Original Article

Physical activity and sedentary behaviour during pregnancy are associated with gestational weight gain in Vietnamese women

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Background and Objectives: Gestational weight gain is known to impact maternal and child health outcomes. Energy intake and energy expenditure are major components of clinical nutrition in relation to weight gain during pregnancy. The study was to determine the association of physical activity and sitting time during pregnancy with gestational weight gain in Vietnamese women. **Methods and Study Design:** A multicentre prospective cohort study was conducted in Vietnam from 2015 to 2017. A total of 1873 women with a singleton pregnancy were included. Physical activity and sitting exposures during pregnancy were determined using an interviewer-administered validated questionnaire. Multiple regression analysis was performed to assess physical activity and sitting time in relation to gestational weight gain, adjusting for the confounding effects of maternal characteristics and total energy intake during pregnancy. **Results:** The mean weight gain was 12.9 (Standard deviation 4.1) kg throughout pregnancy. Pregnant women with prolonged sitting time gained an average of 0.6 kg more weight (p=0.016 for highest versus lowest tertiles). Conversely, women who were physically active, in terms of having higher tertiles of total physical activity, moderate-to-vigorous-intensity, household/caregiving activities, and occupational physical activity, experienced significantly less gestational weight gain ($p<0.05$ for highest versus lowest tertiles). **Conclusions:** Inverse associations were found between gestational weight gain and physical activity (i.e. intensities and several domains), whereas gestational weight gain tended to increase with longer sitting time. Therefore, being physically active and less sedentary is important to regulate weight gain during pregnancy.

Key Words: gestational weight gain, pregnancy, physical activity, sedentary behaviour, Vietnam

INTRODUCTION

Accumulating evidence indicates that many countries in South East Asia are facing the double burden of malnutrition, including Vietnam.[1-4] The prevalence of overweight in women aged ≥20 years has doubled in Vietnam between 1980 and 2015.[5] In addition, the prevalence of overweight is about equivalent to that of underweight in Vietnamese women.[3]

Since 2017, the WHO has addressed pregnancy as a critical period to combat the double burden of malnutrition.[6] Gestational weight gain (GWG) is known to impact maternal and child health outcomes.[7] Excessive GWG may increase the risk of adverse events for both the mother and infant, including eclampsia,[8] unplanned or emergency caesarean delivery,[9] large-for-gestational-age infants,[7,10] higher postpartum weight retention,[11,12] diabetes mellitus,[13,14] and childhood obesity.[15] Moreover, mothers with inadequate GWG are at elevated risk of delivering small-for-gestational-age and preterm infants.[7,16] Because GWG is potentially modifiable, the prevention of inappropriate weight gain during pregnancy is paramount.

Physical activity-related energy expenditure, particular-

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Manuscript received 09 October 2019. Initial review completed 12 November 2019. Revision accepted 01 December 2019.
doi: 10.6133/apjcn.202003_29(1).0018

ly changes in non-exercise physical activity (PA) thermo genesis (i.e. habitual PA with the exception of sleeping, eating, or sports/exercises), is a major determinant of body weight change.[17] Increasing attention has been paid to PA during pregnancy, partly due to its beneficial role in reducing complications, such as caesarean section, gestational diabetes mellitus, and unhealthy GWG.[18-21] Indeed, physically active women are less likely to have excessive GWG as defined by the Institute of Medicine recommendations.[22] Despite this, the evidence to date regarding the association between non-exercise PA during pregnancy and GWG remains inconclusive, particularly the dose-response association.[18] For example, a study of Chinese women found that PA during pregnancy could reduce the risk of excessive GWG,[23] whereas another study from the USA reported no association between GWG and PA domains or intensity of activities during pregnancy (with the exception of occupational PA).[24] Interventional studies demonstrated a somewhat beneficial effect of prenatal PA on excessive GWG.[25,26] However, the findings should be interpreted with caution in view of possible sampling bias, the inclusion of different exercise interventions, and lack of objective PA measurements.[25,26] Although the Vietnam Nutrition Strategy 2011-2020 highlighted the promotion of PA aiming to control overweight and obesity, no national guideline on PA during pregnancy was found.[27]

Limited studies have been performed in Asia concerning PA and GWG,[23,28,29] particularly concerning PA domains and intensities. It is conceivable that Asian women tend to consider family-related and intellectual activities as their highest priorities,[30,31] whereas daily activities, caregiving chores, and sedentary behaviours receive less attention than sports or exercise in previous studies in Asia.[29] Often, Asian women are advised to rest to protect the foetus. They tend to perform less PA and spend more time being sedentary due to their fear of miscarriage and discomfort, yet they may be more engaged in household or caregiving activities.[31,32]

The present study aimed to ascertain the relationship between GWG and PA and sedentary behaviour during pregnancy, adjusting for maternal characteristics and total energy intake simultaneously, using a large prospective cohort of pregnant women in Vietnam.

METHODS

Study design and participants

The present study was part of a large multicentre prospective cohort study, the overall study design and recruitment procedure have been described elsewhere.[33] The sample size was calculated based on the main study objectives at the time of protocol development.[33] Briefly, pregnancy-related information was collected from 2030 pregnant women (90.3% of 2248 women recruited) between 2015 and 2017. The inclusion criteria were age ≥18 years, singleton pregnancy, and residence in Hanoi, Hai Phong, or Ho Chi Minh City, Vietnam. Among these 2030 participants enrolled at baseline, 1906 women completed the second interview before hospital discharge. After further exclusion of 33 cases with missing/implausible information, a total of 1873 (92.3%) women with complete and valid information were included in the statistical analysis. This study was approved by the Human Research Ethics Committees of Curtin University (approval no. HR32/2015) and Hai Phong University of Medicine and Pharmacy (approval no. 05/HPUMPRB/2015). Participation was entirely voluntary, and all participants signed the consent form before commencing their baseline interview.

Study variables

Main outcome

The continuous outcome variable GWG (kg) was calculated by subtracting the pre-pregnancy weight (obtained at the baseline interview) from the pre-birth weight (extracted from medical records).[12,21,34]

Measurement of physical activity and sedentary behaviour

PA during pregnancy was assessed at the time of enrolment using a validated Vietnamese version of the Pregnancy Physical Activity Questionnaire (PPAQ).[35,36] The PPAQ measures time spent performing 32 specified activities in five domains, namely, household/caregiving, occupational, sports/exercise, transportation, and sedentary activity.[36] The duration, frequency, and intensity of PA were calculated in terms of Metabolic Equivalent Task hours per week (MET-hours/week), based on the PPAQ scoring mechanism and the Compendium of Physical Activities.[36,37] Intensity was classified as 'light-intensity' activity (1.5 to <3 METs), 'moderate-to-vigorous-intensity' activity (≥3 METs), and total activity (including light-intensity and above).[36] Each PA variable (total, light-intensity, moderate-to-vigorous-intensity, household/caregiving, occupational and transportation) was divided into tertiles, with the third tertile reflecting the highest level of activity. According to the 2018 PA Guidelines Advisory Committee, pregnant women "should do at least 150 minutes of moderate-intensity aerobic activity a week".[38] Consequently, the weekly duration of moderate-intensity sports/exercise was further categorised as 'below the recommendation' (<150 minutes per week) and 'sufficiently/above the recommendation' (≥150 minutes per week). Sitting time during pregnancy in different scenarios (e.g. car, bus, at work, or watching television) was also elicited.[35] Participants were asked to estimate the time spent performing these sedentary activities during the last three months of their pregnancy. Total sitting time (hours per week) was also categorised into tertiles.

Measurement of covariates

Information on maternal age (<25, 25-34, ≥35 years), employment (yes, no), education (secondary or below, high school or above), parity (nulliparous, multiparous), pre-pregnancy weight, history of health-related problems (yes, no), and total energy intake during pregnancy was collected at the baseline survey. Such self-reported data were verified against hospital medical records whenever feasible. Maternal height was measured using a stadiometer to the nearest one mm at the baseline interview. Pre-pregnancy body mass index (BMI) was calculated by dividing pre-pregnancy weight by the square of maternal height and was categorised according to the cut-off points

recommended by the WHO for Asian populations: underweight (<18.5 kg/m^2), normal (18.5 to <23 kg/m^2), and overweight/obese (≥23 kg/m^2).[39] Total energy intake during pregnancy was derived from data obtained using a validated food frequency questionnaire for Vietnamese adults.[40] Total energy intake was estimated from the frequency (times per day/week/month) and quantity (number of standardised servings each time) of consuming 18 food and beverage groups.[41] History of health-related problems (presence of miscarriage, abortion, pregnancy-induced hypertension, or chronic diseases) was also recorded. Gestational diabetes mellitus status was ascertained by administering a 75-gram oral glucose tolerance test and was diagnosed when at least one glucose value was above the following thresholds: fasting plasma glucose ≥5.1 mmol/L, one-hour plasma glucose ≥10.0 mmol/L, and two-hour plasma glucose ≥8.5 mmol/L.[42] Postnatal information on gestational age (<37, ≥37 weeks) was extracted from hospital records.

Statistical analysis

Descriptive statistics were obtained to summarise the sample characteristics. Comparisons of GWG between subgroups of interest were performed using two-sample t-tests or one-way analysis of variance. The associations between PA exposures during pregnancy and GWG were evaluated using multiple linear regression models. With the exception of sports/exercise, due to insufficient data, all non-exercise PA variables (i.e. total PA, sitting time, light-intensity PA, moderate-to-vigorous-intensity PA, household/caregiving, occupational and transportation PA) were considered. Each PA exposure variable was analysed using two regression models. In Model I, adjustments were made with respect to maternal age, education, employment, parity, history of health-related problems, gestational diabetes mellitus, gestational age, total energy intake during pregnancy, and pre-pregnancy BMI, which were widely regarded as confounders for GWG in the literature.[21,24] In Model II, sitting time was further adjusted to account for its potential attenuation effect.[43,44] Similarly, when assessing the relationship between sitting time and GWG, total PA was adjusted in the multivariable model. The first (lowest) tertile of each PA variable was used as the corresponding reference category. Estimated regression coefficients and adjusted means of GWG, together with their 95% confidence intervals (CIs), are presented. Tests for linear trends were also performed for the PA exposure variables, and their *p* values are reported. A previous study reported that Vietnamese women who gained >15 kg during pregnancy had an increased risk of delivering a large-for-gestational-age infant.[10] Therefore, we additionally examined such excessive GWG (>15 kg) in relation to PA and sitting time using logistic regression analyses. All statistical analyses were performed in the Stata package version 15.1.[45]

RESULTS

Women gained an average of 12.9 (SD 4.1) kg during pregnancy. Table 1 presents participant characteristics and compares mean GWG across categories of these vari-

Table 1. Gestational weight gain by maternal characteristics, Vietnam, 2015-2017 (n=1873)

Characteristic	Total	Gestational weight gain (kg)	
	n (%)	Mean (SD)	*p*†
Maternal age (years)			<0.001
<25	770 (41.1)	13.6 (4.2)	
25-34	906 (48.4)	12.5 (3.9)	
≥35	197 (10.5)	11.7 (4.0)	
Pre-pregnancy BMI (kg/m^2) ‡			<0.001
Underweight (<18.5)	492 (26.3)	13.3 (4.1)	
Normal (18.5 to <23)	1158 (61.8)	12.9 (4.0)	
Overweight/obese (≥23)	223 (11.9)	11.5 (4.2)	
Parity			<0.001
Nulliparous	725 (38.7)	13.7 (4.2)	
Multiparous	1148 (61.3)	12.3 (3.9)	
Education			<0.001
Secondary or below	640 (34.2)	12.3 (4.3)	
High school or above	1233 (65.8)	13.1 (3.9)	
Employment			0.825
No	592 (31.6)	12.8 (4.2)	
Yes	1281 (68.4)	12.9 (4.0)	
Gestational diabetes mellitus			0.057
No	1450 (77.7)	13.0 (4.1)	
Yes	416 (22.3)	12.5 (3.9)	
Gestational age (weeks)			0.007
<37	89 (4.8)	11.7 (3.7)	
≥37	1784 (95.3)	12.9 (4.1)	
History of health-related problems §			0.059
No	1405 (69.2)	13.0 (4.1)	
Yes	625 (30.8)	12.6 (4.0)	

BMI: body mass index; SD: standard deviation.
†Two-sample t-test or one-way analysis of variance.
‡Based on the WHO recommendations for Asian populations.
§Health-related problems include miscarriage, abortion, pregnancy-induced hypertension, and chronic diseases.

Table 2. Sitting time and physical activity during pregnancy, Vietnam, 2015-2017 (n=1873)

Exposure	Mean (SD)	Minimum	Maximum
Sitting time (hours/week)	26.8 (14.2)	1.8	75.3
Total PA (MET-hours/week)	124.0 (57.1)	10.0	362.8
Intensity (MET-hours/week)			
Light	57.8 (33.0)	0	170.8
Moderate-to-vigorous	29.4 (31.9)	0	203.5
Domain (MET-hours/week)			
Household/caregiving	59.8 (41.7)	0	231.0
Occupational	31.6 (29.7)	0	176.2
Transportation	11.6 (13.2)	0	170.6
Sports/exercise	6.1 (9.4)	0	81.4

MET: metabolic equivalent of task; SD: standard deviation; PA: physical activity.

ables. Overall, most participants were under 35 years of age (89.5%) and delivered at 37 weeks of gestation or later (95.3%), with 61.8% of women having normal pre-pregnancy BMI. Approximately two-thirds of the participants exhibited multi-parity (61.3%), attained a high school or above education (65.8%), were employed (68.4%), and had no health-related problems before the current pregnancy (69.2%). Less than one-quarter of them were diagnosed with gestational diabetes mellitus (22.3%). The mean total energy intake was 2123 (SD 744) kcal per day during pregnancy.

The majority of women (81.2%) reported participating in moderate-intensity sports/exercises below the recommendation of the 2018 PA Guidelines Advisory Committee. Household/caregiving activity contributed, on average, 47% (95% CI 46.0% to 47.9%) towards total PA during pregnancy. Table 2 summarises the sitting time of the cohort and their PA by domain and intensity. On average, the pregnant women spent 124 (SD 57.1) MET-hours and 26.7 (SD 14.2) hours per week on total PA and sitting, respectively.

Table 3 shows the results of multiple regression analyses. GWG was inversely associated with total PA, moderate-to-vigorous-intensity PA, household/caregiving, and occupational PA but was positively associated with sitting time. After additionally adjusting for sitting time, physically active women (with the highest tertile of total PA) gained 0.5 kg less weight on average during pregnancy than those who were relatively less active (lowest tertile). Similarly, the weight gains were significantly lower among women with the highest level of moderate-to-vigorous-intensity, household/caregiving, and occupational PA. In contrast, women with longer sitting time (highest tertile) gained 0.6 kg more on average than those who were less sedentary (lowest tertile) after accounting for total PA during pregnancy. However, little association was observed between both light-intensity PA and GWG and transportation PA and GWG. Moreover, the prevalence of excessive GWG (>15 kg) was 22.6% (n=423), and the corresponding logistic regression results (omitted for brevity) were consistent with those in Table 3. Specifically, women with higher PA levels were less likely to gain over 15 kg, whereas spending more time sitting during pregnancy could increase the risk of the excessive GWG (OR=1.73, 95% CI 1.27 to 2.36, *p* trend=0.001).

DISCUSSION

Energy intake and energy expenditure through PA attribute to weight gain during pregnancy. In recent years, researchers have proposed a range of interventions to combat the double burden of malnutrition, including promoting PA and healthy weight.[46] In this large prospective cohort study, we found evidence of inverse associations between GWG and total PA, moderate-to-vigorous-intensity, household/caregiving, and occupational PA, independent of sitting time. On the other hand, GWG was observed to increase with sitting time, even after accounting for the apparent effect of total PA. The present study provides the first report on such dose-response relationships between GWG and non-exercise PA (i.e. intensities and domains) as well as sitting time during pregnancy, with adjustment for energy intake, among Vietnamese women.

Our finding concerning PA and GWG aligns with the results of a cohort study of 862 women in China, in which physically active mothers (i.e. achieving ≥10,000 steps per day) during pregnancy experienced a significantly lower GWG than sedentary mothers (<5000 steps per day).[23] However, a previous large-scale study of Hispanic women in the USA found no such association.[24] The discrepancy in the latter study might be owing in part to the lack of adjustment for total energy intake during pregnancy.[47,48] Another possibility is the difference in ethnicity.[49] Consistent with our result regarding the effect of moderate-to-vigorous-intensity PA, a previous study in the USA reported that women undertaking moderate-intensity PA (>150 minutes per week) had lower odds of excessive GWG.[21] On the other hand, our observed lack of association with light-intensity PA is in accordance with an earlier large-scale study of American women.[44]

There is a theoretical risk that too much PA could result in too little GWG. This was not observed in this study and is unlikely ever to be a real-world risk.[50] In fact, Asian women have been reported to engage in long hours of sedentary behaviours, particularly during pregnancy.[32] The majority of our participants (>80%) performed PA below the recommended guideline, a figure that was slightly higher than that found in a previous study conducted in China (50.4%).[51] In our study, Vietnamese women spent an average of 27 hours per week sitting, mostly at work/classes and for screen viewing (television, computer, and mobile phone). A previous cohort study in Singapore also revealed that one-quarter

Table 3. Association between gestational weight gain, pregnancy physical activity and sitting time, Vietnam, 2015-2017 (n=1873)

Exposure	n (%)	Gestational weight gain (kg)					
		Model I†			Model II‡		
		Coef. (95% CI)	*p*	Adjusted mean (95% CI)	Coef. (95% CI)	*p*	Adjusted mean (95% CI)
Sitting time (hours/week)			0.067§			0.017§	
1st tertile (≤21)	635 (33.9)	Reference		12.78 (12.46, 13.10)	Reference		12.69 (12.36, 13.02)
2nd tertile (>21 to 33.3)	616 (32.9)	-0.14 (-0.58, 0.31)	0.547	12.64 (12.34, 12.94)	-0.05 (-0.50, 0.41)	0.844	12.65 (12.35, 12.95)
3rd tertile (>33.3)	622 (33.2)	0.45 (-0.02, 0.93)	0.062	13.23 (12.89, 13.57)	0.62 (0.12, 1.12)	0.016	13.31 (12.97, 13.66)
Total PA (MET-hours/week)			0.342§			0.043§	
1st tertile (≤92.6)	613 (32.7)	Reference		13.06 (12.74, 13.38)	Reference		13.24 (12.90, 13.58)
2nd tertile (>92.6 to 142.0)	627 (33.5)	-0.36 (-0.81, 0.09)	0.117	12.70 (12.39, 13.01)	-0.59 (-1.06, -0.12)	0.014	12.65 (12.34, 12.97)
3rd tertile (>142.0)	633 (33.8)	-0.23 (-0.69, 0.24)	0.336	12.83 (12.52, 13.15)	-0.53 (-1.03, -0.04)	0.035	12.71 (12.38, 13.03)
Intensity (MET-hours/week)							
Light			0.098§			0.060§	
1st tertile (≤38.3)	622 (33.2)	Reference		13.07 (12.75, 13.39)	Reference		13.10 (12.78, 13.42)
2nd tertile (>38.3 to 68.7)	621 (33.2)	-0.22 (-0.67, 0.23)	0.345	12.85 (12.54, 13.16)	-0.27 (-0.73, 0.18)	0.233	12.83 (12.52, 13.14)
3rd tertile (>68.7)	630 (33.6)	-0.39 (-0.84, 0.07)	0.098	12.68 (12.36, 13.00)	-0.44 (-0.90, 0.02)	0.059	12.66 (12.35, 12.98)
Moderate-to-vigorous			0.009§			0.015§	
1st tertile (≤10.9)	660 (35.2)	Reference		13.18 (12.86, 13.49)	Reference		13.15 (12.84, 13.47)
2nd tertile (>10.9 to 31.0)	571 (30.5)	-0.34 (-0.80, 0.11)	0.137	12.83 (12.51, 13.16)	-0.32 (-0.77, 0.13)	0.167	12.83 (12.51, 13.16)
3rd tertile (>31.0)	642 (34.3)	-0.60 (-1.06, -0.15)	0.009	12.57 (12.26, 12.89)	-0.56 (-1.01, -0.11)	0.015	12.59 (12.28, 12.91)
Domain (MET-hours/week)							
Household/caregiving			0.013§			0.009§	
1st tertile (≤32.8)	615 (32.8)	Reference		13.19 (12.86, 13.51)	Reference		13.20 (12.87, 13.53)
2nd tertile (>32.8 to 67.5)	630 (33.6)	-0.35 (-0.80, 0.10)	0.130	12.84 (12.52, 13.15)	-0.37 (-0.82, 0.08)	0.108	12.83 (12.52, 13.14)
3rd tertile (>67.5)	628 (33.5)	-0.61 (-1.09, -0.13)	0.013	12.58 (12.26, 12.90)	-0.63 (-1.11, -0.16)	0.009	12.57 (12.25, 12.89)
Occupational			0.153§			0.005§	
1st tertile (≤9.3)	628 (33.5)	Reference		12.96 (12.62, 13.31)	Reference		13.24 (12.87, 13.62)
2nd tertile (>9.3 to 39.5)	616 (32.9)	0.04 (-0.44, 0.53)	0.861	13.01 (12.69, 13.33)	-0.35 (-0.89, 0.18)	0.199	12.89 (12.57, 13.22)
3rd tertile (>39.5)	629 (33.6)	-0.34 (-0.84, 0.16)	0.185	12.62 (12.30, 12.95)	-0.79 (-1.35, -0.23)	0.006	12.46 (12.12, 12.79)
Transportation			0.367§			0.690§	
1st tertile (≤5.1)	644 (34.4)	Reference		12.68 (12.37, 13.00)	Reference		12.74 (12.43, 13.06)
2nd tertile (>5.1 to 12.8)	637 (34.0)	0.35 (-0.10, 0.79)	0.129	13.03 (12.72, 13.34)	0.27 (-0.17, 0.72)	0.232	13.02 (12.70, 13.33)
3rd tertile (>12.8)	592 (31.6)	0.20 (-0.25, 0.65)	0.381	12.88 (12.56, 13.21)	0.09 (-0.36, 0.55)	0.689	12.84 (12.51, 13.16)

Coef.: estimated regression coefficient; CI: confidence interval; MET: metabolic equivalent of task; PA: physical activity.

†Model I: Multiple linear regression models adjusted for maternal age, education, gestational diabetes mellitus, history of health-related problems, total energy intake during pregnancy, parity, employment, gestational age, and pre-pregnancy body mass index.

‡Model II: For sitting time, adjusted for total PA in addition to above covariates in Model I; For PA exposures, adjusted for sitting time in addition to above covariates in Model I.

§*p* value for linear trend.

of women spent over 21 hours per week watching television either before or during pregnancy.[32] Therefore, the observed independent and positive association between sitting time and GWG in our cohort is not surprising.

It is worth noting the inverse dose-response relationships between GWG and household/caregiving and occupational PA. Although Asian women are known to be involved in household and caregiving activities,[30,31] the present study was the first report addressing the association of these activities with GWG in Asia. A study of Hispanic women in the USA observed a similar prevalence of household/caregiving PA (50%) as that observed in our cohort of Vietnamese women (47%), and reported significantly lower GWG among those with the highest level of occupational PA but not for household/caregiving activities.[24] The reason for this discrepancy is unclear to us. A possible explanation for this finding might be the differences in study population characteristics (the majority of participants had lower levels of education and were younger, unlike our cohort of Vietnamese women). Further research is required to elucidate the role and underlying mechanism of this PA domain in preventing unhealthy weight gain during pregnancy.

The strengths of our study include a prospective, multicentre cohort design with a large sample size and a high response rate. Treating GWG as a continuous outcome avoided potential misclassification based on the Institute of Medicine's cut-off points.[52] PA was assessed using a validated questionnaire for Vietnamese women that enabled separate estimation of PA intensities and domains as well as sedentary behaviours during pregnancy. Furthermore, all established and potential confounding factors were accounted for in the multivariable analyses, together with the mutual adjustment of total PA and sitting time in the regression models. However, several limitations should be considered. Pre-pregnancy weights were obtained from self-reports, even though we checked them against hospital records whenever available. The present study was conducted in urban and semi-urban areas so that the findings might not be generalisable to the entire population of pregnant women in Vietnam. Moreover, PA, sitting time, and total energy intake were measured at a single time point, which might not reflect the same patterns during each individual's whole pregnancy. Finally, the residual confounding effect could not be ruled out despite adjustment for all plausible confounders in the statistical analyses.

In conclusion, this study provided evidence of dose-response inverse associations between GWG and non-exercise PA (i.e. intensities and some of its domains), whereas GWG appeared to increase with sitting time among pregnant Vietnamese women. These findings suggest that being physically active and less sedentary may contribute to an appropriate GWG. PA interventional programs are needed to consider the influence of non-exercise PA thermogenesis and sedentary behaviour on GWG.

ACKNOWLEDGEMENTS

The authors thank all study participants and participating hospitals for their support in data collection.

AUTHOR DISCLOSURES

The authors have no conflict of interest to disclose. This study was partly funded by Curtin University as a support for higher degree research students.

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