Resting Energy Expenditure Guided Intervention for Gestational Weight Gain in Obese and Overweight Women

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Abstract

Background

There is sparse in the literature on resting energy expenditure guided intervention to manage gestational weight gain in obese and overweight women.

Methods

We conducted a prospective cohort study in Beijing, China between May 1, 2017 and April 30, 2018. Obese/overweight women who visited the Department of Obstetrics and Gynecology at LuHe hospital of Capital Medical University, a tertiary care facility in Beijing, China, for their routine prenatal care at 10-13 weeks of gestation during the study period were recruited into the study after written consent was obtained. Pregnant women who took steroid medication or who were diagnosed with thyroid disease or affected by pre-pregnant diabetes mellitus or for other reasons could not participate in the study assessments were excluded. Women who were recruited between May 1, 2017 and November 30, 2017 were the designated control group with diet recommendation based on pre-pregnancy body mass index and ideal weight, without resting energy expenditure monitoring. Women who were recruited between December 1, 2017 and April 30, 2018 were the intervention group, with resting energy expenditure guided diet recommendation to manage gestational weight gain. Gestational weight gain and perinatal outcomes between the two groups were compared.

Results

A total of 53 eligible women (32 in intervention group and 21 in control group) were recruited and included in the final analysis. There was no difference in baseline demographic and clinical characteristics between the two groups. Gestational weight gain (GWG) in the intervention group (13.45 ± 4.16 Kg) was lower than in the control group (18.20 ± 4.84 Kg). Rate of excess GWG in the intervention group (37.59%) was also lower than in the control group (66.67%). The REE in women of the intervention group with excess GWG increased faster than women with appropriate GWG during pregnancy, especially from 1st trimester to 2nd trimester. Rate of macrosomia in the intervention group (3.12%) was lower than in the control group (19.05%). There was no fetal growth restriction observed in either group.

Conclusion: Resting energy expenditure guided nutrition intervention during pregnancy may lower GWG and lower incidence of macrosomia, with no apparent impact on fetal growth restriction. Future studies with larger sample size and randomized controlled trial design are needed to confirm findings from this small-scale study.

Background

Obesity and overweight have become a major public health problem worldwide. In 2015, rates of obesity and overweight in Chinese adults were 11.9% and 30.1%, respectively, and about 50% women were obese or overweight at the beginning of a pregnancy.^{1,2} Obesity and overweight were associated with a number of adverse pregnancy outcomes, such as gestational diabetes mellitus, macrosomia, hypertensive disorders in pregnancy, the need for cesarean delivery, and elevated risk of cardiovascular disease after childbirth.^{3,4} Excess gestational weight gain (GWG) may play a significant role in long term risks of obesity and cardiovascular diseases in this population. In 1990, The Institute of Medicine (IOM) recommended that women of overweight gain 7-11.5Kg during pregnancy, and obese women limit GWG to 5-9kg⁵. The IOM weight gain guidelines have been widely accepted. Yet in a systematic review⁶, the authors found that about 47% of women gained excess weight and 23% gained less than the recommended weight. This systematic review showed that inappropriate weight gain, whether above or below the recommended level, was associated with an increased risk of adverse outcomes in mothers and their infants. Complicating the relationship between the maternal pre-pregnancy body mass index (BMI) and pregnancy outcomes is the effect of GWG. Theoretically, appropriate GWG will help to decrease the risk of adverse pregnant outcomes.

GWG is closely related to total energy expenditure (TEE), and TEE in pregnant women with obesity/overweight varied greatly. It remains controversial regarding the ideal method to monitor/manage TEE during pregnancy⁷. The most widely used method is based on ideal pre-pregnant BMI, although this method often leads to an overestimation of the caloric needs in women with obesity/overweight.⁷ An excess of caloric intake leads to hyperglycemia with increased CO₂, free fatty acid, and excess GWG. On the other hand, a reduced caloric intake results in deleterious stress response, maternal malnutrition and fetal growth restriction^{8,9}. Alves et al thought indirect calorimetry (IC) should be performed preferentially in pregnant women with obesity/overweight to determine TEE adequately, for the over- or under- feeding.⁷ It is well known that pregnant women usually reduce their activities, expending less energy, especially for obese/overweight women.¹⁰ Therefore, physical activity is not the main contributor of TEE in pregnant women¹¹ and increased basal metabolic rate (BMR) is one of the major components of energy expenditures during pregnancy.¹² Resting energy expenditure (REE) and BMR are interchangeable terms,¹³ and REE instead of BMR is frequently used in clinical practice due to difficulties in the measurement of BMR.

REE increases by approximately 20% in pregnancy because of increased maternal body mass.¹⁴ REE shows a significant correlation with energy intake.¹⁵ GWG and body fat are important factors contributing to variability of REE during pregnancy and are correlated to cumulative REE in pregnancy.¹⁶ Therefore, REE could be a helpful monitoring tool to assess energy intake during pregnancy, especially for obese/overweight women.¹⁷ Some investigators suggested that interventions could be developed to tailor recommendations for energy intake for women's needs based on REE measured in clinical setting.^{18,19} We therefore tested the hypothesis that REE guided management of GWG for pregnant women with obesity/overweight may be helpful in a small-scale study.

Methods

Study design and study population

This was a prospective cohort study. We obtained approval from the Research Ethics Committee of LuHe Hospital of Capital Medical University in Beijing, China before the commencement of this study, and obtained written informed consent from all participating patients.

We recruited obese ($\text{BMI} \geq 30 \text{ Kg/m}^2$) or overweight ($30 \text{ Kg/m}^2 > \text{BMI} \geq 25 \text{ Kg/m}^2$) women who visited LuHe Hospital, Capital Medical University in Beijing, China, for their routine prenatal care at 10-13 weeks of gestation between May 1, 2017 and April 30, 2018. Women who took steroid medication or who were diagnosed with thyroid disease or were affected by pre-pregnant diabetes mellitus or for other reasons could not participate in REE or other assessments for the study were excluded. We divided the recruited women into two groups according to the period recruited into the study: those recruited between May 1, 2017 and November 30, 2017 were the control group with standard diet recommendations based on pre-pregnancy BMI and ideal weight, without REE monitoring during pregnancy; while those recruited between December 1, 2017 and April 30, 2018 were the intervention group with REE guided diet recommendations to manage GWG during pregnancy.

Intervention

For the intervention group, REE was measured at recruitment (1st trimester, 11-13 weeks of gestation) and then again at 2nd trimester (24-28 weeks of gestation) and 3rd trimester (32-36 Weeks of gestation). For this group, TEE was obtained by measuring REE and Physical Activity Index (PAI) at recruitment. The nutritionist made dietary recommendations based on TEE by the way of Food Exchange Share. The dietary recommendations were adjusted, depending on REE measured at 2nd trimester and 3rd trimester. TEE of the control group was calculated at recruitment (1st trimester) by the standard method involving ideal weight and pre-pregnant BMI only. Dietary recommendations for controls were based on TEE by the way of Food Exchange Share as well. An extra 300 Kcal was added to their TEE at 2nd trimester, and an extra 450 Kcal was added at 3rd trimester.²⁰ Weight gain of two groups were monitored and recorded each month. Dietary recommendations for the two groups based on guidelines of GDM²¹. GDM guidelines were used because no dietary guideline exist specifically for pregnant women who are obese/overweight.²² Daily TEE was generally provided by approximately 50%-60% of energy from carbohydrate, 25-30% from fat, and 15-20% from protein, divided into three meals and three snacks.²³

Below is the formula for TEE calculation for the two groups:

Intervention group:

$$\text{TEE} = \text{BMR (REE)} \times \text{PAI}^{24}$$

PAI was assessed using the International Physical Activity Questionnaire (IPAQ). Low level (PAI = 1.2): total physical activity of MET-minutes/week < 600; Moderate level (PAI=1.5): total physical activity of MET-minutes/week between 600 and 3000; and High level (PAI=1.7): total physical activity of MET-minutes/week > 3000. ^{24,25}

We used Vmax Encore 29n (product by CareFusion company USA) to measure REE. The measurement was conducted by a professional technician, at LuHe Hospital Adult Nutrition Research Center. Participants were asked to arrive at the nutrition center in the morning after a 12-h overnight fast. They were instructed to have a 30-min rest in a semi-recumbent position, remaining calm during this time. They were then escorted to a comfortable (temperature maintained at 21-22°C) room and asked to lie down quietly for 30-min. An instrument with a transparent plastic hood was positioned to cover the area from head to neck, with fresh air free flowing through the instrument. After the equilibration period, oxygen consumption (VO₂) and carbon dioxide production (VCO₂) were monitored continuously for 30-min while the participant remained awake, silent, and motionless. Minute by minute values of VO₂, VCO₂, respiratory quotient, and energy expenditure were monitored over the 30-min collection period to obtain the REE. REE and body composition were measured at recruitment (1st trimester, 11-13 gestational weeks), 2nd trimester (24-28 gestational weeks), and 3rd trimester (32-36 gestational weeks).

Control group:

TEE = (Height-105) Kg × EC.²⁶

EC: Energy Coefficient according to the level of Pre-pregnant BMI; EC of overweight = 25-30Cal/Kg ; EC of obese = 20-25 Cal/Kg; Ideal Weight = Height-105 (Kg).¹⁴

Physical examination

At recruitment, height and pre-pregnant weight were obtained by patient's recall. BMI was then calculated. During pregnancy, maternal weight was measured with an electronic scale accurate to 0.1 kg; women were asked to wear a gown of known weight and with no shoes or jewelry on. All measurements were done in duplicate on the same day and by personnel trained according to standard techniques. GWG was obtained by subtracting pre-pregnant weight from their weight before delivery.

Laboratory procedures

Venous blood was drawn from study participants after a 12- hour fast, as well as plasma and serum samples. The plasma and serum samples were stored at -80°C before testing. Analyses of triglycerides, total cholesterol, high-density lipoproteins (HDL), and low-density lipoproteins (LDL) were conducted at the Biochemistry Laboratory of LuHe Hospital based on standard clinical laboratory procedures.

Demographic and clinical data collection

Demographic and clinical data including age, gravidity, gestational age, pregnancy complications, and birth weight were obtained by chart review. At LuHe Hospital, gestational age was based on last date of normal menstrual period and validated by ultrasound examination in early gestation.

Statistical analysis

Statistical analysis was performed using the SPSS 18.0 for Windows. Distribution of continuously distributed data was assessed by Kolmogorov-Smirnov's test. If the P-value of the Kolmogorov-Smirnov's test was higher than 0.05, the data was considered normally distributed and two independent samples Student's *t*-test (two-tailed) was used to compare the mean differences between the two study groups. For categorical data, the differences between the two groups were compared by using the χ^2 or Fisher's exact test.

Results

Comparison of baseline characteristics between the two study groups

Table 1 compares baseline demographic and clinical characteristics. No difference in baseline characteristics between the two study groups was found (Table 1).

Changes of REE during pregnancy

Table 2 presents REE levels measured at different gestation periods in the intervention group. REE increased rapidly from 1st trimester to 2nd trimester, especially the women with excess GWG. Twelve of pregnant women in the intervention group had a GWG exceeded the standard of WHO's. The increase of REE in women with excess GWG was greater than in women with appropriate GWG (Table 2).

Comparison of gestational weight gain and other pregnancy outcomes between the two groups

Table 3 presents the results of analysis for GWG and other pregnancy outcomes. GWG, rate of excess GWG, and rate of macrosomia (birth weight $\geq$ 4,000 g) was lower in the intervention group than those of the control group (Table 3). No fetal growth restriction occurred in either group.

Comparison of lipid metabolism between the two groups

Table 4 compares the concentration of lipids between the two groups. Concentrations of total cholesterol and LDL in the intervention group at second and third trimester were lower than those of the control group (Table 4).

Discussion

Principal findings

Our prospective study involving a cohort of obese/overweight women in China found that REE guided nutrition intervention during pregnancy resulted in lower mean GWG, lower rate of excess GWG, and lower rate of macrosomia, with no apparent impact on fetal growth restriction. REE guided nutrition intervention may also impact other maternal health outcomes such as lipid concentrations.

Strengths and weakness

To the best of our knowledge, this is the first study in China and one of the few studies in the world that has assessed the effect of REE guided nutrition intervention on GWG and other pregnancy outcomes. The study generated results that could be useful in the management of GWG for obese/overweight women. However, this study has several limitations. First, for logistic difficulties and budgetary constraints, we have used a before-after comparison study design, which is not ideal. In addition, to measure REE, we need to have the dedicated space and special equipment ready and participants need to come to the hospital's nutrition center in the morning after a 12-hour overnight fast. Because during the period for control group, our hospital's nutrition center was not ready to measure REE, we measured REE in the intervention group only. On the other hand, the before-after design avoided communication among patients in the intervention group and the control group, so that the risk of cross-contamination is reduced. There is no change in maternity care team and hospital facilities, and the distribution of baseline characteristics of the two groups was essentially the same. As a result, the risk of bias/confounding from non-randomized design may be small. Second, sample size of this study was small. Third, because of logistic difficulties and budgetary constraints, we measured REE only three times during pregnancy. More frequent REE monitoring and therefore more frequent adjustments for diet recommendations could be more effective.

Clinical implications

It well known that excess or inadequate energy intake during pregnancy may have a negative impact on health outcomes for pregnant women and their infants.²² To maintain a healthy pregnancy, positive energy balance is needed, and daily energy intake should consistently exceed energy expenditure. However, excessive energy intake could be harmful. The key is to have the right target of GWG, while recognizing that energy intake above or below requirements could result in inappropriate GWG.²⁷ The magnitude of increase in energy requirements during pregnancy has been a matter of debate.¹⁷ In clinical practice, TEE based on pre-pregnancy BMI is often used to guide the need for energy intake in pregnancy. Byrne et.al²⁸ suggested that TEE based on REE was more accurate than TEE based on pre-pregnant BMI. Moreover, TEE based on pre-pregnant BMI cannot monitor changes during pregnancy. As a result, REE measured during pregnancy could play an important role in the appropriate management of GWG. It is commonly accepted that in obese women, TEE increases during pregnancy, with the additional energy expenditure being primarily attributed to an increased non-absolute resting metabolic rate,^{5, 14} so indirect calorimetry to discover REE should be performed in this population to determine TEE adequately.^{29, 30} Monitoring REE during pregnancy could help to adjust dietary planning for obese/overweight women in order to avoid energy intake that is too high or too low. The changes in REE occur before the changes in

GWG. Especially in 2nd trimester, the rapid increase of REE probably indicate the over weight gain. As a result, REE could be a useful tool which could inform an individualized nutrition plan, reducing the risk of inappropriate energy intake. As Rasmussen¹⁹ has suggested, nutritional interventions should be developed to tailor recommendations for dietary intake to women's needs based on REE measured in clinical settings. Monitoring REE and then adjusting dietary advice accordingly could help better manage GWG. REE guided nutrition could be used not only to assist obese/overweight women but may be useful to inform dietary guidelines for managing GWG for all pregnant women.

Conclusions

In a small-scale prospective cohort study, we found that REE guided nutrition intervention resulted in lower mean GWG, lower rate of excess GWG, and lower incidence of macrosomia, with no apparent impact on fetal growth restriction.

Abbreviations

AEE

Activity energy expenditure

BMI

Body Mass Index

BMR

Basal metabolic rate

EC

Energy coefficient

GDM

gestational diabetes mellitus

GWG

Gestational weight gain

PAI

Physical activity index

REE

Resting energy expenditure

TEE

Total energy expenditure

Declarations

Ethical approval and consent

We obtained approval from the Research Ethics Committee of LuHe Hospital of Capital Medical University in Beijing, China before the commencement of this study, and obtained written informed consent from all participating patients.

Consent for publication

We had obtained consent for publication from all participating patients.

Availability of data and materials

The full dataset or its subset and technical appendix are available from the correspondence authors (Dr. Shi Wu Wen at the University of Ottawa/Ottawa Hospital Research Institute (swwen@ohri.ca) or Dr. Jie Gao at Beijing LuHe hospital Capital Medical University (lhyyzxl@hotmail.com). Access to the dataset is regulated by terms and conditions available on request. The presented data are anonymised, and risk of identification of individual participants is low.

Competing interests

Our authors declare that we have no competing interests

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Authors contributions

XZ, JG, and SWW designed the study, planned the analysis, and wrote the manuscript with assistance from CZ1, PX, and LG. CZ2 and SJ performed nutritional and lab analysis, XZ and SWW performed statistical analysis. All authors participated in the review and critical revisions of the final manuscript. The correspondence authors attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

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Tables

Table 1. Comparison of baseline characteristics of the two groups

	N	Age in years, Mean (SD)	BMI, Mean (SD)	Gravidity, Mean (SD)	Parity, Mean (SD)	TEE, Mean (SD)
Intervention group	32	32.83 (5.39)	29.97 (4.58)	2.24 (1.25)	1.48 (0.51)	1497.16 (290.83)
Control group	21	31.83 (3.85)	28.30 (3.53)	2.72 (1.32)	1.39 (0.50)	1300.42 (245.98)
p		0.49	0.18	0.21	0.52	0.18

Table 2. Changes in REE during pregnancy in intervention group

REE(Kcal/d)	n	First trimester Mean (SD)	Second trimester Mean (SD)	Third trimester Mean (SD)	ΔREE
Excess-GWG	12	1404.46 (320.75)	1914.33 (295.35)	2262.00 (456.80)	988.50 (99.70)
Appropriate-G	18	1472.57 (381.53)	1691.17 (116.63)	1693.33 (98.50)	414.00 (188.63)
T		0.46	1.30	2.09	3.83
P		0.65	0.23	0.128	0.03

Table 3. Comparison of pregnant outcomes between intervention group and control group

Items	Intervention group (N=32)	Control group (N=21)	P-value
Mean GWG (SD)(Kg)	13.45 (4.16)	18.20 (4.85)	0.03
Under- GWG (%)	2/32 (6.25)	0 (0)	–
excess- GWG (%)	12/32 (37.50)	14/21 (66.67)	0.03
Mean birth week (SD)	37.59 (4.60)	38.36 (3.60)	0.54
Pregnancy-induced hypertension(%)	2/32 (6.25)	2/21 (9.52)	0.52
Gestational diabetes mellitus (%)	2/32 (6.25)	5/21 (23.81)	0.08
Mean birth weight (SD) (Kg)	3.27 (0.53)	3.43 (0.60)	0.33
macrosomia (%)	1/32 (3.13)	4/21 (19.05)	0.05
Fetal growth restriction (%)	0(0)	0(0)	–

Table 4. Comparison of concentration of lipids between intervention group and control group

period	item	Intervention group (N=32)	Control group (N=21)	P
		Mean (SD)	Mean (SD)	
		(mmol/L)	(mmol/L)	
First trimester	triglycerides	1.79 (0.81)	1.60 (0.87)	0.23
	Total Cholesterol	4.56 (0.73)	4.99 (1.06)	0.15
	HDL	1.61 (0.28)	1.78 (0.52)	0.22
	LDL	2.53 (0.58)	2.67 (0.77)	0.49
Second trimester	triglycerides	3.08 (1.67)	2.56 (1.16)	0.26
	Total Cholesterol	5.34 (0.94)	6.57 (1.54)	0.00
	HDL	1.88 (0.33)	2.13 (0.52)	0.05
	LDL	2.80 (0.67)	3.75 (0.99)	<0.01
Third trimester	triglycerides	3.21 (1.16)	3.44 (1.21)	0.58
	Total Cholesterol	5.71 (0.98)	6.55 (1.27)	0.04
	HDL	1.88 (0.34)	1.85 (0.33)	0.79
	LDL	3.07 (0.69)	3.70 (1.21)	0.05

Note: NS means P>0.05

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