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. Women whose pre-pregnant body mass index was $< 25\text{Kg/m}^2$ or who took steroid medication or those diagnosed with thyroid disease or affected by pre-pregnant diabetes mellitus or for other reasons could not participate in the study assessments were excluded. Participants who were recruited between May 1, 2017 and December 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. Those who were recruited between November 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 study groups were then 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 in the intervention group (13.45 ± 4.16 Kg) was lower than in the control group (18.20 ± 4.84 Kg). Rate of macrosomia in the intervention group (3.12%) was also lower than in the control group (19.05%). There was no fetal growth restriction observed in either group.

Background

Daily total energy expenditure (TEE) is the sum of basal metabolic rate (BMR), thermic effect of food, and activity energy expenditure (AEE). BMR, which is defined as the energy expended to maintain minimal metabolic activity during a non-active period, is the main component of TEE.¹ It is well known that pregnant women usually reduce their activities, expending less energy, especially for obese/overweight women.² Therefore, physical activity is not the main contributor of TEE in pregnant women³ and increased BMR is one of the major components of energy expenditures during pregnancy.⁴ The elevation in TEE during pregnancy is considered to be a result of increased oxygen consumption due to intensified activities to maintain circulation, respiration, renal function, and increased tissue mass imposed by pregnancy.⁵ Resting energy expenditure (REE) and BMR are interchangeable terms,⁶ 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.⁷ REE shows a significant correlation with energy intake.⁸ Gestational weight gain (GWG) and body fat are

important factors contributing to variability of REE during pregnancy and are correlated to cumulative REE in pregnancy.⁹ Therefore, REE could be a helpful monitoring tool to assess energy intake during pregnancy, especially for obese/overweight women.¹⁰ Some investigators thought that interventions could be developed to tailor recommendations for energy intake for women's needs based on REE measured in clinical setting.^{11,12}

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,¹³ and about 50% women were obese or overweight at the beginning of a pregnancy.¹⁴ Obesity and overweight were associated with a number of adverse pregnancy outcomes, such as gestational diabetes mellitus (GDM), macrosomia, hypertensive disorders in pregnancy, the need for cesarean delivery, and elevated risk of cardiovascular disease after childbirth.^{15,16} Excessive GWG may play a significant role in long term risks of obesity and cardiovascular diseases in this population. Current recommendations for GWG, including healthy eating consistent with standard dietary recommendations, has been used to advise patients affected by GDM. During pregnancy, TEE is usually calculated based on ideal body weight by pre-pregnant body mass index (weight in kg/height in m²; or BMI). This method is easy and convenient but not precise. A systematic review found that about 47% of women gained more weight and 23% gained less than the recommended weight.¹⁷ 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.¹⁷ Managing GWG is crucial to decrease the risk of pregnancy related complications, and REE is closely associated with GWG. Because REE can be measured before GWG, it is possible to manage GWG using REE in pregnancy. There is very little literature on REE guided intervention for managing GWG among obese/overweight pregnant women. In this study, we aimed to assess the impact of REE guided management of GWG among this population.

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 (BMI ≥ 30 Kg/m²) or overweight (30 Kg/m² > BMI ≥ 25 Kg/m²) 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 whose pre-pregnant BMI was < 25 Kg/m² or those who took steroid medication or 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 December 30, 2017 acted as the control group with standard diet recommendations based on pre-pregnancy BMI and ideal weight, without REE monitoring during pregnancy; while those recruited between November 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 (first trimester, 11-15 weeks of gestation) and then again at second trimester (22-28 weeks of gestation) and third trimester (32-36 Weeks of gestation). For this group, TEE was obtained by measuring REE and Physical Activity Index 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 second trimester and third trimester. For the control group, TEE was calculated at recruitment (first trimester) by the standard method involving ideal weight and pre-pregnant BMI. Dietary recommendations were based on their TEE. An extra 300 Kcal was added to their TEE at second trimester, and an extra 400 Kcal was added at third trimester.¹⁸ Weight gain among the two groups was monitored and recorded each month. Dietary recommendations for the two groups based on guidelines for GDM¹⁹. GDM guidelines were used because no dietary guideline exist specifically for pregnant women who are obese/overweight.²⁰ Daily total energy expenditure 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.²¹

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

Intervention group:

$$EE = BMR (REE) \times PAI^{22}$$

PAI = The Physical Activity Index. PAI was assessed using a long form Physical Activity Questionnaire. Low level: total physical <600 MET-

minutes/week; moderate level: $600 < \text{total physical activity} < 3000$ MET-minutes/week.²³

Control group:

$\text{TEE} = (\text{Height} - 105) \text{ Kg} \times \text{EC}$.²⁴

EC: Energy Coefficient according to the level of Pre-pregnant BMI; EC of overweight = 25-30; EC of obese = 20-25; Ideal Weight = Height-105 (Kg).⁷

Measurement of resting energy expenditure

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 (VO_2) and carbon dioxide production (VCO_2) were monitored continuously for 30-min while the participant remained awake, silent, and motionless. Minute by minute values of VO_2 , VCO_2 , 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 (11-13 gestational weeks), second trimester (24-28 gestational weeks), and third trimester (32-36 gestational weeks).

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

At the recruitment, 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 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 first trimester to second trimester and then dropped in third trimester. For the component of REE, changes in volume O₂ (V_{O₂}) and volume CO₂ (V_{CO₂}) were consistent with

changes in REE, while for respiration quotient (RQ), no apparent change during pregnancy was observed (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 in the intervention group was lower than the control group and rate of macrosomia (birth weight > 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 GWG and lower rates of macrosomia, with no 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. 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 intake during gestation may have a negative impact on health outcomes for pregnant women and their infants.²⁰ 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.²⁵ The magnitude of increase in energy requirements during pregnancy has been a matter of much debate.¹⁰ In clinical practice, TEE based on pre-pregnancy BMI is often used to guide the need for energy intake in pregnancy. Byrne et.al²⁶ 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. On the other hand, 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,^{7, 27} so indirect calorimetry to discover REE should be performed in this population to determine TEE adequately.^{28, 29} Monitoring REE during pregnancy could help to adjust dietary planning for obese/overweight women in order to avoid intake that is too high or too low. The changes in REE occur before the changes in GWG. As a result, REE could be a useful tool which could inform an individualized nutrition plan, reducing the risk of inappropriate energy intake. As Rasmussen¹² 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 prospective cohort study, we found that REE guided nutrition intervention resulted in lower mean GWG, 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

Ethics approval and consent to participate

This study was approved by the Research Ethics Committee of LuHe Hospital of Capital Medical University in Beijing, China, and written informed consent was obtained from all participating patients.

Consent to publish

Not applicable.

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

No competing interest is declared by any author of this manuscript.

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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, and XZ and SWW performed statistical analysis. All authors participated in the review and critical revisions of the final manuscript. The correspondence authors attest that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

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References

1. Ryan M, Salle A, Guilloteau G, et al. Resting energy expenditure is not increased in mildly hyperglycaemic obese diabetic patients. *Br J Nutr.* 2006;96(5):945-948.
2. Lof M, Forsum E. Activity pattern and energy expenditure due to physical activity before and during pregnancy in healthy Swedish women. *Br J Nutr.* 2006;95(2):296-302.
3. Forsum E, Lof M. Energy metabolism during human pregnancy. *Annu Rev Nutr.* 2007;27:277-292.

4. Butte NF, Wong WW, Treuth MS, et al. Energy requirements during pregnancy based on total energy expenditure and energy deposition. *Am J Clin Nutr.* 2004;79(6):1078-1087.
5. Hronek M, Zadak Z, Hrnčiarikova D, et al. New equation for the prediction of resting energy expenditure during pregnancy. *Nutrition.* 2009;25(9):947-953.
6. Cuerda C, Ruiz A, Velasco C, et al. How accurate are predictive formulas calculating energy expenditure in adolescent patients with anorexia nervosa? *Clin Nutr.* 2007;26(1):100-106.
7. Melzer K, Schutz Y, Boulvain M, et al. Pregnancy-related changes in activity energy expenditure and resting metabolic rate in Switzerland. *Eur J Clin Nutr.* 2009;63(10):1185-1191.
8. Carrasco F, Papapietro K, Csendes A, et al. Changes in resting energy expenditure and body composition after weight loss following Roux-en-Y gastric bypass. *Obes Surg.* 2007;17(5):608-616.
9. Prentice AM, Spaaij CJ, Goldberg GR, et al. Energy requirements of pregnant and lactating women. *Eur J Clin Nutr.* 1996;50 Suppl 1:S82-110; discussion S110-111.
10. Eto E, Maki J, Tamada S, et al. Assessment of resting energy expenditure and body composition in Japanese pregnant women with diabetes. *J Diabetes Investig.* 2018;9(4):959-966.
11. Berggren EK, O'Tierney-Ginn P, Lewis S, et al. Variations in resting energy expenditure: impact on gestational weight gain. *Am J Obstet Gynecol.* 2017;217(4):445 e441-445 e446.
12. Rasmussen KM. Association of resting energy expenditure with fat gain during pregnancy. *Am J Obstet Gynecol.* 2017;217(4):387-388.
13. Chinese Practical Rural Doctor J. "Report on Chinese Residents' Nutrition and Chronic Diseases (2015)". 2015(15):1-5.
14. Black KI, Gordon A. Obesity before pregnancy: new evidence and future strategies. *Med J Aust.* 2016;205(4):152-154.
15. Thrift AP, Callaway LK. The effect of obesity on pregnancy outcomes among Australian Indigenous and non-Indigenous women. *Med J Aust.* 2014;201(10):592-595.
16. Gaudet L, Ferraro ZM, Wen SW, et al. Maternal obesity and occurrence of fetal macrosomia: a systematic review and meta-analysis. *BioMed research international.* 2014;2014:640291.
17. Goldstein RF, Abell SK, Ranasinha S, et al. Association of Gestational Weight Gain With Maternal and Infant Outcomes: A Systematic Review and Meta-analysis. *JAMA.* 2017;317(21):2207-2225.
18. Chinese Nutrition Society Dietary Guidelines Revision Expert Committee Women and Children's Dietary Guidelines Revision Expert Working Group. Dietary Guidelines for Pregnant Women. *Clinical Pediatrics Journal.* 2016;11(34):877-880.
19. Moreno-Castilla C, Mauricio D, Hernandez M. Role of Medical Nutrition Therapy in the Management of Gestational Diabetes Mellitus. *Curr Diab Rep.* 2016;16(4):22.
20. Flynn AC, Dalrymple K, Barr S, et al. Dietary interventions in overweight and obese pregnant women: a systematic review of the content, delivery, and outcomes of randomized controlled trials. *Nutr Rev.* 2016;74(5):312-328.
21. Division Obstetrics, Chinese Medical Association Obstetrics and Gynecology Branch. Guidelines for the diagnosis and treatment of pregnancy with diabetes (2014) *Chinese Journal of Obstetrics and Gynecology.* 2014;8(49).
22. Westerterp KR, Plasqui G. Physical activity and human energy expenditure. *Curr Opin Clin Nutr Metab Care.* 2004;7(6):607-613.
23. Mishra S, Kishore S. Effect of Physical Activity during Pregnancy on Gestational Diabetes Mellitus. *Indian J Endocrinol Metab.* 2018;22(5):661-671.
24. Yang HX. Practical Handbook of Pregnancy with Diabetes. Beijing: People's Health Publishing House 2012.
25. Thornton YS, Smarkola C, Kopacz SM, et al. Perinatal outcomes in nutritionally monitored obese pregnant women: a randomized clinical trial. *J Natl Med Assoc.* 2009;101(6):569-577.
26. Byrne NM, Groves AM, McIntyre HD, et al. Changes in resting and walking energy expenditure and walking speed during pregnancy in obese women. *Am J Clin Nutr.* 2011;94(3):819-830.
27. In Rasmussen KM, Yaktine AL, (Eds). *Weight Gain During Pregnancy: Reexamining the Guidelines.* Washington (DC) 2009.

28. Dickerson RN. Specialized nutrition support in the hospitalized obese patient. *Nutr Clin Pract.* 2004;19(3):245-254.
29. Ireton-Jones CS, Francis C. Obesity: nutrition support practice and application to critical care. *Nutr Clin Pract.* 1995;10(4):144-149.

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)	REE, 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 and components of REE during pregnancy in intervention group

	First trimester Mean (SD)	Second trimester Mean (SD)	Third trimester Mean (SD)
Vo ₂ L/min	0.22(0.04)	0.27(0.04)	0.26 (0.01)
Vco ₂ L/min	0.18(0.04)	0.22(0.04)	0.21 (0.02)
RQ	0.83(0.07)	0.82 (0.050)	0.82 (0.050)
REE Kcal/d	1497.16 (290.83)	1888.20 (269.21)	1657.00 (255.01)

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
Excess GWG (%)	15/32 (46.88)	3/21 (14.29)	0.02
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
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	—

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

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