FACTORS ASSOCIATED WITH UNDERWEIGHT, OVERWEIGHT AND OBESITY AMONG SCHOOL-AGE CHILDREN IN A HIGH-ALTITUDE REGION OF CHINA

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Abstract. Childhood undernutrition and overnutrition are major public health problems among school-age children in high-altitude multi-ethnic regions of the People's Republic of China. In this study, we aimed to determine factors independently associated with underweight, overweight and obesity among school-age children in Qinghai Province, a high-altitude multi-ethnic region of western China, in order to inform efforts to prevent these conditions. The students were chosen by multi-stage stratified cluster random sampling. One primary school from each city or prefecture was selected and then one class per grade (grades 1-6) was selected from each study school and the parents of all the students in that class were invited to participate in the study. Inclusion criteria for the students were enrollment in a selected class, being aged 7-12 years, being a resident of Qinghai Province for at least 3 years prior to the study, having parents able to communicate in the survey language and being willing to participate in the study. Exclusion criteria for the students were not meeting inclusion criteria, being hospitalized during the previous month, having a chronic disease that could affect their weight, currently taking glucocorticoids and having a major weight change prior to the study. The minimum number of students calculated to be needed for the study was 807. Study subjects were a parent from each student invited to participate. A parent of each student was asked to complete a self-administered questionnaire asking about demographic factors, socioeconomic status of the family, student early-life factors, student diet, student lifestyle (outdoor physical activity, electronic device use and sleep duration), parental knowledge and attitudes about nutrition and parental behaviors (parental perception of the student subject's body-size category, parental use of food as a reward, parental restriction of snacks, parental physical exercise habits and joint parent-child exercise). Parental knowledge about nutrition was assessed with 10 questions on the questionnaire. A correct answer was given one point

and an incorrect answer was given 0 point. The total possible score had a range of 0-10. A higher score indicated better parental nutritional knowledge. Parental attitudes about balanced nutrition were assessed using 11 questions answered using a 5-point Likert scale (each question had a score from 0 (disagreement with the statement) to 4 points (completely agreed with the statement) giving a total possible score of 0-44 points, with a higher score indicating more favorable parental attitudes. We measured each student's height, weight and waist and hip circumferences. Body mass index (BMI) was calculated as weight (in kg) / height (in m^2). Subjects were classified into four weight-status categories using age- and sex-specific cut-off points obtained from International Obesity Task Force criteria for underweight and Working Group on Obesity in China criteria for overweight and obesity. The underweight, normal weight, overweight and obese criteria for boys aged 7, 8, 9, 10, 11 and 12 years were ≤13.9, 14.0-17.3, 17.4-19.1, ≥19.2; ≤14.0, 14.1-18.0, 18.1-20.2, ≥20.3; ≤14.1, 14.2-18.8, 18.9-21.3, ≥21.4; ≤14.4, 14.5-19.5, 19.6-22.4, ≥22.5; ≤14.9, 15.0-20.2, 20.3-23.5, ≥23.6; and ≤15.4, 15.5-20.9, 21.0-24.6, ≥24.7 kg/m^2, respectively; and for girls of the same ages were ≤13.4, 13.5-17.1, 17.2-18.8, ≥18.9; ≤13.6, 13.7-18.0, 18.1-19.8, ≥19.9; ≤13.8, 13.9-18.9, 19.0-20.9, ≥21.0; ≤14.0, 14.1-19.9, 20.0-22.0, ≥22.1; ≤14.3, 14.4-21.0, 21.1-23.2, ≥23.3; and ≤14.7, 14.8-21.8, 21.9-24.4, ≥24.5 kg/m^2, respectively. The study was conducted during September 2021-October 2022. We used univariate and multivariate logistic regression analysis to identify factors significantly associated with underweight, overweight and obesity and the results are expressed as odds ratios (ORs) with 95% confidence intervals (CI). A total of 1,561 student subjects were included in our study: 52.0% (n = 811) females. The mean (±standard deviation (SD)) age of student subjects was 9.2 (±1.7) years. 279 student subjects (17.9%) were underweight, 1,065 (68.2%) had a normal weight, 122 (7.8%) were overweight and 95 (6.1%) were obese. On multivariate analysis variables significantly associated with higher odds of the student subject being underweight were student subject male sex (aOR: 1.61; 95%CI: 1.22-2.12, p-value <0.001) and having a higher parental subject nutrition-related attitude score (for each 1-point increase in the score there was an increase in the aOR of 1.04; 95%CI: 1.02-1.07, p-value = 0.002). The factors significantly associated with lower odds of the student subject being underweight were: having been born by cesarean section (versus vaginal delivery; aOR: 0.58; 95%CI: 0.40-0.85, p-value = 0.005), having a parental subject perception of the student subject being in a higher BMI class than the student

subject's actual BMI class (for each higher BMI class than the actual student subject class the aOR decreased by 0.62; 95%CI: 0.49-0.78, *p*-value <0.001), more frequent parental physical exercise (for each one-level increase on the 4-level exercise scale the aOR decreased by 0.68; 95%CI: 0.54-0.87, *p*-value = 0.002) and more frequent parent-child joint exercise (for each one-level increase on the 4-level exercise scale the aOR decreased by 0.72; 95%CI: 0.52-0.98, *p*-value = 0.039). The variables significantly associated with higher odds of the student subject being overweight (versus normal weight) were the student subject having been born by cesarean section (aOR: 1.80; 95%CI: 1.12-2.89, *p*-value = 0.015) and having a parental subject perception of the student subject being in a higher BMI category than the actual category (for each category higher than the actual category the aOR increased by 2.24; 95%CI: 1.72-2.92, *p*-value <0.001). The variables significantly associated with lower odds of the student subject being overweight were older student subject age (for every 1-year increase in the student subject age the aOR decreased by: 0.87; 95%CI: 0.76-0.98, *p*-value = 0.028), having a higher parental subject nutrition-related attitude score (for every 1-point increase in the score the aOR decreased by: 0.95; 95%CI: 0.92-0.98, *p*-value = 0.002) and more frequent parental physical exercise (for each one-level increase on the 4-level exercise scale the aOR decreased by 0.64; 95%CI: 0.46-0.89, *p*-value = 0.009). The factor significantly associated with higher odds of student subject obesity (versus normal weight), was having a parental subject perception of the student subject being in a higher BMI category than the actual BMI category (for each higher BMI category than the actual category the aOR increased by 1.83; 95%CI: 1.36-2.47, *p*-value <0.001). The factors significantly associated with lower odds of student subject obesity were older student subject age (for every 1-year increase in age the aOR decreased by: 0.71; 95%CI: 0.62-0.83, *p*-value <0.001) and more frequent parental physical exercise (for each one-level increase on the 4-level exercise scale the aOR decreased by 0.45; 95%CI: 0.29-0.70, *p*-value <0.001). In summary, factors significantly associated with greater odds of the student subject being underweight were student subject male sex and having a higher parental subject nutrition-related attitude score and with lower odds of being underweight were being born by cesarean section and having a parental subject perception of the student subject being in a higher BMI class than the actual BMI class, more frequent parental physical exercise, and more frequent parent-child joint exercise. Factors significantly associated with higher odds of student subject being overweight were

having been born by cesarean section and a parental subject perception of the student subject being in a higher BMI class than the actual BMI class and with lower odds of being overweight were older student subject age, higher parental subject nutrition-related attitude score and more frequent parental physical exercise. The factor significantly associated with higher odds of student subject obesity was having a parental subject perception of the student subject being in a higher BMI class than the actual BMI class and lower odds of obesity were older student subject age and more frequent parental physical exercise. We conclude, there is a need for education of study students and their parents regarding exercise and whether the student's weight was normal or not. Further studies are needed to determine how to improve both student and parental attitudes about exercise and nutrition.

Keywords: childhood underweight, overweight, obesity, factor analysis, high-altitude

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INTRODUCTION

Childhood malnutrition, encompassing both undernutrition (underweight) and overnutrition (overweight and obesity), is a major public health problem worldwide. Globally, the age-standardized prevalence of obesity among school-aged children and adolescents aged 5-19 years increased approximately four-fold between 1990 and 2022, rising from 1.7% to 6.9% in girls and from 2.1% to 9.3% in boys, with Asia accounting for a substantial proportion of this burden (NCD-RisC, 2024). In China, the prevalence of overweight and obesity among children and adolescents aged 7-18 years rose steadily from 0.1% in 1985 to 8.25% in 2019 (Song *et al*, 2024), while underweight remains a concern in socioeconomically disadvantaged western and high-

altitude regions, consistent with the persistent burden of undernutrition seen across low- and middle-income countries (Song *et al*, 2024; Victora *et al*, 2021; Zhang *et al*, 2021).

Childhood malnutrition can develop by genetic, environmental and behavioral factors (Yuan *et al*, 2024). Family-related characteristics, such as parental feeding behavior, parenting styles and the home environment, can contribute to childhood obesity (Ayine *et al*, 2020; Shloim *et al*, 2015). Parental misperception of child body size, use of food as a reward and limited physical activity are all linked to obesity (Ayine *et al*, 2020; Xiang *et al*, 2021). A study from China of preschoolers found more than 60% of caregivers underestimated the weight status of overweight and obese children (Tang *et al*, 2018). Early-life factors, such as the method of delivery and infant feeding also influence later weight, with cesarean delivery being associated with a greater risk of childhood overweight and obesity (Liang *et al*, 2017). Factors associated with childhood underweight are less well studied and studies regarding the effect of socioeconomic factors, such as household income, on childhood weight have yielded inconsistent results (Luo *et al*, 2023).

Qinghai Province, located on the northeastern Qinghai-Tibet Plateau, has a distinctive plateau climate and is home to Tibetan, Hui, and Tu ethnic minorities with diverse dietary habits (Huang *et al*, 2020; Li *et al*, 2023). Previous studies have reported a lower prevalence of overweight and obesity in this province among Tibetan children compared with the national average but a higher prevalence of underweight (Du *et al*, 2022; Zhang *et al*, 2021). There have been economic and lifestyle changes in western China which could affect nutrition levels in this province.

In this study, we aimed to determine factors independently associated with underweight, overweight and obesity among school-age children in Qinghai

Province, a high-altitude multi-ethnic region in western China, in order to inform efforts to prevent these conditions.

MATERIALS AND METHODS

Study subjects

We used multi-stage stratified cluster random sampling to select study subjects. Six cities or prefectures in Qinghai Province were purposively selected as study sites: Xining, Haidong, Hainan Tibetan Autonomous Prefecture, Haixi Mongol and Tibetan Autonomous Prefecture, Huangnan Tibetan Autonomous Prefecture, and Golog Tibetan Autonomous Prefecture. A primary school was randomly selected from each city or prefecture. At each school a class was randomly selected from each of grades 1 through 6. All the students in each selected class and their parents were invited to participate in the study.

Inclusion and exclusion criteria

Inclusion criteria for study subjects were being in the selected class, being aged 7-12 years, residing in the study province for at least 3 years in the period prior to the study, having parents who could understand the language of the survey and being able to communicate in that language and being willing to participate in the study. Exclusion criteria for study subjects were not meeting inclusion criteria, being hospitalized during the previous month, having a chronic disease that could affect their weight, currently taking a glucocorticoid, and having a major weight change prior to the study.

Sample size calculation

The minimum number of subjects needed for the study was calculated assuming an underweight prevalence of 12%, a relative error of 10% and a significance level of $\alpha = 0.05$. This gave a minimum calculated number of study subjects of 734. The sample size was increased by 10% to account for missing or incorrect data, giving a total of 807 subjects required for the study.

Assessment of weight status

Height, weight, waist circumference and hip circumference were measured for each study subject. Body mass index (BMI) was calculated using the formula: BMI = weight (kg) / height^2 (m^2). Subjects were then classified using age- and sex-specific BMI cut-off points.

Underweight was defined as a BMI ≤13.9, ≤14.0, ≤14.1, ≤14.4, ≤14.9 and ≤15.4 kg/m^2 for boys aged 7, 8, 9, 10, 11 and 12 years, respectively; and ≤13.4, ≤13.6, ≤13.8, ≤14.0, ≤14.3 and ≤14.7 kg/m^2 for girls aged 7, 8, 9, 10, 11 and 12 years, respectively (Cole *et al*, 2007).

Normal weight was defined as a BMI 14.0-17.3, 14.1-18.0, 14.2-18.8, 14.5-19.5, 15.0-20.2 and 15.5-20.9 kg/m² for boys aged 7, 8, 9, 10, 11 and 12 years, respectively; and 13.5-17.1, 13.7-18.0, 13.9-18.9, 14.1-19.9, 14.4-21.0 and 14.8-21.8 kg/m² for girls aged 7, 8, 9, 10, 11 and 12 years, respectively.

Overweight was defined as a BMI 17.4-19.1, 18.1-20.2, 18.9-21.3, 19.6-22.4, 20.3-23.5 and 21.0-24.6 kg/m² for boys aged 7, 8, 9, 10, 11 and 12 years, respectively; and 17.2-18.8, 18.1-19.8, 19.0-20.9, 20.0-22.0, 21.1-23.2 and 21.9-24.4 kg/m² for girls aged 7, 8, 9, 10, 11 and 12 years, respectively.

Obesity was defined as ≥19.2, ≥20.3, ≥21.4, ≥22.5, ≥23.6 and ≥24.7 kg/m^2 for boys aged 7, 8, 9, 10, 11 and 12 years, respectively; and ≥18.9, ≥19.9, ≥21.0, ≥22.1, ≥23.3 and ≥24.5 kg/m^2 for girls aged 7, 8, 9, 10, 11 and 12 years, respectively. These cut-offs are based on the Chinese national BMI reference developed by the Working Group on Obesity for China (Ji, 2005).

Assessment of factors potentially associated with an abnormal BMI

Data were collected between September 2021 and October 2022. Members of the research team and the class teachers first explained the purpose of the study and the instructions for completing the questionnaire to the parents of all eligible children. The questionnaire was completed by one of the parents on behalf of the child; the children

themselves did not complete any part of the questionnaire. For parents who were able to use electronic devices, an electronic version of the questionnaire was distributed and submitted online. For parents who were not familiar with electronic questionnaires, the questionnaire was completed through a face-to-face interview conducted by a trained member of the research team.

Data were collected using a structured questionnaire comprised of parts: subject factors and parental factors. The factors assessed were divided into seven categories: demographic characteristics, socioeconomic factors, early-life factors, dietary factors, lifestyle factors, parental nutrition-related knowledge and attitudes, and parental factors.

Demographic characteristics collected were subject age, sex, region, ethnicity, and household registration type (hukou status, categorized as agricultural/rural or non-agricultural/urban under China's household registration system, which historically determines access to public services such as education and health care in a person's place of registration).

The socioeconomic factor assessed was annual household income.

Early-life factors were delivery method (vaginal or cesarean section), birth weight and infant feeding method (exclusive breastfed, mixed feeding, or formula fed).

Dietary factors were whether or not the subject ate breakfast, frequency of eating breakfast, how regular meal consumption was and preferences about food.

Lifestyle factors were outdoor physical activity, electronic device use, and sleep duration.

Parental nutrition-related knowledge and attitudes were assessed using a pre-tested instrument with a knowledge component and an attitude component. The knowledge component consisted of 10 binary

items covering recognition of obesity definitions, causes, and consequences, as well as identification of energy-dense, fat-rich, sugar-rich, and vitamin-rich foods; each item was scored 0 (incorrect) or 1 (correct), giving a total knowledge score of 0 to 10, with higher scores indicating better parental nutritional knowledge. The attitude component consisted of 11 items rated on a 5-point Likert scale (0 = strongly disagree, 1 = disagree, 2 = neither agree nor disagree, 3 = agree, 4 = strongly agree), giving a total attitude score of 0 to 44, with higher scores indicating more favorable parental attitudes toward balanced nutrition (*eg,* agreement that breakfast is important, that diversified diets are needed, and that excessive snacking should be avoided). Both scores were analyzed per 1-point increase.

Parental factors were parental perception of child's body size category (underweight, normal weight, overweight or obese), parental use of food as a reward, parental restriction of snacks, parental physical exercise habits and parent-child joint exercise. Parental physical exercise habits, parent-child joint exercise, parental use of food as a reward and parental restriction of snacks were all reported by the parent using the following 4-level scale: 1 = never (0 times/week), 2 = sometimes (1-2 times/week), 3 = often (3-4 times/week), and 4 = always (≥5 times/week). Based on this, the numbers 1 to 4, where appropriate, were used in the regression model, and the corresponding adjusted odds ratio (aOR) represents the change in odds per one-level increase on this scale (*eg,* from never to sometimes). The aOR represents the change in odds per one-category increase. Among these, parental perception of the child's body size, parental use of food as a reward, and parental restriction of snacks were assessed using items adapted from the Child Feeding Questionnaire and the Comprehensive Feeding Practices Questionnaire (Birch *et al,* 2001; Musher-Eizenman and Holub, 2007; Xiang *et al,* 2021).

Statistical analysis

Continuous variables with normal distribution are expressed as means (±standard deviations (±SD)). Categorical variables are expressed as frequencies and percentages. The assessed factors were compared by the weight-status group (underweight, normal weight, overweight and obesity). Between-group differences in continuous variables were assessed using one-way analysis of variance (ANOVA) and between-group differences by categorical variable were assessed using chi-square ($\chi 2$) tests.

We used univariate multinomial logistic regression analysis to assess the crude association between each potential associated factor and the odds of being classified as underweight, overweight or obesity relative to normal weight (reference group). Variables with a *p*-value <0.20 for any of the three contrasts (underweight vs normal, overweight vs normal and obese vs normal) on univariate analysis were entered into the multivariable multinomial logistic regression model to identify factors independently associated with each abnormal weight category. The results of the analyses are expressed as aORs with 95% confidence intervals (CIs). Ordinal categorical variables (such as income level, parental perception of body type, and the 4-point Likert-scale parental behavior items) were assessed as continuous for the purposes of regression modeling, so each aOR represents the change in odds per one-level increase. To address multicollinearity, Pearson's correlation coefficients were calculated by candidate feature and redundant features with an absolute correlation coefficient >0.8 were removed prior to multivariable modeling.

All statistical analyses were performed using R statistical software (version 4.5.3; R Foundation for Statistical Computing, Vienna, Austria) available at https://www.R-project.org/. All hypothesis tests were two-sided and a *p*-value <0.05 was considered statistically significant.

Ethical consideration

This study was reviewed and approved by the Ethics Committee of Qinghai University Medical College (Approval No. PJ202401-04). This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Written informed consent was obtained from the parents of all study subjects prior to data collection.

RESULTS

A total of 1,561 subjects were included in the study; 52.0% (*n* = 811) females. 279 subjects (17.9%) were underweight, 1,065 (68.2%) were normal weight, 122 (7.8%) were overweight and 95 (6.1%) were obese (Table 1). The mean (±SD) age of study subjects was 9.2 (±1.7) years. The mean ages of study subjects differed significantly by size category (*p*-value <0.001). Obese subjects had the lowest mean (±SD) age (8.5 ± 1.4 years), followed by underweight subjects (9.15 ± 1.74 years), normal weight subjects (9.23 ± 1.68 years) and overweight subjects (9.02 ± 1.66 years).

The distribution of sex differed significantly across the four weight-status groups (*p*-value = 0.004). In the underweight group, significantly more boys (*n* = 161, 57.7%) than girls (*n* = 118, 42.3%) were underweight (*p*-value = 0.010). In the normal weight group, girls accounted for the majority (*n* = 577, 54.2%) compared to boys (*n* = 488, 45.8%) (*p*-value = 0.006). No significant differences in sex distribution were observed in the overweight group (*p*-value = 0.717) or the obesity group (*p*-value = 0.259).

The delivery method differed significantly (*p*-value = 0.004) among the four groups. The highest proportion of cesarean section births was observed in the overweight group (*n* = 36, 29.5%), followed by the normal weight group (*n* = 223, 20.9%), the underweight group (*n* = 45, 16.1%), and the obesity group (*n* = 12, 12.6%).

The type of infant feeding

Table 1

Baseline characteristics of study subjects by weight status

Variable	Overall (N = 1,561)	Underweight (N = 279)	Normal weight (N = 1,065)	Overweight (N = 122)	Obesity (N = 95)	*p*-value
Demographic characteristics						
Age (years), mean ± SD	9.15 ± 1.68	9.15 ± 1.74	9.23 ± 1.68	9.02 ± 1.66	8.45 ± 1.41	<0.001
Sex, *n* (%)						0.004
Female	811 (52.0)	118 (42.3)	577 (54.2)	*63 (51.6)*	53 (55.8)	
Male	750 (48.0)	161 (57.7)	488 (45.8)	59 (48.4)	42 (44.2)	
Socioeconomic factors						
Annual household income, *n* (%)						0.956
<RMB 50,000	615 (39.4)	114 (40.9)	414 (38.9)	54 (44.3)	33 (34.7)	
RMB 50,000–100,000	500 (32.0)	87 (31.2)	341 (32.0)	36 (29.5)	36 (37.9)	
RMB 100,001–200,000	265 (17.0)	47 (16.8)	187 (17.6)	*16 (13.1)*	15 (15.8)	
RMB 200,001–300,000	122 (7.8)	21 (7.5)	82 (7.7)	*12 (9.8)*	7 (7.4)	
>RMB 300,000	59 (3.8)	10 (3.6)	41 (3.8)	4 (3.3)	4 (4.2)	

Table 1 (cont)

Variable	Overall (N = 1,561)	Underweight (N = 279)	Normal weight (N = 1,065)	Overweight (N = 122)	Obesity (N = 95)	*p*-value
Early-life factors						
Delivery mode, *n* (%)						0.004
Vaginal	1,245 (79.8)	234 (83.9)	842 (79.1)	86 (70.5)	83 (87.4)	
Cesarean section	316 (20.2)	45 (16.1)	223 (20.9)	36 (29.5)	12 (12.6)	
Birth weight, *n* (%)						0.6
2,500-4,000 g	879 (56.3)	154 (55.2)	605 (56.8)	68 (55.7)	52 (54.7)	
<2,500 g	379 (24.3)	73 (26.2)	261 (24.5)	24 (19.7)	21 (22.1)	
>4,000 g	303 (19.4)	52 (18.6)	199 (18.7)	30 (24.6)	22 (23.2)	
Infant feeding method, *n* (%)						0.03
Exclusive breastfeeding	761 (48.7)	125 (44.8)	513 (48.2)	*66 (54.1)*	57 (60.0)	
Mixed feeding	591 (37.9)	124 (44.4)	401 (37.6)	*37 (30.3)*	29 (30.5)	
Formula feeding	209 (13.4)	30 (10.8)	151 (14.2)	19 (15.6)	9 (9.5)	

Table 1 (cont)

Variable	Overall (N = 1,561)	Underweight (N = 279)	Normal weight (N = 1,065)	Overweight (N = 122)	Obesity (N = 95)	*p*-value
Dietary behaviors						
Breakfast intake, *n* (%)						0.003
Yes	1,508 (96.6)	273 (97.8)	1,031 (96.8)	*111 (91.0)*	93 (97.9)	
No	53 (3.4)	6 (2.2)	34 (3.2)	11 (9.0)	2 (2.1)	
Breakfast frequency, *n* (%)						0.5
<3 times/week	85 (5.4)	14 (5.0)	56 (5.3)	9 (7.4)	6 (6.3)	
3–5 times/week	160 (10.2)	30 (10.8)	103 (9.6)	12 (9.8)	15 (15.8)	
>5 times/week	1,316 (84.4)	235 (84.2)	906 (85.1)	101 (82.8)	74 (77.9)	
Meal regularity, *n* (%)						0.700
Regular	1,399 (89.6)	253 (90.7)	956 (89.8)	107 (87.7)	83 (87.4)	
Irregular	162 (10.4)	26 (9.3)	109 (10.2)	15 (12.3)	12 (12.6)	

Table 1 (cont)

Variable	Overall (N = 1,561)	Underweight (N = 279)	Normal weight (N = 1,065)	Overweight (N = 122)	Obesity (N = 95)	*p*-value
Lifestyle factors						
Outdoor physical activity, *n* (%)	927 (59.4)	159 (57.0)	645 (60.6)	70 (57.4)	53 (55.8)	0.60
Electronic device use, *n* (%)	1,299 (83.2)	230 (82.4)	889 (83.5)	102 (83.6)	78 (82.1)	>0.9
Sleep duration, *n* (%)						0.8
<8 h/day	359 (23.0)	69 (24.7)	238 (22.3)	31 (25.4)	21 (22.1)	
8–10 h/day	1,112 (71.2)	195 (69.9)	767 (72.0)	80 (65.6)	70 (73.7)	
10–12 h/day	75 (4.8)	14 (5.0)	49 (4.6)	9 (7.4)	3 (3.2)	
≥12 h/day	15 (1.0)	1 (0.4)	11 (1.0)	2 (1.6)	1 (1.1)	
Parental knowledge and attitudes						
Parental nutritional knowledge score (0–10), mean ± SD	5.30 ± 1.93	5.49 ± 1.93	5.29 ± 1.90	5.16 ± 2.14	5.14 ± 1.90	0.3
Parental attitude score, mean ± SD	34.57 ± 6.12	35.83 ± 5.70	34.43 ± 6.18	32.55 ± 6.83	35.11 ± 4.80	<0.001

Table 1 (cont)

Variable	Overall (N = 1,561)	Underweight (N = 279)	Normal weight (N = 1,065)	Overweight (N = 122)	Obesity (N = 95)	*p*-value
Parental factors						
Parental perception of child's body type, *n* (%)						<0.001
Underweight	473 (30.3)	131 (47.0)	310 (29.1)	14 (11.5)	18 (18.9)	
Normal	875 (56.1)	124 (44.4)	645 (60.6)	58 (47.5)	48 (50.5)	
Overweight	169 (10.8)	18 (6.4)	77 (7.2)	48 (39.4)	26 (27.4)	
Obese	44 (2.8)	6 (2.2)	33 (3.1)	2 (1.6)	3 (3.2)	
Parental restriction of snacks, *n* (%)						0.711
Never (0 times/week)	158 (10.1)	22 (7.9)	111 (10.5)	15 (12.3)	10 (10.5)	
Sometimes (1-2 times/week)	499 (32.0)	89 (31.9)	345 (32.4)	34 (27.8)	31 (32.6)	
Often (3-4 times/week)	724 (46.4)	133 (47.7)	485 (45.5)	64 (52.5)	42 (44.3)	
Always (≥5 times/week)	180 (11.5)	35 (12.5)	124 (11.6)	9 (7.4)	12 (12.6)	
Parental use of food as reward, *n* (%)						0.004
Never (0 times/week)	549 (35.2)	79 (28.3)	378 (35.4)	52 (42.6)	40 (42.1)	
Sometimes (1-2 times/week)	854 (54.6)	172 (61.6)	579 (54.4)	60 (49.2)	43 (45.3)	
Often (3-4 times/week)	140 (9.0)	25 (9.0)	100 (9.4)	7 (5.7)	8 (8.4)	
Always (≥5 times/week)	18 (1.2)	3 (1.1)	8 (0.8)	3 (2.5)	4 (4.2)	

Table 1 (cont)

Variable	Overall (N = 1,561)	Underweight (N = 279)	Normal weight (N = 1,065)	Overweight (N = 122)	Obesity (N = 95)	*p*-value
Parental physical exercise habit, *n* (%)						<0.001
Never (0 times/week)	80 (5.1)	11 (3.9)	45 (4.2)	14 (11.5)	10 (10.5)	
Sometimes (1-2 times/week)	942 (60.3)	179 (64.2)	620 (58.2)	75 (61.5)	68 (71.6)	
Often (3-4 times/week)	371 (23.8)	63 (22.6)	270 (25.4)	25 (20.5)	13 (13.7)	
Always (≥5 times/week)	168 (10.8)	26 (9.3)	130 (12.2)	8 (6.5)	4 (4.2)	
Parent-child joint exercise, *n* (%)						0.169
Never (0 times/week)	147 (9.4)	17 (6.1)	101 (9.5)	17 (13.9)	12 (12.7)	
Sometimes (1-2 times/week)	1,106 (70.8)	199 (71.4)	750 (70.4)	86 (70.5)	71 (74.7)	
Often (3-4 times/week)	240 (15.4)	47 (16.8)	167 (15.7)	16 (13.1)	10 (10.5)	
Always (≥5 times/week)	68 (4.4)	16 (5.7)	47 (4.4)	3 (2.5)	2 (2.1)	

Underweight: ≤13.9, ≤14.0, ≤14.1, ≤14.4, ≤14.9 and ≤15.4 kg/m² for boys aged 7, 8, 9, 10, 11 and 12 years, respectively; and ≤13.4, ≤13.6, ≤13.8, ≤14.0, ≤14.3 and ≤14.7 kg/m² for girls aged 7, 8, 9, 10, 11 and 12 years, respectively (Cole *et al*, 2007); normal weight: 14.0–17.3, 14.1-18.0, 14.2-18.8, 14.5-19.5, 15.0-20.2 and 15.5-20.9 kg/m² for boys aged 7, 8, 9, 10, 11 and 12 years, respectively; and 13.5-17.1, 13.7-18.0, 13.9-18.9, 14.1-19.9, 14.4-21.0 and 14.8-21.8 kg/m² for girls aged 7, 8, 9, 10, 11 and 12 years, respectively; overweight: 17.4-19.1, 18.1-20.2, 18.9-21.3, 19.6-22.4, 20.3-23.5 and 21.0-24.6 kg/m² for boys aged 7, 8, 9, 10, 11 and 12 years, respectively; and 17.2-18.8, 18.1-19.8, 19.0-20.9, 20.0-22.0, 21.1-23.2 and 21.9-24.4 kg/m² for girls aged 7, 8, 9, 10, 11 and 12 years, respectively (Ji, 2005); Obesity: ≥19.2, ≥20.3, ≥21.4, ≥22.5, ≥23.6 and ≥24.7 kg/m² for boys aged 7, 8, 9, 10, 11 and 12 years, respectively; and ≥18.9, ≥19.9, ≥21.0, ≥22.1, ≥23.3 and ≥24.5 kg/m² for girls aged 7, 8, 9, 10, 11 and 12 years, respectively (Ji, 2005).

g: grams; h: hour; kg/m²: kilograms per square meter; RMB: Renminbi (Chinese yuan; 1 USD ≈ 6.59 RMB based on the average exchange rate during the study period of September 2021 to October 2022); SD: standard deviation

method differed significantly among the four weight-status groups (p-value = 0.030). Exclusive breastfeeding was most common among children with obesity (n = 57, 60.0%), followed by those with overweight (n = 66, 54.1%), normal weight (n = 513, 48.2%), and underweight (n = 125, 44.8%). Mixed feeding was most common among children with underweight (n = 124, 44.4%), followed by normal weight (n = 401, 37.6%), obesity (n = 29, 30.5%), and overweight (n = 37, 30.3%). Formula feeding was most common among children with overweight (n = 19, 15.6%), followed by normal weight (n = 151, 14.2%), underweight (n = 30, 10.8%), and obesity (n = 9, 9.5%).

The proportion of children who ate breakfast differed significantly across the four weight-status groups (p-value = 0.003). The highest proportion of not eating breakfast was observed in the overweight group (n = 11, 9.0%), followed by the underweight group (n = 6, 2.2%), the normal weight group (n = 34, 3.2%), and the obesity group (n = 2, 2.1%). Correspondingly, the proportion of children who ate breakfast was highest in the underweight group (n = 273, 97.8%), followed by the obesity group (n = 93, 97.9%), the normal weight group (n = 1,031, 96.8%), and the overweight group (n = 111, 91.0%).

The mean (±SD) parental attitude score differed significantly across the four weight-status groups (p-value <0.001). The highest mean parental attitude score was observed in the underweight group (35.83 ± 5.70), followed by the obesity group (35.11 ± 4.80), the normal weight group (34.43 ± 6.18), and the overweight group (32.55 ± 6.83).

Parental perception of the child's body type differed significantly across the four weight-status groups (p-value <0.001). Among parents of children with underweight, the majority perceived their child as underweight (n = 131, 47.0%), followed by normal (n = 124, 44.4%), overweight (n = 18, 6.4%), and obese (n = 6, 2.2%). Among parents of children with normal weight, most perceived their child as normal (n =

Table 2

Univariate multinomial logistic regression of factors associated with underweight, overweight, and obesity

Variable	Underweight *vs* Normal		Overweight *vs* Normal		Obesity *vs* Normal	
	cOR (95% CI)	*p*-value	cOR (95% CI)	*p*-value	cOR (95% CI)	*p*-value
Demographic characteristics						
Age (per year)	0.97 (0.90-1.05)	0.509	0.93 (0.83-1.04)	0.185	0.74 (0.64-0.85)	<0.001
Male (*vs* Female)	1.61 (1.24-2.11)	<0.001	1.11 (0.76-1.61)	0.594	0.94 (0.61-1.43)	0.763
Rural (*vs* Urban)	0.88 (0.67-1.15)	0.343	1.07 (0.73-1.57)	0.734	1.04 (0.68-1.60)	0.858
Socioeconomic factors						
Annual household income (per level)	0.97 (0.86-1.09)	0.604	0.94 (0.79-1.12)	0.491	1.02 (0.85-1.24)	0.813
Early-life factors						
Cesarean section (*vs* Vaginal)	0.73 (0.51-1.03)	0.074	1.58 (1.04-2.40)	0.031	0.55 (0.29-1.02)	0.057
Birth weight <2,500 g (*vs* 2,500-4,000 g)	1.10 (0.80-1.50)	0.557	0.82 (0.50-1.33)	0.420	0.94 (0.55-1.59)	0.806
Birth weight >4,000 g (*vs* 2,500-4,000 g)	1.03 (0.72-1.46)	0.884	1.34 (0.85-2.12)	0.209	1.29 (0.76-2.17)	0.346
Mixed feeding (*vs* Exclusive breastfeeding)	1.27 (0.96-1.68)	0.096	0.72 (0.47-1.10)	0.124	0.65 (0.41-1.04)	0.071
Formula feeding (*vs* Exclusive breastfeeding)	0.82 (0.53-1.26)	0.361	0.98 (0.57-1.68)	0.936	0.54 (0.26-1.11)	0.093

Table 2 (cont)

Variable	Underweight *vs* Normal		Overweight *vs* Normal		Obesity *vs* Normal	
	cOR (95% CI)	*p*-value	cOR (95% CI)	*p*-value	cOR (95% CI)	*p*-value
Dietary behaviors						
Skipping breakfast (*vs* eating)	0.67 (0.28-1.60)	0.365	3.01 (1.48-6.10)	0.002	0.65 (0.15-2.76)	0.561
Breakfast frequency (per level)	0.98 (0.76-1.26)	0.863	0.86 (0.62-1.20)	0.379	0.77 (0.54-1.09)	0.143
Irregular meals (*vs* regular)	0.90 (0.57-1.41)	0.651	1.23 (0.69-2.19)	0.482	1.27 (0.67-2.40)	0.465
Lifestyle factors						
No outdoor activity (*vs* yes)	1.16 (0.89-1.51)	0.279	1.14 (0.78-1.67)	0.496	1.22 (0.80-1.86)	0.363
No electronic device use (*vs* yes)	1.08 (0.76-1.52)	0.680	0.99 (0.60-1.64)	0.970	1.10 (0.64-1.91)	0.731
Sleep duration (per level)	0.89 (0.69-1.14)	0.355	1.03 (0.73-1.46)	0.858	0.96 (0.65-1.42)	0.839
Parental knowledge and attitudes						
Parental nutritional knowledge score (per point)	1.06 (0.99-1.13)	0.111	0.97 (0.88-1.06)	0.478	0.96 (0.86-1.07)	0.463
Parental attitude score (per point)	1.04 (1.02-1.07)	<0.001	0.96 (0.93-0.98)	0.002	1.02 (0.98-1.06)	0.297
Parental factors						
Parental perception (per level heavier)	0.62 (0.50-0.77)	<0.001	2.37 (1.85-3.04)	<0.001	1.77 (1.34-2.33)	<0.001
Parental food as reward (per level)	1.19 (0.97-1.46)	0.087	0.84 (0.62-1.12)	0.238	0.98 (0.72-1.36)	0.925
Parental restriction of snacks (per level)	1.10 (0.94-1.29)	0.242	0.95 (0.76-1.19)	0.658	1.01 (0.78-1.30)	0.951
Parental physical exercise habit (per level)	0.86 (0.72-1.03)	0.102	0.64 (0.48-0.84)	0.001	0.49 (0.35-0.69)	<0.001
Parent-child joint exercise (per level)	1.19 (0.97-1.45)	0.094	0.75 (0.55-1.03)	0.072	0.70 (0.49-1.01)	0.056

CI: confidence interval; cOR: crude odds ratio; g: grams; *vs*: versus

645, 60.6%), followed by underweight (*n* = 310, 29.1%), overweight (*n* = 77, 7.2%), and obese (*n* = 33, 3.1%). Among parents of children with overweight, most perceived their child as normal (*n* = 58, 47.5%), followed by overweight (*n* = 48, 39.4%), underweight (*n* = 14, 11.5%), and obese (*n* = 2, 1.6%). Among parents of children with obesity, most perceived their child as normal (*n* = 48, 50.5%), followed by overweight (*n* = 26, 27.4%), underweight (*n* = 18, 18.9%), and obese (*n* = 3, 3.2%).

The frequency of parental use of food as a reward differed significantly across the four weight-status groups (*p*-value = 0.004). "Sometimes" using food as a reward was the most common response across all groups: underweight (*n* = 172, 61.6%), normal weight (*n* = 579, 54.4%), overweight (*n* = 60, 49.2%), and obesity (*n* = 43, 45.3%). "Never" using food as a reward was most common in the overweight group (*n* = 52, 42.6%), followed by obesity (*n* = 40, 42.1%), normal weight (*n* = 378, 35.4%), and underweight (*n* = 79, 28.3%).

Parental physical exercise habits differed significantly across the four weight-status groups (*p*-value <0.001). "Sometimes" exercising was the most common response in all groups: obesity (*n* = 68, 71.6%), underweight (*n* = 179, 64.2%), overweight (*n* = 75, 61.5%), and normal weight (*n* = 620, 58.2%). "Never" exercising was most common among parents of overweight (*n* = 14, 11.5%) and obese (*n* = 10, 10.5%) children, compared with normal weight (*n* = 45, 4.2%) and underweight (*n* = 11, 3.9%) children. No significant difference was observed in parent-child joint exercise across the four groups (*p*-value = 0.169).

On univariate analysis, the variables significantly associated with higher odds of the student subject being underweight (versus normal weight) were student subject male sex (cOR: 1.61; 95%CI: 1.24-2.11, *p*-value <0.001) and having a higher parental subject nutrition-related attitude score (for each 1-point increase in the score the cOR increased by 1.04; 95%CI: 1.02-1.07, *p*-value <0.001).

The variable significantly associated with lower odds of the student subject being underweight (versus normal weight) was having a parental subject perception of the student subject being in a higher BMI class than the actual BMI class (for each higher BMI class than the actual class the cOR decreased by 0.62; 95%CI: 0.50-0.77, *p*-value <0.001).

On univariate analysis, the variables significantly associated with higher odds of the student subject being overweight (versus normal weight) were the student subject having been born by cesarean section (versus vaginal delivery; cOR: 1.58; 95%CI: 1.04-2.40, *p*-value = 0.031), the student subject skipping breakfast (versus eating breakfast; cOR: 3.01; 95%CI: 1.48-6.10, *p*-value = 0.002), and having a parental subject perception of the student subject being in a higher BMI class than the actual BMI class (for each higher BMI class than the actual class the cOR increased by 2.37; 95%CI: 1.85-3.04, *p*-value <0.001).

The variables significantly associated with lower odds of the student subject being overweight (versus normal weight) were having a higher parental subject nutrition-related attitude score (for each 1-point increase in the score the cOR decreased by 0.96; 95%CI: 0.93-0.98, *p*-value = 0.002) and more frequent parental physical exercise (for each one-level increase on the 4-level exercise scale the cOR decreased by 0.64; 95%CI: 0.48-0.84, *p*-value = 0.001).

On univariate analysis, the variable significantly associated with higher odds of the student subject being obese (versus normal weight) was having a parental subject perception of the student subject being in a higher BMI class than the actual BMI class (for each higher BMI class than the actual class the cOR increased by 1.77; 95%CI: 1.34-2.33, *p*-value <0.001).

The variables significantly associated with lower odds of the student subject being obese (versus normal weight) were older student subject age (for every 1-year

increase in age the cOR decreased by 0.74; 95%CI: 0.64-0.85, *p*-value <0.001) and more frequent parental physical exercise (for each one-level increase on the 4-level exercise scale the cOR decreased by 0.49; 95%CI: 0.35-0.69, *p*-value <0.001).

On multivariable multinomial logistic regression analysis, 13 variables with a univariate *p*-value <0.20 in any of the three contrasts were entered simultaneously (Table 3). The variables significantly associated with higher odds of the student subject being underweight (versus normal weight) were student subject male sex (aOR: 1.61; 95%CI: 1.22-2.12, *p*-value <0.001) and having a higher parental subject nutrition-related attitude score (for each 1-point increase in the score the aOR increased by 1.04; 95%CI: 1.02-1.07, *p*-value = 0.002).

The factors significantly associated with lower odds of the student subject being underweight (versus normal weight) were: the student subject having been born by cesarean section (versus vaginal delivery; aOR: 0.58; 95%CI: 0.40-0.85, *p*-value = 0.005), having a parental subject perception of the student subject being in a higher BMI class than the student subject's actual BMI class (for each higher BMI class than the actual student subject class the aOR decreased by 0.62; 95%CI: 0.49-0.78, *p*-value <0.001), more frequent parental physical exercise (for each one-level increase on the 4-level exercise scale the aOR decreased by 0.68; 95%CI: 0.54-0.87, *p*-value = 0.002) and more frequent parent–child joint exercise (for each one-level increase on the 4-level exercise scale the aOR decreased by 0.72; 95%CI: 0.52-0.98, *p*-value = 0.039).

The variables significantly associated with higher odds of the student subject being overweight (versus normal weight) were the student subject having been born by cesarean section (versus vaginal delivery; aOR: 1.80; 95%CI: 1.12-2.89, *p*-value = 0.015) and having a parental subject perception of the student subject being in a higher BMI class than the actual BMI class (for each higher BMI class than

Table 3

Multivariable multinomial logistic regression of factors associated with underweight, overweight, and obesity

Variable	Underweight *vs* Normal		Overweight *vs* Normal		Obesity *vs* Normal	
	aOR (95% CI)	*p*-value	aOR (95% CI)	*p*-value	aOR (95% CI)	*p*-value
Demographic characteristics						
Age (per year)	1.01 (0.93-1.10)	0.826	0.87 (0.76-0.98)	0.028	0.71 (0.62-0.83)	<0.001
Male (*vs* Female)	1.61 (1.22-2.12)	<0.001	1.09 (0.73-1.63)	0.664	0.90 (0.58-1.40)	0.644
Early-life factors						
Cesarean section (*vs* Vaginal)	0.58 (0.40-0.85)	0.005	1.80 (1.12-2.89)	0.015	0.52 (0.27-1.00)	0.051
Mixed feeding (*vs* Exclusive breastfeeding)	1.24 (0.93-1.67)	0.146	0.68 (0.43-1.07)	0.092	0.66 (0.40-1.07)	0.091
Formula feeding (*vs* Exclusive breastfeeding)	0.87 (0.55-1.36)	0.534	0.96 (0.54-1.70)	0.878	0.52 (0.25-1.10)	0.088
Dietary behaviors						
Skipping breakfast (*vs* eating)	0.89 (0.36-2.21)	0.795	2.06 (0.93-4.56)	0.077	0.58 (0.13-2.59)	0.478
Breakfast frequency (per level)	0.84 (0.64-1.09)	0.195	1.05 (0.73-1.50)	0.808	0.79 (0.53-1.16)	0.223
Parental knowledge and attitudes						
Parental nutritional knowledge score (per point)	1.03 (0.96-1.12)	0.419	1.03 (0.92-1.16)	0.561	1.03 (0.91-1.17)	0.666
Parental attitude score (per point)	1.04 (1.02-1.07)	0.002	0.95 (0.92-0.98)	0.002	1.03 (0.99-1.07)	0.188

Table 3 (cont)

Variable	Underweight *vs* Normal		Overweight *vs* Normal		Obesity *vs* Normal	
	aOR (95% CI)	*p*-value	aOR (95% CI)	*p*-value	aOR (95% CI)	*p*-value
Parental factors						
Parental perception (per level heavier)	0.62 (0.49-0.78)	<0.001	2.24 (1.72-2.92)	<0.001	1.83 (1.36-2.47)	<0.001
Parental food as reward (per level)	1.14 (0.91-1.43)	0.242	0.93 (0.67-1.28)	0.658	1.15 (0.80-1.66)	0.435
Parental physical exercise habit (per level)	0.68 (0.54-0.87)	0.002	0.64 (0.46-0.89)	0.009	0.45 (0.29-0.70)	<0.001
Parent-child joint exercise (per level)	0.72 (0.52-0.98)	0.039	1.02 (0.70-1.50)	0.915	1.17 (0.72-1.90)	0.529

Only variables with univariate *p*-value <0.20 in any of the three contrasts were included in the multivariable model.

aOR: adjusted odds ratio; CI: confidence interval; *vs*: versus

the actual class the aOR increased by 2.24; 95%CI: 1.72-2.92, *p*-value <0.001).

The variables significantly associated with lower odds of the student subject being overweight (versus normal weight) were older student subject age (for every 1-year increase in age the aOR decreased by 0.87; 95%CI: 0.76-0.98, *p*-value = 0.028), having a higher parental subject nutrition-related attitude score (for each 1-point increase in the score the aOR decreased by 0.95; 95%CI: 0.92-0.98, *p*-value = 0.002), and more frequent parental physical exercise (for each one-level increase on the 4-level exercise scale the aOR decreased by 0.64; 95%CI: 0.46-0.89, *p*-value = 0.009).

The factor significantly associated with higher odds of the student subject being obese (versus normal weight) was having a parental subject perception of the student subject being in a higher BMI class than the actual BMI class (for each higher BMI class than the actual class the aOR increased by 1.83; 95%CI: 1.36-2.47, *p*-value <0.001).

The factors significantly associated with lower odds of the student subject being obese (versus normal weight) were older student subject age (for every 1-year increase in age the aOR decreased by 0.71; 95%CI: 0.62-0.83, *p*-value <0.001) and more frequent parental physical exercise (for each one-level increase on the 4-level exercise scale the aOR decreased by 0.45; 95%CI: 0.29-0.70, *p*-value <0.001).

DISCUSSION

In our study of 1,561 school-age children in the high-altitude region of Qinghai Province, 17.9% had underweight, 7.8% were overweight, and 6.1% had obesity, indicating coexistence of undernutrition and overnutrition within the same population (Popkin *et al*, 2020). The 17.9% underweight prevalence exceeds the national estimate of 3.37-8.49% reported in Chinese school-age children (Song *et al*, 2024), consistent with previously reported elevated underweight among Tibetan and high-altitude populations (Zhang

et al, 2021). Multivariable analysis further revealed that the three weight abnormalities share only partly overlapping factor profiles, suggesting that category-specific rather than uniform anti-obesity interventions are needed in this population.

Parental perception of child body type was significant across all three contrasts, but in opposite directions: heavier perception was associated with higher odds of overweight and obesity, and lower odds of underweight. Notably, 18.9% of parents of obese children still perceived them as underweight, indicating systematic underestimation at the heavier end of the distribution. Similar underestimation has been reported in Chinese preschoolers (Zhang *et al*, 2021) and in international meta-analyses (Lundahl *et al*, 2014). Correcting parental perception is a promising intervention lever. The Greenlight Plus randomized trial showed that engaging parents as agents of behavior change reduced early childhood obesity (Heerman *et al*, 2024), and family-based multicomponent programs have shown consistent benefits (Johnson *et al*, 2024).

Parental physical exercise habit was the second factor independently significant across all three contrasts: more frequent parental exercise was associated with lower odds of underweight, overweight, and obesity. This supports the role of parents as physical activity role models (Davison *et al*, 2020) and identifies family-level activity promotion as a common protective pathway across malnutrition categories. Parent-child joint exercise was independently protective only against underweight, possibly reflecting reverse causation whereby parents of thinner children engage more actively to promote growth.

Cesarean section was associated with nearly 2-fold higher odds of overweight but lower odds of underweight, most likely reflecting a distributional shift toward higher weight, consistent with disruption of gut microbiota establishment

(Rutayisire *et al*, 2016; Sandall *et al*, 2018) and findings from Chinese cohort studies (Li *et al*, 2014; Liang *et al*, 2017). Younger age was independently associated with both overweight and obesity suggesting earlier onset in this region and the importance of early-school-age prevention (Pan *et al*, 2021). Student subject male sex was linked to underweight only, paralleling prior Tibetan and western Chinese data. Interestingly, a higher parental attitude score was protective against overweight but associated with higher odds of underweight, suggesting that health education in this region should emphasize balanced nutrition rather than dietary restriction. Traditionally recognized dietary factors (fast food, sweets, beverages, skipping breakfast) were not independently associated with any weight abnormality, likely reflecting limited accessibility of highly processed foods in this high-altitude underdeveloped region (Jia *et al*, 2021).

Statistically significant differences were observed across weight-status groups for several variables, including delivery mode, infant feeding method, breakfast intake, attitude score, and parental behaviors. However, these differences did not follow a monotonic gradient from underweight to obesity. For instance, the proportion of children not eating breakfast was highest in the overweight group (9.0%) but comparable and low across the underweight (2.2%), normal weight (3.2%), and obesity (2.1%) groups. Similarly, cesarean section was most frequent among overweight children (29.5%) but least frequent among children with obesity (12.6%), rather than rising monotonically with weight category. Such non-monotonic patterns are consistent with the broader literature on the double burden of malnutrition, which emphasizes that undernutrition and overnutrition arise from partly distinct, and sometimes opposing, etiologic pathways rather than

from a single linear continuum (Popkin *et al*, 2020; Wells *et al*, 2020). Comparable non-linear or category-specific patterns have also been reported in Chinese children, where machine-learning analyses have shown that the strongest correlates of underweight, overweight, and obesity differ in identity and in direction across categories (Chen *et al*, 2025). These observations support interpreting our findings as evidence of category-specific associations rather than a single dose-response relationship between any one factor and child weight, and they argue against summarizing the results simply as the factor having varied with weight status. The relatively small numbers of overweight (n = 122) and obese (n = 95) children in our sample may have additionally contributed to some of the irregular group-level estimates.

This study had several strengths. We used a relatively large sample with standardized anthropometric measurements, and simultaneously examined three weight categories in a high-altitude multi-ethnic population. However, our study also had limitations. First, the cross-sectional design prevents causal inference, and some associations (*eg*, parent-child joint exercise with underweight) may reflect reverse causation. Second, dietary and activity variables were self-reported and subject to recall and social desirability bias. Third, unmeasured confounders such as genetic predisposition, gut microbiota, and parental BMI were not available. Fourth, the relatively small number of overweight (n = 122) and obese (n = 95) children may have limited statistical power for less common exposures. Finally, as the study population was restricted to Qinghai Province, findings may not generalize beyond high-altitude multi-ethnic regions.

In summary, underweight, overweight, and obesity coexist in the school-age population of the high-altitude Qinghai Province, with partly overlapping but largely distinct profiles of associated factors. Parental perception of child body type and parental

physical exercise habit emerged as pivotal family-level factors, being independently associated with all three outcomes. Family- and school-based interventions that simultaneously address undernutrition and overnutrition, that correct parental weight perception, and that foster regular family-level physical activity are therefore recommended in this high-altitude multi-ethnic region. Further prospective studies are needed to confirm whether interventions targeting these factors can prevent or reduce the double burden of childhood malnutrition in this population and in similar high-altitude settings.

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CONFLICT OF INTEREST DISCLOSURE

The authors declare no conflicts of interest related to the content of this article. No financial or personal relationships with other individuals or organizations have inappropriately influenced this work.

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