Original Article

The association between maternal healthy lifestyle factors during pregnancy and the neonatal anthropometric indicators based on a prospective cohort study

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Background and Objectives: We aimed to evaluate the associations between a combined healthy lifestyle during the second and third trimesters and offspring anthropometric outcomes in China. **Methods and Study Design:** We examined these associations among 548 participants from nine community health centers and three hospitals in the North China cohort. A pregnant women's healthy lifestyle score (HLS) was constructed based on six lifestyle factors: smoking, alcohol consumption, physical activity, sedentary behavior, diet, and gestational weight gain. Anthropometric indicators at birth like birth weight (BW), head circumference (HC), and birth length (BL) were collected, and weight to head circumference ratio (WHC, kg/m), body mass index (BMI, kg/m^2) and Ponderal Index (PI, kg/m^3) were calculated. Multivariate linear and logistic regression models were used to examine the effects of HLS during the second and third trimesters on anthropometric outcomes at birth, respectively. **Results:** In fully adjusted models, we found a negative association between second and third-trimester HLS and offspring HC and a positive relationship between second-trimester HLS and BL (p<0.05). Neonates with mothers in the highest HLS tertile had a 5.6% relatively lower HC and 2.3% relatively longer body length than women in the lowest tertile. Each additional unit in third-trimester HLS had an associated decrease in HC by 0.96 cm. None of the associations between HLS and BW, WHC, BMI, and PI of offspring were observed. **Conclusions:** A healthy lifestyle score may significantly impact offspring head circumference and body length, supporting the important role of healthy lifestyles in improving the health of offspring.

Key Words: healthy lifestyle score, anthropometric indicators, large for gestational age, prospective study

INTRODUCTION

Neonatal health status has always been the focus of maternal and child health care in China and the world. Physical growth assessment at birth, including birth weight (BW), body length (BL), and head circumference (HC), as well as the derivative index birth weight to head circumference ratio (WHC), body mass index (BMI), and ponderal index (PI) are important means to understand intrauterine growth and development. Additionally, they are essential for predicting disease risk, growth, future development, and even adult health.[1-4] The Developmental Origins of Health and Disease theory[5] highlights that the early-life environment, especially maternal lifestyle factors during pregnancy, has an important impact on the growth and development of newborns,[6,7] including cigarette smoking,[8,9] drinking,[10] gestational weight gain,[11] physical inactivity[12] and diet.[13]

Individual lifestyle factors can be complex because of the coexistence of other risk factors (e.g., people with obesity are more likely to be physically inactive). Thus, a healthy lifestyle score (HLS) such as diet quality, smoking, physical activity (PA), alcohol consumption, sedentary behavior, and BMI has been used by researchers to summarize lifestyle factors as a whole to evaluate their impact on health in different populations.[14-17] Notably,

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different studies may choose various indicators for their research goals. Therefore, previous studies have found a negative relationship between a HLS (where a high score indicates a healthier lifestyle) and the risk of cancer,[18,19] cardiovascular diseases,[16] metabolic syndrome,[15] and hypertension.[20]

Few studies suggest that maternal adherence to a higher healthy lifestyle score during pregnancy is associated with a reduced risk of adverse offspring birth outcomes.[21,22] It is worth noting that the existing research did not consider gestational weight gain (GWG) as the indicator for HLS, which was associated with a higher risk of adverse maternal and infant outcomes being proved by many of studies.[23] To our knowledge, there is limited research regarding maternal associations between a composite HLS in different trimesters and birth anthropometric indicators, including BW, HC, and BL, combined with the calculated composite indicators like WHC, PI, and birth BMI. Furthermore, we are unaware of any related studies among Chinese maternal-child pairs.

Considering the limited research, we conducted a prospective study at nine community health centers and three hospitals in Shijiazhuang in North China. We aimed to investigate longitudinal associations between maternal HLS during the second and third trimesters derived from diet, smoking, alcohol intake, sedentary behavior, PA, and velocity of GWG and adverse offspring birth outcomes.

METHODS

Study population

This prospective study was conducted between March 2013 and May 2014 and aimed to assess the relevance of maternal nutrition before and during pregnancy for health outcomes among mothers and offspring, as published elsewhere.[24] Pregnant women were eligible if they had regular prenatal care until delivery and maintained complete data during the study period. Women aged 20–35 with a living singleton pregnancy and < 12 weeks pregnant were included in this study. The subjects with multiple pregnancies or insufficient information about their height, pre-pregnancy weight, and gestational weight and who had pre-existing diabetes mellitus or hypertension, endocrine disease, and other complications were excluded from this study. A total of 567 participants were initially recruited. Of those initially recruited, pregnant women with incomplete data (missing lifestyle data or information on potential confounders, n = 19) were excluded. Finally, 548 pairs of maternal-fetus were included in the analysis (Figure 1). This study was approved by the Chinese Nutrition Society Ethics Committee (Ethical Approval Number: CNS2014305-9Z) and adhered to the Helsinki Declaration during implementation. All participants gave written informed consent.

Data collection occurred during the first trimester of pregnancy (0–13 weeks), and follow-up measurements were taken during the second (14–27 weeks) and third trimesters (28–41 weeks) by trained interviewers through face-to-face interviews. A structured questionnaire was scheduled, which included: a) socio-demographic characteristics, e.g., maternal/paternal birthdate, maternal/paternal educational level, maternal/paternal occupation, family monthly income; b) pre-pregnancy body weight, lifestyle (e.g., regular and passive smoking, alcohol drinking, sleep state, screen time and physical activity); c) menstrual and reproductive history and history of diseases. Additionally, trained investigators interviewed pregnant women in person concerning their diet using a 24-hour dietary recall questionnaire during the first, second, and third trimesters. In the interview, participants were asked to recall all foods and beverages consumed and the corresponding timing for the preceding 24 hours. Furthermore, trained dietitians obtained information on recipes and the types and brands of all food items reported.

Anthropometrics measurements

Height and pre-pregnancy weight data were obtained from the pregnant women's baseline interview at 0–13 weeks of gestation. Height was measured in m (two decimal places), and weight in kg (one decimal place) was recalled by the pregnant women and surveyed by a trained nurse. BMI was calculated by dividing body weight (kg) by height-squared (m^2). Maternal pre-pregnancy BMI was divided into two groups (normal BMI < 24.0, pre-pregnancy overweight/obesity ≥ 24.0) by the Chinese BMI cutoff.[25]

Physical development indices included BW, HC, and BL of neonates collected as outcomes. BW was measured within 12 hours of birth with an electronic scale (maxi-

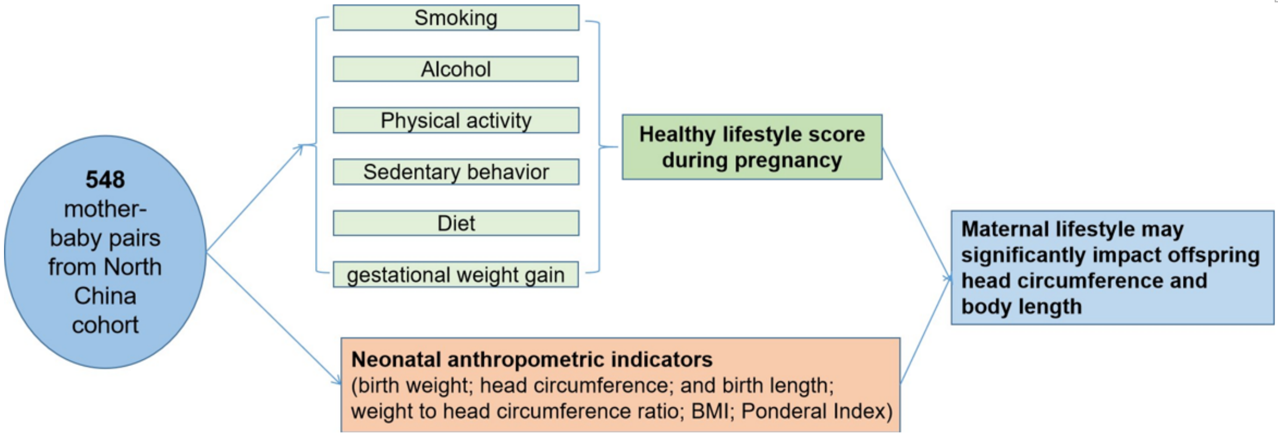

Figure 1. Graphical abstract.

mum range 20 kg, accurate to 10 g). BL was measured within 24 hours with an infant meter (maximum range 65 cm, accurate to 0.1 cm) for babies. HC was measured within 24 hours with a flexible non-stretchable plastic tape (0.7 cm wide, maximum range 100 cm, accurate to 0.1 cm). Furthermore, BW, BL, and HC were each averaged based on two measurements in a standardized measurement procedure.

The 10th percentile and the 90th of growth standards were assigned as the cutoff points for identifying small for gestational age (SGA) and large for gestational age (LGA), respectively, according to the China national newborn growth standards developed by the Capital Institute of Pediatrics, the Coordinating Study Group of Nine Cities on the Physical Growth and Development of Children in China.[26,27] WHC, birth PI, and birth BMI of newborn infants were calculated according to the following formula: [weight (kg)/HC (m)], [length (cm)/HC (cm)], [weight (kg)/length (m)^3] and [weight (kg)/length (m)^2].[28]

Assessment of healthy lifestyle factors

Considering that multiple lifestyle factors are interrelated and associated with maternal and neonatal outcomes, we constructed an HLS as the sum scores of six lifestyle factors (smoking, alcohol consumption, physical activity, sedentary behavior, diet, and GWG) during the second and third trimester,[29] which were collected via in-person interviews. Each factor was given a point score of zero or one to represent an unhealthy or healthy lifestyle, respectively. The definitions of each HLS component for pregnant women during the second and third trimesters are shown in Table 1. A healthy lifestyle was defined as no smoking or no alcohol consumption, doing 75-150 min of moderate-intensity activities per week, sitting for less than 4 h/day, with a healthy diet and suitable gestation weight gain. Dietary quality was evaluated using the dietary recommendation for pregnant women by the Chinese Nutrition Society.[30] Ten dietary components were considered: dairy, soy/nuts, lean meat & poultry, fish and shrimp, eggs, vegetables, fruit, whole grains and miscellaneous beans, tubers, and water. A healthy diet was defined as meeting at least half of the dietary recommendations (at least 5 items).[31] Weight gain rate during pregnancy was classified by combining the Chinese BMI classification standard[32] with the Institute of Medicine (IOM) 2009 Guidelines for weight gain during pregnancy.[33] According to the recommended range of weight gain rates, we assigned 1 point for whom weight gain rate was in the suitable value range and 0 points for lower or higher weight gain rates. A combined score (0 to 6 points) was obtained by summing up the scores of the six factors.

Statistical analysis

SAS procedures (SAS, version 9.4, 2002-2012, SAS Institute Inc., Cary, NC, USA) were used for data analyses. All continuous variables' normality was examined using normal probability plots and the Kolmogorov-Smirnov test. Pregnant-offspring's characteristics were presented as means with standard deviations (SD) for normally distributed or median with interquartile range (IQR)] for non-normally distributed continuous variables and proportions with numbers for categorical variables. HLS in the second and third trimesters were grouped into tertiles (T1–T3) to illustrate their relationship to offspring's characteristics. Significant differences for mean continuous variables by tertiles (T1–T3) of HLS in the second and third trimester were evaluated by ANOVA with Dunnett's or Bonferroni's significant difference adjustment for multiple comparisons for median variables by Kruskal–Wallis tests and for categorical variables by Chi-square tests.

We used multivariable linear generalized regression models to investigate the associations of HLS in second and third trimesters with neonatal growth and development (BW, HC, BL, WHC, birth PI, and birth BMI). We defined HLS in the second or third trimesters as independent variables, and BW, HC, BL, WHC, PI, and BMI were the dependent variable in separate models. Due to the non-normal distribution of BW and HC, their logarithm was calculated to improve the fitting effect of the models. The linear models' least-squares means and 95% confidence interval computed were back-transformed and then presented in the results.

The basic models carried out the correlation analyses between HLS and infant physical development indices. Potential covariates that may affect these associations were added in a further step. These included continuous variables—maternal age at delivery (years), fasting blood glucose (mmol/L), gestational age at delivery (weeks), per capita monthly household income (CNY); and categorical variables—pre-pregnancy BMI category (normal, overweight, and obese), gravida, parity, gestational hypertension (yes or no), maternal education level (< 6 years, 6–12 years, and > 12 years of schooling), delivery mode (natural childbirth, cesarean section, forceps delivery, attractor assists in childbirth, and others), and sex of the newborn. Each variable was initially considered separately: only variables that had a significant independent effect in the basic models or substantially modified the association were included in the subsequent multivariable analyses.

Furthermore, logistic regression analysis was used to evaluate the odds ratio (OR) and 95 % confidence interval (CI) for SGA and LGA.

RESULTS

In the present analysis, nearly three-quarters of the women scored over 3 points in the second trimester and a half in the third trimester. Of the 548 women, 17% were overweight or obese before pregnancy (n = 94), and 6.9% had hypertension during pregnancy (n = 35). The majority of participants were primipara. Almost half of all women had chosen cesarean delivery (n = 239, 43.6%) (Table 2). Pregnant women who scored over 3 points in the second trimester were older, with higher fasting blood-glucose and education level, and whose baby's HC were relatively smaller than participants who scored under 3 points ($p < 0.05$). In contrast, women who scored over 3 points during the third trimester were older ($p < 0.05$), had higher education levels, and had longer babies ($p = 0.053$) with smaller HC ($p < 0.05$).

We first examined the linear association between HLS in the second trimester and neonatal anthropometric indicators (Table 3). After adjusting for maternal age, maternal educational level, multiparity, multiple pregnancies, delivery mode, pre-pregnancy body mass index category, gestational hypertension, and fasting glucose in the second trimester, HLS of pregnant women in the second trimester was positively associated with offspring BL and negatively with their HC (all p values < 0.05). Neonates whose mothers were in the highest HLS tertile had 5.6% relative lower HC and 2.3% relative longer BL than women in the lowest tertile.

We observed an association between third-trimester HLS and offspring birth anthropometric outcomes. Figure 1 shows that a third-trimester HLS was negatively associated with offspring HC after the adjustment for all the covariates we considered ($p < 0.05$). Each additional unit in third-trimester HLS had an associated decrease in HC by 0.96 cm.

We then examined the relationship of second- and third-trimester HLS to the odds of offspring anthropometric indicators (Table 4). In fully adjusted models, HLS in the second trimester was significantly associated with the odds of LGA (OR = 1.97, 95% CI: 1.02, 4.09). This suggests that pregnant women with higher second-trimester HLS had 1.97 increased odds of giving birth to LGA compared with women with relatively lower HLS.

None of the associations were observed between HLS and BW, WHC, BMI, and PI of offspring.

DISCUSSION

The present study suggests that a mother’s healthy lifestyle, especially during second-trimester pregnancy, is associated with appropriate HC, longer BL, and low risk of LGA in the offspring after adjusting for the potential covariates. These findings support the critical role of healthy lifestyles in improving the health of offspring. Simultaneously, these results also partly verify the usability of the HLS we developed.

As stated in the previous paragraph, neonatal anthropometric indexes were reproducibly associated with their future growth, development, and the occurrence of various metabolic diseases,[1-3] which has gained wide interest. Based on the new curve of China's national newborn growth standards, the longitudinal association between HLS and anthropometric indicators was analyzed. We found that the baby whose mother had a higher HLS during the second trimester, whose HC was closer to a health condition. This suggests that when mothers live an unhealthy life during mid-pregnancy, the newborns may have larger HC, well above the population average, which is inconsistent with the previous studies.[21, 22,34] This may be due to the high level of the head circumference of newborns and shortcomings in dietary quality evaluation in the present study. Dietary nutrition is essential for fetal growth and development. However, dietary quality in our HLS was based on food species, no upper limit on intake,[32] and did not include oil or salt. In brief, HC at birth is a widely available proxy measure reflecting fetal brain growth[35] during the period with the most rapid growth of the developing human brain.[36,37] This was also reported to impact childhood cognition,[38] school performance in reading and mathematics,[39] attention deficit hyperactivity disorder,[40] and adiposity rebound.[41] Therefore, it is important to improve newborns' birth quality and keep HC as appropriate by modifying the lifestyle of pregnant women. Importantly, our results demonstrate that healthy lifestyle nutrient intake should be “moderate” not excessive or less.

Birth weight is a valuable indicator of the fetal experience and has been associated with multiple child and adult health outcomes.[42-44] We divided the newborns into AGA, SGA, and LGA based on the P10 and P90 of the birth weight reference curve.[27] We found that pregnant women with higher second-trimester HLS had 1.97 increased odds of giving birth to LGA compared with women with relatively lower HLS, suggesting that the nutritional intake of pregnant women is too high to control. Maintaining maternal nutritional intake within the

Table 1. Classification of healthy lifestyle factors

Variable	Unhealthy (Score=0)	Healthy (Score=1)
Smoking	Passive smoking/Smoke	Never
Second trimester	18 (3.28)	530 (96.7)
Third trimester	11 (2.01)	537 (98.0)
Alcohol consumption	Ever drank	Never drank
Second trimester	3 (0.55)	545 (99.5)
Third trimester	1 (0.18)	547 (99.8)
Physical activity	0-74.9 min/week moderate intensity	75-150 min/week moderate intensity
Second trimester	396 (72.3)	152 (27.7)
Third trimester	395 (72.1)	153 (27.9)
Sedentary time	≥ 4 hours/day	< 4 hours/day
Second trimester	428 (78.1)	120 (21.9)
Third trimester	458 (83.6)	90 (16.4)
Diet	Unhealthy	Healthy
Second trimester	372 (67.9)	176 (32.1)
Third trimester	479 (87.4)	69 (12.6)
Gestation weight gain	Low or high rate	suitable growth
Second trimester	402 (73.4)	146 (26.6)
Third trimester	456 (83.2)	92 (16.8)
Total	0-6 points	

Ten dietary components including dairy, soy/nuts, lean meat & poultry, fish and shrimp, eggs, vegetable, fruit, whole grains and miscellaneous beans, tubers, and water were considered. A healthy diet was defined as meeting at least half of the dietary recommendation (at least 5 items)

Table 2. Characteristics of pregnant-offspring according to tertiles of second-trimester and third-trimester healthy lifestyle score (n = 548)†

Variable	Total	Tertiles of second-trimester healthy lifestyle score			*p*
		Low (1, 2)	Medium (3, 3)	High (4, 5)	
n (%)	548	132 (24.1)	246 (44.9)	170 (31.0)	
Maternal characteristics					
Age at delivery (yrs)	27.7 (25.7, 30.1)	26.7 (25.0, 29.7)	27.5 (25.6, 30.2)	28.2 (26.4, 30.1)	0.04
Multiple gravidities (%)	147 (26.8)	38 (28.8)	61 (24.8)	48 (28.2)	0.6
Multiparity (%)	9 (1.64)	2 (0.36)	5 (0.91)	2 (0.36)	0.8
Gestational hypertension (%)	35 (6.39)	11 (8.33)	15 (6.10)	9 (5.29)	0.5
Fasting blood-glucose	4.7 (4.4, 5.0)	4.60 (4.30, 4.90)	4.70 (4.40, 4.99)	4.80 (4.50, 5.10)	0.001
Pre-pregnancy BMI (kg/m^2)‡	20.7 (19.1, 22.9)	21.3 (19.5, 23.8)	20.7 (19.1, 22.5)	20.4 (19.1, 22.7)	0.06
Pre-pregnancy BMI category (%)§					
Normal	363 (66.2)	80 (14.6)	168 (30.7)	115 (21.0)	0.3
Overweight	83 (15.15)	28 (5.11)	31 (5.66)	24 (4.38)	
Obesity	11 (2.01)	4 (0.73)	5 (0.91)	2 (0.36)	
High educational level (%)¶	408 (74.5)	90 (68.2)	185 (75.2)	133 (78.2)	0.005
High family income (%)††	324 (59.1)	69 (52.3)	155 (63.0)	100 (58.8)	0.3
Offspring characteristics					
Gestational age at delivery (weeks)	39.0±1.39	39.1±1.18	38.9±1.47	39.0±1.42	0.7
Delivery mode-cesarean section	239 (43.6)	62 (25.9)	107 (44.8)	70 (29.3)	0.2
Sex-female (%)	297 (54.2)	66 (50.0)	142 (57.7)	189 (52.4)	0.3
Birth weight (kg)	3.34 (3.1, 3.6)	3.30 (3.10, 3.50)	3.33 (3.10, 3.60)	3.40 (3.10, 3.65)	0.5
Gestational age (%)					
Normal	430 (78.5)	106 (29.3)	199 (36.3)	115 (22.8)	0.1
Small for gestational age	37 (6.75)	12 (2.19)	12 (2.19)	13 (2.37)	
Large for gestational age	81 (14.8)	14 (2.55)	35 (6.39)	32 (5.84)	
Head circumference (cm)	34.0 (33.0, 35.0)	34.0 (33.0, 37.5)	33.6 (33.0, 35.0)	33.8 (33.0, 34.5)	<0.0001
Body length (cm)	49.7±3.19	48.9±5.79	50.0±1.69	50.1±1.43	0.06
Birth weight to head circumference	0.49±0.77	0.50±0.69	0.46±0.77	0.53±0.83	0.5
Birth PI (kg/m^3)	26.8 (24.8, 28.8)	27.2 (25.0, 28.8)	26.4 (24.8, 28.8)	26.8 (24.9, 28.8)	0.4
Birth body mass index (kg/m^2)	13.4 (12.4, 14.4)	13.6 (12.6, 14.4)	13.4 (12.2, 14.4)	13.5 (12.4, 14.4)	0.7

†Values are medians (Q1, Q3) or frequencies. Test for difference between tertiles of second-trimester healthy lifestyle score and third-trimester healthy lifestyle score was performed by using Kruskal-Wallis tests for non-normally distributed continuous variables and ANOVA for normally distributed continuous and chi-square test or fisher's exact test for categorical variables.
‡ BMI: Body mass index (kg/m^2) =weight / (height*height).
§According to the Chinese BMI cutoff. [25]
¶At least 12 years of school education.
††Average month income of family at least ≥ 3,000 CNY (Chinese Yuan).
‡‡According to growth standard curves developed by Capital Institute of Pediatrics.[26,27]

appropriate range during pregnancy is extremely important for newborns and children's future growth, development, and health.

BL is an indicator of fetal linear growth. Many studies showed that short BL is closely related to childhood growth retardation and adult short stature. This is significantly higher than the correlation between low body weight and delayed growth or adult short stature, which suggests that BL can be more effective in identifying high-risk children with growth retardation. In recent decades, BL has increased linearly with the improvement of the nutritional status of residents and the rapid growth of the economic level, which is to be expected. Therefore, the mother's influence on the fetus cannot be ignored.

The comprehensive evaluation of HC, BW, and BL can better reflect newborns' body proportion and intrauterine nutrition status, which is important for assessing early postnatal catch-up growth, especially for premature infants.[26,45] However, no significant association was found between WHC, LHC, BMI at birth, and PI and maternal HLS. That might lie in the other environmental factors that can influence abdominal obesity in childhood and our study's relatively small sample size. Further research is needed to focus on their relationship.

Some strengths of our study should be mentioned. Constructed HLS was based on six lifestyle factors closely related to fetus growth, which can comprehensively reflect the important influence of pregnant women on the fetus. The prospective nature and repeated detailed measurements of anthropometric and dietary data in participants in conjunction with the ability to consider a wide range of maternal lifestyle factors including dietary, smoking, alcohol intake, PA, sedentary behaviour, and potential confounders including sex of newborn, education level, gravidity, parity, maternal delivery mode, maternal FPG and hypertension were considerable. More-

Table 3. Multiple linear regression for the association of second-trimester healthy lifestyle score with neonatal physical development (n = 548)†

	Tertiles of second-trimester healthy lifestyle score‡			p for trend
	Low (1, 2)§	Medium (3, 3)§	High (4, 5)§	
Body weight (kg)				
Unadjusted model	3.33 (3.25, 3.40)	3.36 (3.30, 3.41)	3.38 (3.31, 3.44)	0.6
Model 1¶	3.40 (3.19, 3.60)	3.43 (3.24, 3.63)	3.45 (3.25, 3.65)	0.6
Model 2††	3.40 (3.20, 3.61)	3.45 (3.25, 3.64)	3.46 (3.25, 3.66)	0.6
Model 3‡‡	3.40 (3.19, 3.61)	3.44 (3.24, 3.64)	3.46 (3.25, 3.66)	0.5
Head circumference (cm)				
Unadjusted model	37.0 (36.2, 37.7)	34.5 (34.0, 35.1)	34.0 (33.4, 34.7)	<0.0001
Model 1¶	37.6 (35.6, 39.6)	34.6 (33.7, 37.5)	35.2 (33.3, 37.2)	<0.0001
Model 2††	37.9 (35.97, 39.9)	35.9 (34.0, 37.9)	35.6 (33.6, 37.6)	0.0001
Model 3‡‡	37.7 (35.8, 39.7)	35.8 (33.9, 37.7)	35.6 (33.6, 37.6)	0.0003
Body length (cm)				
Unadjusted model	48.9 (48.3, 49.4)	50.0 (49.6, 50.4)	50.1 (49.6, 50.5)	0.0006
Model 1¶	48.9 (47.4, 50.4)	49.9 (48.5, 51.4)	50.0 (48.5, 51.4)	0.002
Model 2††	49.1 (47.6, 50.6)	50.2 (48.8, 51.7)	50.2 (48.8, 51.8)	0.002
Model 3‡‡	49.1 (47.6, 50.6)	50.2 (48.7, 51.6)	50.2 (48.8, 51.7)	0.002
Body weight to head circumference ratio (kg/m)				
Unadjusted model	9.2 (8.6, 9.8)	10.1 (9.6, 10.5)	10.0 (9.4, 10.5)	0.2
Model 1¶	9.4 (7.7, 11.0)	10.2 (8.6, 11.8)	10.0 (8.4, 11.7)	0.2
Model 2††	9.3 (7.6, 11.0)	10.1 (8.5, 11.8)	9.9 (8.2, 11.6)	0.3
Model 3‡‡	9.3 (7.6, 11.0)	10.1 (8.5, 11.8)	9.9 (8.2, 11.6)	0.3
Birth PI (kg/m^3)				
Unadjusted model	27.4 (26.9, 28.0)	26.9 (26.5, 27.3)	26.8 (26.4, 27.3)	0.1
Model 1¶	27.9 (26.5, 29.4)	27.5 (26.1, 28.9)	27.4 (25.9, 28.8)	0.1
Model 2††	27.8 (26.3, 28.8)	27.4 (25.9, 28.8)	27.4 (25.8, 28.7)	0.1
Model 3‡‡	27.8 (26.3, 29.3)	27.3 (25.9, 28.8)	27.3 (25.8, 28.7)	0.2
Birth BMI (kg/m^2)				
Unadjusted model	13.6 (13.3, 13.8)	13.4 (13.2, 13.6)	13.4 (13.2, 13.7)	0.4
Model 1¶	13.8 (13.1, 14.5)	13.7 (13.1, 14.4)	13.7 (13.0, 14.4)	0.4
Model 2††	13.8 (13.1, 14.5)	13.7 (13.0, 14.4)	13.7 (13.0, 14.4)	0.4
Model 3‡‡	13.8 (13.1, 14.5)	13.7 (13.0, 14.4)	13.7 (13.0, 14.4)	0.5

†Values are models adjusted least-squares means and 95% confidence interval. Linear trends (p for trend) were obtained with second-trimester healthy lifestyle score as continuous variables.
‡ Ranges for tertiles (T) 1 through 3 (Tertile 1—Low, Tertile 2—Medium, Tertile 3—High).
§Values are (min, max) of tertiles of second-trimester healthy lifestyle score.
¶Model 1: adjusted for maternal age, maternal educational level, multiparity, multiple pregnancy, delivery mode.
††Model 2: as model 1 and additionally adjusted for pre-pregnancy body mass index category
‡‡Model 3: as model 2 and additionally adjusted for gestational hypertension and fast glucose in the second trimester

over, according to the regional statistic books, our participants and their parents/families represented the general population in age, economic, and education status.

Nevertheless, we also acknowledge that our study has several limitations. First, the relative sample size may reduce the test effectiveness of the study. Secondly, the lifestyle score derived from a sum of the number of healthy lifestyle factors assumed that all lifestyle factors had similar effects on health outcomes, which might not be true because of the complex interactions of lifestyle factors. Finally, although we controlled for key personal characteristics and comorbidities, residual confounding was still possible, and causal inference cannot be made because of the nature of observational studies.

Conclusions

Our study suggests that a healthy lifestyle score may significantly impact offspring neurodevelopment and body length, supporting the essential role of healthy lifestyles in improving the health of offspring.

AUTHOR DISCLOSURES

The authors declare that the research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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Table 4. Multiple logistic regression for the association of second- and third-trimester healthy lifestyle score with small gestation age and large gestation age (n = 548)

	Small for gestation age				Large for gestation age			
	Unadjusted model	Model 1	Model 2	Model 3	Unadjusted model	Model 1	Model 2	Model 3
Second-trimester healthy life-style score								
Low	1	1	1	1	1	1	1	1
Medium	0.53 (0.23, 1.24)	0.49 (0.20, 1.17)	0.47 (0.20, 1.13)	0.48 (0.20, 1.14)	1.33 (0.70, 2.66)	1.38 (0.71, 2.79)	1.32 (0.68, 2.69)	1.29 (0.66, 2.64)
High	0.92 (0.40, 2.13)	0.87 (0.36, 2.09)	0.81 (0.33, 1.97)	0.81 (0.33, 1.98)	1.94 (1.00, 3.93)	2.02 (1.02, 4.16)	1.96 (1.02, 4.05)	1.97 (1.02, 4.09)
Third-trimester healthy lifestyle score								
Low	1	1	1	1	1	1	1	1
Medium	0.76 (0.34, 1.64)	0.75 (0.33, 1.65)	0.74 (0.32, 1.62)	0.72 (0.31,1.59)	1.15 (0.68, 1.92)	1.20 (0.70, 2.05)	1.18 (0.69, 2.03)	1.21 (0.71, 2.09)
High	1.27 (0.50, 2.96)	1.17 (0.45, 2.82)	1.10 (0.42, 2.67)	1.12 (0.42, 2.72)	0.95 (0.45, 1.89)	0.97 (0.45, 1.97)	0.93 (0.43, 1.90)	0.93 (0.43, 1.89)

[†]Values are odds ratio and 95% confidence interval
[‡]Model 1: adjusted for maternal age, maternal educational level, multiparity, multiple pregnancy, delivery mode
[§]Model 2: as model 1 and additionally adjusted for pre-pregnancy body mass index category
[¶]Model 3: as model 2 and additionally adjusted for gestational hypertension, and FPG in the second trimester for and FPG in the third trimester respectively

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