of Science for English language papers, as well as Wanfang, Weipu, and China National Knowledge Infrastructure for Chinese language papers. Search terms included combinations of (infant OR child OR adolescent) AND (overweight OR obesity OR central obesity OR macrosomia OR large for gestational age (LGA)) AND (cross-sectional studies OR cohort studies OR case–control studies) AND (China). Details of this search strategy were provided in Table S1. We also reviewed the reference lists of identified studies and relevant reviews, including prior meta-analysis, to identify additional sources.

Two independent reviewers screened titles and abstracts against predefined eligibility criteria (Table S2), excluding irrelevant studies. The predefined inclusion criteria encompassed cohort studies, case–control trials, and cross-sectional studies that (1) investigated children and adolescent (<18 years) in China; (2) targeted the general population (i.e., healthy individuals without specific illnesses); (3) examined the association between risk factors and categorical obesity-related outcomes (e.g., overweight, obesity, overweight/obesity, central obesity, macrosomia, or LGA); (4) had a sample size of ≥2000; and (5) were published between January 2014 and June 2024.

Full texts of potentially relevant studies were then assessed thoroughly by two reviewers, with discrepancies resolved by a third reviewer. The selection process was illustrated in Fig. 2.

Data extraction

Data from eligible studies were extracted independently by two reviewers using a standardized data extraction form, which included publication details, participant characteristics, study design, exposures, outcomes, key covariates, and findings (see Table S3 for details). To harmonize exposure categories, we adopted the most common classifications across studies, consolidating disparate categories when possible. For example, instances of children's physical activity duration exceeding 4 h per day were integrated into the more common category of over 2 h per day. Definitions for specific risk factor groups were provided in Table S4. Based on the SEM,[31] we categorized risk factors into six hierarchical levels: individual, family, school, community, societal, and policy. Individual-level risk factors were further subdivided into immutable biological factors, early-life risk factors (primarily influenced by mothers and caregivers), and modifiable behavioral factors.

Outcome measures included categorical weight classifications, such as overweight, obesity, overweight/obesity (defined by IOTF, WHO, CDC, WGOC, and national standard, details seen in Table S3), and central obesity (defined by WC or WHtR). We focused on the overweight/obesity category as the primary outcome of this study, with results for other outcome measures provided in Supplementary Materials. Neonatal outcomes included macrosomia (birth weight ≥4000 g) and LGA (birth weight >90th percentile for gestational age) as proxies for fetal overgrowth and predictors of later-life obesity.[32] The quality of included studies was assessed

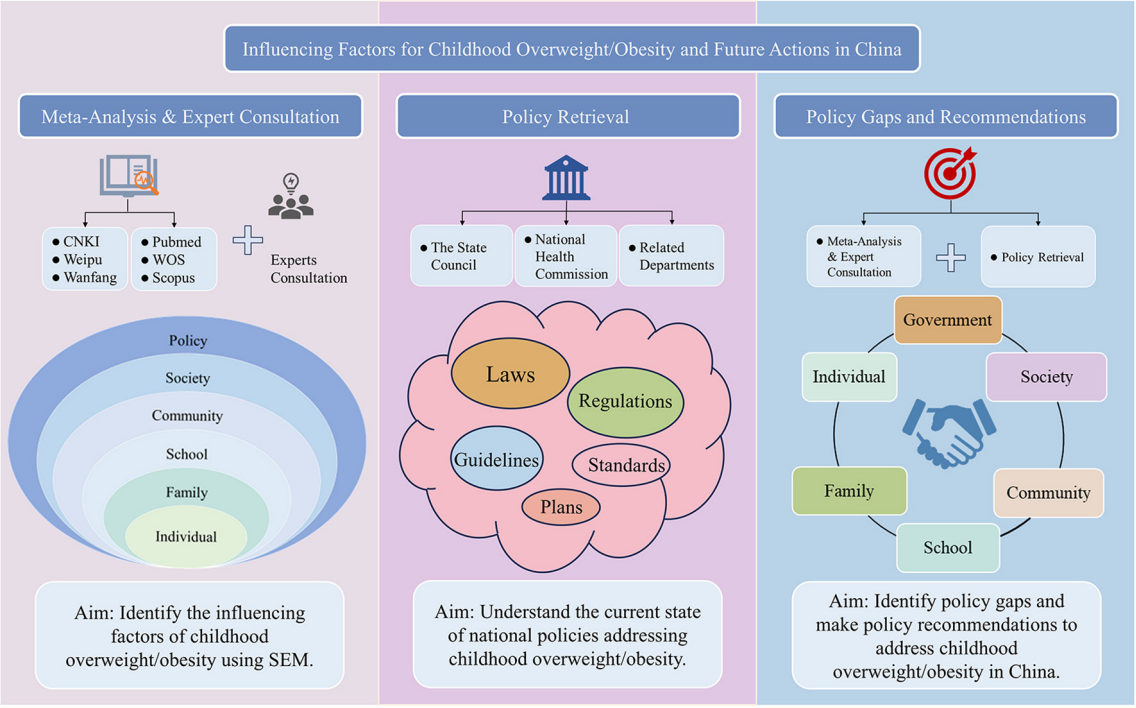


Fig. 1: Theoretical framework for the study on a comprehensive analysis of childhood obesity risk factors in China and future strategic interventions. CNKI, China National Knowledge Infrastructure; WOS, Web of Science; SEM, Social Ecological Model.

by two independent evaluators (YF J and BR L) using a modified Newcastle–Ottawa Scale (NOS).[33] Discrepancies were resolved by consensus with a third reviewer (FY CH). Studies were classified into three quality tiers: low (0–4 points), moderate (5–6 points), and high (7–9 points),[34] with low-quality studies interpreted with additional caution.

Data analysis

We performed quantitative random-effects meta-analyses for risk factors examined in three or more independent studies, calculating pooled odds ratios (OR) and 95% confidence intervals (CI) for each association. To strengthen causal inference, we developed directed acyclic graphs (DAGs) for major actionable risk factor-overweight/obesity pathways, identifying key confounders for adjustment. For modifiable risk factors with available national prevalence data, we computed population-attributable risk percentages (PAR%) using the formula: $\text{PAR\%} = \frac{p(OR-1)}{p(OR-1)+1} \times 100\%$, where p represents the national prevalence (proportion) of the risk factor (see Table S4 for details). All prevalence data were derived from authoritative sources such as the China National Bureau of Statistics,[35] representative national surveys (e.g., the National Survey on Physical Activity and Health Behaviors of Children and Adolescents),[36] or comprehensive meta-analyses,[37] prioritizing the most recent and representative studies.

To assess the robustness of our findings, we conducted sensitivity analysis restricted to high-quality studies (NOS 7–9 points) that adequately adjusted for key confounders. We assessed heterogeneity across studies using the I^2 statistic ($I^2 > 50\%$ indicating high heterogeneity) and the Cochrane Q test ($p < 0.05$ suggesting potential heterogeneity).[38] Publication bias was evaluated using Egger's tests, funnel plots, and Duval and Tweedie's trim-and-fill method.[39,40] All statistical analyses were performed using Stata 16 and R version 4.0.0, with significance set at $p < 0.05$.

To present the full scope of childhood obesity risk factors, we organized the identified determinants according to the SEM, classifying them at macro (e.g., policy and society), meso (e.g., community and school), and micro (family and individual) levels.[31]

Expert consultation and ranking process

A total of 14 specialists from China in childhood obesity prevention and control completed a structured SEM questionnaire (Table S5). This helped to identify and prioritize obesogenic determinants across macro, meso, and micro levels. The experts' information, including age, sex, job title, affiliations, and research field, was provided in Table S6.

To evaluate the importance of risk factors at the meso and macro levels, experts assigned individual scores to each dimension and corresponding factors.

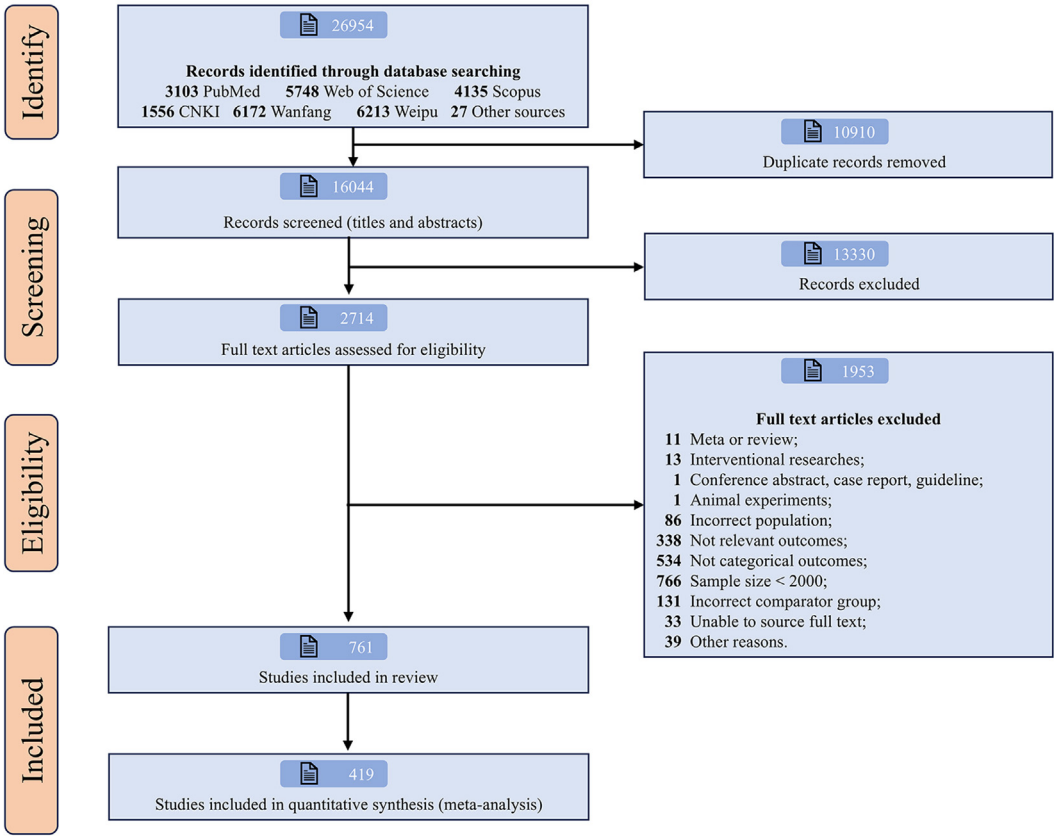


Fig. 2: Study selection process for the systematic review and meta-analysis. CNKI, China National Knowledge Infrastructure.

These scores were aggregated to calculate total rankings, illustrating the relative importance of each dimension and factor. For the micro level, 34 specific factors were carefully identified from the data extraction process of meta-analysis. Experts ranked these factors using a scoring system: three points for those in the top ten, two points for factors ranked 11th–20th, and one point for factors ranked 21st–30th.

Policy research and screen

Policy documents for inclusion were sourced from central government agencies, such as the National People's Congress, the State Council, the Ministry of Education, the National Health Commission, and the General Administration of Sport of China. Policies and actions led by social organizations without government endorsement, such as "Action Plan for Promoting Sports and Health for Children and Adolescents in China"[41] were excluded.

To systematically identify policies related to childhood obesity, we searched the official websites of the aforementioned entities, using a strategy which included five specific Chinese keywords, "ertong" (children), "qingshaonian" (adolescent), "tizhong" (weight), "feipang" (obesity), and "chaozhong" (overweight). Additionally, a manual review of policy documents focusing on childhood health and nutrition was conducted, informed by literature on childhood obesity-related policy.[4,42] This process helped to identify influential policies that might not have emerged from the keyword search alone.

We then compared the current policies against the priorities identified through the meta-analysis and expert consultations to reveal the existing policy gaps.

Role of funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

From six databases, we identified a total of 26,954 studies. After removing duplicates, 16,044 remained. Following an examination of the titles and abstracts, 13,330 non-relevant articles were excluded. Of the remaining 2714 studies, 761 met the inclusion criteria after a full-text review. Due to challenges in classifying exposures into specific risk factor groups and the occurrence of groups with fewer than three articles, only

419 out of 761 studies were included in the meta-analysis, encompassing 30,074,342 children. Study characteristics were summarized in Table S3, while quality assessments were shown in Table S7. Of the included studies, 157 were rated as high-quality, 205 as medium-quality, and 57 as low-quality.

Risk factors of combined childhood overweight/obesity

Individual-level risk factors

Among immutable biological risk factors, child sex was associated with the risk of overweight/obesity, with boys exhibiting a higher risk compared to girls (OR = 1.69; 95% CI: 1.60–1.77) (Figure S1).

Among early-life risk factors, those associated with a higher risk of childhood overweight/obesity included maternal pre-pregnancy overweight/obesity (OR = 1.74, 95% CI: 1.48–2.05), high birth weight (OR = 1.70, 95% CI: 1.53–1.88), excessive gestational weight gain (GWG) (OR = 1.32, 95% CI: 1.26–1.38), gestational diabetes mellitus (GDM) (OR = 1.32, 95% CI: 1.14–1.52), cesarean delivery (OR = 1.28, 95% CI: 1.23–1.34), and breastfeeding for less than six months (OR = 1.18, 95% CI: 1.01–1.39) (Fig. 3A). The associations between early-life risk factors and overweight, obesity, and central obesity were presented in Figure S2.

For modifiable behavioral factors during childhood, higher risks of childhood overweight/obesity were associated with rapid eating speed (OR = 1.91, 95% CI: 1.21–3.01), lower dietary knowledge score (OR = 1.73, 95% CI: 1.38–2.17), insufficient sleep (OR = 1.29, 95% CI: 1.17–1.42), sugar-sweetened beverage (SSB) consumption (OR = 1.26, 95% CI: 1.14–1.39), exceeding 2 h of daily screen time (OR = 1.19, 95% CI: 1.11–1.28), skipping breakfast (OR = 1.13, 95% CI: 1.08–1.18), milk consumption (OR = 1.12, 95% CI: 1.00–1.25), and less than 2 h of physical activity per day (OR = 1.11, 95% CI: 1.00–1.23) (Fig. 3B). Interestingly, higher consumption of fruits (OR = 1.13, 95% CI: 1.09–1.18) and vegetables (OR = 1.11, 95% CI: 1.01–1.21) was associated with a higher risk of overweight (Figure S3). The associations between modifiable behavioral factors and overweight, obesity, and central obesity were presented in Figures S3 and S4.

For macrosomia and LGA, immutable factors such as male sex and birth during the spring season were associated with higher risks, alongside maternal factors such as pregnancy age ≥35 years, excessive GWG, pre-pregnancy overweight/obesity, GDM, post-term birth, and gravidity ≥2 (Figure S5).

Family, school, and societal-level risk factors

At the family-level, significant risk factors for childhood overweight/obesity included parental overweight/obesity (OR = 3.04, 95% CI: 2.16–4.29), maternal overweight/obesity (OR = 1.86, 95% CI: 1.54–2.25), paternal overweight/obesity (OR = 1.68, 95% CI: 1.46–1.93), urban residency (OR = 1.54, 95% CI: 1.39–1.69), and being an only child (OR = 1.29, 95% CI: 1.19–1.40) (Fig. 3C).

At the school dimension, boarding at school was associated with a higher risk of overweight/obesity (OR = 1.22, 95% CI: 1.12–1.34) (Fig. 3C). The lack of sports facilities was correlated to an increased risk of childhood obesity (OR = 1.31, 95% CI: 1.08–1.59) (Figure S6).

At the societal dimension, a higher regional economic status was linked to a higher overweight/obesity risk (OR = 1.48, 95% CI: 1.29–1.70) (Fig. 3C). The associations between family- and school-level factors and overweight, obesity, and central obesity were detailed in Figure S6.

PAR of risk factors

The PAR% for key obesogenic factors were shown in Table 1. Among early-life risk factors, maternal pre-pregnancy overweight/obesity had the highest PAR% (16.7%), followed by breastfeeding for less than six months (14.1%), cesarean delivery (11.1%), excessive GWG (10.5%), high birth weight (4.2%), and GDM (3.6%).

For modifiable behavioral factors, SSB consumption emerged as the leading contributor (PAR%: 16.4%), followed by insufficient sleep (15.0%), rapid eating speed (14.7%), physical activity less than 2 h per day (6.3%), and exceeding 2 h of daily screen time (5.6%). Among the most significant determinants of overweight and obesity (Table S4), eating speed was the strongest risk factor (PAR%: 31.3%).

At the family dimension, urban residency had the highest PAR% (25.4%), followed by maternal overweight/obesity (24.3%), paternal overweight/obesity (23.5%), and being an only child (14.8%).

Heterogeneity, publication bias and sensitive analysis

Results of heterogeneity and publication bias were presented in Table S8. High heterogeneity was found for several factors, primarily due to studies reporting smaller or greater impact sizes in the same direction. Although the funnel plot and Egger's test revealed that several components exhibited publication bias, the trim-and-fill approach indicated that most of the modified results remained significant.

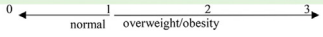
Sensitive analysis within the high-quality subset of studies demonstrated the robustness of our results (Table S9). Results of the evaluation of the confounders with DAGs were shown in Figure S7.

Expert consultation results

Expert opinions are important for developing policies and intervention efforts. Expert consultation refined the ranking of the top 15 obesity determinants across individual and family dimensions, with 12 overlapping factors from the meta-analysis. These included behavioral

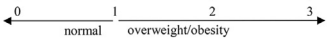
A

Dimension/factor	Studies	Samples	Studied group	Reference	Outcome	OR(95% CI)	PAR%(95% CI)
Maternal pre-pregnancy BMI							
	12	13	overweight/obesity	normal	overweight/obesity	1·74 (1·48-2·05)	16·7 (11·5-22·2)
	3	3	obesity	normal	overweight/obesity	1·71 (1·22-2·40)	4·1 (1·3-7·8)
	3	3	overweight	normal	overweight/obesity	1·53 (1·04-2·25)	10·0 (0·8-20·8)
	10	11	underweight	normal	overweight/obesity	0·60 (0·53-0·68)	NA
Birth weight							
	24	25	HBW	NBW	overweight/obesity	1·70 (1·53-1·88)	4·2 (3·2-5·3)
	21	21	LBW	NBW	overweight/obesity	0·60 (0·52-0·69)	NA
Gestational weight gain							
	13	14	excessive	adequate	overweight/obesity	1·32 (1·26-1·38)	10·5 (8·7-12·2)
	13	14	inadequate	adequate	overweight/obesity	0·86 (0·80-0·93)	NA
Gestational diabetes mellitus							
	10	11	yes	no	overweight/obesity	1·32 (1·14-1·52)	3·6 (1·6-5·7)
Type of delivery							
	18	18	cesarean delivery	vaginal delivery	overweight/obesity	1·28 (1·23-1·34)	11·1 (9·3-13·1)
Gestational age							
	6	6	preterm	term	overweight/obesity	1·27 (0·89-1·79)	NA
Breastfeeding duration							
	5	5	< 6 months	≥ 6 months	overweight/obesity	1·18 (1·01-1·39)	14·1 (0·5-26·1)
	3	3	≥12 months	<12 months	overweight/obesity	0·83 (0·65-1·06)	NA
Maternal age at pregnancy							
	5	5	≥35 years	<35 years	overweight/obesity	0·92 (0·26-3·20)	NA
Feeding patterns during 6 months							
	6	6	exclusive breastfeeding	formula feeding	overweight/obesity	0·85 (0·69-1·05)	NA
Parity							
	4	4	multiparity	primiprity	overweight/obesity	0·81 (0·71-0·92)	NA



B

Dimension/factor	Studies	Samples	Studied group	Reference	Outcome	OR(95% CI)	PAR%(95% CI)
Eating speed							
	5	5	rapid	normal	overweight/obesity	1·91 (1·21-3·01)	14·7 (3·8-27·6)
Dietary knowledge score							
	3	3	low	high	overweight/obesity	1·73 (1·38-2·17)	NA
Sleep duration							
	9	13	insufficient	sufficient	overweight/obesity	1·29 (1·17-1·42)	15·0 (9·4-20·4)
Sugar-sweetened beverage consumption							
	10	14	drinking	no drinking	overweight/obesity	1·26 (1·14-1·39)	16·4 (9·6-22·7)
Screen time							
	20	27	≥ 2 h/d	< 2 h/d	overweight/obesity	1·19 (1·11-1·28)	5·6 (3·3-8·0)
Skipping breakfast							
	11	12	yes	no	overweight/obesity	1·13 (1·08-1·18)	1·1 (0·7-1·6)
Milk consumption							
	5	5	no drinking	drinking	overweight/obesity	1·12 (1·00-1·25)	NA
Physical activity							
	10	12	< 2 h/d	≥ 2 h/d	overweight/obesity	1·11 (1·00-1·23)	6·3 (0·0-12·4)
Commuting to school							
	3	3	inactive	active	overweight/obesity	1·08 (0·95-1·23)	NA
Fast food consumption							
	2	5	yes	no	overweight/obesity	1·08 (0·90-1·29)	NA
Sweet food consumption							
	3	4	yes	no	overweight/obesity	0·97 (0·56-1·69)	NA



C

Dimension/factor	Studies	Samples	Studied group	Reference	Outcome	OR(95% CI)	PAR%(95% CI)
Family dimension							
Parental overweight/obesity							
	3	3	yes	no	overweight/obesity	3·04 (2·16-4·29)	13·1 (7·9-19·6)
Maternal overweight/obesity							
	14	15	yes	no	overweight/obesity	1·86 (1·54-2·25)	24·3 (16·8-31·8)
Paternal overweight/obesity							
	14	15	yes	no	overweight/obesity	1·68 (1·46-1·93)	23·5 (17·2-29·6)
Residency							
	34	44	city	rural	overweight/obesity	1·54 (1·39-1·69)	25·4 (19·7-30·3)
Only child							
	18	19	yes	no	overweight/obesity	1·29 (1·19-1·40)	14·8 (10·2-19·4)
Household income level							
	6	7	high	low	overweight/obesity	1·19 (0·52-2·69)	NA
	6	7	middle	low	overweight/obesity	0·62 (0·29-1·34)	NA
Maternal educational level							
	21	24	middle school and below	high school and above	overweight/obesity	1·05 (0·91-1·20)	NA
Paternal educational level							
	19	21	middle school and below	high school and above	overweight/obesity	0·97 (0·88-1·06)	NA
Primary caregiver							
	4	4	others	parents	overweight/obesity	0·98 (0·88-1·08)	NA
School dimension							
Boarding at school							
	5	5	no	yes	overweight/obesity	1·22 (1·12-1·34)	NA
Homework burdern							
	3	3	heavy	not heavy	overweight/obesity	1·10 (0·79-1·53)	NA
Societal dimension							
Level of regional economic development							
	4	5	high	low	overweight/obesity	1·48 (1·29-1·70)	NA
	4	5	middle	low	overweight/obesity	1·05 (0·82-1·36)	NA

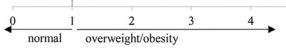


Fig. 3: **A** Forest plot of early life risk factors at the individual dimension. BMI, Body Mass Index. **B** Forest plot of behavioral factors at the individual dimension. **C** Forest plot of risk factors at the family-, school-, and societal dimensions. Parental overweight/obesity is defined as both parents being overweight or obese.

Dimension/factor	Reference	OR (95% CI)	p[a]	PAR % (95% CI)
Immutable biological risk factors				
Sex	male vs female (ref)	1.69 (1.60–1.77)	0.53[35]	26.9 (24.2–29.1)
Early-life risk factors				
Maternal prepregnant BMI	overweight/obesity vs normal (ref)	1.74 (1.48–2.05)	0.27[43]	16.7 (11.5–22.2)
Breastfeeding duration	<6 months vs ≥ 6 months (ref)	1.18 (1.01–1.39)	0.91[44]	14.1 (0.5–26.1)
Type of delivery	cesarean vs vaginal (ref)	1.28 (1.23–1.34)	0.44[45]	11.1 (9.3–13.1)
GWG	excessive vs adequate (ref)	1.32 (1.26–1.38)	0.37[46]	10.5 (8.7–12.2)
Maternal pregnant BMI	overweight vs normal (ref)	1.53 (1.04–2.25)	0.21[43]	10.0 (0.8–20.8)
Birth weight	HBW vs NBW (ref)	1.70 (1.53–1.88)	0.06[45]	4.2 (3.2–5.3)
Maternal pregnant BMI	obesity vs normal (ref)	1.71 (1.22–2.40)	0.06[43]	4.1 (1.3–7.8)
GDM	yes vs no (ref)	1.32 (1.14–1.52)	0.12[45]	3.6 (1.6–5.7)
Modifiable behavioral factors				
SSB consumption	drinking vs no drinking (ref)	1.26 (1.14–1.39)	0.76[47]	16.4 (9.6–22.7)
Insufficient sleep	insufficient vs sufficient (ref)	1.29 (1.17–1.42)	0.61[37]	15.0 (9.4–20.4)
Eating speed	rapid vs normal (ref)	1.91 (1.21–3.01)	0.19[48]	14.7 (3.8–27.6)
Physical activity	<2 h/d vs ≥ 2 h/d (ref)	1.11 (1.00–1.23)	0.61[49]	6.3 (0.0–12.4)
Screen time	≥2 h/d vs < 2 h/d (ref)	1.19 (1.11–1.28)	0.31[36]	5.6 (3.3–8.0)
Skipping breakfast	yes vs no (ref)	1.13 (1.08–1.18)	0.09[50]	1.1 (0.7–1.6)
Family dimension				
Residency	city vs rural (ref)	1.54 (1.39–1.69)	0.63[35]	25.4 (19.7–30.3)
Maternal overweight/obesity	yes vs no (ref)	1.86 (1.54–2.25)	0.37[51]	24.3 (16.8–31.8)
Paternal overweight/obesity	yes vs no (ref)	1.68 (1.46–1.93)	0.45[51]	23.5 (17.2–29.6)
Only child	yes vs no (ref)	1.29 (1.19–1.40)	0.60[35]	14.8 (10.2–19.4)
Parental overweight/obesity[b]	yes vs no (ref)	3.04 (2.16–4.29)	0.07[52]	13.1 (7.9–19.6)

[a]Refers to the proportion of risk factors in national population rather than p-value from a significance test. [b]Parental overweight/obesity is defined as both parents being overweight or obese. BMI, Body Mass Index; SSB, Sugar-Sweetened Beverage; GWG, Gestational Weight Gain; HBW, High Birth Weight; LBW, Low Birth Weight; GDM, Gestational Diabetes Mellitus; OR, Odds Ratio; PAR, Population Attributable Risk.

Table 1: **Assessment of the impact of risk factors on childhood overweight/obesity using ORs and PAR%.**

factors (SSB consumption, physical activity, screen time, and sleep duration), early life factors (birth weight, GWG, feeding patterns, maternal pre-pregnancy BMI, and maternal pregnancy complications), and family factors (household economic status, family residency, and parental weight status). Experts also highlighted gene polymorphisms, dietary patterns, and vegetable and fruit consumption, which were underrepresented in the meta-analysis due to insufficient studies or unavailable PAR% estimates (see Fig. 4, Table S10). As seen in Table 2, expert consultation also emphasized the priority of individual and family dimensions. At the individual-dimension, diet and eating behaviors emerged as the primary concern, followed by physical activity and sleep patterns. At the family-dimension, socioeconomic status, parenting style, and parental weight status were deemed most critical.

For meso and macro level, experts also highlighted the prioritization of school- and public policy dimension. At the school-dimension, the emphasis was placed on the availability of physical activity opportunities, alongside healthy food accessibility, academic pressures, and time management recognized as important determinants. At the public policy dimension, standards for students' physical health and fitness emerged as the primary concern, followed by nutrition-targeted taxation policies and food and agricultural policies (Table 2).

Policy landscape of childhood obesity in China

We conducted an extensive review and identified 48 official documents related to childhood obesity issued by the State Council and various ministries, with the majority enacted before 2020. Of these documents, 25 specially targeted childhood obesity, focusing on various aspects such as health (9), nutrition (4), physical activity (8), sleep (2), and breastfeeding (2) to combat obesity. The remaining 23 policies, while geared towards all age groups, included specific content on children only. Among these policies, five offered a broad spectrum of prevention and control of obesity; seven were dedicated to medical and health services for obesity intervention and treatment; five emphasized healthy diets for obesity prevention; and six addressed the importance of physical activity.

Additionally, our policy synthesis identified 48 official documents addressing childhood obesity, but only four were legally enforceable. These included two laws (Law on Sports and the Law on Basic Medical and Health Care and the Promotion of Health) and two regulations (Working Regulations of School Physical Education, and School Food Safety and Nutrition and

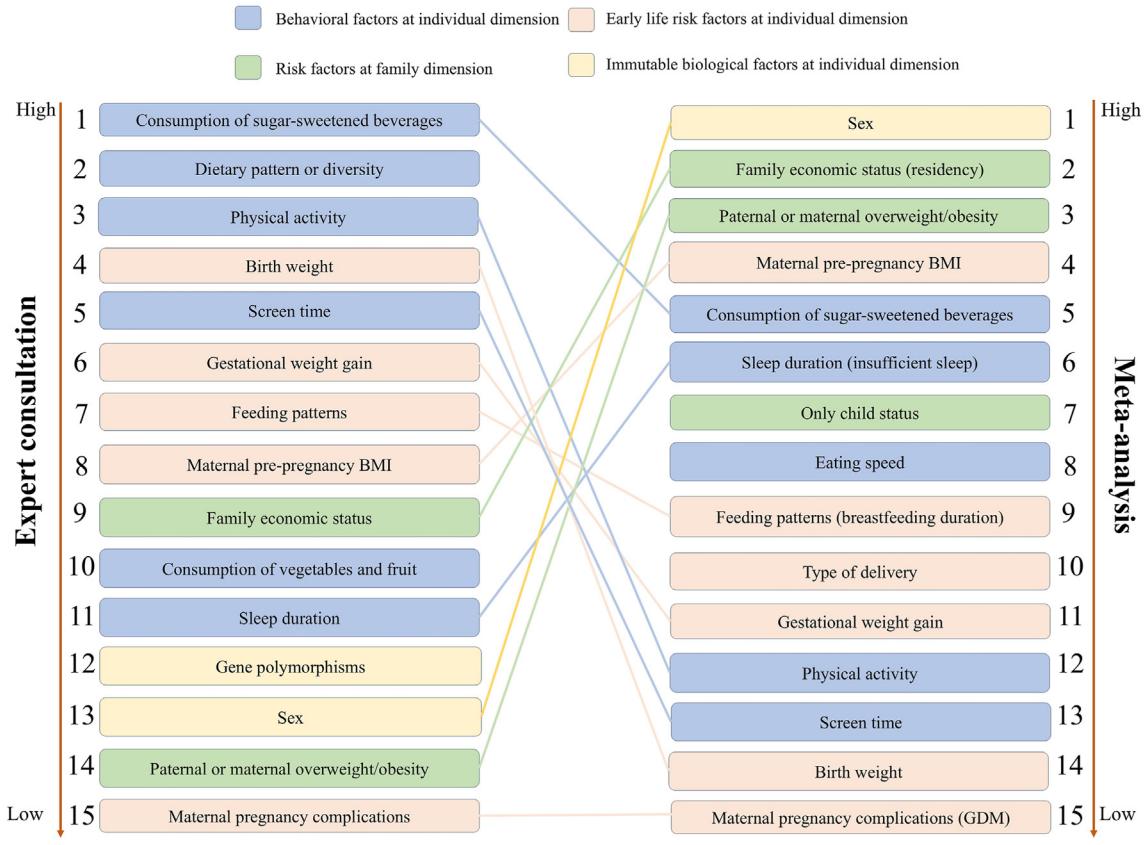


Fig. 4: Comparisons of the top 15 risk factors for childhood overweight/obesity in China as identified through meta-analysis and expert consultation. The figure illustrates the top fifteen factors contributing to childhood overweight/obesity based on expert consultation (left panel) and meta-analysis (right panel), ranked by total scores and PAR%, respectively, with a higher ranking signifying greater importance. GDM, Gestational Diabetes Mellitus; BMI, Body Mass Index; PAR, Population Attributable Risk.

Health Management Regulations). However, even within these legal frameworks, imposed only mild consequences for non-compliance, such as corrective actions or administrative sanctions.

The remaining 44 documents consisted of action plans (19), guidelines (13), and policy opinions (12), which were broad in scope, lack detailed implementation strategies, and primarily focus on individual behavioral changes while overlooking structural and policy-level challenges. For example, the Guideline for Prevention and Control of Overweight and Obesity in Chinese Children and Adolescents promoted a multi-sector collaboration (family, schools, healthcare institutions, and government agencies) but lacked specifics on funding, monitoring, communication strategies, and accountability measures. It also failed to address the diverse needs of specific groups (e.g., urban vs rural children) or different life stages (e.g., early childhood intervention).

Fig. 5 outlined the 36 nationwide policies addressing risk factors identified by meta-analysis, excluding five general obesity prevention policies and seven emphasized healthcare services. Detailed information on lead sectors and major contents concerning childhood obesity for all 48 documents was provided in Table S11.

Discussion

This study provided the first comprehensive investigation into the multifactorial risk factors for childhood obesity in China, identifying 33 significant risk factors across individual-, familial-, scholastic-, and societal levels. Our findings highlighted the role of maternal pre-pregnancy BMI, individual unhealthy behaviors such as SSB consumption and insufficient sleep, and parental overweight and obesity, specifically due to their high PAR%. In addition, our expert consultation also addressed the importance of public policy.

Our policy review showed that over 90% (44/48) of childhood obesity-related policy documents in China were non-binding guidelines or action plans. While they raised awareness, their advisory nature–without clearly budget allocation, interagency accountability, enforcement mechanisms, or structured implementation plans–limited

Dimensions	Ranks on dimensions	Factors	Ranks on factors
1. Individual dimension	1	1.1 Immutable biological factors	5
		1.2 Early life risk factors	4
		1.3 Eating behaviors	1
		1.4 Physical activity	2
		1.5 Sleep behaviors	3
		1.6 Environmental chemical pollutants exposures	6
2. Family dimension	2	2.1 Family socio-economic status	1
		2.2 Family structures	5
		2.3 Parental weight statuses	3
		2.4 Household food safety	4
		2.5 Parenting styles	2
3. School dimension	3	3.1 Healthy food accessibility	2
		3.2 Opportunities for physical activity	1
		3.3 Academic demands and time management	3
		3.4 Health education accessibility	5
		3.5 Physical education evaluation systems	4
		3.6 Monitoring of students' health and body weight	6
4. Community dimension	5	4.1 Health awareness and education campaigns	4
		4.2 Child-friendly recreational facilities	1
		4.3 Nutritional food choices	2
		4.4 Infrastructure for active living	3
		4.5 Public health and medical services	5
5. Societal dimension	6	5.1 Geographical and climate factors	4
		5.2 Urban vs rural residency	2
		5.3 Public health literacy and obesity perception	1
		5.4 Media influence on diet and physical activity	3
		5.5 Environmental pollutants and obesogens	5
6. Public policy dimension	4	6.1 Food and agricultural policies	3
		6.2 Nutrition-targeted taxation policies	2
		6.3 Healthcare service equity	5
		6.4 Standards for students' physical health and fitness	1
		6.5 Media and advertising regulations	4

Dimensions and factors, established via SEM, were ranked by experts to derive scores, facilitating their comparison by magnitude. SEM, Social-ecological Model.

Table 2: **Results of expert consultation on the risk factors of childhood overweight/obesity in China.**

their real-world impacts. Strengthening the policy framework with enforceable measures, funding commitments, and clear implementation strategies is crucial for effectively addressing childhood obesity in China.

Individual- and family-level risk factors for childhood obesity

Our study identified several key risk factors for childhood obesity that require urgent attention. Among immutable risk factors, male sex and urbanization played significant roles. In Chinese society, cultural perceptions often associate larger body sizes with better health, particularly for boys,[53] leading caregivers to encourage higher food intake. In contrast, girls may experience societal pressure to maintain slimmer figures, contributing to sex-based disparities in obesity.[54,55] Urbanization further exacerbates these trends, fostering obesogenic environments characterized by easy access to energy-dense foods and limited opportunities for physical activity.[56,57] Given the high PAR% associated with these factors, prevention efforts should prioritize high-risk groups, such as boys in urban settings. It is important to note that this trend is now expanding into rural areas.[58,59]

Our study also highlighted several modifiable behavioral determinants. Sugary drink consumption emerged as a significant yet age-variable risk factor,[60] while rapid eating, linked to impaired calorie recognition and overeating, was strongly associated with childhood obesity.[61–63] Physical inactivity (<2 h/day) contributed to obesity through reduced energy expenditure,[64] hormonal dysregulation,[65] and gut microbiota disruption.[66] The decline in active commuting to school, driven by increased vehicle ownership in China,[67] further compounds this issue, though our statistical power limited definitive conclusions. Additional excessive screen time and insufficient sleep were identified as key risk factors, promoting sedentary habits[68,69] and disrupting metabolic regulation.[70,71] Our subgroup analysis (Figure S4) suggested that even small improvements in activity levels and sleep duration could significantly reduce obesity risk, providing valuable guidance for lifestyle-targeted interventions and policy refinements.

Early life factors also play a critical role in shaping obesity risks, supporting the Developmental Origins of Health and Disease (DOHaD) hypothesis.[72] Maternal pre-pregnancy overweight/obesity, excessive GWG, and GDM were strongly linked to large birth size and subsequent childhood obesity, potentially through alterations in the uterine environment and gut microbiome.[73–76] Shorter breastfeeding duration (<6 months) was also associated with a higher obesity risk, though findings remain inconsistent across studies.[75] These insights highlight early life as a critical window for primary prevention.

However, these individual risk factors do not operate in isolation but are deeply embedded within broader social determinants of health. For example, parental income and education influence health literacy, food security, and diet quality, while policy measures, such as student physical health standards and taxation, shape access to a healthy school and food environment. Expert insights suggested that a holistic, multi-level strategy addressing not only individual and family behaviors but also school, community, social, and policy environments was essential for effective childhood obesity prevention.

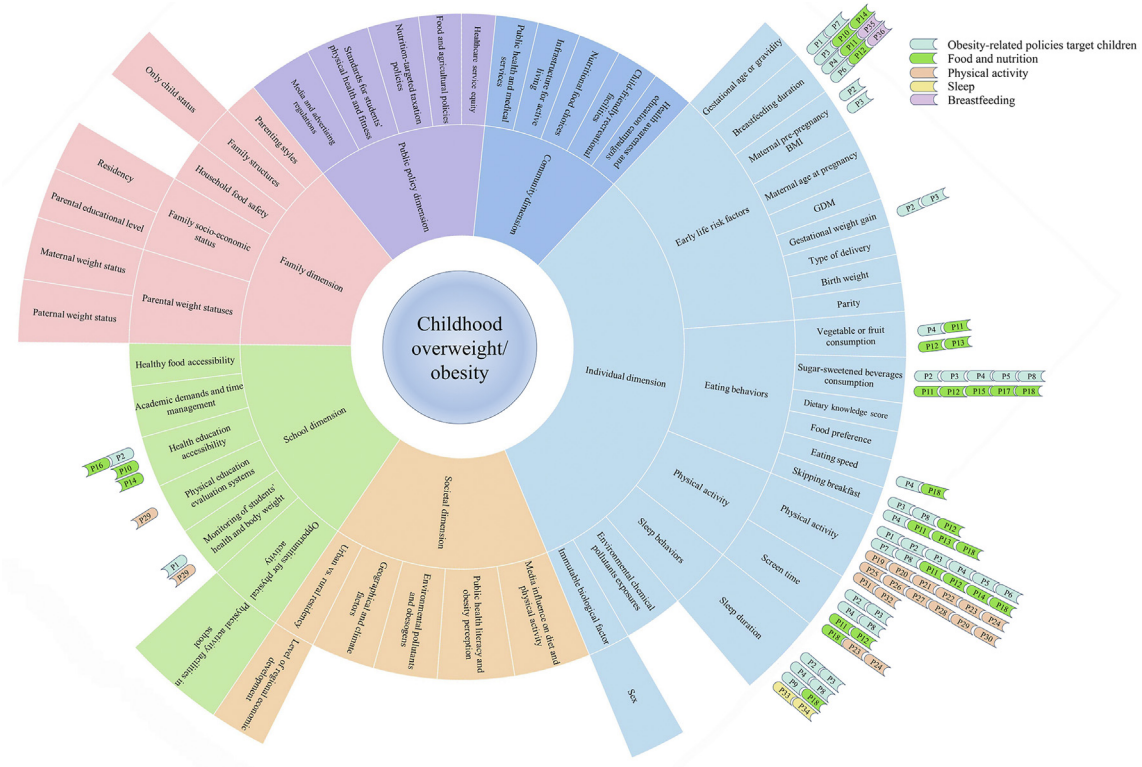


Fig. 5: Overview of policies addressing key factors of childhood overweight/obesity in China. The innermost layer illustrates the dimensions of childhood overweight/obesity as defined by the SEM, followed by a second layer that specifies related factors. The third layer depicts risk factors as determined by meta-analysis, aligned with the SEM dimensions and factors. The outermost layer outlines the nationwide policies addressing these risk factors. SEM, Social-ecological Model. P1: Action Plan for Healthy Children (2018). P2: Implementation Plan for Prevention and Control of Obesity in Children and Adolescents (2020), P3: Guidelines for Prevention and Control of Overweight and Obesity in Chinese Children (2021), P4: Guidelines for Evaluation, Treatment, and Prevention of Childhood Obesity in China (2021), P5: Opinions on Comprehensively Strengthening and Improving School Health and Hygiene Education in the New Era (2021), P6: Enhanced Action Plan for Healthy Children (2021), P7: The Outline on the Development of Chinese Children (2021–2030) (2021), P8: Technical Guidelines for Comprehensive Prevention and Control of Overweight and Obesity in Primary and Secondary School Students (2024), P9: Opinions of the State Council Leading Group on Juvenile Protection on Strengthening the Protection of Minors (2021). P10: Outline of Food and Nutrition Development in China (2014), P11: Dietary Guidelines for Chinese Residents (2016), P12: Dietary Guidelines for Chinese Residents (2022), P13: Nutrition Guidelines of School Meals (2017), P14: National Nutrition Plan (2017), P15: Chinese Children and Adolescent Snacks Guide (2018), P16: School Food Safety and Nutrition and Health Management Regulations (2019), P17: China's Oral Health Action Plan (2019–2025) (2019), P18: Dietary Guidelines for Obesity in Children and Adolescents (2024), P19: Opinions on Strengthening School Physical Education for the Holistic Development of Students' Physical and Mental Health (2016), P20: National Fitness Program (2016), P21: National Fitness Program (2021), P22: Implementation of the Youth Sports Promotion Plan (2017), P23: Physical Activity Guideline for Chinese Preschoolers Aged 3–6 (2018), P24: Physical Activity Guideline for Chinese Children and Adolescents (2018), P25: Notice of State Council General Office on the Distribution of the Outline for Developing a Strong Sporting Nation (2019), P26: Opinions on Comprehensively Strengthening and Improving School Physical Education in the New Era (2020), P27: Opinions on Deepening the Integration of Sports and Education to Promote the Healthy Development of Adolescents (2020), P28: The "14th Five - Year Plan" for Sports Development (2021), P29: Notice on Further Strengthening the Physical Fitness Management among Primary and Secondary School Students (2021), P30: Working Regulation of School Physical Education (2022), P31: Law of the People's Republic of China on Sports (2023), P32: Chinese Expert Consensus on Exercise Prescription (2023), P33: Guideline for Sleep Hygiene among Children Aged 0–5 (2017), P34: Notice on Strengthening Sleep Management among Primary and Secondary School Students (2021), P35: Guideline for Breastfeeding Promotion Strategies (2018), P36: Action Plan Promoting Breastfeeding (2021).

Differences between findings of meta-analysis and expert consultation

The integration of meta-analysis and expert consultations offered complementary insights into childhood obesity risk factors. Meta-analysis quantified population-level associations, such as early puberty (OR = 2.48) and only-child status (OR = 1.29), reflecting biological factors and socio-cultural contexts. In contrast, expert consultations prioritized modifiable factors and intervention-relevant factors (e.g., dietary habits, screen time).

While 12 of the 15 risk factors overlapped, their differing rankings illustrated the complexity of

childhood obesity. Genetic factors, accounting for 40%–70% of BMI variability,[77] which experts emphasized were underrepresented in the meta-analysis due to study heterogeneity. However, our meta-analysis indirectly supported this through early puberty, often associated with specific genetic loci.[78,79] Similarly, the only-child status, a unique outcome of China's One-Child Policy, emerged as a socio-cultural driver of obesity. Termed the "little emperor" syndrome, this phenomenon reflected familial overnutrition as a form of parental affection-an aspect less emphasized by the experts but critical for understanding China's obesity landscape.[80,81]

These discrepancies highlighted the strengths of both approaches. Meta-analysis uncovered and quantified population-level trends shaped by structural factors, while expert consultations distilled actionable priorities. By integrating quantitative and qualitative perspectives, we could develop evidence-based strategies that target macro-level drivers (e.g., sociocultural norms, taxation policies, physical education standards) alongside modifiable behaviors (e.g., feeding practice, dietary choices, physical activity). For example, improving student fitness standards and increasing funding for school sports could enhance children's physical activity levels and contribute to obesity prevention.

Policy gaps and recommendations for childhood obesity prevention and control in China

Integrating findings from meta-analysis and expert consultations enabled a comprehensive assessment of China's ongoing strategies against childhood obesity and pinpointed policy deficiencies. Despite advancements and interdepartmental efforts, critical gaps persisted. First, current policies lack enforceability and are predominantly advisory without a legal mandate, which undermines accountability in obesity prevention. Second, an undue focus on individual behavioral changes–such as diet, physical activity, and screen time, overlooks the importance of societal and environmental support for sustainable lifestyle modifications.[42,82] Third, early-life intervention strategies are fragmented and lack a cohesive approach to mitigate these risks from the outset. Although policies promote actions like breastfeeding, they often overly rely on public health education without encompassing broader, actionable interventions.[83] Fourth, there is a notable deficiency in data-driven decision-making due to limited comprehensive and longitudinal research,[4,84] which hampers the development of effective policies. Fifth, public health communication strategies inadequately address the diversity of socioeconomic, ethnic, and rural considerations, failing to engage all population segments effectively. The involvement of the media and private sector in obesity discussions often complicates public communication due to their potential lack of professional expertise and intent to profit from the issue. Moreover, current policies remain overly generic and fail to address the unique needs of diverse populations, ultimately hindering progress toward equitable health outcomes.

To address these challenges, we propose the following recommendations.

1) Strengthen the legal and regulatory framework by establishing a government-led coordination group with sector-specific duties as endorsed by the WHO[85] and the UK,[86] enhancing enforcement of existing laws, implementing fiscal policies like taxing unhealthy foods and restricting child-targeted marketing,[87,88] and mandating comprehensive nutrition labeling on children's foods to promote transparency.[89]
2) Promote a health-supportive environment by improving community infrastructure that would encourage physical activity (e.g., footpaths, bicycle lanes, public sports facilities), integrating health education into school curricula alongside nutrition and physical activity programs, ensuring availability and affordability of healthy food options, and supporting families in modeling and fostering healthy behaviors in children.[4]
3) Focus on early-life interventions by integrating obesity prevention into the antenatal care framework,[85] revitalizing the Baby-Friendly Hospital Initiative for breastfeeding promotion as a critical measure in obesity prevention,[90] and providing targeted education on the hazardous impacts associated with high pre-pregnancy BMI, excessive GWG, and GDM, and the benefits of breastfeeding.[91,92] Also, target multiple early-life risk factors at the same time, given the known cumulative effect of these risk factors on child obesity.[93]
4) Commit to data-driven policies through the refinement of monitoring systems for data compatibility,[94] ensuring timely data dissemination to inform policy adjustments and public health practices,[42] fostering interdisciplinary research networks, supporting research on etiology and prevention, and organizing conferences to encourage interdisciplinary academic dialogue and stimulate innovative thinking.
5) Enhance public health communication strategies by developing coordinated messages tailored to diverse populations and strengthening partnerships with media, the private sector, and social organizations to maximize the reach and impact of health campaigns.[4]
6) Promote health equity, childhood obesity policies should be tailored to meet the specific needs of diverse populations through targeted interventions and equitable resource allocation and support vulnerable groups. Engaging stakeholders across healthcare, education, industrial and community

sectors is essential to ensuring relevance and effectiveness. Some specific measures for future actions were presented in Table 3.

Strengths and limitations

This study has several strengths. Firstly, it represented the first comprehensive investigation with literature search and expert consultation to examine the multifactorial contributors to childhood obesity in China. Secondly, its novel incorporation of pooled OR and PAR % not only revealed consistent obesogenic factors but also quantified the impact of various factors, highlighting those with the greatest potential for mitigating obesity prevalence.[95,96] Additionally, our policy review filled a critical gap in existing interventional frameworks, guiding the refinement of targeted policy recommendations.

However, there are limitations. The reliance on BMI and weight-to-height ratio (or some others) as indicators of obesity, due to the unavailability of more precise methods, limited our capacity to dissect their roles on adiposity proportion and distribution. The predominance of observational studies, particularly cross-sectional designs, limited causal inference due to potential residual confounding.[97] While we employed DAG to map major risk factor–outcome pathways and conducted sensitivity analyses on high-quality studies, confirming the robustness of our conclusions, caution remains warranted when interpreting interventions' effectiveness. Additionally, the absence of prevalence data for certain risk factors limited the calculation of PAR% for some variables, suggesting a gap in comprehensive risk factor measurement in existing studies. Recognizing that prevalence rates evolve over

Policy gaps	Policy recommendations	Specific measures
1. Insufficient enforcement mechanism	1. Establish a comprehensive legal and regulation system	a Form a government-led coordination group: create a central coordination group with clear responsibilities for different sectors, as recommended by WHO[85] and UK.[86] b Enhance enforcement: develop and enforce laws and regulations that strengthen existing policies. c Implement fiscal measures such as introduce taxes on unhealthy foods and beverages, and restrict unethical marketing strategies targeting children. d Promote nutritional transparency: mandate clear and comprehensive nutrition labeling on children's food.
2. Over-reliance on individual responsibility	2. Develop supportive health environments	a Community-dimension initiatives: enhance community infrastructure to promote physical activity, such as footpaths, bicycle lanes, and public sports facilities. b School-dimension strategies: intergrade health education into school curricula and promote nutrition and physical activities programs, and ensure healthy food provision at school. c Family-dimension support: encourage families to model healthy behaviors and environment to support and enable the development of healthy habit in children.
3. Lack of holistic policy on addressing early-life risk factors	3. Focus on early life opportunities	a Integrate obesity prevention into antenatal care: Leverage China's Three-tiered Maternal and Child Health Framework to incorporate obesity prevention and management services into pre-conception and antenatal programs.[85] b Revitalize the Baby-Friendly Hospital Initiative (BFHI): strengthen BFHI by promoting breastfeeding as a key obesity prevention measure. Successful initiation of breastfeeding in hospitals is crucial for achieving exclusive breastfeeding for at least six months.[90] c Educate on early-life factors: provide targeted health education for pregnant women and families on the hazardous impacts of excessive pre-pregnancy BMI, excessive GWG, and GDM, as well as the long-term benefits of breastfeeding.[91,92]
4. Lack of data-driven decision-making	4. Enhance childhood obesity monitoring and data use and promote interdisciplinary research and collaboration	a Improve monitoring systems: continuously update monitoring methods[94] and establish a standardized platform for data compatibility and exchange. b Disseminate data effectively: ensure timely dissemination of data and findings to the public and key stakeholders, such as government agencies, legislators, public health organizations, healthcare providers, and community leaders, to inform evidence-based policy changes and improve public health practices. c Establish research platforms: create interdisciplinary research networks to enhance collaboration and address complex obesity issue. d Support collaborative proposals: fund research proposals that explore the causes, intervention effectiveness, and innovative strategies for preventing and treating childhood obesity. e Facilitate academic events: organize regular conferences and seminars to foster interdisciplinary academic dialogue and stimulate innovative thinking.
5. Inadequate public health communication and campaigns	5. Improve public health communication	a Develop effective and coordinated public health communication strategies. Ensure that public health messages are accessible and tailored to diverse socioeconomic, racial, and geographical contexts. b Strengthen collaborations with mass media, private sector, and activist groups to enhance the reach and impact of public health campaigns.
6. Fail to address the unique needs of diverse populations	6. Promote health equity	a Tailor childhood obesity policies to meet the specific needs of diverse populations through targeted interventions and equitable resource allocation. b Engage stakeholders across healthcare, education, industrial and community sectors to ensure the relevance and effectiveness.

WHO, World Health Organization; UK, the United Kingdom; BFHI, Baby-Friendly Hospital Initiative; BMI, Body Mass Index; GWG, Gestational Weight Gain; GDM, Gestational Diabetes Mellitus.

Table 3: **The policy gaps and recommendations for addressing childhood overweight/obesity in China.**

time, we advocate for national surveys to refine future PAR% calculations, capture a broader range of obesity-related factors, and explore their complex interactions in greater depth.

Conclusion

This study identified key risk factors contributing to childhood obesity in China and emphasized the need to prioritize high-risk populations and address modifiable behaviors. For meaningful real-world impact, interventions must extend beyond individual behavioral changes and adopt a system-wide approach. This requires integrating school, community, societal, and policy-level interventions, with a government-led framework that bridges health, education, food industry, and policy sectors. Urgently, coordinated actions are needed to curb this epidemic and safeguard future generations. Continuing research is critical to deepening our understanding of obesity risk factors, refining interventions, and guiding future policy improvement.

Contributors

YF J, JJ H, and FY CH contributed equally as co-first authors. YF W and JD ZH conceptualized the study and developed the protocol. YF J, JJ H, and FY CH designed the search strategy and conducted the literature search. YF J, FY CH, BR L, and MN W performed data screen and extraction. YF J, FY CH, and BR L assessed data quality. YF J, FY CH and WQ X conducted data analysis. JJ H and JD ZH provided expert supervision during data extraction and analysis. YF J, FY CH, JJ H and MN W drafted the initial manuscript. YK Y, JC X, SF D, XY T, I. M. Aris, YF W, and JD ZH critically revised the manuscript for important intellectual content and supervised data interpretation. All authors had full access to the data and shared final responsibility for the decision to submit for publication.

Data sharing statement

Data are available at request from the correspondence authors, and some are included in the appendix.

Declaration of interests

We 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.2025.101553.

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