



## Article

# Associations of Cooking Salt Intake During Pregnancy with Low Birth Weight and Small for Gestational Age Newborns: A Large Cohort Study

Tongtong Li <sup>1,†</sup>, Zhengyuan Wang <sup>2,†</sup>, Zilin Xiao <sup>1</sup>, Chengwu Feng <sup>1</sup>, Zhuo Sun <sup>2</sup>, Dou Mao <sup>1</sup>, Puchen Zhou <sup>1</sup>, Caimei Yuan <sup>1</sup>, Danyang Zhao <sup>1</sup>, Wanning Shang <sup>1</sup>, Yunman Liu <sup>3</sup>, Changzheng Yuan <sup>4</sup>, Li Hong <sup>3,‡</sup> , Jiajie Zang <sup>2,\*,‡</sup> and Geng Zong <sup>5,\*,‡</sup> 

<sup>1</sup> CAS Key Laboratory of Nutrition, Metabolism and Food Safety, Shanghai Institute of Nutrition and Health, University of Chinese Academy of Sciences, Chinese Academy of Sciences, Shanghai 200031, China

<sup>2</sup> Division of Health Risk Factors Monitoring and Control, Shanghai Municipal Center for Disease Control and Prevention, Shanghai 200336, China

<sup>3</sup> Department of Clinical Nutrition, Shanghai Children's Medical Center Affiliated to School of Medicine, Shanghai Jiao Tong University, Shanghai 200127, China

<sup>4</sup> School of Public Health, The Second Affiliated Hospital, Zhejiang University School of Medicine, Hangzhou 310058, China

<sup>5</sup> Institute of Nutrition, Fudan University, No.130 Dong-An Road, Shanghai 200032, China

\* Correspondence: zangjiajie@scdc.sh.cn (J.Z.); zonggeng@sinh.ac.cn (G.Z.)

† These authors contributed equally as first authors.

‡ These authors contributed equally as senior authors.

**Abstract: Background:** Excessive salt intake has been strongly associated with multiple health conditions, while evidence linking salt consumption during pregnancy and birth outcomes remains limited. We aimed to investigate the association between salt intake during pregnancy and adverse outcomes of birth weight. **Methods:** Our study was based on a prospective cohort study that has followed 4267 mother–child pairs since 2017 in Shanghai, China. Salt consumption was estimated based on the cooking salt and soy sauce from household condiments consumed, weighing measurements over a week, and then categorized into <5.0 (reference), 5.0–10.0, and ≥10.0 g/day. Salt density was calculated as the amount of salt divided by the total energy intake from food frequency questionnaires. Outcomes related to birth weight were defined according to standard clinical cutoffs, including low birth weight (LBW), macrosomia, small for gestational age (SGA), and large for gestational age (LGA). **Results:** Multivariable-adjusted odds ratios (ORs) of LBW were 1.72 (95% CI 1.01–2.91) for 5.0–10.0 g/day salt intake, and 2.06 (95% CI 1.02–4.13) for ≥10.0 g/day, compared to those of <5.0 g/day (*p*-trend = 0.04). For SGA, ORs were 1.46 (95% CI 1.09–1.97) for 5.0–10.0 g/day and 1.69 (95% CI 1.16–2.47; *p*-trend = 0.006) for ≥10.0 g/day. Similarly, the OR comparing the extreme tertile (high vs. low) of salt density was 1.91 (95% CI 1.08–3.36; *p*-trend = 0.01) for LBW and 1.63 (95% CI 1.18–2.25; *p*-trend < 0.001) for SGA. No significant associations were observed for salt intake in relation to macrosomia or LGA. These findings remain stable in all sensitivity and subgroup analyses. **Conclusions:** In this study, habitual cooking salt intake above 5 g/day was associated with increased risks of LBW and SGA, which warrants confirmation by interventional studies.

**Keywords:** salt intake; pregnancy; low birth weight; small for gestational age; cohort



Academic Editors: Luis A. Moreno and Pedro Moreira

Received: 1 January 2025

Revised: 4 February 2025

Accepted: 6 February 2025

Published: 11 February 2025

**Citation:** Li, T.; Wang, Z.; Xiao, Z.; Feng, C.; Sun, Z.; Mao, D.; Zhou, P.; Yuan, C.; Zhao, D.; Shang, W.; et al. Associations of Cooking Salt Intake During Pregnancy with Low Birth Weight and Small for Gestational Age Newborns: A Large Cohort Study. *Nutrients* **2025**, *17*, 642. <https://doi.org/10.3390/nu17040642>

**Copyright:** © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

## 1. Introduction

The World Health Organization (WHO) recommends a salt intake of <5.0 g/day (2000 mg/day of sodium), yet the average daily salt intake globally is estimated to be 10.8 g of salt (4310 mg/day of sodium) [1–3]. According to a recent report, the average salt consumption for most countries worldwide exceeds the recommended level [2]. A high amount of sodium consumption is a leading risk factor for hypertension [4–6], cardiovascular disease [7–9], and mortality among adults [10,11], yet findings on birth outcomes are lacking [12]. Several observational studies found no significant association of sodium in food frequency questionnaires (FFQ) or 24 h urinary samples with birth weight or infants being small for gestational age (SGA) [4,13–15], while others suggested that reducing sodium or following diets low in salt during pregnancy was associated with a higher birth weight [16–18].

Most existing observational studies estimated sodium intake using FFQ, 24 h recall, spot urines, or single 24 h urine samples. However, self-reported assessments of these methods are subject to recall bias and low accuracy in measuring the salt content of foods when it is added during cooking or at the table, while urinary measures show a large day-to-day variation [19]. China is among the countries with the highest salt intake [3], and the average daily consumption is 11.1 g/day [20]. It has been shown that the majority (82.2%) of dietary salt comes from salt and soy sauce added during home cooking among Chinese people [21], while dietary salt mainly comes from processed foods and ready meals in Western countries (90%), and salt added during home cooking or at the table accounts for about 10% of the daily intake [21,22]. In this regard, measuring salt and other condiments' consumption in the kitchen may provide further insight into the health impacts of high amounts of sodium exposure among the Chinese population.

Here, we aimed to investigate the associations of cooking salt intake during pregnancy, estimated by weighing household condiment consumption over a week, with infant low birth weight (LBW), macrosomia, SGA, and infants being large for gestational age (LGA) in a cohort of pregnant women in China.

## 2. Methods

### 2.1. Study Population and Design

Starting in 2017, the Iodine Status in Pregnancy and Offspring Health Cohort (ISPOHC) study recruited 5042 pregnant women in Shanghai, China [23]. The study utilized a multistage, stratified random sampling approach to acquire a representative sample. At baseline, participants at 6 to 38 gestational weeks were recruited, with approximately one-third in each trimester. Specifically, each district (16 districts in Shanghai) was subdivided into five distinct sampling areas: east, west, south, north, and central. From each of these sampling areas, a street was randomly chosen, and 40 to 70 pregnant women were selected from each street. At baseline, they completed initial questionnaires and biological sample collection. Dietary data included a validated 69-item FFQ and household condiment consumption measurement over a week. In this study, women were excluded if they subsequently had not delivered a live, singleton baby ( $n = 76$ ), reported an implausibly high or low energy intake (less than 500 kcal/day or more than 5000 kcal/day;  $n = 295$ ), had a missing value on their salt intake ( $n = 232$ ), or had missing values on offspring birth weight ( $n = 172$ ), resulting in 4267 mother–child pairs for analysis.

The ISPOHC study obtained ethical approval from the Ethics Committee of the Shanghai Centre for Disease Control and Prevention. All participants provided informed consent by signing a written document.

## 2.2. Salt Intake and Other Dietary Data

At baseline, cooking salt and soy sauce in the home inventory were weighed and recorded at the start and end of a seven-day sampling period. Daily personal intake of salt was estimated based on the number of meals consumed at home over the same period, and then divided by family size and seven days [24]. The amount of salt in soy sauce was estimated by multiplying the weight of soy sauce with 0.15 [25]. Total cooking salt intake (hereafter referred to as salt intake) was calculated by summing the salt added in its solid form during cooking and the salt from soy sauce. We grouped daily salt intake into 3 categories:  $<5.0$  (reference), 5.0–10.0, and  $\geq 10.0$  g/day according to the WHO's maximum intake recommendation of 5 g/day salt for adults [2]. The secondary exposure was dietary salt density, which is the ratio of daily salt (mg) to total energy intake (kcal). Daily food intake was estimated based on FFQ, and energy (kcal/day) and nutrient intakes were converted using the China Food Composition Database [25].

## 2.3. Outcome Ascertainment

Birth weight in grams and gestational age in weeks were obtained through city-wide medical records. The newborns were classified as LBW (birth weight  $< 2500$  g), normal birth weight (birth weight 2500–4000 g), and macrosomia (birth weight  $> 4000$  g). Additionally, SGA was defined as a birth weight below the 10th percentile of the sex-and-gestational-age-specific birth weight, while LGA was defined as above the 90th percentile, per the neonatal growth standards in China [26]. The analysis for SGA and LGA was limited to infants with a gestational age of 24–42 completed weeks.

## 2.4. Covariate Assessment

Trained staff administered questionnaires to collect information on participants' sociodemographic characteristics (domicile place, household income, and education), lifestyle (smoking and physical activity), medical history (gestational diabetes and pregnancy-induced hypertension), parity, pre-pregnancy body weight, and eating behavior at baseline. Pre-pregnancy body mass index (BMI) was calculated as body weight (kg) divided by the square of measured standing height at baseline ( $\text{m}^2$ ) [27]. Family size was divided into two categories ( $<4$  and  $\geq 4$  members). Sufficient leisure-time physical activity was defined as at least 150 min/week of moderate activity or 75 min/week of vigorous activity or an equivalent combination [28]. Passive smoking was defined as exposure to others' smoking for at least one day/week. Eating at home was specifically defined as consuming meals at home every day.

## 2.5. Statistical Analyses

Maternal characteristics were described as means (SDs) for continuous variables and  $n$  (%) for categorical variables. We imputed missing values using medians or modes if missingness is  $<5\%$  of covariates, otherwise missing indicators were used.

Three multivariable logistic regression models were constructed to estimate the odds ratios (ORs) and 95% confidence intervals (CIs) of the association between salt intake and birth weight outcomes. Model 1 was adjusted for maternal age (year) and infant sex (male or female). Model 2 was additionally adjusted for maternal domicile location (northern China, Shanghai surrounding area, or southern China), pre-pregnancy BMI ( $<18.5$ , 18.5–23.9, or  $\geq 24.0$   $\text{kg}/\text{m}^2$ ), height (cm), household income ( $<100,000$ , 100,000–350,000, or  $\geq 350,000$  yuan/year), education ( $<13$  or  $\geq 13$  years), gestational periods at recruitment (first, second, or third trimester), passive smoking (never or ever), drinking (never or ever), and physical activity ( $<150$  or  $\geq 150$  min/week) based on model 1. Model 3 further included eating at home (yes or no) and total energy intake (kcal/day) based on model 2.

In the analysis of salt density as exposure, total energy intake was no longer considered as a covariate. For LBW and macrosomia, we further adjusted for gestational age at birth in the final model.  $p$  values for trends were obtained by modeling the median values of each category.

We also conducted prespecified subgroup analyses by maternal age, infant sex, baseline gestational periods, family size, passive smoking, physical activity, and eating at home to investigate the potential effect modification of each variable on the associations of salt intake with birth outcomes. Statistical significance of an interaction term between salt intake and the potential effect modifiers was used to evaluate interactions. To reduce the risk of false positive findings, we applied Bonferroni correction to the  $p$  values of interactions ( $p < 0.05 \div [7 \text{ subgroups} \times 4 \text{ outcomes}]$ ).

Finally, we performed the following sensitivity analyses to test the robustness of our findings. First, a series of exploratory models were conducted to examine potential confounding from the following factors based on the final model: (1) a further adjusted model for fruit and vegetable intakes, which are important sources of potassium that may counteract the effects of a high-salt diet; (2) additionally adjusted models for multivitamin, calcium tablets, and folic acid supplements; (3) an additionally adjusted model for gestational diabetes, which could lead to changes in dietary habits; (4) an additionally adjusted model for sodium from foods to examine the independent effects of sodium added during cooking; and (5) an additionally adjusted model for parity, as it may influence lifestyle choices during pregnancy [29]. Second, we excluded participants with pregnancy-induced hypertension at baseline. Third, we limited analyses to natural labor to examine the influence of delivery mode. Fourth, we limited analyses to term (born between 37 to <42 completed weeks) infants. Fifth, we filled missing data using multiple imputations to evaluate the impact of imputation methods on findings by creating 5 imputed datasets and pooling the estimates from logistic regression models across the imputed datasets [30]. Finally, we analyzed salt intake as a tertile variable.

A two-sided  $p$  value  $< 0.05$  was considered statistically significant unless otherwise noted. All statistical analyses were performed in R (v4.2.1, R Foundation for Statistical Computing, Vienna, Austria).

## 2.6. Role of the Funding Source

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

## 3. Results

### 3.1. Basic Characteristics of Participants

Basic characteristics of the participants by salt intake were presented in Table 1 and by tertiles of salt density in Table S1. The study participants had a mean (SD) age of 29.6 (4.4) years and a mean BMI of 21.4 (2.9) kg/m<sup>2</sup>. The mean (SD) of salt intake was 5.9 (4.7) g/day, and the mean (SD) of estimated salt density was 3.4 (2.9) mg/kcal. The proportions of participants with a salt intake  $< 5.0$  g/day were 52.2%, 34.3% for 5.0–10.0 g/day, and 13.5% for  $\geq 10.0$  g/day. Participants with a higher salt intake were more likely to be younger and recruited during the second trimester, come from the northern regions, have lower education and income, eat at home, and have higher intakes of energy and vegetables (Table 1).

**Table 1.** Characteristics of pregnant women by salt intake in Shanghai, China.

	Salt Intake				<i>p</i>
	Overall	<5.0 g/day	5.0–10.0 g/day	≥10.0 g/day	
N	4267	2228	1465	574	
Maternal age, mean (SD), years	29.6 (4.4)	29.8 (4.3)	29.5 (4.5)	28.8 (4.6)	<0.001
Infants sex, male, <i>n</i> (%)	2190 (51.3)	1160 (52.1)	753 (51.4)	277 (48.3)	0.27
Maternal domicile location, <i>n</i> (%)					0.03
Northern China	695 (16.3)	360 (16.2)	234 (16.0)	101 (17.6)	
Shanghai surrounding area	2789 (65.4)	1496 (67.1)	928 (63.3)	365 (63.6)	
Southern China	783 (18.4)	372 (16.7)	303 (20.7)	108 (18.8)	
Baseline gestational periods, <i>n</i> (%)					<0.001
First trimester	1369 (32.1)	801 (36.0)	400 (27.3)	168 (29.3)	
Second trimester	1630 (38.2)	804 (36.1)	586 (40.0)	240 (41.8)	
Third trimester	1268 (29.7)	623 (28.0)	479 (32.7)	166 (28.9)	
Maternal Education, <13 years, <i>n</i> (%)	1316 (30.8)	569 (25.5)	525 (35.8)	222 (38.7)	<0.001
Household income, yuan/year, <i>n</i> (%)					<0.001
<100,000	727 (17.0)	310 (13.9)	295 (20.1)	122 (21.3)	
100,000–350,000	3041 (71.3)	1603 (71.9)	1029 (70.2)	409 (71.3)	
≥350,000	499 (11.7)	315 (14.1)	141 (9.6)	43 (7.5)	
Pre-pregnancy BMI, kg/m <sup>2</sup> , <i>n</i> (%)					0.48
<18.5	553 (13.0)	299 (13.4)	174 (11.9)	80 (13.9)	
18.5–23.9	3002 (70.4)	1551 (69.6)	1055 (72.0)	396 (69.0)	
≥24.0	712 (16.7)	378 (17.0)	236 (16.1)	98 (17.1)	
Maternal height, mean (SD), cm	160.9 (5.2)	161.0 (5.1)	160.7 (5.2)	160.8 (5.3)	0.24
Alcohol drinking, never, <i>n</i> (%)	3842 (90.0)	2002 (89.9)	1314 (89.7)	526 (91.6)	0.38
Passive smoking, never, <i>n</i> (%)	2488 (58.3)	1311 (58.8)	843 (57.5)	334 (58.2)	0.73
Leisure-time physical activity, <i>n</i> (%)					0.09
<150 min/week	2347 (55.0)	1213 (54.4)	794 (54.2)	340 (59.2)	
≥150 min/week	1920 (45.0)	1015 (45.6)	671 (45.8)	234 (40.8)	
Gestational age at birth, weeks	38.9 (1.3)	38.9 (1.3)	38.9 (1.4)	39.0 (1.3)	0.07
Eating at home every day, yes, <i>n</i> (%)	1898 (44.5)	738 (33.1)	818 (55.8)	342 (59.6)	<0.001
Total energy intake, mean (SD), kcal/day	1890.6 (725.2)	1791.1 (694.2)	1958.1 (722.4)	2104.4 (783.2)	<0.001
Fruits, mean (SD), g <sup>a</sup>	281.4 (226.0)	275.5 (226.3)	283.6 (216.9)	298.6 (246.0)	0.08
Vegetables, mean (SD), g <sup>a</sup>	221.1 (183.8)	213.8 (178.6)	228.2 (189.8)	230.9 (187.1)	0.03
Sodium, mean (SD), mg <sup>a</sup>	2804.5 (1432.0)	2798.9 (1411.6)	2826.6 (1452.8)	2770.0 (1458.5)	0.70
Multivitamin, yes, <i>n</i> (%)	1782 (41.8)	935 (42.0)	603 (41.2)	244 (42.5)	0.82
Calcium, yes, <i>n</i> (%)	1752 (41.1)	870 (39.0)	643 (43.9)	239 (41.6)	0.01
Folic acid, yes, <i>n</i> (%)	2636 (61.8)	1399 (62.8)	873 (59.6)	364 (63.4)	0.10
Gestational diabetes, yes, <i>n</i> (%)	244 (5.7)	114 (5.1)	92 (6.3)	38 (6.6)	0.20
Pregnancy-induced hypertension, yes, <i>n</i> (%)	106 (2.5)	52 (2.3)	40 (2.7)	14 (2.4)	0.75
Nulliparity, yes, <i>n</i> (%)	2482 (58.2)	1307 (58.7)	821 (56.0)	354 (61.7)	0.05
Natural labor, yes, <i>n</i> (%)	2251 (52.8)	1190 (53.4)	746 (50.9)	315 (54.9)	0.18
Gestational age at delivery, <i>n</i> (%)					0.004
Pre-term	170 (4.0)	97 (4.4)	58 (4.0)	15 (2.6)	
Term	4077 (95.5)	2124 (95.3)	1402 (95.7)	551 (96.0)	
Post-term	20 (0.5)	7 (0.3)	5 (0.3)	8 (1.4)	

Abbreviations: SD, standard deviation. <sup>a</sup> The intake of fruits, vegetables, and sodium was assessed through the Food Frequency Questionnaire.

### 3.2. Salt Intake and Birth Weight Traits

We documented 106 LBW (2.5%), 234 macrosomia (5.5%), 250 SGA (5.9%), and 735 LGA (17.2%) cases. Associations between salt intake and the risks of birth weight outcomes were shown in Table 2. In the maternal-age-and-infant-sex-adjusted model (model 1), a



higher salt intake was significantly associated with higher risks of LBW and SGA. The associations were stronger after further adjustment for other socioeconomic and lifestyle factors (model 2) or eating at home and total energy intake (model 3). In the final model, multivariable-adjusted ORs of LBW were 1.72 (95% CI 1.01–2.91) for participants consuming 5.0–10.0 g/day of salt intake and 2.06 (95% CI 1.02–4.13) for  $\geq 10.0$  g/day compared to those with  $<5.0$  g/day ( $p$ -trend = 0.04). For SGA, ORs were 1.46 (95% CI 1.09–1.97) for 5.0–10.0 g/day and 1.69 (95% CI 1.16–2.47;  $p$ -trend = 0.006) for  $\geq 10.0$  g/day. No significant associations were observed for salt intake in relation to macrosomia or LGA.

**Table 2.** Associations of salt intake and salt density with birth outcomes among pregnant women in Shanghai, China <sup>a</sup>.

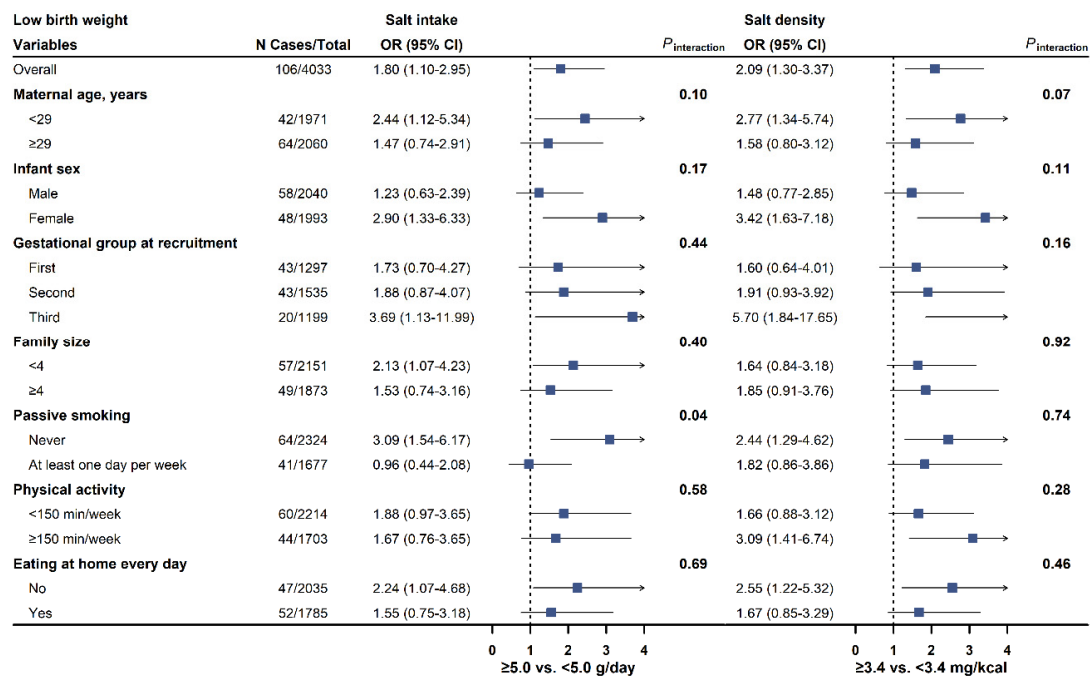
Outcome	Salt Intake (g/day)				Salt Density (mg/kcal) <sup>b</sup>			
	<5.0	5.0–10.0	$\geq 10.0$	$p$ -Trend <sup>c</sup>	T1 (<1.9)	T2 (1.9 to 3.7)	T3 ( $\geq 3.7$ )	$p$ -Trend
<b>Low birth weight <sup>g</sup></b>								
N cases/Total	47/2122	42/1372	17/539		31/1347	32/1342	43/1344	
Model 1 <sup>d</sup>	1.00 (ref)	1.41 (0.92–2.15)	1.49 (0.85–2.62)	0.13	1.00 (ref)	1.04 (0.63–1.72)	1.45 (0.90–2.31)	0.09
Model 2 <sup>e</sup>	1.00 (ref)	1.75 (1.04–2.94)	2.13 (1.08–4.21)	0.02	1.00 (ref)	0.96 (0.52–1.77)	1.99 (1.14–3.48)	0.006
Model 3 <sup>f</sup>	1.00 (ref)	1.72 (1.01–2.91)	2.06 (1.02–4.13)	0.04	1.00 (ref)	0.93 (0.50–1.73)	1.91 (1.08–3.36)	0.01
<b>Small for gestational age</b>								
N cases/Total	105/1861	99/1191	46/478		68/1174	67/1176	115/1180	
Model 1	1.00 (ref)	1.49 (1.12–1.98)	1.71 (1.19–2.46)	0.003	1.00 (ref)	0.98 (0.69–1.38)	1.69 (1.23–2.31)	<0.001
Model 2	1.00 (ref)	1.50 (1.12–2.01)	1.73 (1.20–2.51)	0.003	1.00 (ref)	0.99 (0.69–1.40)	1.70 (1.24–2.34)	<0.001
Model 3	1.00 (ref)	1.46 (1.09–1.97)	1.69 (1.16–2.47)	0.006	1.00 (ref)	0.96 (0.68–1.37)	1.63 (1.18–2.25)	<0.001
<b>Macrosomia <sup>g</sup></b>								
N cases/Total	106/2181	93/1423	35/557		75/1391	80/1390	79/1380	
Model 1	1.00 (ref)	1.37 (1.03–1.83)	1.35 (0.91–2.00)	0.09	1.00 (ref)	1.08 (0.78–1.50)	1.08 (0.78–1.50)	0.68
Model 2	1.00 (ref)	1.34 (1.00–1.80)	1.28 (0.85–1.93)	0.17	1.00 (ref)	1.08 (0.77–1.50)	1.02 (0.73–1.42)	>0.99
Model 3	1.00 (ref)	1.29 (0.96–1.75)	1.22 (0.80–1.85)	0.30	1.00 (ref)	1.05 (0.76–1.47)	0.98 (0.69–1.38)	0.83
<b>Large for gestational age</b>								
N cases/Total	367/2123	274/1366	94/526		248/1354	246/1355	241/1306	
Model 1	1.00 (ref)	1.21 (1.02–1.44)	1.07 (0.83–1.37)	0.40	1.00 (ref)	1.00 (0.82–1.21)	1.04 (0.85–1.26)	0.69
Model 2	1.00 (ref)	1.20 (1.00–1.43)	1.04 (0.81–1.34)	0.55	1.00 (ref)	1.00 (0.82–1.22)	1.03 (0.84–1.25)	0.79
Model 3	1.00 (ref)	1.15 (0.96–1.38)	0.98 (0.75–1.27)	0.97	1.00 (ref)	0.98 (0.80–1.20)	0.99 (0.81–1.22)	0.98

Abbreviations: N Cases/Total = number of cases and total participants in the study. OR = odds ratio. I = confidence interval. Ref = reference.  $p$ -trend =  $p$  value for trend. <sup>a</sup> ORs and 95% CIs for the association were calculated in logistic models. <sup>b</sup> The first and second tertiles of salt density in the population are 1.9 and 3.7 mg/kcal, respectively. <sup>c</sup> The  $p$  values for trends were obtained through modeling the median value of each category into the logistic regression models. <sup>d</sup> Model 1, adjusted for maternal age (continuous variables, in years) and infant sex (male or female). <sup>e</sup> Model 2, additionally adjusted for maternal domicile (northern China, surrounding area of Shanghai, or southern China), baseline gestational periods (first, second, or third), maternal education ( $<13$  or  $\geq 13$  years), annual family income ( $<100,000$ ,  $100,000$ – $350,000$ , or  $\geq 350,000$  yuan/year), pre-pregnancy BMI ( $<18.5$ ,  $18.5$ – $23.9$ , or  $\geq 24.0$  kg/m<sup>2</sup>), height (continuous variables, in cm), passive smoking during pregnancy (never or ever), drinking (never or ever), physical activity ( $<150$  or  $\geq 150$  min/week) based on model 1. <sup>f</sup> Model 3, further adjusted for eating at home every day (yes or no) and energy intake per day (continuous variables, kcal/day) based on model 2. <sup>g</sup> Analyses for low birth weight and macrosomia were additionally adjusted for gestational week at birth in the final model.

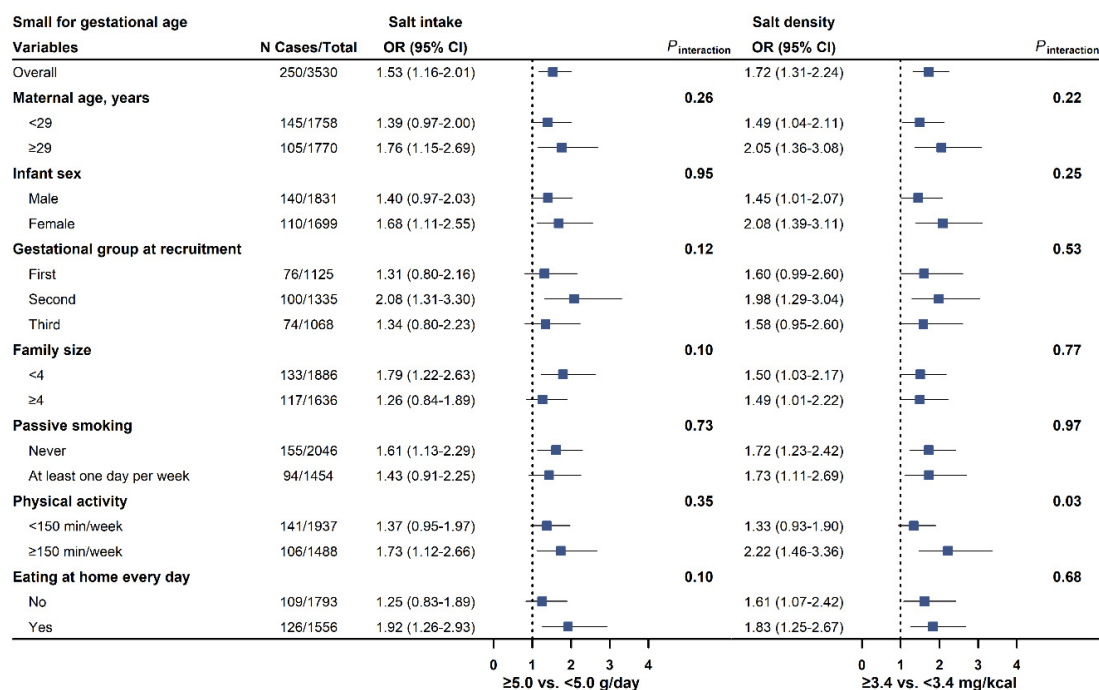
Higher salt density was also associated with higher risks of LBW and SGA (Table 2), while no associations were observed for macrosomia or LGA. Specifically, ORs comparing extreme tertile of salt density were 1.91 (95% CI 1.08–3.36;  $p$ -trend = 0.01) for LBW and 1.63 (95% CI 1.18–2.25;  $p$ -trend < 0.001) for SGA in the final model.

### 3.3. Subgroup Analyses

The associations of salt intake and salt density with LBW and SGA were consistently observed across subgroups stratified by maternal age, infant sex, baseline gestational periods, family size, passive smoking, physical activity, and eating at home (Figures 1 and 2; Figures S1–S4 in the Supplementary Materials).



**Figure 1.** Forest plots for the association of salt intake (left, <5.0 g/day as reference) and salt density (right, <3.4 mg/kcal as reference) with the risk of low birth weight in pre-specified subgroups. ORs and 95% CI were calculated in logistic model adjusted for maternal age (continuous variables, in years), infant sex (male or female), maternal domicile (northern China, surrounding area of Shanghai, or southern China), baseline gestational periods (first, second, or third trimester), maternal education (<13 or ≥13 years), annual family income (<100,000, 100,000–350,000, or ≥350,000 yuan/year), pre-pregnancy BMI (<18.5, 18.5–23.9, or ≥24.0 kg/m<sup>2</sup>), height (continuous variables, in cm), passive smoking during pregnancy (never or ever), drinking (never or ever), physical activity (<150 or ≥150 min/week), eating at home every day (yes or no), energy intake per day (continuous variables, in kcal/day, not for salt density) and gestational week at birth (continuous variables, in weeks). N Cases/Total = number of cases and total participants in the study. OR = odds ratio. CI = confidence interval.



**Figure 2.** Forest plots for the association of salt intake (left, <5.0 g/day as reference) and salt density (right, <3.4 mg/kcal as reference) with the risk of small for gestational age in pre-specified subgroups.

ORs and 95% CI were calculated in the logistic model adjusted for maternal age (continuous variables, in years), infant sex (male or female), maternal domicile (northern China, surrounding area of Shanghai, or southern China), baseline gestational periods (first, second, or third trimester), maternal education (<13 or ≥13 years), annual family income (<100,000, 100,000–350,000, or ≥350,000 yuan/year), pre-pregnancy BMI (<18.5, 18.5–23.9, or ≥24.0 kg/m<sup>2</sup>), height (continuous variables, in cm), passive smoking during pregnancy (never or ever), drinking (never or ever), physical activity (<150 or ≥150 min/week), eating at home every day (yes or no), and energy intake per day (continuous variables, in kcal/day, not for salt density). N Cases/Total = number of cases and total participants in the study. OR = odds ratio. CI = confidence interval.

### 3.4. Sensitivity Analyses

The findings were largely found in sensitivity analyses that assessed the effect of other potential confounding factors, missing covariates, and exposure reclassification (Tables S2–S6 in Supplement). Among spontaneous labors (N = 2251), the association between salt intake and LBW was not significant (OR comparing ≥10.0 g/day with <5.0 g/day, 2.14; 95% CI 0.72–6.37; *p*-trend = 0.15, Table S2).

## 4. Discussion

In this prospective cohort study of pregnant women in China, cooking salt intake above 5 g/day was associated with significantly higher risks of LBW and SGA. These findings were independent of potential confounding factors and remained stable in sensitivity analyses and stratified analyses.

To our knowledge, this is the first large prospective cohort study to examine the associations between salt intake and LBW, using a weighted method of household condiment consumption over a seven-day period. Two studies with sample sizes of less than 1000 participants, one conducted by Lee et al. in Australia and another by Birukov et al. in Denmark, observed no significant association of maternal sodium exposure with birth weight [4,14]. In addition, a recent study by Bank et al., which involved 7458 participants in the United States, found no significant differences in birth weight or SGA risk based on salt intake group [15]. Lee et al. and Bank et al. evaluated sodium intake with self-reported data from an FFQ, which is susceptible to known recall bias [31]. Correlation coefficients of sodium intake estimated from FFQ and urinary measures tend to be <0.37 [32]. In contrast, Birukov et al. used a single 24 h urine sample, which is inadequate for capturing the participant's typical sodium intake due to substantial day-to-day variations [8]. Balance studies under controlled conditions suggest that the likelihood of the estimated salt intake from a single 24 h urine sample being within 3 g of the actual salt intake is 49% [33]. Moreover, the study conducted by Birukov et al. was subject to selection bias, as women who provided 24 h urine samples had higher pre-specified risk factors for gestational diabetes mellitus, such as overweight and glucosuria detected during pregnancy. Notably, salt sensitivity is higher in Asians than in Europeans, which may lead to a stronger association between salt intake and health consequences [34]. Therefore, findings from our study warrant confirmation in other populations.

Our findings are supported by several lines of evidence that collectively supported an inverse association between sodium exposure and birth weight. In a small clinical trial (*n* = 142) among pregnant women in South Korea, 16-week nutritional education on salt reduction led to 1140 mg/day lower maternal sodium intake, 277 g higher birth weight, and a lower proportion of infants with birth weights below 3000 g compared to the control group [35]. A pooled analysis of 24,861 mother–child pairs from 7 European cohorts also showed the Dietary Approaches to Stop Hypertension score, characterized by lower sodium intake, was associated with higher birth weight and lower risk of delivering LBW



and SGA infants [16]. In addition, dietary patterns rich in high sodium foods, such as pizza and processed meat, have been associated with lower birth weight and a higher risk of SGA [17,18]. In light of these findings, further studies should examine the association of sodium and salt with birth weight, as well as optimal doses of salt intake during pregnancy.

Potential mechanisms that account for the observed associations are unclear. Previous studies showed that excessive salt intake was positively associated with risks of pregnancy-induced hypertension and pre-eclampsia, which are established risk factors of LBW or SGA [6,36,37]. In our study, the results were substantially unchanged when we excluded participants with pregnancy-induced hypertension at baseline, suggesting that other independent mechanisms may exist. It has been found that a high salt intake resulted in the inactivation of the renin–angiotensin–aldosterone system [38] which is essential to placental growth and fetal development. Both animal and human studies observed a positive relationship between plasma aldosterone levels and placental sizes. Pregnant mice with lower levels of aldosterone exhibited reduced fetal umbilical blood flow and smaller fetuses [39,40]. Additionally, a high salt intake has been associated with an increased risk of diabetes in the general population [41], while gestational diabetes is a known risk factor of macrosomia [42]. This indicates that gestational diabetes may modulate these relationships. However, we did not find an association between high salt intake and a higher risk of macrosomia or LGA (Table 2), even after adjusting for baseline gestational diabetes (Tables S3 and S5). These data underscored the complexity of these interactions, and clearly showed that our observational data needs confirmation by more experimental evidence. Collectively, current evidence highlights the need for further clinical or animal studies to explore the biological explanations for our findings.

Several limitations of our study must be noted. First, salt intake could be underestimated using cooking salt and soy sauce, and certainly does not fully reflect sodium exposure. It has been found that other foods, such as pickles and salted eggs, contributed to 5% of salt intake (3.6% total sodium) among Chinese people, and 7% of the sodium came from other sources including monosodium glutamate, soda, noodles, and stuffed buns [21]. Second, personal salt intake was estimated by averaging family condiment consumption and without accounting for the amount of salt from eating-out occasions that has been rapidly growing [43], which might be non-differential and attenuate the expected findings. In addition, findings were consistent when we restricted the analysis to participants who had all meals at home or when the analysis was stratified by family size. Third, the lack of data on low-salt soy sauce in this cohort may lead to an overestimation of sodium intake from soy sauce. However, given that only 6.4% of sodium intake is attributed to soy sauce and the limited salt reduction practices in China, such overestimation is likely to have minimal impact on our results. Fourth, salt intake in our study was estimated over one week, which was not sufficiently representative of usual salt intake owing to the potential day-to-day variations in salt intake. Previous validation studies among the Chinese population reported a strong correlation ( $r = 0.58$ ) of dietary sodium estimated by combining household condiment-weighing and 24 h dietary recalls, with sodium excretions measured in 24 h urine samples over three consecutive days [44]. Fifth, we cannot exclude the possibility of residual confounding from other sources, such as gestational weight gain. Sixth, our study was based on pregnant women in Shanghai, which is a developed area in China; hence, the generalizability of results to other areas or ethnic populations is unknown. Finally, as in any observational studies, causal inferences cannot be made in this study.

## 5. Conclusions

In summary, we found that a daily cooking salt intake above the recommended amount during pregnancy is associated with increased risks of LBW and SGA in a large cohort

of pregnant women in China. Whether salt reduction among women with an excessive intake may improve maternal and infant health warrants systematical evaluations through high-quality observational studies and clinical trials.

**Supplementary Materials:** The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/nu17040642/s1>, Table S1. Baseline characteristics of pregnant women by salt density in Shanghai, China. Table S2. Sensitivity analysis for salt intake and salt density with low birth weight. Table S3. Sensitivity analysis for salt intake and salt density with macrosomia. Table S4. Sensitivity analysis for salt intake and salt density with small for gestational age. Table S5. Sensitivity analysis for salt intake and salt density with large for gestational age. Table S6. Sensitivity analysis for salt intake with birth weight outcomes. Figure S1. Forest plots for the association of salt intake with macrosomia risk in pre-specified subgroups. Figure S2. Forest plots for the association of salt density with macrosomia risk in pre-specified subgroups. Figure S3. Forest plots for the association of salt intake with the risk of large for gestational age in pre-specified subgroups. Figure S4. Forest plots for the association of salt density with the risk of large for gestational age in pre-specified subgroups.

**Author Contributions:** T.L., J.Z. and G.Z. had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Concept and design: T.L., J.Z., C.Y. (Changzheng Yuan) and G.Z. Acquisition, analysis, or interpretation of data: all authors. Drafting of the manuscript: T.L. and G.Z. Critical revision of the manuscript for important intellectual content: all authors. Statistical analysis: T.L., Z.S., C.F. and Z.W. Administrative, technical, or material support: Z.W., P.Z., C.Y. (Caimei Yuan), D.Z. and L.H. Supervision: L.H., J.Z. and G.Z. All authors have read and agreed to the published version of the manuscript.

**Funding:** The current study was supported by the National Key R&D Program of China (2023YFF1104301), the Noncommunicable Chronic Diseases-National Science and Technology Major Project (2023ZD0508300), the National Natural Science Foundation of China (82373576 and 81922060), the key projects in the three-year plan of Shanghai municipal public health system (2023–2025) (GWVI-4), key disciplines in the three-year plan of Shanghai municipal public health system (2023–2025) (GWVI-11.1-42), the academic leader in the three-year plan of Shanghai municipal public health system (2023–2025) (GWVI-11.2-XD21), the Brands Health Special Fund (CNS-YUM2024-122), the Chinese Nutrition Society's Leadership Development Support Program, and the Shanghai Sailing Program (No. 23YF1437000).

**Institutional Review Board Statement:** The ISPOHC study obtained ethical approval from the Ethics Committee of the Shanghai Centre for Disease Control and Prevention, approval code: 2016-33; approval date: 18 November 2016.

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** The data during the current study are available from the corresponding author on reasonable request.

**Conflicts of Interest:** All authors declare no conflicts of interest.

## References

1. WHO. Guidelines Approved by the Guidelines Review Committee. In *Guideline: Sodium Intake for Adults and Children*; World Health Organization: Geneva, Switzerland, 2012.
2. World Health Organization. WHO global report on sodium intake reduction. In *WHO Global Report on Sodium Intake Reduction*; World Health Organization: Geneva, Switzerland, 2023.
3. Reddin, C.; Ferguson, J.; Murphy, R.; Clarke, A.; Judge, C.; Griffith, V.; Alvarez, A.; Smyth, A.; Mente, A.; Yusuf, S.; et al. Global mean potassium intake: A systematic review and Bayesian meta-analysis. *Eur. J. Nutr.* **2023**, *62*, 2027–2037. [[CrossRef](#)] [[PubMed](#)]
4. Birukov, A.; Andersen, L.B.; Herse, F.; Rakova, N.; Kitlen, G.; Kyhl, H.B.; Golic, M.; Haase, N.; Kräker, K.; Müller, D.N.; et al. Aldosterone, Salt, and Potassium Intakes as Predictors of Pregnancy Outcome, Including Preeclampsia. *Hypertension* **2019**, *74*, 391–398. [[CrossRef](#)] [[PubMed](#)]

5. Arvizu, M.; Bjerregaard, A.A.; Madsen, M.T.B.; Granström, C.; Halldorsson, T.I.; Olsen, S.F.; Gaskins, A.J.; Rich-Edwards, J.W.; Rosner, B.A.; Chavarro, J.E. Sodium Intake during Pregnancy, but Not Other Diet Recommendations Aimed at Preventing Cardiovascular Disease, Is Positively Related to Risk of Hypertensive Disorders of Pregnancy. *J. Nutr.* **2020**, *150*, 159–166. [[CrossRef](#)] [[PubMed](#)]
6. Hu, J.; Li, Y.; Zhang, B.; Zheng, T.; Li, J.; Peng, Y.; Zhou, A.; Buka, S.L.; Liu, S.; Zhang, Y.; et al. Impact of the 2017 ACC/AHA Guideline for High Blood Pressure on Evaluating Gestational Hypertension-Associated Risks for Newborns and Mothers. *Circ. Res.* **2019**, *125*, 184–194. [[CrossRef](#)]
7. O'Donnell, M.; Mente, A.; Rangarajan, S.; McQueen, M.J.; Wang, X.; Liu, L.; Yan, H.; Lee, S.F.; Mony, P.; Devanath, A.; et al. Urinary sodium and potassium excretion, mortality, and cardiovascular events. *N. Engl. J. Med.* **2014**, *371*, 612–623. [[CrossRef](#)]
8. Ma, Y.; He, F.J.; Sun, Q.; Yuan, C.; Kieneker, L.M.; Curhan, G.C.; MacGregor, G.A.; Bakker, S.J.L.; Campbell, N.R.C.; Wang, M.; et al. 24-Hour Urinary Sodium and Potassium Excretion and Cardiovascular Risk. *N. Engl. J. Med.* **2022**, *386*, 252–263. [[CrossRef](#)]
9. Emmerik, N.E.; de Jong, F.; van Elburg, R.M. Dietary Intake of Sodium during Infancy and the Cardiovascular Consequences Later in Life: A Scoping Review. *Ann. Nutr. Metab.* **2020**, *76*, 114–121. [[CrossRef](#)]
10. Ma, H.; Xue, Q.; Wang, X.; Li, X.; Franco, O.H.; Li, Y.; Heianza, Y.; Manson, J.E.; Qi, L. Adding salt to foods and hazard of premature mortality. *Eur. Heart J.* **2022**, *43*, 2878–2888. [[CrossRef](#)]
11. Cook, N.R.; Appel, L.J.; Whelton, P.K. Sodium Intake and All-Cause Mortality Over 20 Years in the Trials of Hypertension Prevention. *J. Am. Coll. Cardiol.* **2016**, *68*, 1609–1617. [[CrossRef](#)]
12. Ando, K. Proper Salt Intake During Pregnancy. *Circ. J. Off. J. Jpn. Circ. Soc.* **2016**, *80*, 2094–2095. [[CrossRef](#)]
13. Inoue, M.; Tsuchihashi, T.; Hasuo, Y.; Ogawa, M.; Tominaga, M.; Arakawa, K.; Oishi, E.; Sakata, S.; Ohtsubo, T.; Matsumura, K.; et al. Salt Intake, Home Blood Pressure, and Perinatal Outcome in Pregnant Women. *Circ. J. Off. J. Jpn. Circ. Soc.* **2016**, *80*, 2165–2172. [[CrossRef](#)] [[PubMed](#)]
14. Lee, Y.Q.; Lumbers, E.R.; Schumacher, T.L.; Collins, C.E.; Rae, K.M.; Pringle, K.G.; Gomeroi Gaaynggal Advisory, C. Maternal Diet Influences Fetal Growth but Not Fetal Kidney Volume in an Australian Indigenous Pregnancy Cohort. *Nutrients* **2021**, *13*, 569. [[CrossRef](#)] [[PubMed](#)]
15. Bank, T.C.; Grash, J.L.; Chung, J.; Mercer, B.M.; McNeil, R.B.; Parry, S.; Saade, G.; Shanks, A.; Silver, R.M.; Simhan, H.; et al. “Sodium intake and the development of hypertensive disorders of pregnancy”. *Am. J. Obstet. Gynecol. MFM* **2023**, *5*, 101166. [[CrossRef](#)] [[PubMed](#)]
16. Chen, L.W.; Aubert, A.M.; Shivappa, N.; Bernard, J.Y.; Mensink-Bout, S.M.; Geraghty, A.A.; Mehegan, J.; Suderman, M.; Polanska, K.; Hanke, W.; et al. Associations of maternal dietary inflammatory potential and quality with offspring birth outcomes: An individual participant data pooled analysis of 7 European cohorts in the ALPHABET consortium. *PLoS Med.* **2021**, *18*, e1003491. [[CrossRef](#)]
17. Mikeš, O.; Brantsæter, A.L.; Knutsen, H.K.; Torheim, L.E.; Bienertová Vašků, J.; Pruša, T.; Čupr, P.; Janák, K.; Dušek, L.; Klánová, J. Dietary patterns and birth outcomes in the ELSPAC pregnancy cohort. *J. Epidemiol. Community Health* **2022**, *76*, 613–619. [[CrossRef](#)]
18. Liu, Y.; Zhang, H.; Zhao, Y.; Chen, F.; Mi, B.; Zhou, J.; Chen, Y.; Wang, D.; Pei, L. Geographical variations in maternal dietary patterns during pregnancy associated with birth weight in Shaanxi province, Northwestern China. *PLoS ONE* **2021**, *16*, e0254891. [[CrossRef](#)]
19. Cook, N.R.; He, F.J.; MacGregor, G.A.; Graudal, N. Sodium and health-concordance and controversy. *BMJ* **2020**, *369*, m2440. [[CrossRef](#)]
20. Tan, M.; He, F.J.; Wang, C.; MacGregor, G.A. Twenty-Four-Hour Urinary Sodium and Potassium Excretion in China: A Systematic Review and Meta-Analysis. *J. Am. Heart Assoc.* **2019**, *8*, e012923. [[CrossRef](#)]
21. Anderson, C.A.; Appel, L.J.; Okuda, N.; Brown, I.J.; Chan, Q.; Zhao, L.; Ueshima, H.; Kesteloot, H.; Miura, K.; Curb, J.D.; et al. Dietary sources of sodium in China, Japan, the United Kingdom, and the United States, women and men aged 40 to 59 years: The INTERMAP study. *J. Am. Diet Assoc.* **2010**, *110*, 736–745. [[CrossRef](#)]
22. Jachimowicz-Rogowska, K.; Winiarska-Mieczan, A. Initiatives to Reduce the Content of Sodium in Food Products and Meals and Improve the Population's Health. *Nutrients* **2023**, *15*, 2393. [[CrossRef](#)]
23. Wang, Z.; Zhao, S.; Cui, X.; Song, Q.; Shi, Z.; Su, J.; Zang, J. Effects of Dietary Patterns during Pregnancy on Preterm Birth: A Birth Cohort Study in Shanghai. *Nutrients* **2021**, *13*, 2367. [[CrossRef](#)]
24. Zhuang, P.; Mao, L.; Wu, F.; Wang, J.; Jiao, J.; Zhang, Y. Cooking Oil Consumption Is Positively Associated with Risk of Type 2 Diabetes in a Chinese Nationwide Cohort Study. *J. Nutr.* **2020**, *150*, 1799–1807. [[CrossRef](#)] [[PubMed](#)]
25. Yang, Y.; Wang, Z.J. *China Food Composition Tables Standard Edition*; Peking University Medical Press: Beijing, China, 2018.
26. Zong, X.N.; Li, H.; Zhang, Y.Q.; Wu, H.H.; Zhao, G.L.; Working Committee of the China National Newborn Growth Standards Project. Construction of China national newborn growth standards based on a large low-risk sample. *Sci. Rep.* **2021**, *11*, 16093. [[CrossRef](#)] [[PubMed](#)]

27. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet* **2004**, *363*, 157–163. [[CrossRef](#)]
28. Piercy, K.L.; Troiano, R.P.; Ballard, R.M.; Carlson, S.A.; Fulton, J.E.; Galuska, D.A.; George, S.M.; Olson, R.D. The Physical Activity Guidelines for Americans. *JAMA* **2018**, *320*, 2020–2028. [[CrossRef](#)]
29. Goñi, L.; Cuervo, M.; Santiago, S.; Zazpe, I.; Martínez, J.A. Parity implications for anthropometrical variables, lifestyle behaviors and dietary habits in pregnant women. *An. Sist. Sanit. Navar.* **2014**, *37*, 349–362. [[CrossRef](#)]
30. White, I.R.; Royston, P.; Wood, A.M. Multiple imputation using chained equations: Issues and guidance for practice. *Stat. Med.* **2011**, *30*, 377–399. [[CrossRef](#)]
31. Naska, A.; Lagiou, A.; Lagiou, P. Dietary assessment methods in epidemiological research: Current state of the art and future prospects. *F1000Research* **2017**, *6*, 926. [[CrossRef](#)]
32. National Academies of Sciences, Engineering, and Medicine; Health and Medicine Division; Food and Nutrition Board; Committee to Review the Dietary Reference Intakes for Sodium and Potassium. The National Academies Collection: Reports funded by National Institutes of Health. In *Dietary Reference Intakes for Sodium and Potassium*; Oria, M., Harrison, M., Stallings, V.A., Eds.; National Academies Press (US): Washington, DC, USA, 2019. [[CrossRef](#)]
33. Lerchl, K.; Rakova, N.; Dahlmann, A.; Rauh, M.; Goller, U.; Basner, M.; Dinges, D.F.; Beck, L.; Agureev, A.; Larina, I.; et al. Agreement between 24-hour salt ingestion and sodium excretion in a controlled environment. *Hypertension* **2015**, *66*, 850–857. [[CrossRef](#)]
34. Eljovich, F.; Weinberger, M.H.; Anderson, C.A.; Appel, L.J.; Burszty, M.; Cook, N.R.; Dart, R.A.; Newton-Cheh, C.H.; Sacks, F.M.; Laffer, C.L. Salt Sensitivity of Blood Pressure: A Scientific Statement From the American Heart Association. *Hypertension* **2016**, *68*, e7–e46. [[CrossRef](#)] [[PubMed](#)]
35. Seo, Y.; Jeong, Y.S.; Koo, K.A.; Yang, J.I.; Park, Y.K. Maternal nutrition intervention focused on the adjustment of salt and sugar intake can improve pregnancy outcomes. *Food Sci. Nutr.* **2020**, *8*, 3900–3911. [[CrossRef](#)] [[PubMed](#)]
36. Getaneh, T.; Negesse, A.; Dessie, G.; Desta, M. The impact of pregnancy induced hypertension on low birth weight in Ethiopia: Systematic review and meta-analysis. *Ital. J. Pediatr.* **2020**, *46*, 174. [[CrossRef](#)] [[PubMed](#)]
37. Kyojima, H.; Fukusda, T.; Murata, T.; Yamaguchi, A.; Kanno, A.; Yasuda, S.; Sato, A.; Ogata, Y.; Kuse, M.; Hosoya, M.; et al. Impact of preconception sodium intake on hypertensive disorders of pregnancy: The Japan Environment and Children's study. *Pregnancy Hypertens.* **2021**, *23*, 66–72. [[CrossRef](#)]
38. Nielsen, L.H.; Ovesen, P.; Hansen, M.R.; Brantlov, S.; Jespersen, B.; Bie, P.; Jensen, B.L. Changes in the renin-angiotensin-aldosterone system in response to dietary salt intake in normal and hypertensive pregnancy. A randomized trial. *J. Am. Soc. Hypertens. JASH* **2016**, *10*, 881–890.e884. [[CrossRef](#)]
39. Gennari-Moser, C.; Khankin, E.V.; Schüller, S.; Escher, G.; Frey, B.M.; Portmann, C.B.; Baumann, M.U.; Lehmann, A.D.; Surbek, D.; Karumanchi, S.A.; et al. Regulation of placental growth by aldosterone and cortisol. *Endocrinology* **2011**, *152*, 263–271. [[CrossRef](#)]
40. Todkar, A.; Di Chiara, M.; Loffing-Cueni, D.; Bettoni, C.; Mohaupt, M.; Loffing, J.; Wagner, C.A. Aldosterone deficiency adversely affects pregnancy outcome in mice. *Pflug. Arch. Eur. J. Physiol.* **2012**, *464*, 331–343. [[CrossRef](#)]
41. Wang, X.; Ma, H.; Kou, M.; Tang, R.; Xue, Q.; Li, X.; Harlan, T.S.; Heianza, Y.; Qi, L. Dietary Sodium Intake and Risk of Incident Type 2 Diabetes. *Mayo Clin. Proc.* **2023**, *464*, 331–343. [[CrossRef](#)]
42. Ye, W.; Luo, C.; Huang, J.; Li, C.; Liu, Z.; Liu, F. Gestational diabetes mellitus and adverse pregnancy outcomes: Systematic review and meta-analysis. *BMJ* **2022**, *377*, e067946. [[CrossRef](#)]
43. You, J. *Dietary Change, Nutrient Transition and Food Security in Fast-Growing China*; Edward Elgar Publishing: Cheltenham, UK, 2014; pp. 204–245.
44. Du, S.; Batis, C.; Wang, H.; Zhang, B.; Zhang, J.; Popkin, B.M. Understanding the patterns and trends of sodium intake, potassium intake, and sodium to potassium ratio and their effect on hypertension in China. *Am. J. Clin. Nutr.* **2014**, *99*, 334–343. [[CrossRef](#)]

**Disclaimer/Publisher's Note:** The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.