School of Public Health

A Prospective Cohort Study of Gestational Weight Gain, Postpartum Weight Retention, and Maternal Health in Vietnam

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This thesis is presented for the Degree of
Doctor of Philosophy
of
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Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgement has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Human Ethics The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC00262), Approval Number #HR32/2015, and the Hai Phong University of Medicine and Pharmacy Human Research Ethics Committee, Approval Number #05/HPUMPRB/2015.

Signature:

Date: 13/7/2020

Abstract

Background

Periconceptional folic acid supplementation has been recommended to prevent neural tube defects (NTDs) in infants. Gestational weight gain has been associated with pregnancy outcomes, including mode of delivery, foetal growth, gestational diabetes, hypertension, and pre-eclampsia. Mothers having substantial postpartum weight retention are also more likely to be overweight or obese. The current literature has shown a protective role of physical activity during pregnancy on postpartum low back pain. However, several gaps are needed to address. The magnitude of maternal health outcomes and health-related behaviours have been underestimated, including maternal weight changes, physical health, physical activity from pregnancy to postpartum period, and periconceptional folic acid supplementation. To the authors' knowledge, these studies are the first investigations on periconceptional folic acid supplementation, postpartum low back pain, and maternal weight changes in associations with physical activity during pregnancy and in the postpartum period in Vietnam.

Aims and Objectives

This doctoral thesis aimed to investigate maternal weight changes (pre-pregnancy BMI, gestational weight gain, and postpartum weight retention), physical health (postpartum low back pain), patterns of physical activity, and dietary supplement use among Vietnamese mothers within twelve months postpartum, with the following specific objectives:

Objective 1: To assess the association of pre-pregnancy BMI and gestational weight gain with weight retention at twelve months postpartum in Vietnam.

Objective 2: To evaluate the role of physical activity during pregnancy on gestational weight gain in Vietnam.

Objective 3: To ascertain the role of postpartum physical activity on weight retention within twelve months postpartum in Vietnam.

Objective 4: To investigate the prevalence of postpartum low back pain and its relation to physical activity during pregnancy in Vietnam.

Objective 5: To determine the prevalence of periconceptional folic acid supplementation in Vietnam and ascertain the maternal characteristics associated with folic acid use.

Methods

Data were retrieved from a larger project, which was a multicentre prospective cohort study in Vietnam between August 2015 and November 2017. In total, 2030 singleton pregnant women aged 18 years and over were recruited in Hanoi (*n*=905), Hai Phong (*n*=298), and Ho Chi Minh City (*n*=827), Vietnam, at baseline interviews. After delivery, participants were further followed up before discharge and then at one, three, six, and twelve months postpartum. Interviewers collected information on maternal characteristics, anthropometric data, periconceptional folic acid supplementation, pregnancy and maternal health outcomes, energy intake during pregnancy, and prenatal and postpartum physical activity using validated questionnaires for Vietnamese adults. Descriptive statistics and univariate analyses were conducted initially. Subsequently, with the adjustment for plausible covariates (and or confounders), different multivariable regression models (linear, logistic, and general linear model with repeated measures) were performed to achieve the five study objectives. The covariates (and/or confounders) were selected based on their plausibility with reference to the literature and their availability of such information in the study.

Results

Results (Objective 1): Of 2030 pregnant women recruited at baseline interview, a total of 1666 women were followed up for 12 months postpartum and available for analysis. The mean maternal age was 27.5 (Standard Deviation [SD] 5.2) years at baseline interview. More than a quarter of study participants (*n*=433, 25.99%) retained 5 kg or more at 12 months postpartum. Both pre-pregnancy BMI and gestational weight gain were significantly associated with postpartum weight retention (all p values <0.001). On average, women with pre-pregnancy underweight

retained 3.71 (95% confidence interval (CI) 3.37, 4.05) kg, which was higher than those with normal pre-pregnancy weight (adjusted mean=2.34, [95% CI 2.13, 2.54] kg). Women who gained excessive gestational weight (compared to the 2009 Institute of Medicine [IOM] recommendations) also retained significantly more weight at twelve months postpartum (adjusted mean=5.07, [95% CI 4.63, 5.50] kg), compared to women who gained gestational weight adequately (adjusted mean=2.92, [95% CI 2.67, 3.17] kg).

Results (Objective 2): Of 1873 women available for analysis in this study, the mean maternal age was 27. 6 (SD 5.3) years and 16.7% (n=312) women had excessive gestational weight gain (compared to the 2009 IOM recommendations). More sitting time during pregnancy was statistically significantly associated with higher gestational weight gain (0.62 kg comparing the highest tertile to the lowest tertile [95% CI 0.12, 1.12] kg, $p=0.016$). Higher levels of total physical activity, moderate-to-vigorous-intensity, household or caregiving, or occupational physical activity during pregnancy were statistically significantly associated with lower gestational weight gain ($p<0.05$ for highest versus lowest level).

Results (Objective 3): There were 1617 women included, with mean age 27.5 (SD 5.2) years, in this study. The prevalence of overweight/obesity at 12-month postpartum was 21.7% (n=351). Both multiple linear regression and general linear model (GLM) with repeated measures analyses indicated that total physical activity and light-intensity physical activity were inversely associated with postpartum weight retention (p for linear trend <0.01). Total physical activity in the early postpartum period was inversely associated with weight retention within twelve months postpartum (estimated coefficient = -0.58 kg comparing the high level to the low level [95% CI -0.97, -0.19]). Mothers with a high level of light-intensity physical activity retained a significantly lower weight within twelve months postpartum, compared to those with a low level of light-intensity physical activity (estimated coefficient = -0.57 kg comparing the high level to the low level [95% CI -0.96, -0.18]).

Results (Objective 4): Of the 1807 women available for the final analysis of this study, the prevalence of postpartum low back pain was 12.3% (n=222). Study

participants were on average 27.5 (SD 5.2) years old. Increasing prenatal total physical activity was statistically significantly associated with lower odds of low back pain reported during the six months postpartum period (adjusted odds ratio=0.55 comparing the highest tertile to the lowest tertile [95% CI 0.38, 0.80]). Statistically significant inverse associations with postpartum low back pain were also observed for light-intensity, moderate-to-vigorous-intensity, household, or caregiving, occupational, and transportation physical activities (all p values for linear trend <0.05).

Results (Objective 5): Of 2030 singleton pregnant women available for the final analysis of this study, 32.2% reported correctly taking either supplements containing folic acid alone or multivitamins containing folic acid. 24.9% of women reported correctly taking supplements containing folic acid alone. The mean age of participants was 27.6 (SD 5.3) years. Maternal age, education, employment, parity, and planned pregnancy were found to be statistically significantly associated with periconceptional folic acid supplementation (all p values <0.001). Women aged 30 years or over, who had low educational levels, had formal employment, and whose current pregnancy was first or unplanned were less likely to report a correct periconceptional folic acid supplementation, following the WHO recommendations.

Conclusions

Our whole cohort exhibited a low prevalence of periconceptional folic acid supplementation in Vietnam and maternal characteristics associated with this low supplementation. We also found that both pre-pregnancy BMI, postpartum physical activity, and gestational weight gain had significant impacts on postpartum weight retention among Vietnamese women. Furthermore, the research supports the protective role of prenatal physical activity on gestational weight gain and postpartum low back pain. Relevant health programs and guidelines for public health professionals working for Vietnamese mother-infant dyad should take these findings into consideration. In particular, more health promotion campaigns, which provide information on folic acid supplementation, weight control before and during pregnancy, prenatal and postnatal physical activity, and postpartum weight retention, can be developed to target reproductive women for their pregnancy planning.

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List of Publications

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Paper I

Ha, A. V. V., Zhao, Y., Pham, N. M., Nguyen, C. L., Nguyen, P. T. H., Chu, T. K., . . . Lee, A. H. (2019). Postpartum weight retention in relation to gestational weight gain and pre-pregnancy body mass index: A prospective cohort study in Vietnam. *Obesity Research & Clinical Practice*, *13*(2), 143-149. http://dx.doi.org/https://doi.org/10.1016/j.orcp.2019.02.001

Paper II

Ha, A. V. V., Zhao, Y., Pham, N. M., Nguyen, C. L., Nguyen, P. T. H., Chu, T. K., . . . Lee, A. H. (2019). Physical activity and sedentary behaviour during pregnancy are associated with gestational weight gain in Vietnamese women. *Asia Pacific Journal of Clinical Nutrition*, *29*(1) http://dx.doi.org/10.6133/apjcn.201912/PP.0003

Paper III

Ha, A. V. V., Zhao, Y., Binns, C. W., Pham, N. M., Nguyen, P. T. H., Nguyen, C. L., . . . Lee, A. H. (2020). Postpartum Physical Activity and Weight Retention within One Year: A Prospective Cohort Study in Vietnam. *International Journal of Environmental Research and Public Health*, *17*(3), 1105. Retrieved from https://www.mdpi.com/1660-4601/17/3/1105

Paper IV

Ha, V. V. A., Zhao, Y., Pham, M. N., Binns, C. W., Nguyen, C. L., Nguyen, P. T. H., … Lee, A. H. (2019). Physical Activity during Pregnancy and Postpartum Low Back Pain: A Prospective Cohort Study in Vietnam. *Asia Pacific Journal of Public Health*, *31*(8), 701–709. https://doi.org/10.1177/1010539519890148

Paper V

Ha, V. V. A., Zhao, Y., Binns, W. C., Pham, M. N., Nguyen, L. C., Nguyen, T. P., . . . Lee, H. A. (2019). Low Prevalence of Folic Acid Supplementation during Pregnancy: A Multicenter Study in Vietnam. *Nutrients, 11*(10). http://dx.doi.org/10.3390/nu11102347

Statement of the Contribution of Others

The School of Public Health at Curtin University provided the research environment that supported the Ph.D. candidate to undertake this research. The Ph.D. candidate was responsible for designing the methodology, undertaking recruitment, implementing data collection and analysis, and writing all the publications presented in this thesis, with inputs from co-authors. Details are summarised as follows:

Associate Professor Yun Zhao contributed as the principal supervisor and provided ongoing close support and involvement with the study. She was involved in study design, revising manuscripts, and giving comments to improve all five publications.

Professor Andy H. Lee was an associate supervisor who was involved in study design, revising manuscripts, and giving comments to improve all five publications.

John Curtin Distinguished Professor Colin W. Binns contributed as an associate supervisor. He was also involved in study design, revising manuscripts, and giving comments to improve all five publications.

Dr. Ngoc Minh Pham contributed as an associate supervisor. He was also involved in study design, revising manuscripts, and giving comments to improve all five publications.

Statements of the contributions of others for publications are provided in Appendix B.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

BMI	Body Mass Index
CI	Confidence Interval
DNA	Deoxyribonucleic Acid
GWG	Gestational Weight Gain
IOM	Institute of Medicine
IQR	Interquartile Range
LBW	Low Birth Weight
MET	Metabolic Equivalent Task
NTDs	Neural Tube Defects
OR	Odds Ratio
PAR	Population-Attributable Risk Fraction
PPAQ	Pregnancy Physical Activity Questionnaire
RR	Relative Risk
SD	Standard Deviation
UNICEF	United Nations Children's Fund
USA	United States of America
WHO	World Health Organization

Chapter 1. Introduction and Thesis Overview

1.1 Overview

Maternal nutrition and health are worldwide public health concerns (Black et al., 2013). The World Health Organization (WHO) defined the double burden of malnutrition as "the coexistence of undernutrition (wasting, stunting, and micronutrient deficiencies) along with overweight and obesity, or diet-related non-communicable diseases, within individuals, households and populations, and across the life course" (WHO, 2016). Recent evidence shows that low- and middle-income Asian countries, including Vietnam, are now experiencing a double burden of malnutrition among women: the coexistence of underweight and overweight and often vitamin deficiencies (Biswas, Magalhaes, Townsend, Das, & Mamun, 2020; Black et al., 2013). This is especially the case during pregnancy when nutritional problems are associated with adverse pregnancy outcomes and maternal and infant health, including foetal growth restriction, birth defects, gestational diabetes, pre-eclampsia, preterm births, and caesarean deliveries (Black et al., 2013).

Gestational weight gain (GWG) is carefully monitored throughout pregnancy to ensure the health of mothers and infants. In 2009, the Institute of Medicine (IOM) recommendations on GWG were updated; and have been in widespread use in most countries as the only set of objective guidelines available (Institute of Medicine & National Research Council Committee to Reexamine IOM Pregnancy Weight Guidelines, 2009). If GWG is too excessive or too little (using the 2009 IOM recommendations as a reference), it is associated with many maternal and foetal problems including gestational diabetes, hypertension, pre-eclampsia, caesarean delivery, preterm births, foetal growth, and postpartum weight retention (Goldstein et al., 2017; N. Li et al., 2013; Rong et al., 2015). In 2016, the WHO published a recommendation stating that physical activity during pregnancy has a beneficial role in preventing excessive GWG (WHO Reproductive Health Library, 2016). However, the magnitude of the association between prenatal physical activity and GWG has not been documented in Asian countries, including Vietnam. The current evidence of the association between prenatal physical activity and GWG has only been observed in a small number of studies in Asia, including China and Singapore (Jiang et al., 2012; Koh et al., 2013; Xiang et al., 2019). However, physical activity assessments in these studies were inconsistent and included only limited assessments (Jiang et al., 2012; Koh et al., 2013; Xiang et al., 2019).

A high level of weight retention during the postpartum period is associated with long-term obesity (Linne, Dye, Barkeling, & Rossner, 2004; Reynolds et al., 2020). Some risk factors for high postpartum weight retention can be modified before, during, or in the postpartum period. These include pre-pregnancy BMI, GWG, and postpartum physical activity. Low pre-pregnancy BMI was associated with higher weight retention in several Asian studies, including in Taiwan and Malaysia (Fadzil et al., 2018; Shao, Hwang, Huang, & Hsu, 2018). However, these studies had relatively small sample sizes and short follow-ups (i.e., between one and six months postpartum). For GWG, previous findings have indicated a positive relationship between GWG and postpartum weight retention, but mainly in Western countries, with the exception of limited studies from China, Singapore, Taiwan, and Malaysia (Fadzil et al., 2018; X. He, Hu, Chen, Wang, & Qin, 2014; Koh et al., 2013; Rong et al., 2015). The benefit of postpartum physical activity on postpartum weight retention has been documented in Western countries, but not in Asian populations (Dipietro et al., 2019; Dodd et al., 2018). The absence of Asian guidelines on postpartum physical activity might be attributable to the limited literature on the relationship between postpartum physical activity and weight retention among Asian women. Only one small-scaled study from Malaysia had results similar to previous findings in Western countries, indicating that women who were more physically active after childbirth had a reduced risk of high weight retention in the between six and twelve months postpartum period (Fadzil et al., 2018; Ng, Cameron, Hills, McClure, & Scuffham, 2014; Oken, Taveras, Popoola, Rich-Edwards, & Gillman, 2007).

Public health studies have shown that low back pain is prevalent after childbirth (Chien, Tai, Hwang, & Huang, 2009; Fenwick, Hauck, Schmeid, Dhaliwal, & Butt, 2012; Woolhouse, Perlen, Gartland, & Brown, 2012). But again, there have been few published studies in Asian women, with the exception of one small-scaled study in Taiwanese women (Chien et al., 2009). The presence of postpartum low back pain results in difficulties in undertaking routine daily tasks (Thompson, Roberts, Currie,

& Ellwood, 2002). Changes in muscle physiology from increased physical activity may protect the spine from developing pathology that causes back pain (Campello, Nordin, & Weiser, 1996). Existing evidence has shown that high levels of physical activities are associated with reduced odds of reporting back pain in general populations (R. Shiri & Falah-Hassani, 2017). Prenatal physical activity has been recommended as a useful activity to prevent adverse maternal outcomes (Evenson, Mottola, & Artal, 2019). Limited findings from studies in Western countries suggest that there is a positive association between prenatal physical activity and less postpartum low back pain (Nilsson-Wikmar, Pilo, Pahlback, & Harms-Ringdahl, 2003; Stomp-van den Berg et al., 2012). These studies have only included small samples of pregnant women with a limited range of physical activities during pregnancy.

In 2018, the WHO and the United Nations Children’s Fund (UNICEF) and Nutrition International addressed the need for developing programs on prenatal micronutrient supplementation (Garcia-Casal, Estevez, & De-Regil, 2018). This aimed to respond to maternal micronutrient malnutrition and reduce the health burden during pregnancy and after birth (Garcia-Casal et al., 2018). Folic acid is a common micronutrient deficiency that occurs during pregnancy and if present in the first trimester from conception may result in neural tube defects (NTDs). Based on evidence from randomised controlled trials, most governments now recommend that folic acid supplementation be taken in the periconceptional period (and continued throughout pregnancy) may prevent NTDs and improve pregnancy outcomes (MRC Vitamin Study Research Group, 1991). Programs to promote this supplementation may be improved when maternal factors determining adherence to supplementation have been identified.

1.2 Study Settings

Vietnam occupies the eastern portion of mainland Southeast Asia and borders Cambodia, Laos, and China (Buttinger et al., 2020). It is a low-middle-income country consisting of 63 administrative management provinces (and cities) (General Statistics Office, 2015). Haiphong City and Hanoi (the capital city) are in Northern Vietnam. Ho Chi Minh City is the largest city and the economic and commercial centre of Southern Vietnam. In the health sector in Vietnam, the highest level of administration is the Ministry of Health; the second is provincial health departments; the third is district health centres. The health system consists of tertiary hospitals, district hospitals, health centres, and the lowest level is commune health stations. There are also private hospitals and small clinics operated by medical practitioners.

The population growth of Vietnam has slowed in recent years, but it has still risen from 86.2 to 95.5 million people between 2008 and 2018 (The World Bank, 2019b). The total fertility rate has increased slightly from 1.907 to 2.042 births per woman between 2007 and 2017, or just above the replacement level (The World Bank, 2019a). In recent years, Vietnam has had one of the fastest-growing economies in Southeast Asia. Vietnam is described as undergoing the nutrition and demographic transitions, the latter including rapid urbanisation. Following the pattern in many lower- and middle-income countries, the prevalence of overweight and obesity has risen from 12.0% in 2010 to 17.5% in 2015 (Ministry of Health, 2016; Swinburn et al., 2019) .

In Vietnamese society, married women typically live with their husband’s family, and are expected to undertake household tasks while being employed (Knodel, Loi, Jayakody, & Huy, 2005). In a national survey of 1776 Vietnamese women aged 30 to 49 years in 2015, 25.8% reported insufficient physical activity as recommended by the WHO (Ministry of Health, 2016). A systematic review estimated an overweight/underweight ratio of 0.9 among women in Vietnam (Abdullah, 2015). In Thai Nguyen, a province located in northern Vietnam, the prevalence of completely (100%) adhering to folic acid and multivitamin supplementations were 14.7% and 17.2%, respectively (Gonzalez-Casanova et al., 2017). Of 488 women participating in a cross-sectional study in Ho Chi Minh City, 49% aged 40 years and over reported low back pain and related symptoms (Ho-Pham et al., 2015).

In summary, overweight is now increasing, coupled with the coexistence of underweight, and the double burden of malnutrition in Vietnam (Popkin, Corvalan, & Grummer-Strawn, 2020). In addition, Vietnamese women have confronted with problems of insufficient physical activity, a low adherence to dietary supplementation, and a high prevalence of low back pain.

1.3 Aims and Objectives

The aims of this thesis were to investigate maternal weight changes (pre-pregnancy BMI, GWG, and postpartum weight retention), physical health (postpartum low back pain), patterns of physical activity, and dietary supplement use among Vietnamese mothers within twelve months postpartum.

Its five specific objectives are:

Objective 1:

To assess the association of pre-pregnancy BMI and GWG with weight retention at twelve months postpartum in Vietnam.

Objective 2:

To evaluate the role of physical activity during pregnancy on GWG in Vietnam.

Objective 3:

To ascertain the role of postpartum physical activity on weight retention within twelve months postpartum in Vietnam.

Objective 4:

To investigate the prevalence of postpartum low back pain and its relation to physical activity during pregnancy in Vietnam.

Objective 5:

To determine the prevalence of periconceptional folic acid supplementation in Vietnam and ascertain the maternal characteristics associated with folic acid use.

1.4 Study approach

This thesis was a separate component of the larger ‘Maternal lifestyle and diet in relation to pregnancy, postpartum, and infant health outcomes in Vietnam’ project, a multicentre prospective cohort study in Vietnam, between August 2015 and November 2017 (Nguyen et al., 2017). Pregnant women were recruited from participating hospitals when they visited for prenatal care. Interviewers then administered further questionnaires before hospital discharge after delivery and again at one, three, six, and twelve months postpartum. This study collected information on maternal sociodemographic, physical activity, periconceptional folic acid supplementation, GWG, postpartum weight retention, and maternal health outcomes from pregnancy to postpartum.

1.5 Significance of this Study and this Thesis

The findings of this thesis are significant for the following reasons:

- Firstly, the investigation on postpartum weight retention and its associations with pre-pregnancy BMI and GWG were the first conducted in Vietnamese women. The findings suggest that monitoring pre-pregnancy BMI and GWG (following the 2009 recommendations) can help Vietnamese women prevent postpartum weight retention and the onset of long-term obesity.
- The second focus of this thesis was on physical activity during pregnancy and in the postpartum period as potentially modifiable behaviours, which can support Vietnamese women to reduce adverse outcomes, including excess weight gain and low back pain after childbirth. The thesis used a physical activity assessment scale that had been validated in Vietnam. Weights were measured by the interviewers, using a standard protocol at the time of the follow-up interviews (Nguyen et al., 2017). The large sample size and long follow-up period enhanced the quality of this study. The results will provide evidence-based recommendations to public health professionals to support Vietnamese women in weight management and postpartum health care.
- This thesis, the first published study in Vietnam, provided valuable information about folic acid supplementation in the periconceptional period. Because of the protective role of periconceptional folic acid supplementation on the prevention of NTDs, it is important to promote an increase in folic acid supplementation. These results assist in developing detailed guidelines, including implementing routine surveillance on periconceptional folic acid supplementation. The information will be useful to Vietnamese health administrators and the national and provincial government health authorities.

The prescription of periconceptional folic acid supplementation should be considered an important mandatory practice among healthcare providers.

Overall, the thesis and published papers will provide healthcare providers and policymakers with a better understanding of women's health in Vietnam.

1.6 Outline of the Thesis

This thesis consists of five peer-reviewed, published journal papers, and six chapters as follows:

- Chapter 1 provides an overview, an introduction to Vietnam, study aims and objectives, and the significance of the study and the thesis.
- Chapter 2 contains the literature is reviewed in.
- Chapter 3 describes the methods used in this study in brief since detailed methods are provided in published papers in Chapter 4.
- Chapter 4 includes descriptive findings and published papers following the five study objectives.
- Chapter 5 discusses the results of all five published papers in general and the study limitations.
- Chapter 6 includes a conclusion and recommendations for future practice and research.

Ethical approval letters, a declaration of authorship, permissions from journals, questionnaires, information sheets, and informed consent forms are contained in the Appendices.

Chapter 2. Literature review

2.1 Overview

The purpose of this study was to investigate maternal weight changes during pregnancy and after childbirth, and physical health, together with patterns of physical activity and dietary supplementations among Vietnamese mothers within twelve months postpartum. Studies on these similar issues have been conducted in Western countries. However, to date, large-scale studies on maternal nutrition and health remain sparse in Asian countries. This literature review supplements the shorter reviews that are in the published papers, which make up most of this thesis.

This chapter includes a review of the relevant studies that were prospective or retrospective cohorts or randomised controlled trials (RCTs) with a focus on Asian populations, including Vietnamese. This chapter has the following five sections, gestational weight gain (GWG) (Section 2.2), postpartum weight retention (Section 2.3), physical activity in pregnancy and the postpartum period (Section 2.4), postpartum low back pain (Section 2.5), and folic acid supplementation in the periconceptional period (Section 2.6).

2.2 Gestational Weight Gain

Weight gain during pregnancy has been documented as a significant contributor to pregnancy outcomes in high-income countries since the 1940s. Most studies worldwide adopt the United States (US) Institute of Medicine (IOM) to define GWG (Institute of Medicine & National Research Council Committee to Reexamine IOM Pregnancy Weight Guidelines, 2009), which has been found to impact on mother-infant dyad (Goldstein et al., 2017).

2.2.1 Definitions and Measurement in Public Health Research

The total GWG comprises foetus and uterus weight, amniotic fluid, placenta, maternal blood volume, fat, and lean mass (Vinter, 2012). The Institute of Medicine defined the total GWG as the weight just before delivery weight (pre-delivery weight) minus weight just before conception (pre-pregnancy weight) (Institute of Medicine & National Research Council Committee to Reexamine IOM Pregnancy

Weight Guidelines, 2009). Accordingly, the pre-delivery weight can be retrieved ideally as the last available measured weight from clinical records. To date, most studies have adopted the definition of IOM (Abrams et al., 2017; S. He et al., 2019; Widen et al., 2015), and this is the definition used in the thesis.

2.2.2 Historical Background of the Use of Gestational Weight Gain in Research Studies and Clinical Guidelines.

During the 1940s and 1950s in the USA, pregnant women were recommended to gain less than nine kilograms (or 20 lbs) for the entire pregnancy, aiming to reduce the risk of toxaemia and birth complications related to large babies (Institute of Medicine Committee on Nutritional Status During & Lactation, 1990). However, either low or high weight gain during pregnancy had been found to have adverse effects on infant mortality and morbidity from the 1970s to 1980s. Later, in 1990, the IOM firstly released a formal guideline on GWG based on pre-pregnancy body mass index (BMI) for four categories: low (<19.8 kg/m^2), normal (19.8 to 26.0 kg/m^2), high (>26.0 to 29.0 kg/m^2), and abuse (>29 kg/m^2) (Table 2-1).

Table 2- 1. Institute of Medicine recommendations* on total gestational weight gain (GWG) by pre-pregnancy BMI

In 1990		In 2009	
Pre-pregnancy BMI (kg/m^2) [a]	**Recommended total GWG (kg)**	**Pre-pregnancy BMI (kg/m^2) [b]**	**Recommended total GWG (kg)**
Low (<19.8)	12.5 to 18	Underweight (<18.5)	12.5 to 18
Normal (19.8 to 26.0)	11.5 to 16	Normal weight (18.5 to 24.9)	11.5 to 16
High (>26 to 29.0)	7 to 11.5	Overweight (25.0 to 29.9)	7 to 11.5
Abuse (>29.0)	≥6.8	Obese (≥30)	5 to 9

***** According to the IOM recommendations on GWG in 1990 (Institute of Medicine Committee on Nutritional Status During & Lactation, 1990) and 2009 (Institute of Medicine & National Research Council Committee to Reexamine IOM Pregnancy Weight Guidelines, 2009).

[a] Derived from the Metropolitan Life Insurance tables (Institute of Medicine Committee on Nutritional Status During & Lactation, 1990).

[b] Based on the World Health Organisation (WHO) cut-off points (Institute of Medicine & National Research Council Committee to Reexamine IOM Pregnancy Weight Guidelines, 2009)

Considering possible joint effects of GWG and maternal weight (particularly overweight and obesity) on both infant and maternal health, the IOM updated its guideline on GWG in 2009 . Significant changes in this updated guideline (compared to the 1990 guideline) included (a) the pre-pregnancy BMI was classified based on the WHO BMI categories, rather than the previous categories from the Metropolitan Life Insurance tables; and (b) obese women were recommended by a specific and relatively narrow range of weight gain. According to the 2009 IOM recommendations on total GWG (Table 2-1), adequate IOM GWG is classified as weight gain during pregnancy within, inadequate IOM GWG is below, and excessive IOM GWG is above the recommended GWG range, for each pre-pregnancy BMI category, respectively. The 2009 IOM recommendations on GWG are applied to all women, including those who differ from ethnic groups (Institute of Medicine & National Research Council Committee to Reexamine IOM Pregnancy Weight Guidelines, 2009). These recommendations have been adapted in some Asian countries, including Korea (Wie et al., 2017), Japan (Enomoto et al., 2016), and China (Tan et al., 2018).

In Vietnam, a study of 2989 women examined optimal weight gain during pregnancy to reduce risks of having an infant too large or too small for gestational age between 2007 and 2008. This study found that a GWG of less than ten kg and greater than 15 kg was associated with the risk of having an infant too large or too small for gestational age. The optimal GWG for each pre-pregnancy BMI category (underweight, normal, and overweight) was also computed in this study. However, the pre-pregnancy BMI classification in this study differs from that in the 2009 IOM recommendations on GWG. For this reason, their findings on optimal GWG for each pre-pregnancy BMI category are not directly comparable to that in the IOM GWG ranges (Ota et al., 2011).

2.2.3 Gestational Weight Gain in Asia

The proportions of inadequate IOM GWG and excessive IOM GWG (following the 2009 IOM recommendations) vary by countries in Asia. For example, studies in China and Singapore reported a lower proportion of women who gained inadequate weight, compared to the proportion of women who gained excessive weight during pregnancy (following the 2009 IOM recommendations). Specifically of 5733 women in China, the prospective cohort study by Wei et al. (2019) indicated that the proportions of inadequate and excessive IOM GWG were 21.5% and 31.3%, respectively. The prospective cohort of 1166 Singaporean women found 27.7% with inadequate IOM GWG and 36.2% with excessive IOM GWG (Koh et al., 2013). In contrast, a retrospective study of 2012 women in Eastern Thailand reported a higher proportion of women with inadequate IOM GWG (37.5%) and a lower proportion of women with excessive IOM GWG (29.6%) (Sananpanichkul & Rujirabanjerd, 2015). Differences in the proportions of GWG categories might be associated with ethnicity, which has been mentioned previously. The studies mentioned above included pregnant women from one specific province or hospital, which might also be not generalizable.

Vietnamese women are often persuaded to gain as many weights as possible during pregnancy. However, in an RCT of 20 rural communes of Vietnam between October 2011 and May 2012, most women had inadequate IOM GWG (73.4%, n=1436), which might be explained by the rural residency of the participants (Young et al., 2017). Moreover, most of their occupations were related to farming; hence, they may engage with higher physical activity levels than urban populations. It has been reported that rural Vietnamese women were classified five times more than their urban counterparts in the poorest wealth index quintile (General Statistics Office and UNICEF, 2015). Rural women also have limited access to prenatal care and food insecurity (General Statistics Office and UNICEF, 2015).

2.2.4 Effects of Gestational Weight Gain on Maternal and Infant Health Outcomes

2.2.4.1 Gestational Hypertension and Pre-Eclampsia

Hypertension in pregnancy is defined as ≥140 mmHg in systolic blood pressure and/or ≥90 mmHg in diastolic blood pressure (Lowe et al., 2014). Gestational hypertension (or pregnancy-induced hypertension) is diagnosed based on the new onset of hypertension after 20 weeks of gestation without any maternal or foetal clinical features of pre-eclampsia (Lowe et al., 2014). The blood pressure then returns to be normal within three months postpartum. The earlier the gestation at presentation, the higher is the likelihood of developing pre-eclampsia and consequently adverse pregnancy outcomes. Pre-eclampsia is also diagnosed based on hypertension after 20 weeks of gestation (some rare cases earlier than this gestational week) (Lowe et al., 2014). It is accompanied by one or more of the following signs, including renal, haematological, liver, neurological involvement, pulmonary oedema, and foetal growth restriction (Lowe et al., 2014).

It has been previously observed the significant relationships between GWG and gestational hypertension and pre-eclampsia. Of 33,973 mother-infant pairs, a study in urban Tianjin (China) reported women with excessive IOM GWG increased the risk of pregnancy-induced hypertension, compared to those with adequate IOM GWG (adjusted OR=1.93 [95% CI 1.62, 2.31]) (N. Li et al., 2013). This Chinese study by Li et al. is one of a few studies on the association between pregnancy-induced hypertension and IOM GWG in Asia (N. Li et al., 2013). Another study of 21,674 underweight pre-pregnancy women living in the USA also showed a consistent finding (Gavard, 2017). In this study, excessive IOM GWG was positively associated with an increased risk of pre-eclampsia (adjusted OR=1.94 [95% CI 1.56-2.42]) (Gavard, 2017). The findings gleaned from these two studies consistently indicate that excessive IOM GWG can increase risk of both gestational hypertension and pre-eclampsia. The associations of GWG with gestational hypertension and pre-eclampsia may be explained in part by the effect of obesity on placental function and perfusion through hyperlipidaemia, insulin resistance, and hyperinsulinemia (Lopez-Jaramillo, Barajas, Rueda-Quijano, Lopez-Lopez, & Felix, 2018).

2.2.4.2 Mode of Delivery

The role of GWG and its impact on mode of delivery has been studied previously in very few observational studies in Asia, but findings are inconsistent. A recent study in China found that excessive GWG (following the 2009 IOM recommendations) was positively associated with caesarean deliveries (adjusted risk ratio (RR)=1.21 [95% CI 1.19, 1.23]) in 1,009,987 nulliparous women (Zhou et al., 2017). Of 1883 Japanese singleton pregnant women, another prospective cohort did not observe a significant relationship between GWG and emergency caesarean deliveries; and the authors explained this is probably due to low emergency caesarean rates in their study (Tanaka et al., 2014). We did not locate any studies conducted in Vietnam or similar countries regarding the relationship between GWG and mode of delivery. Studies with larger sample sizes are warranted across different Asian populations, particularly those with rising rates of caesarean deliveries, including Vietnam.

2.2.4.3 Preterm Births

Preterm births include all births born alive before completing 37 weeks of pregnancy (WHO, 2018). Most studies on the relationship between GWG and preterm births are from non-Asian countries.

A retrospective cohort of 33,872 US women, who gave birth between 1995 and 2003, observed a significant relationship between GWG and preterm birth (all births under 37 weeks of gestation). Women of normal pre-pregnancy BMI and low GWG (0 to 9 kg) (adjusted OR=1.5 [95% CI 1.2, 1.7]), or high GWG (≥20 kg) [adjusted OR=1.3 [95% CI 1.1, 1.5]) had an increased risk of preterm birth (Savitz, Stein, Siega-Riz, & Herring, 2011). Another retrospective cohort study in Peru examined the association of GWG with preterm birth subtypes, including idiopathic preterm birth, preterm premature rupture of membrane, and preterm birth resulting from medical intervention. The authors reported that idiopathic preterm birth accounts for most of deliveries under 37 weeks (85.7%) among 8964 women. Underweight women who gained inadequate weight recommended by the IOM had double the risk of all preterm subtypes (adjusted OR=2.03 [95% CI 1.25, 3.30]) (Carnero, Mejia, & Garcia, 2012). However, the authors observed the null relationship between excessive IOM GWG and all preterm subtypes (the OR included the value of 1.00).

Few studies have also been conducted to examine the relationship between GWG and preterm delivery in Asian women. A study of 1593 Chinese women in Wuhan found significantly increased odds of delivering preterm infants in women with inadequate GWG (based on the 2009 IOM recommendations) (Guan, Tang, Sun, & Ren, 2019). However, no relationship between excessive IOM GWG and preterm delivery was confirmed (Guan et al., 2019). Another cohort study retrieved retrospective data from six provinces of China in 2013, and the results are in line with the aforementioned findings in the USA (Huang et al., 2016; Savitz et al., 2011). The results also indicated GWG, which is below or above the 2009 IOM

GWG, was associated with an increased risk of preterm delivery (Huang et al., 2016).

Overall, these studies highlight that either too much or too little GWG is associated with preterm delivery, although the results of the studies varied. The observed studies, which retrospectively examined the relationship between GWG and preterm delivery, retrieved data from healthcare facilities. Therefore, caution must be applied, as the findings might not capture the confounding effects of maternal lifestyle behaviours that are unlikely available in medical records.

Up to now, little attention has been paid to the impact of GWG on preterm delivery in Vietnam. In a recent cross-sectional study on preterm birth in Vietnam in 2016, the preterm rate in live births was 5% of 20,762 births. Nonetheless, this study lacked data on maternal anthropometric measures (Giang, Ulrich, Tran, & Bechtold-Dalla Pozza, 2018). Further studies are needed to elucidate the association between preterm birth and GWG because previous studies were confined to one or few healthcare facilities in Vietnam.

2.2.4.4 Foetal Growth

Many studies observed statistically significant relationships between GWG and foetal growth in terms of birth weight and infant size for gestational age.

Regardless of gestational age, low birth weight (LBW) and macrosomia are defined as the newborn's first weight of less than 2500 grams and greater than 4000 grams, respectively (WHO, 2006; Ye et al., 2015). A meta-analysis including eleven studies in Western and Asian countries (Japan, Taiwan, and Korea) reported a positive association between excessive GWG (above the 2009 IOM recommendations) and macrosomia (adjusted OR=1.95 [95% CI 1.79, 2.11]) (Goldstein et al., 2017). LBW rates in some Asian countries (i.e., Thailand, Malaysia, and Indonesia) have been declining (WHO, 2019a). It might be related to nutrition improvement for women during pregnancy. However, few studies in Asia have linked inadequate GWG (below the 2009 IOM recommendations) to LBW. In a recent population-based study of 21248 Taiwanese women, mothers with inadequate IOM GWG were found to be less likely to have a macrosomia delivery (adjusted OR = 0.59 [95% CI 0.42, 0.83]), but more likely to deliver a LBW baby (adjusted OR=2.26 [95% CI 1.95, 2.62]), relative to those with adequate IOM GWG (Chen, Chen, & Hsu, 2020). To elucidate if maternal nutrition has been related to changes in low-birth-weight trends in Asian countries, further studies are needed to address whether maternal nutrition may drive low birth weight trends in this region.

Foetal growth can also be assessed using infant sizes for gestational age. A recent meta-analysis with 265,270 births, which collected data of 39 cohorts from Europe, North American, and Oceania, reported that women with inadequate IOM GWG were more likely to have an infant with a small size for gestational age (Population-attributable risk fraction in percentage (PAR) =11.0). In contrast, excessive IOM GWG was associated with a higher risk of giving births to babies who are large size for gestational age (PAR=31.6) (Santos et al., 2019). Several studies in China and Vietnam also reported consistent findings on the association between excessive IOM GWG and delivering a large-for-gestational-age infant (Su et al., 2019; Young et al., 2017). In Vietnam, Young et al. examined the association between GWG and infant size for gestational age, using prospective data from a randomized controlled trial in 1599 rural women. Their finding was in line with Santos et al. (2019) that inadequate IOM GWG was associated with the increased odds of delivering an infant with a small size for gestational age (adjusted OR=2.5 [95% CI 1.6, 4.0]) (Young et al., 2017). These findings suggest that GWG is associated with foetal growth outcomes.

2.2.5 Factors Associated with Gestational Weight Gain

2.2.5.1 Energy Balance during Pregnancy

Energy intake should not exceed energy expenditure to control weight gain. Energy expenditure and its relationship with GWG have been reviewed in Section 2.4.4.1 (Physical activity during pregnancy and GWG). Of 3314 Dutch women who participated in the Generation R cohort prospective study, the authors found that total energy intake was positively associated with excessive GWG, albeit no information on physical activity during pregnancy (Gaillard et al., 2013). However, the observed relationship between energy intake and GWG was not statistically significant in a meta-analysis of 18 observational studies and RCTs (Jebeile, Mijatovic, Louie, Prvan, & Brand-Miller, 2016). This meta-analysis included studies in Caucasian and Asian populations (Japan and India) between 1992 and 2013 (Jebeile et al., 2016).

These findings may be somewhat limited by sparse observational studies in Asian countries, where pregnant women have been observed 'eating-for-two' norm during pregnancy, including Vietnam and Thailand (Hashmi et al., 2018; Hirst et al., 2012).

2.2.5.2 Pre-pregnancy Body Mass Index (BMI)

Pre-pregnancy BMI is calculated as pre-pregnancy weight in kilos (kg) divided by height in meters squared (m^2). Data from several studies suggest that women who were overweight or obese prior to pregnancy had a greater likelihood of gaining excessive weight during pregnancy than women who had a normal weight before pregnancy (Dolin et al., 2020; Restall et al., 2014). An Australian study among 1950 pregnant women found that women who were pre-pregnancy overweight were 2.9 times as likely to have excessive GWG (following the 2009 IOM recommendations) (95% CI 2.20, 3.82) (Restall et al., 2014). A recent study of women living in the USA also indicated pre-pregnancy obesity was associated with increased risk of excessive IOM GWG, compared to pre-pregnancy normal weight (relative risk ratio=2.13 [95% CI 1.16, 3.90]) (Dolin et al., 2020). However, this study is limited by a small sample size (*n*=508) and only included Hispanic low-income women (Dolin et al., 2020). Another limitation of this study is that studied women, who were underweight before pregnancy, were excluded from their analysis due to a small number of participants (Dolin et al., 2020). As a result, their results are not generalizable to women who are underweight before pregnancy.

One cohort study in Asia has examined the association between pre-pregnancy BMI and GWG (Koh et al., 2013). The prospective cohort study of 1166 women living in Singapore showed that odds of inadequate GWG (following the 2009 IOM recommendations) were significantly higher for women who were underweight before pregnancy, compared to those with normal weight (adjusted OR=3.09 [95% CI 2.06, 4.65]) (Koh et al., 2013). However, the study in Singapore did not observe a significant association between pre-pregnancy overweight and excessive IOM GWG, which is not consistent with previous studies mentioned above in Australia and the USA. This discrepancy suggests that other factors may interact with pre-pregnancy BMI to influence excessive IOM GWG in Singapore, and perhaps in other Asian populations too. However, little attention has been paid to the relationship between pre-pregnancy BMI and GWG in other Asian countries including Vietnam, where has been observed the coexistence of underweight and overweight or obesity.

2.2.5.3 Maternal Sociodemographic Factors

Age, education, and ethnicity are common determinants of GWG. Using data from 54,022 singleton pregnancies in a prospective cohort study in Belgium, women aged 20-24 years, being single, belonging to ethnic minority groups (non-Belgians and non-Dutch) were associated with increased risk of excessive and inadequate IOM GWG. Besides, mothers with high or highest educational levels had lower odds for excessive and inadequate IOM GWG (Bogaerts et al., 2012). This finding was in line with another study in the USA regarding the associations of maternal age and education with GWG (Deputy, Sharma, Kim, & Hinkle, 2015). Few studies conducted in the associations between maternal socio-demographic factors and GWG in Asia. The study by Koh et al. found that women aged ≥31 years old were less likely to have excessive GWG (adjusted OR=0.66 [95% CI 0.48, 0.91]), compared to women aged 20 to 30 years old in Singapore (Koh et al., 2013). Due to the multi-ethnic characteristic of Singapore, another notable finding was that women who belonged to the Malay ethnic group were more likely to have either inadequate or excessive GWG, compared to women who belonged to the Chinese ethnic group (Koh et al., 2013). In a recent cohort study, Singaporean women with the junior college or polytechnic educational level were more likely to have excessive IOM GWG, compared to women with university or higher educational level (adjusted OR=1.96 [95% CI 1.25, 3.07]) (S. He et al., 2019). The above-mentioned studies are from developed countries (the USA and Singapore); therefore, they may not be generalizable to Asian countries with lower socio-economic or undernourished status. Socio-demographic determinants of GWG might help design and tailor programs promoting healthy GWG.

2.3 Postpartum Weight Retention

Since the Institute of Medicine (IOM) published its guideline on GWG in 2009, many studies have turned their attention to maternal weight change after giving birth. This section describes the postpartum weight retention definition, measurement, and common effects of high postpartum weight retention on maternal long-term health outcomes. Two major factors associated with postpartum weight retention, namely pre-pregnancy BMI and GWG, are discussed in this section, followed by a discussion of the association between physical activity, which is another behavioural factor, and postpartum weight retention. Lastly, patterns on postpartum weight retention are described in Asian countries, including Vietnam.

2.3.1 Definition and Measurement in Public Health Research

Postpartum weight retention has been recommended for routine surveillance at the national level by the IOM since 2009. The 2009 IOM guideline recommends that total postpartum weight retention measurement is repeated at three, six, nine, twelve, and 18 months postpartum (Institute of Medicine & National Research Council Committee to Reexamine IOM Pregnancy Weight Guidelines, 2009). The weight retention is calculated by the difference between pre-pregnancy weight and postpartum weight. This absolute weight retention calculation has been adapted in many observational studies in the literature (Cheng, Walker, Tseng, & Lin, 2011; Rong et al., 2015; Soria-Contreras et al., 2020).

2.3.2 Postpartum Weight Retention in Asia

Previous findings suggest higher weight retention in some Asian populations than in the Caucasian population (Kinnunen et al., 2019; Waage et al., 2016). Although there have been a limited number of studies on postpartum weight retention in Asia, a systematic review included twelve studies of six Asian countries and indicated that Asian women were from 1.56 to 4.1 kg heavier at six months postpartum than before pregnancy.

A study of 1122 Chinese women showed women retained 5.0 (interquartile range [IQR] 7.0) kg and 3.0 (IQR 5.5) kg on average at six and twelve months postpartum, respectively (X. He et al., 2014). Another study among 924 Chinese women indicated that weight retention was 3.25 (SD 4.64) kg on average at six months postpartum (Sha et al., 2019). A study of 461 women in Taiwan noted that the mean weight retention at six months postpartum was 2.1 (SD 3.3) kg (Shao et al., 2018). A later study in 1166 Singaporeans reported 32.7% of women who retained over five kg at six months postpartum (Koh et al., 2013). Similarly, the proportion of women retaining over five kg at six months postpartum was 33.8% of 420 women in

Malaysia (Fadzil et al., 2018). These data show that a notable proportion of women in many Asian countries did not return to their pre-pregnancy weight after giving birth.

2.3.3 Effects of High Postpartum Weight Retention on Women's Health

Existing prospective cohort studies in Western countries recognises the critical role played by postpartum weight retention on women's weight trajectories and the onset of long-term obesity (Linne et al., 2004; Reynolds et al., 2020). In a nine-year study of 9724 women with a singleton pregnancy in Dublin (Ireland), the incidence of maternal obesity increased from 11.6% in the first pregnancy to 16.0% in the subsequent pregnancy (Reynolds et al., 2020). In a follow-up of the Stockholm Pregnancy and Weight Development study, one-quarter of the examined sample of 887 Swedish women had pre-pregnancy normal weight and developed overweight at the 15-year follow-up (Linne et al., 2004). Previous observational studies on postpartum weight retention in Asia have followed up mothers until 24 months postpartum (Cheng et al., 2011; Rong et al., 2015). It remains unknown whether postpartum weight retention significantly influences Asian women's weight trajectories in a longer period.

Increased BMI in women might contribute to hormone changes. For example, increased fat tissue can increase maternal oestrogen levels, thus, increasing endometrial cancer risk. A systematic review and meta-analysis, which included 282,137 incident cancer patients between 1966 and 2007, recorded strong associations of increased BMI in women with several cancers. For instance, a five kg/m^2 increase in BMI was strongly associated with endometrial cancer (risk ratio (RR)=1.59 [95% CI 1.50, 1.68]) and renal cancer (RR=1.34 [95% CI 1.25,1.43]) (Renehan, Tyson, Egger, Heller, & Zwahlen, 2008). These studies highlight the impact of increased BMI, which might be caused by high postpartum weight retention in women on their long-term health outcomes. Sparse long-term follow-ups on postpartum weight retention in Asian women result in gaps in understanding of the impact of postpartum weight retention on maternal long-term health outcomes.

2.3.4 Association between Pre-Pregnancy BMI and Postpartum Weight Retention

The relationship between pre-pregnancy BMI and postpartum weight retention has received increasing attention since the 2009 IOM recommendations, and data remains inconsistent. A prospective cohort study of 887 Sweden women indicated no association between pre-pregnancy BMI and one-year postpartum weight retention (p>0.05), which was categorized into three levels (<0.2 kg, 0.2 to 2.2 kg, >2.2 kg) in a simple correlation analysis (Linne et al., 2004). What is less evident in this analysis is the absence of adjustment for GWG and energy expenditure, which have been reported previously as associated factors with postpartum weight retention (Cheng et al., 2011; Rong et al., 2015). In contrast, another prospective cohort study including 550 women in the USA indicated that women having pre-pregnancy underweight were more likely to retain one to ten lb weight at three months (relative risk (RR) =1.7 [95% CI 1.4, 2.1]) and one year (RR=2.0 [95% CI 1.6, 2.7]) postpartum, compared to those having pre-pregnancy normal weight (Siega-Riz et al., 2010). Notably, pre-pregnancy overweight or obesity was inversely associated with retaining higher than ten lb at twelve months postpartum (RR=0.6 [95% CI 0.5, 0.8]) (Siega-Riz et al., 2010).

In Asia, there is a paucity of studies addressing the relationship between pre-pregnancy BMI and postpartum weight retention, and results are also inconsistent. A cohort study of 461 Taiwanese women reported an inverse association between pre-pregnancy BMI and postpartum weight retention at one month (adjusted OR=0.85 [95% CI 0.77-0.94]) (Shao et al., 2018). In another cohort study of 638 women in Malaysia, mothers with pre-pregnancy BMI <25 kg/m^2 were observed to have higher postpartum weight retention at six months on average than those with pre-pregnancy BMI ≥25 kg/m^2; whereas, the association was non-significant (Fadzil et al., 2018). Given the relatively small sample size, the findings of these studies have a lack of generalisability to all populations in either Taiwan or Malaysia. There is also insufficient evidence to link pre-pregnancy BMI and postpartum weight retention in Asian women, as most studies had a short follow-up period of between one and six months postpartum.

2.3.5 Association between Gestational Weight Gain and Postpartum Weight Retention

GWG is a major contributor to postpartum weight retention (Institute of Medicine & National Research Council Committee to Reexamine IOM Pregnancy Weight Guidelines, 2009). A meta-analysis of 17 studies (in Taiwan, Singapore, Iran, Sweden, Netherlands, Canada, Denmark, Australia, and the USA) suggested that GWG, following the 2009 IOM, remained to be associated with postpartum weight retention in both short- and long-term periods (Rong et al., 2015). The relationship between GWG and postpartum weight retention has been reported in limited studies in Asian countries, including China, Singapore, and Malaysia.

A study among 1166 Singaporean women found positive associations between excessive GWG and retaining ≥five kg at six, twelve, and 24 months postpartum; and the highest increase was observed at 24 months postpartum (adjusted OR =2.81 [95% CI 1.80, 4.39]) (Koh et al., 2013). An inverse association between inadequate GWG and weight retention of over five kg was also observed at six months postpartum only (adjusted OR=0.32 [95% CI 0.19, 0.53]). The strength of this study was the inclusion of weight retention at multiple time points (i.e., from six to 24 months). However, it is essential to bear in mind the possible recall bias in all self-reported postpartum weights, which were retrospectively interviewed on the phone. This limitation might explain why the 95% confidence intervals were moderately wide when computing odds for retaining postpartum weight at twelve months in women with excessive GWG (adjusted $OR_{\text{12 months postpartum}}$=5.00 [95% CI 2.35, 10.6]).

Using prospective data from a cohort of 1289 Chinese women in Anhui province, followed up until twelve months postpartum between 2010 and 2012, the authors observed that excessive IOM GWG was approximately four times likely to gaining ≥4.55 kg (an approximation of ≥10 lbs) at twelve months postpartum (X. He et al., 2014). In addition, a prospective cohort study including 420 Malaysian women indicated a significant positive relationship between gaining ≥12 kg during pregnancy and early postpartum weight retention (i.e., at six months) (estimated coefficient=2.64, [95% CI 2.001, 3.282], p<0.001) (Fadzil et al., 2018). The above studies revealed a positive association between GWG and postpartum weight retention in Asian women, though data is still lacking. The first twelve months were acknowledged as the minimum period for postpartum health recovery. However, only two studies (China (X. He et al., 2014) and Singapore (Koh et al., 2013)) on weight retention at greater or equal to twelve months postpartum have been observed in Asia. To date, there has been no study investigating the association between GWG and postpartum weight retention up to twelve months in Vietnam.

2.4 Physical Activity in Pregnancy and the Postpartum Period

In the literature, a variety of instruments have been used to measure physical activity during pregnancy and in the postpartum period. Guidelines on physical activity during pregnancy and in the postpartum period have recommended the benefits of physical activity on pregnancy and postpartum health outcomes. One important health benefit of physical activity concerns bodyweight management, which has been well documented for the general population in the literature. The impact of physical activity on both maternal body weight during pregnancy and the postpartum period in Asian countries is the primary interest of this review.

2.4.1 Physical Activity and Bodyweight

Energy balance is the balance of total energy expenditure and total energy intake. Total daily energy expenditure comprises 60-75% basal metabolic rate, 10% thermic effects from eating (food), and 15-30% physical activity energy expenditure (McArdle, 2015). Physical activity is the most influential and changeable component of total energy expenditure. Physical activity energy expenditure consists mainly of purposeful-voluntary physical activity (exercise) and non-exercise activity thermogenesis. Non-exercise activity thermogenesis refers to energy expenditure associated with daily and non-exercise physical activity, including housework, occupational, and traveling activities in daily life (Levine, Vander Weg, Hill, & Klesges, 2006; Villablanca et al., 2015). An increase in physical activity energy expenditure can increase total energy expenditure and then redress an energy balance (Pontzer et al., 2016). Therefore, both exercise and non-exercise physical activity should be considered together in body weight management.

Studies are scarce regarding the association between physical activity (both exercise and non-exercise physical activity) and body weight (BMI) in Asian women. In

Thailand, a large cross-sectional study of 74,981 women aged between 15 and 87 years old investigated the relationship between obesity and physical activity in 2005 (Banks, Lim, Seubsman, Bain, & Sleigh, 2011). It found an inverse relationship between Thai women being obese and mild exercise-related physical activity over 20 minutes per week or walking for at least ten minutes per week or doing gardening and housework for at least twice per week (p for trend <0.0001). In addition, there was a statistically significant positive relationship between sedentary time (at least four hours per day) and overweight/obesity in Thai women (p for trend <0.001). The findings were in line with another large cross-sectional study in China (n= 466,605) among women aged 35 to 74 years old, where an inverse association was found between household activity or sports/exercise and BMI (Du et al., 2014). To date, only one study (with a sample of 14,706 respondents aged 25-64 years) reported a negative association between physical activity (i.e., total physical activity or work activity) and BMI in Vietnamese women (Bui et al., 2015). The findings mentioned above suggested that physical activity plays an important role in women's weight trajectory.

2.4.2 Association between Physical Activity during Pregnancy and Gestational Weight Gain

Increasing attention has been paid to physical activity during pregnancy, partly due to its beneficial role in reducing complications, including unhealthy GWG (Kraschnewski et al., 2013; Wang, Wen, Liu, & Liu, 2019). Under the 2018 guidelines in Canada and the USA, healthy GWG was identified as a critical outcome of physical activity throughout pregnancy (Evenson et al., 2019).

A recent meta-analysis of interventional studies demonstrated a protective effect of light- to moderate-intensity exercise on GWG, despite potential sampling bias, different exercise interventions, and lack of non-exercise physical activity measurements. In this meta-analysis, four of 23 included studies were from Asian populations, including China, Japan, and Iran (Wang et al., 2019). Similarly, a few cohort studies investigated the relationship between physical activity and GWG in Asian countries, such as China (Jiang et al., 2012; Xiang et al., 2019) and Singapore (Koh et al., 2013). However, no study has examined the role of physical activity during pregnancy on GWG in Vietnam.

A cohort study of 862 pregnant women in China measured physical activity within four days in each second and third trimester (two working days and two weekend days) (Jiang et al., 2012). Women in the active group gained less weight during pregnancy than women in the sedentary group. Despite the use of objective and repetitive measurements of physical activity and the inclusion of energy intake in all models, 70% of its studied women were office-based employees. Moreover, the physical activity assessment relied on limited pedometer-wearing days. A retrospective cohort study of 1166 Singaporean women, which showed an inverse relationship between exercise and having excessive GWG (adjusted OR=1.42 [95% CI 1.03, 1.98]) (Koh et al., 2013). The authors defined “exercise” spending 15 minutes or more of any exercise at least once a week before or during pregnancy. Due to such limited physical activity assessment, their finding could not distinguish physical activity undertaken before and during pregnancy.

Another recent cohort study of 1,077 Chinese women investigated the relationship between physical activity during pregnancy and GWG in the Sichuan province of Western China (Xiang et al., 2019). Respondents who reported the highest level (the fourth quartile) of total physical activity at last trimester had reduced risks of either inadequate (adjusted OR=0.31 [95% CI 0.10, 0.91]) or excessive IOM GWG (adjusted OR=0.33 [95% CI 0.12, 0.91]), compared to those reported the lowest level (the first quartile) of total physical activity (≤23 MET-hour per week). The study observed a small number of women engaged in a high level of occupational physical activity (*n*=158, 14.7%), which might explain the undetectable relationship between occupational physical activity and GWG.

In summary, all studies among Asian populations reviewed above suggested that total physical activity during pregnancy appears to be beneficial to achieving a healthy GWG. However, there was a lack of consistency between studies regarding the physical activity measurements at different time points during pregnancy.

2.4.3 Association between Physical Activity in the Postpartum Period and Postpartum Weight Retention.

In total, between 1990 and 2013, guidelines on physical activity during the postpartum period were identified in five countries, namely Australia, Canada, Norway, the United Kingdom, and the USA (Evenson, Mottola, Owe, Rousham, & Brown, 2014). Postpartum physical activity has been suggested to resume with mild intensity and gradual increase, particularly in women who did not engage in vigorous-intensity physical activity before and during pregnancy. However, the guidelines were inconsistent regarding the frequency and type of activities. The benefits of postpartum physical activity in maternal weight management have been documented in the United Kingdom and the USA. No guidelines on postpartum physical activity have been found in Asian countries.

Several studies have examined the relationship between postpartum physical activity and postpartum weight retention, but they were restricted mainly to Caucasian populations and in developed countries (Dipietro et al., 2019; Dodd et al., 2018). A prospective cohort study in 1213 Australian women reported that women who spent less than once a week on walking ≥30 minutes had an increased risk of high one-year postpartum weight retention (adjusted OR=1.69 [95% CI 1.06, 2.71], p=0.029) (Ng et al., 2014). A major strength of this Australian study is its assessment of a broad range of activities in caregiving, occupation, and recreation domains (i.e., recreational activity with baby, moderate physical activity less than once a week, having a paid job after birth) after delivery (Ng et al., 2014).

A prospective cohort study of 902 women in the USA exhibited an inverse relationship between walking at least 30 minutes per day (for exercise and travelling) at six months postpartum and weight retention at twelve months postpartum (Oken et al., 2007). Walking is a common activity used to assess postpartum physical activity. However, the impact of total physical activity women spent per week on postpartum weight retention remained unknown from this study.

There is little evidence on the relationship between postpartum physical activity and weight retention in the postpartum period among Asian women, with the exception of a prospective cohort study in Malaysia. The cohort study of 420 Malaysian women suggested that increasing postpartum physical activity could lead to less weight retention at six months postpartum (*Beta*= -5.92 [95% CI -6.77, -5.07], p<0.001) (Fadzil et al., 2018). Total physical activity (the combination of walking and moderate-, and vigorous-intensity activities measured by the validated short version of International Physical Activity Questionnaire) was the mean of physical activity scores at two, four, and six months postpartum, and was dichotomised as 'less active' (<3000 MET-minutes/week) and 'active' (≥3000 MET-minutes/week) in their study. Additional studies on the relationships between a variety of postpartum physical activity intensities and domains; and postpartum weight retention are warranted.

2.5 Postpartum Low Back Pain

This section describes low back pain definitions and prevalence of low back pain in the postpartum period. There has been limited research on postpartum low back pain in Asia. Therefore, most epidemiologic studies, which will be discussed in this section, were in Western countries and with large sample sizes. Definitions and prevalence of low back pain are outlined first. Several common factors associated with postpartum low back pain are discussed next, including maternal weight, mode of delivery, and parity. Attention will then be turned to the relationship between physical activity during pregnancy and postpartum low back pain.

2.5.1 Definitions and Prevalence of Postpartum Low Back Pain

Stresses in the sacroiliac joints and lumbosacral spine through weight gain, lordosis, and ligament laxity contribute to postpartum low back pain (Salzberg, 2012). The development of low back pain in the postpartum period might be independent of pregnancy-related pains, which suggests the critical role of prevention against the postpartum low back pain (Dunn et al., 2019; Gutke, Boissonnault, Brook, & Stuge, 2018).

Definitions of back pain vary amidst studies (Hurwitz, Randhawa, Yu, Cote, & Haldeman, 2018). Clinical studies have distinguished between continuous (or persistent) and recurrent low back pain (Bergstrom, Persson, & Mogren, 2019; Y. P. Li, Cui, Liu, Zhang, & Zhao, 2018). Public health studies, however, have defined postpartum low back pain as a yes or no symptom after childbirth (Woolhouse et al., 2012). Two studies on postpartum back pain with a large sample size were found from Australia (Fenwick et al., 2012; Woolhouse et al., 2012). The first prospective cohort study in Melbourne (Australia) showed that 49% of 1378 women reported low back pain at six months postpartum. At ten weeks postpartum, 41% reported back pain symptoms in a cross-sectional of 2699 Western Australian women (Fenwick et al., 2012). Another study in Canada also indicated 77% (*n*=1212) women with some level of back pain reported at twelve months postpartum (Mannion, Vinturache, McDonald, & Tough, 2015). Both studies showed a high prevalence of back pain after childbirth.

Despite the growing recognition of low back pain as a common postpartum health problem, there is a paucity of data regarding the prevalence of low back pain in postpartum women in Asian countries, including Vietnam. Of 166 Taiwanese women in a prospective cohort, 51.8% reported back pain symptoms at one year postpartum (Chien et al., 2009). The studies on postpartum low back pain found in the literature were in high-income countries, which makes generalizability limited.

2.5.2 Associated Factors with Postpartum Low Back Pain

2.5.2.1 Socio-demographic and Pregnancy-Associated Factors

Factors commonly associated with postpartum low back pain include maternal weight, parity, and mode of delivery. Based on previous literature related to low back pain, women with high BMI seem to have increased odds of low back pain. In a prospective cohort study of 1574 Canadian women, women who were obese before pregnancy were more likely to report impairment of daily tasks due to back pain than those who were normal or underweight at twelve months postpartum (adjusted OR=1.70 [95% CI 1.07, 2.68]) (Mannion et al., 2015). Another study in Australia indicated the positive relationship between having caesarean delivery and reporting low back pain at six months postpartum (adjusted OR=1.37 [95% CI 1.06, 1.77]), whereas this relationship did not observe at twelve months postpartum (Woolhouse et al., 2012).

Several studies on postpartum low back pain reported parity as another associated factor, but the findings are inconsistent (Mannion et al., 2015; Thompson et al., 2002). Of 1193 Australian mothers in a prospective cohort study, multiparous women did not report significant declines in postpartum back pain between eight and 24 weeks postpartum, compared to nulliparous women (Thompson et al., 2002). The findings are in line with a later finding in Canada. The authors also reported that multiparous mothers were more likely to report impairment of daily tasks due to back pain than nulliparous mothers at twelve months postpartum (adjusted OR=1.80 [95% 1.10, 2.95]). These results may be explained by the fact that multiparous mothers might have more required caregiving activities than nulliparous mothers.

2.5.2.2 Physical Activity during Pregnancy

Low back pain is a leading global cause of disability, and it becomes even more common after giving birth (Cooklin et al., 2015; GBD 2015 Disease and Injury Incidence and Prevalence Collaborators, 2016). Previous studies of Swedish women with postpartum low back pain reported impairments to their daily routines, but they seldom sought healthcare assistance or treatment (Bergstrom, Persson, Nergard, & Mogren, 2017; Nilsson-Wikmar et al., 2003). Several studies in Taiwan and Australia focused on the treatment of low back pain in the postpartum period; however, few prevention studies have been undertaken in postpartum women (Fogarty, McInerney, Stuart, & Hay, 2019; Ko & Lee, 2014).

Physical activity results in changes in muscle physiology, which protects the spine (Campello et al., 1996). The positive relationship between being physically active and low back pain in the general population was indicated in a meta-analysis of prospective cohort studies (Relative risk [RR] = 0.84 [95% CI 0.77, 0.92]) (R. Shiri & Falah-Hassani, 2017). A longitudinal study also showed an inverse relationship between gardening activities and back pain (adjusted OR=0.55 [95% CI 0.38, 0.80]) in 10,007 Canadian women (Kopec, Sayre, & Esdaile, 2004). Besides, a positive relationship between activity restriction and back pain was observed in their studied women (adjusted OR=1.98 [95% CI 1.45, 2.72]). These findings suggest that a variety of activities is essential to include when investigating the relationship between physical activity and low back pain.

Physical activity during pregnancy has been recommended to prevent adverse maternal and infant outcomes (Evenson et al., 2019). It has been suggested as a protective role of physical activity during pregnancy on postpartum low back pain, but the results are inconsistent. Nilsson-Wikmar et al. studied three physical activity treatment groups of Sweden women with diagnosed prenatal low back pain (Ko & Lee, 2014). The first group (*n*=40) was provided with information on low back pain and sacroiliac belt. The second group (*n*=41) was provided the same treatment with the first and a home exercise program. The third (*n*=37) was provided the same treatment as in the first and a clinic-based exercise program. No significant differences in postpartum pain at twelve months were observed amidst these groups (p=0.54) (Nilsson-Wikmar et al., 2003).

Uncomfortable postures at work might be related to moderate-to-vigorous intensity in occupational activities. A previous study found that uncomfortable work posture was positively associated with odds of back pain at twelve weeks postpartum (adjusted OR=1.35 [95% CI 1.11, 1.64]) (Stomp-van den Berg et al., 2012). This study investigated 548 pregnant women who were employed at least twelve hours per week during pregnancy in the Netherlands (Stomp-van den Berg et al., 2012). The authors did not observe the relationship between the number of working hours per week and postpartum low back pain. One explanation for this discrepancy is the difference in activity intensity amid work types.

Overall, there appears to be a link between physical activity during pregnancy and postpartum low back pain. However, previous studies demonstrated limitations due to small sample sizes and lacking assessment of intensity and duration of activity (Nilsson-Wikmar et al., 2003; R. Shiri & Falah-Hassani, 2017; Stomp-van den Berg et al., 2012). Besides, physical activity during pregnancy has been measured inconsistently and in limited types. It suggests further investigation on the influence of a variety of physical activity intensities and domains during pregnancy on postpartum low back pain.

2.6 Folic Acid Supplementation in the Periconceptional Period

2.6.1 Folic Acid and Neural Tube Defects

Folate has a vital role in periods of rapid cell division and growth, especially during foetal development (Ifergan & Assaraf, 2008). It is difficult to measure folate intake from food because it exists in multiple forms of polyglutamates, which have varying levels of bioactivity and can easily be destroyed by sunlight, cooking, and storage processes (Bailey, 2009). Its synthetic form, folic acid, is used in dietary supplements and food fortification. Folic acid contains only the monoglutamate form, which is more biologically active than polyglutamates and more efficient for preventing adverse health effects due to folate deficiency (Bailey, 2009).

Folate deficiency is a common micronutrient deficiency during pregnancy as the demand for folate is increased due to foetal growth and development. The deficiency can occur if a mother's dietary intake of folate is inadequate during pregnancy (Looman et al., 2018; Pinto, Barros, & dos Santos Silva, 2009). Folate is required for methylation reactions, particularly of deoxyribonucleic acid (DNA), leading to impaired cellular function (Copp, Stanier, & Greene, 2013). The impairment of DNA synthesis or methylation reactions can adversely affect genomic responses (e.g., impaired gene expression, genomic instability, and DNA damage), possibly preventing the proper closure of the neural tube (Beaudin & Stover, 2007). Interventional studies have demonstrated the protective effects of folic acid supplementation against some types of neural tube defects (NTDs) (Castillo-Lancellotti, Tur, & Uauy, 2013; Garrett & Bailey, 2018) and congenital heart defects (Liu et al., 2016; Mao et al., 2017). Evidence has accumulated supporting the protective effect of folic acid in preventing NTDs. In 1991, the Medical Research Council Vitamin Study, a double-blind, placebo-controlled trial, showed that periconceptional folic acid supplementation prevented 72% of NTDs (95% CI 29%, 88%) (MRC Vitamin Study Research Group, 1991). These results confirmed the finding of a Hungarian study that found a 100% reduction in NTDs and a significant reduction in congenital malformations (22.9 per 1000 persons in the intervention group versus 13.3 per 1000 persons in the control group, p=0.02). These findings suggested that folic acid supplementation can be recommended to all women of childbearing age in the periconceptional period.

2.6.2 Current Recommendations on Folic Acid Supplementation in the Periconceptional Period

As a result of these studies, the World Health Organization (WHO) recommends periconceptional folic acid supplementation, i.e., that all women of childbearing age take a daily supplement of 400 mcg folic acid from the moment they plan to conceive until twelve weeks of gestation (WHO, 2019b). Since then, most Western countries have recommended periconceptional folic acid supplementation, including the USA, New Zealand, and the United Kingdom (Force et al., 2017; Ministry of Health, 2003;

National Health Services (NHS), 2019). For example, in Australia, it is recommended that women begin to take folic acid when they are trying to become pregnant (Department of Health, 2018). In order to provide some protection for women who do not take the folic acid tablets early enough, flour in Australia is also fortified (National Health and Medical Research Council, 2014). To date, limited recommendations on periconceptional folic acid supplementation were found in Asia, including Singapore, Japan, and China (Gomes, Lopes, & Pinto, 2016; Yamamoto & Wada, 2018; Zhu & Ling, 2008). These national-level recommendations have acknowledged the WHO's recommendations.

In Vietnam, the national guidelines on nutrition for pregnant women (following the Decision 776/2017-QD-BYT) has recommended dietary supplementation with a daily dose of 400 mcg folic acid during pregnancy since 2017 (Vietnam Ministry of Health, 2017). However, it is recommended that health professionals start the prescription of folic acid supplements to pregnant women at their first antenatal visit (Vietnam Ministry of Health, 2017), which, on average, is at four months of pregnancy (General Statistics Office and UNICEF, 2015), i.e., later than the commencement date recommended by the WHO (WHO, 2019b). This is too late to be of any value in preventing NTDs which occur in the first two to three months after conception (MRC Vitamin Study Research Group, 1991; WHO, 2019b).

2.6.3 Availability and Accessibility of Folic Acid Supplementation in Vietnam

Folic acid supplement tablets can be purchased at prenatal care clinics and pharmaceutical stores without prescriptions in Vietnam. The cost is estimated to be about $0.15 Australian dollar per tablet. However, no studies have assessed the preference and acceptability of Vietnamese pregnant women on the cost of folic acid. Folic acid supplement tablets could be described in prenatal care visits, although such practice is not mandatory (Vietnam Ministry of Health, 2017).

Free-of-charge distribution of folic acid supplements to women might help women with limited resources; however, resources are restricted in terms of government funding and administration. Programs and trials on free-of-charge folic acid tablets were rather limited in time frame (Aikawa, Jimba, Nguen, & Binns, 2008; Berger et al., 2005; Casey et al., 2011; Gonzalez-Casanova et al., 2017). A study in northern Vietnam showed a decline in adherence to iron-folic acid supplementation, despite the provision of weekly free-of charge tablets to women (Casey et al., 2017). The program was also interrupted in several study sites due to a considerable turnover of local staff. Another study in Vietnam attempted to reduce cost by selling iron-folic acid tablets to non-pregnant women and used the profit to fund the free-of-charge distribution of tablets to pregnant women (Khan et al., 2005). Nevertheless, the rate of sales was much lower than the rate of usage (Khan et al., 2005). Therefore, successful folic acid supplementation would require assessments on cost-effectiveness and sustainable distribution system and stakeholders. Before determining the feasibility of providing free-of-charge tablets, consideration may be given to health communication and education campaigns on the benefits of folic acid supplementation.

2.6.4 Prevalence and Factors Associated with Periconceptional Folic Acid Supplementation

In Asia, the prevalence rates of folic acid supplementation in the periconceptional period have been reported in Thailand, China, and Japan. A cross-sectional study in Thailand recruited participants at one antenatal clinic in Bangkok in 2005 (Nawapun & Phupong, 2007). Of 401 participants, 9.7% took folic acid during their periconceptional period. This finding was the earliest report on periconceptional folic acid supplementation in Southeast Asia. Maternal educational level was the only significant predictor of the supplementation, that university-educated women were more likely to supplement with folic acid in the correct period (adjusted OR=3.67 [95% CI 1.29, 10.43], p=0.015). Age, parity, and planned pregnancy were not significantly associated with the correct supplementation in the multivariable analysis. The low prevalence of periconceptional folic acid in these Thai women might be explained by a high proportion of women whose pregnancies had not been planned (n=242, 60.3%). The study findings, however, could not be generalised to other parts of Thailand because of the small sample size.

A study of 4290 women in Anhui Province of China indicated that 67.7% reported correct periconceptional folic acid supplementation (Xing et al., 2012). In line with the Thai study (Nawapun & Phupong, 2007), higher-educated women were more likely to take folic acid supplements in the periconceptional period ($p<0.001$) (Xing et al., 2012). In addition, a non-significant difference in supplementation was observed between multiparous and nulliparous women (Xing et al., 2012). Besides, women aged over 25 years reported higher odds of periconceptional supplementation compared to women aged less than 25 years ($p<0.001$) (Xing et al., 2012). Planning of pregnancy was also associated with increased odds of the supplementation (adjusted OR=2.16 [95% CI 1.72, 2.71]). The duration of optimal intake was limited until four weeks after conception, which is earlier than the end date recommended by the WHO (i.e., 12 weeks of gestation) (WHO, 2019b; Xing et al., 2012). Similar to the Thai study, it remained unknown if the folic acid users took the supplements on a daily basis (Nawapun & Phupong, 2007; Xing et al., 2012).

In Japan, of 1862 Japanese women who participated in Osaka, the result indicated a lower prevalence of periconceptional folic acid supplementation (20.5%), compared to those reported in previous studies in China (Anhui Province) and Thailand (Bangkok) (Yamamoto & Wada, 2018). This survey was conducted in only one medical centre (Yamamoto & Wada, 2018). The study did not survey if the index pregnancy was planned. The role of maternal age on the periconceptional supplementation corroborates the earlier findings in Anhui, China (Xing et al., 2012; Yamamoto & Wada, 2018). Besides, multiparous women were more likely to have correct supplementation, compared to nulliparous women in Japan ($p<0.01$) (Yamamoto & Wada, 2018). This result differs from the previous finding in the studies mentioned above in Thailand and China (Nawapun & Phupong, 2007; Xing et al., 2012; Yamamoto & Wada, 2018). No information on maternal education and planning of pregnancy were investigated in order to compare to the literature (Yamamoto & Wada, 2018).

All of these studies suggest the varying prevalence of folic acid supplementation in the periconceptional period amidst Asian countries, including Thailand, China, and Japan (Nawapun & Phupong, 2007; Xing et al., 2012; Yamamoto & Wada, 2018). Although the recommendations on periconceptional folic acid supplementation in China and Japan were introduced at the national level between 2000 and 2001(Yamamoto & Wada, 2018; Zhu & Ling, 2008), the prevalence of supplementation, which were measured in China between October 2008 and

September 2009, and in Japan between September 2014 and December 2015, were not high as expected (Xing et al., 2012; Yamamoto & Wada, 2018). Based on these studies, more campaigns promoting the role of periconceptional folic acid supplementation are essential. These findings also suggest more studies on periconceptional folic acid supplementation in Asia, especially Southeast Asian countries and low- or middle-income countries.

Previous studies have found that factors associated with folic acid supplementation in the periconceptional period were maternal age, educational level, planning of pregnancy, and parity, albeit inconsistent findings observed in the studies mentioned above (Nawapun & Phupong, 2007; Xing et al., 2012; Yamamoto & Wada, 2018). Maternal age, parity, and planning of pregnancy were also found to be associated factors with the periconceptional folic acid supplementation in several non-Asian countries, including Ireland, New Zealand, and Brazil (da Rosa et al., 2019; McKeating et al., 2015; Teixeira et al., 2018).

One recent study described several associated factors with the adherence to dietary supplements prior to and during pregnancy (Gonzalez-Casanova et al., 2017). This study retrieved data from 4417 Vietnamese women participating in an RCT, which examines the effect of micronutrient supplementation on birth outcomes in Thai Nguyen province, Northern Vietnam. Maternal occupation and parity were found as determinants of adherence. However, these findings cannot be extrapolated to all Vietnamese women due to the interventional design (Gonzalez-Casanova et al., 2017). To date, no studies with a large sample size have observed the prevalence of periconceptional folic acid supplementation in Vietnam.

2.7 Conclusion

This literature review has highlighted many areas important to pregnancy outcomes for mothers and babies where data from Asia are lacking.

GWG is a public health concern worldwide. The 2009 IOM recommendations on GWG have been adapted in several Asian countries. Studies commonly reported the relationship between GWG (following the 2009 IOM recommendations) and health outcomes: gestational hypertension, pre-eclampsia, mode of delivery, preterm births, foetal growth (i.e., macrosomia, low birth weight, and infant size for gestational age). However, the impacts of GWG on some of these outcomes are not well-understood in Vietnam, with the exception of infant size for gestational age. Age, education, ethnicity, pre-pregnancy BMI have been found as significant determinants of GWG, albeit inconsistent findings. The prevalence of GWG varied across Asian countries with a lack of generalizability.

Accumulated evidence has established the long-term impacts of postpartum weight retention on women's weight trajectories. A significant number of Asian women were reported not to have returned to their pre-pregnancy weight after giving birth. Pre-pregnancy BMI and GWG have been recognised as two major factors significantly associated with postpartum weight retention. Most studies, which have linked pre-pregnancy BMI and postpartum weight retention in Asian women, had a maximum of the six-month follow-up period and a small sample size. A few studies, which had greater or equal to twelve months follow-up, reported the relationship between GWG and postpartum weight retention in Asian countries.

Physical activity is a modifiable factor of bodyweight. It has been recommended in pregnancy and postpartum period in several recommendations. Studies in several Asian countries suggested physical activity as a beneficial behaviour to achieve healthy GWG. Little evidence was found on the relationship between postpartum physical activity and postpartum weight retention. Physical activity has been measured inconsistently in pregnancy and postpartum period.

Low back pain is reported as a common health problem after delivery, albeit few prevention studies in Asian women. Common determinants of low back pain were maternal weight, parity, and mode of delivery. Several studies suggested that physical activity can help reduce postpartum low back pain. However, these results were based on small sample size, limited physical activity types, and lacking assessment of activity intensity and duration.

The WHO recommends folic acid supplementation in the periconceptional period to prevent neural tube defects. The prevalence rates of periconceptional folic acid supplementation varied across Asian countries, ranging between 9.7% in Thailand and 67.7% in China. A few studies reported periconceptional folic acid supplementation in Asia. Associated factors with folic acid supplementation included maternal age, educational level, planning of pregnancy, and parity. However, the results were inconsistent.

Chapter 3: Methods

This chapter presents methods for achieving the study objectives and ethics.

3.1 Study Design

This present thesis is a separate component of a large-scale multicentre prospective cohort study of 'Maternal lifestyle and diet in relation to pregnancy, postpartum and infant health outcomes in Vietnam', which was conducted in Vietnam between August 2015 and November 2017. Its protocol paper has been published previously (Nguyen et al., 2017). The purpose of this multicentre study was to collect mother-infant information, including sociodemographic, maternal modifiable risk factors, breastfeeding, and health outcomes during pregnancy and after delivery.

3.2 Study Settings

The multicentre study was conducted in three cities: Hanoi, Haiphong, and Ho Chi Minh City, in Vietnam. Hanoi and Haiphong are the cities in Northern Vietnam. Ho Chi Minh City locates in Southern Vietnam. At baseline, participants were recruited and interviewed at six participating hospitals listed below: Dong Anh District Hospital (in Hanoi City), Vinh Bao District Hospital (in Haiphong City), and Tan Phu District Hospital, Hoc Mon District Hospital, District 2 Hospital, and Hung Vuong Hospital (in Ho Chi Minh City). The total population in Dong Anh District (Hanoi) has an estimated total population of 300,000 residents covering an area of 182 km^2 in 2013 (People's committee of Dong Anh District, 2013). Vinh Bao is a coastal district with an estimated population of 180,000 residents in a land area of 180 km^2 in 2008 (People's committee of Vinh Bao District, 2008). Total populations in Tan Phu District (16.1 km^2), District 2 (49.7 km^2), and Hoc Mon District (109.2 km^2) estimated 464,000, 147,000 and 422,000 residents, respectively (Viet Nam General Statistics Office, 2015). Among the six participating hospitals, five hospitals (Dong Anh District Hospital, Vinh Bao District Hospital, Tan Phu District Hospital, Hoc Mon District Hospital, and District 2 Hospital) are secondary-level hospitals, which are funded and administered by People’s Committees at districts and cities. Hung Vuong Hospital is a tertiary-level hospital, which is administered by Ho Chi Minh City People’s Committee.

Tan Phu District Hospital, District 2 Hospital, and Hoc Mon District Hospital could refer their patients to Hung Vuong Hospital, particularly in the event of pregnancy complications. The additional inclusion of Hung Vuong Hospital as a participating hospital aimed to capture more participants referred from District 2 Hospital, Tan Phu District Hospital, and Hoc Mon District Hospital.

3.3 Selection Criteria

3.3.1 Inclusion Criteria

At baseline interviews, the interviewers recruited pregnant women who visited any one of the six recruiting hospitals for prenatal check-ups between August 2015 and July 2016. Pregnant women were invited to participate if they were 18 years old or over, in a singleton pregnancy, at between 24 and 28 weeks of gestation, and were able to read the information sheet and sign consent forms. In this study, the participants were not required to be a citizen in a selected district/city, or to present permanent residence identification cards. Women who had been living for more than one year in Hanoi, Hai Phong, and Ho Chi Minh City before pregnancy, planned to deliver babies in the six participating hospitals and intended to live in these three recruiting cities after delivery were recruited.

3.3.2 Exclusion Criteria

The study excluded individuals who reported any serious pre-existing health conditions and medical precautions (including cancer and ischaemic heart disease, according to information provided by their medical doctors) at baseline interviews.

3.4 Study Procedure

3.4.1 Sample Size and Flow Chart of Participants

The sample size of the multicentre study was calculated based on one of the research objectives to examine the relationship between breastfeeding and gestational hyperglycaemia (Nguyen et al., 2017). Assuming 20% prevalence of gestational hyperglycaemia in the Vietnamese women (Tran, Hirst, Do, Morris, & Jeffery, 2013), 42% and 52% prevalence of exclusive breastfeeding at three months postpartum in mothers with and without diagnosed gestational hyperglycaemia, respectively (Verd, de Sotto, Fernandez, & Gutierrez, 2016), the sample size of 1662 women was calculated to detect an expected odds ratio of 0.7 with 90% power.

To allow for a potential 20% rate of attrition (withdrawal and loss to follow-up), the final required sample size was adjusted to 2000 pregnant women. Proportional to the population of each recruiting city, 900, 300, and 800 pregnant women were interviewed at baseline in Hanoi, Haiphong, and Ho Chi Minh cities, respectively (General Statistics Office, 2015; Nguyen et al., 2017).

3.4.2 Participant Recruitment

Baseline Interviews

In the stage of baseline interviews, singleton pregnant women with 24-28 weeks of gestation, who received prenatal care from any of the six recruiting hospitals in Hanoi, Haiphong, and Ho Chi Minh cities between August 2015 and July 2016, were invited to participate in the study. Individuals were recruited until the desired sub-sample quota for each studied city was attained, following the given selection criteria. Interviewers provided study information sheets for participants. Informed consent was obtained at baseline interviews.

Participants provided information on socio-demographics, energy intake, and physical activity during pregnancy, previous history of health problems and pregnancies, and current pregnancy (i.e., gestational age, gestational diabetes, pre-pregnant weight), using standard or validated questionnaires for Vietnamese adults. Interviewers measured maternal height to calculate pre-pregnancy BMI.

Follow-Up Interviews

After the delivery and before hospital discharge, information on birth delivery, including mode of delivery, pre-delivery weight (the last weight measured before birth delivery), infant weight at delivery, and infant gender was retrieved from medical records. After the hospital discharge, the study interviewers visited the participants' homes to collect follow-up information at one, three, six, and twelve months postpartum. Specifically, detailed information on physical activity at three months postpartum, maternal low back pain outcomes at six months postpartum, maternal anthropometric measures at six and twelve months postpartum were collected.

The flow chart of participant recruitment is given in Figure 3-1 below. Of 2248 eligible women, 90.3% (*n*=2030) of women participated and supplied baseline data. In the parent research, of 2030 women participated at baseline interviews, 90.39%, 89.01%, and 85.2% followed up at three, six, and twelve months postpartum, respectively.

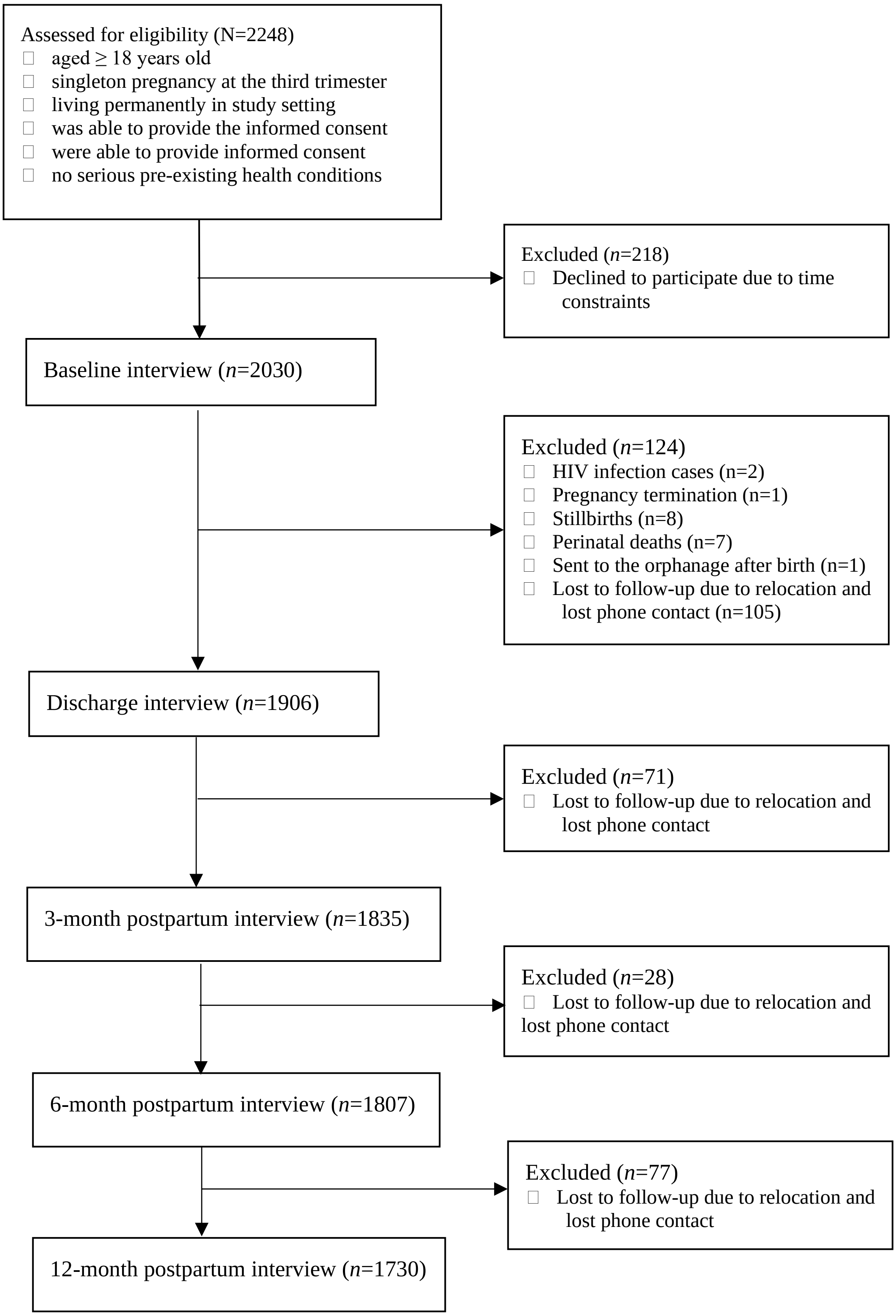

Figure 3- 1. Flow chart of participants‘ recruitment

3.5 Description of Study Variables

3.5.1 Anthropometric Assessment

Trained interviewers measured maternal height (their standing height at baseline interviews) using a stadiometer to the nearest one millimetre. The interviewers asked participants (a) to remove any items from the top of the head and their shoes, (b) to stand up straight with "the back of her head, shoulder blades, buttocks, and heels make contact with the backboard".

Regarding postpartum weight assessment, interviewers brought portable weight scales to respondents' houses to measure maternal weight at follow-ups. The interviewers checked batteries of weight scales before interviews. The weight measurement was ensured using a checklist adapted from the Anthropometry Procedures Manual for US National Health and Nutrition Examination Survey: (a) place the portable scale on the floor, (b) place 11 of the 10-kg weights on the scale to control the used scales' quality, (c) ask mothers remove coats or jackets, their foot wears and socks, watches, and all items from their pockets (Centers for Disease Control and Prevention, 2016).

3.5.2 Pre-Pregnancy BMI Assessment

Pre-pregnancy BMI was calculated by dividing pre-pregnancy weight (in kg) by the square of maternal height (in meters). It was further categorised in underweight (<18.5 kg/m^2), normal weight (18.5 to 22.9 kg/m^2), and overweight/obesity (≥23 kg/m^2), following the cut-offs from the WHO for Asian populations (WHO Expert Consultation, 2004).

3.5.3 Gestational Weight Gain Assessment

GWG was defined as the difference between pre-delivery weight and pre-pregnancy weight, and further classified as below (inadequate), within (adequate), or above (excessive), following the 2009 Institute of Medicine recommendations on weight gain during pregnancy (Institute of Medicine & National Research Council Committee to Reexamine IOM Pregnancy Weight Guidelines, 2009). The definition and categorisation of GWG were used in some previous practice (Ketterl, Dundas, Roncaioli, Littman, & Phipps, 2018; McKeating et al., 2015; Rong et al., 2015).

3.5.4 Postpartum Weight Retention Assessment

Postpartum weight retention at six and twelve months postpartum was calculated by subtracting the pre-pregnancy weight from the weight measured at six and twelve months postpartum, respectively. Other studies used the same definition and calculations for postpartum weight retention (Ketterl et al., 2018; Leonard, Rasmussen, King, & Abrams, 2017; Rong et al., 2015).

3.5.5 Postpartum Low Back Pain

Low back pain is pain at the lower back (lumbosacral spine). Trained interviewers subsequently asked mothers for details of locations of their pains to confirm the low back pain, which makes mothers difficult to do their routine activities during the six months postpartum period. In this study, the frequency and duration of low back pain during six months postpartum were not recorded due to the subjectivity and perception of Vietnamese women on low back pain. Low back pain during six months postpartum was categorised as a binary variable in the data analysis of this study. Responses of "yes, low back pain is presence" were coded as "1" and those of "no, low back pain is absent" were coded as "0".

3.5.6 Periconceptional Folic Acid Supplementation

Trained interviewers collected information on dietary supplementation via a validated Vietnamese version of the Food Frequency Questionnaire at baseline interview (Appendix G) (Van Dinh, Van Dong, Nguyen, & Lee, 2013). Women were asked, "Have you ever taken folic acid or multivitamin supplements during this pregnancy?” Further consumption details of their supplementation were solicited in terms of frequency (number of times on a daily or weekly or monthly basis), quantity (number of tablets taken per time), and duration (number of months or weeks or days taken during pregnancy). The information was cross-checked against their pregnancy health books and medical records whenever possible. Any discrepancy was subsequently re-confirmed with mothers.

The periconceptional folic acid supplementation was assessed using two primary outcomes. Given that multivitamins available in Vietnam contain folic acid, the first binary outcome was the correct use of either supplement containing folic acid alone or multivitamins containing folic acid (1=correct use, 0=incorrect use). The second binary outcome was the correct use of supplements containing folic acid alone (1=correct use, 0=incorrect use). The actual amount of supplemented folic acid was not assessed. However, prenatal supplements provided to pregnant women are required to contain at least 600 mcg of folic acid daily (Vietnam Ministry of Health, 2014). Common commercial prenatal supplements contain a minimum amount of 400 mcg folic acid in the Vietnamese market (Aikawa et al., 2008; Ramakrishnan et al., 2016). For both outcomes, "correct use" was referred to the daily use of a supplement containing 400 mcg (or more) folic acid and the commencement from the time when the pregnancy was planned until twelve weeks of gestation (i.e., periconceptional period), following the World Health Organization (WHO) recommendations.

3.5.7 Physical Activity Assessment

A validated Vietnamese version of the Pregnancy Physical Activity Questionnaire (PPAQ) was used to assess physical activity during both pregnancy and three months postpartum (Appendix G) (Ota et al., 2008). The PPAQ measures time spent on 32 habitual activities in four domains, namely household or caregiving, occupational, sports or exercise, transportation. The duration, frequency, and intensity of physical activity were calculated and expressed in terms of metabolic equivalent task hours per week (MET-hour/week), based on the PPAQ scoring mechanism and the Compendium of Physical Activities (L. Chasan-Taber et al., 2004). Total physical activity was defined as the sum of all activities across domains. The intensity was further classified as “light-intensity” (1.5 to <3.0 METs), “moderate-intensity” (3.0 to 6.0 METs), and “vigorous-intensity” (>6.0 METs) (L. Chasan-Taber et al., 2004). Hours per week spent on sitting activities were also assessed (i.e., watching television, sitting in front of a computer, reading, talking, riding a motorcycle, or driving, and sitting at work or classes). To investigate the associations of physical activity exposures with outcomes of interest, physical activity variables were further categorised into tertiles with the highest (third) tertile reflecting the high-level activity. Several physical activity variables, namely sports or exercise and occupational activities at three months postpartum, were dichotomised (yes/no) due to low participation in these activities.

3.5.8 Other Independent Variables' Assessment

Total energy intake (Kcal per day) during pregnancy was estimated using a validated food frequency questionnaire for Vietnamese adults (Appendix G) (Van Dinh et al., 2013). The questionnaire has been previously validated in the Vietnamese population and showed to be an appropriate instrument to assess energy intake for Vietnamese adults. Its reliability was evaluated using intra-class correlation coefficients (from 0.15 to 0.83), which were comparable to those from the original questionnaire for 15 main food groups of 128 food and beverage items (Van Dinh et al., 2013). Sociodemographic characteristics, including maternal age, educational level, formal employment ("yes": office-based staff, service, sales, manufacturing workers, or technicians; "no": housewives, freelancers, unskilled farmers, or planters, or unemployed), were recorded at the baseline interview. Information on current pregnancy, including whether the current pregnancy was planned, parity (first pregnancy, multiparous), gestational age, mode of delivery (vaginal, caesarean), birth weight (in kg), infant gender (male, female), history of previous health problems was also captured from either self-reporting or medical records. Gestational diabetes status was obtained from the 75-gram oral glucose tolerance test in the third trimester (Nguyen et al., 2018).

3.5.9 Description of Variables and Instruments

The main variables and instruments used in this thesis are presented in the following Table 3-1.

Table 3- 1. Description of the main variables and instruments used in this thesis.

Variables	Instrument	Time Assessment
Maternal age, education, employment status, occupation, pre-pregnant weight, planning of current pregnancy, history of previous health problems, and pre-pregnant weight.	A structured questionnaire	Baseline
Maternal height	Stadiometer	Baseline

Variables	Instrument	Time Assessment
Gestational diabetes status (based on 75-gram oral glucose tolerance test), and parity.	Medical records	Baseline
Energy intake during pregnancy, periconceptional folic acid supplementation.	a validated Vietnamese version of Food Frequency Questionnaire [a]	Baseline
Physical activity subtypes during pregnancy and in the postpartum period	a validated Vietnamese version of PPAQ [b]	Baseline, Three months postpartum
Pre-delivery weight, gestational age at birth, mode of delivery, birthweight, and infant gender.	Medical records	Hospital discharge
Postpartum low back pain	A structured questionnaire	Six months postpartum
Maternal weight in the postpartum period	Portable weight scales	Six and twelve months postpartum

[a] According to the validated Vietnamese version of Food Frequency Questionnaire (Van Dinh et al., 2013)
[b] According to the validated Vietnamese version of PPAQ (Ota et al., 2008)

3.6 Data Management

Data collected by the multicentre study were checked for errors and missing information before entering to EpiData Entry package 3.1, and de-identified and then transferred to Stata 15.0 for further cleaning and analysis (StataCorp, 2017). Data of the present thesis were retrieved from the larger multicentre prospective cohort study (Nguyen et al., 2017). Data storage and management of the present thesis have been following the Research Data Management Plan and the Curtin University Research Data and Primary Materials Policy. Specifically, all the data used for the present thesis have been stored in an R drive, which is administered by the Curtin University network. Only the candidate and principal supervisor are permitted to access their R-drive account.

3.7 Statistical Analysis

Statistical analyses were conducted using Stata software version 15.1 (StataCorp, 2017). The statistical significance level for all tests was set at 5% (i.e., a *p*-value of less than 0.05 was considered statistically significant).

This thesis used different statistical methods for achieving the five research objectives mentioned in Chapter 1. Each statistical method has two steps.

In the Step I analysis, the following primary analyses were performed:

- Descriptive statistics were used to summarise the sample characteristics.
- Normality was assessed for continuous dependent (outcome) variables.
- Differences between groups were compared by using Chi-square or Fisher's exact test (for categorical variables), and independent samples t-test or one-way analysis of variance (for continuous variables).

In step II analysis, regression analyses were performed:

For achieving Objective 1:

> *To assess the association of pre-pregnancy BMI and GWG with weight retention at twelve months postpartum in Vietnam*

Simple and multiple linear regression models were used to assess the associations between pre-pregnancy BMI, GWG, and twelve-month postpartum weight retention, with the adjustment for a set of covariates and plausible confounding factors: maternal age, education, formal employment, parity, gestational diabetes status, gestational age, mode of delivery; and total energy intake and total physical activity during pregnancy. The selection of covariates was based on their plausibility to achieve the research objective with reference to the pertinent literature (Fadzil et al., 2018; X. He et al., 2014; Oken et al., 2007; Siega-Riz et al., 2010). The interactive effect between pre-pregnancy BMI and GWG on twelve-month postpartum weight retention was assessed using a likelihood ratio test. Further regression analyses were performed by stratifying participants according to their pre-pregnancy BMI and GWG. In addition, a sensitivity analysis was conducted after removing 62 (3.7%) individuals who delivered LBW infants (<2500 g).

For achieving Objective 2:

To evaluate the role of physical activity during pregnancy on GWG in Vietnam.

Multiple linear regression analyses were used to investigate the associations between physical activity during pregnancy and GWG. Each physical activity exposure variable was analysed using two regression models. Firstly, the regression model (model I) included 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 have been previously regarded as plausible confounders in the literature (Lisa Chasan-Taber et al., 2014; Kraschnewski et al., 2013). Subsequently, accounting for its potential attenuation effect, sitting time was further adjusted in the regression model (model II) for each physical activity exposure variable (Di Fabio, Blomme, Smith, Welk, & Campbell, 2015). Similarly, total physical activity was adjusted in the multivariable model for assessing the association between sitting time and GWG. Logistic regression analyses were also performed to additionally investigate the association of having excessive GWG (>15 kg) with physical activity and sitting time.

For achieving Objective 3:

To ascertain the role of postpartum physical activity on weight retention within twelve months postpartum in Vietnam

Multiple linear regression analyses were conducted separately to ascertain the relationships between postpartum weight retention at six and twelve months postpartum and each postpartum physical activity exposure, controlling for potential confounding factors (maternal age, education, formal employment, parity, mode of delivery, pre-pregnancy BMI, total energy intake and total physical activity during pregnancy, gestational age, and GWG). These confounding factors were included in the regression models based on our literature review and their availability in our study (Fadzil et al., 2018; Levine et al., 2006; Öhlin & Rössner, 1994; Oken et al., 2007; Siega-Riz et al., 2010). Following that, the general linear model with repeated measures was used to further ascertain the relationship by using weight retention measured at six and twelve months postpartum simultaneously, with the adjustments for the same set of confounding factors as above.

For achieving Objective 4:

To investigate the prevalence of postpartum low back pain and its relation to physical activity during pregnancy in Vietnam.

Multivariable logistic regression analyses were performed to ascertain the relationships between low back pain and physical activity exposures, including total physical activity, sitting time, light-intensity, moderate-to-vigorous-intensity, household/caregiving, occupational, transportation physical activity, and sports/exercise during pregnancy. The covariates were firstly selected from previous literature and their availability in our study (Mogren, 2008; Rahman Shiri et al., 2009). In the final model, maternal age, education, formal employment, parity, pre-pregnancy BMI, and gestational diabetes mellitus were included with a priori clinical relevance before applying the backward elimination method.

For achieving Objective 5:

To determine the prevalence of periconceptional folic acid supplementation in Vietnam and ascertain the maternal characteristics associated with folic acid use.

Univariate and multivariable logistic regression analyses were conducted to investigate the associations between maternal characteristics and the two separate outcomes of folic acid supplementation, namely, the ‘correct use of either supplement containing folic acid alone or multivitamins containing folic acid’ (outcome 1) and the ‘correct use of supplements containing folic acid alone’ (outcome 2). All measured independent variables were used in the full regression models, including age, formal employment, educational level, parity, pre-pregnancy BMI, and planning of pregnancy. These covariates or confounders were based on available information and with reference to the literature as plausible factors affecting folic acid supplementation (Binns et al., 2006; Kinnunen, Sletner, Sommer, Post, & Jenum, 2017; Nawapun & Phupong, 2007; Teixeira et al., 2018; Xing et al., 2012; Yamamoto & Wada, 2018). Additional regression analyses were also conducted by removing 601 (29.7%) women who did not plan for their current pregnancy to assess the robustness of the analysis results; however, the new results were still in line with the original results based on the full sample.

3.8 Ethical Considerations

The study was approved by the Human Research Ethics Committee of Curtin University (Approval number HR32/2015) and the Human Research Ethics Committee of Hai Phong University of Medicine and Pharmacy (Approval number 05/HPUMPRB/2015) (Appendix A). Verbal and written information on the purpose of the study and participation rights were provided when inviting and recruiting pregnant women (Appendix H). Each consented woman agreed and signed in the written agreements (Appendix I). Women were emphasized that study participation was voluntary, and they could withdraw from the study whenever they wanted without prejudice. Study confidentiality has been ensured under the requirements of ethics approval.

Chapter 4. Results

This chapter presents the results of this thesis for achieving the five study objectives, which were published in international peer-reviewed journals.

The statement of the primary contribution of the first author and the permission of co-authors to include the five publications in this thesis can be found in Appendix B. The permission to reproduce the material from the publisher can be found in Appendix D.

4.1 Results for Objective 1

Objective 1:

To assess the association of pre-pregnancy BMI and GWG with weight retention at twelve months postpartum in Vietnam.

The results addressing Objective 1 have been published in the following paper:

Ha, A. V. V., Zhao, Y., Pham, N. M., Nguyen, C. L., Nguyen, P. T. H., Chu, T. K., . . . Lee, A. H. (2019). Postpartum weight retention in relation to gestational weight gain and pre-pregnancy body mass index: A prospective cohort study in Vietnam. *Obesity Research & Clinical Practice*, *13*(2), 143-149. http://dx.doi.org/https://doi.org/10.1016/j.orcp.2019.02.001

The permission of the journal is attached in Appendix C.

Objective 1

Obesity Research & Clinical Practice 13 (2019) 143–149

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Original Article

Postpartum weight retention in relation to gestational weight gain and pre-pregnancy body mass index: A prospective cohort study in Vietnam

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ABSTRACT

Background: The prevalence of maternal overweight and obesity is increasing in Asia. This study prospectively investigated the association between pre-pregnancy body mass index (BMI), gestational weight gain (GWG) and 12-month postpartum weight retention (PPWR) in a large cohort of Vietnamese mothers.
Methods: Of the 2030 pregnant women recruited from three cities in Vietnam at 24–28 weeks of gestation, a total of 1666 mothers were followed up for 12 months after delivery and available for analysis. The outcome variable PPWR was determined by subtracting the pre-pregnancy weight from the 12-month postpartum measured weight, while GWG and pre-pregnancy BMI were classified according to the Institute of Medicine and WHO criteria for adults, respectively. Linear regression models were used to ascertain the association between pre-pregnancy BMI, GWG and PPWR accounting for the effects of plausible confounding factors.
Results: Both pre-pregnancy BMI and GWG were significantly associated with PPWR ($P < 0.001$). The adjusted mean weight retention in underweight women before pregnancy (3.71 kg, 95% confidence interval (CI) 3.37–4.05) was significantly higher than that in those with normal pre-pregnancy weight (2.34 kg, 95% CI 2.13–2.54). Women with excessive GWG retained significantly more weight (5.07 kg, 95% CI 4.63–5.50) on average at 12 months, when compared to mothers with adequate GWG (2.92 kg, 95% CI 2.67–3.17).
Conclusions: Being underweight before pregnancy and excessive GWG contribute to greater weight retention twelve months after giving birth. Interventions to prevent postpartum maternal obesity should target at risk women at the first antenatal visit and control their weight gain during the course of pregnancy.

Introduction

The prevalence of overweight and obesity has surged worldwide [1]. In Asia, the mean body mass index (BMI) of high-income countries has reached a plateau, but is increasing in adults in lower and middle income countries [2]. Located in Southeast Asia, Vietnam is facing the double burden of simultaneous underweight and overweight/obesity, with an estimated ratio of women overweight to underweight being 0.9 according to a recent systematic review [3].

BMI has a dose response relationship with diabetes mellitus and cancers of the breast, ovary, liver and kidney [4]. A low BMI before pregnancy may pose a higher risk of preterm birth and delivering a small-for-gestational-age infant [5]. On the other hand, a high maternal BMI before pregnancy or excessive gestational weight gain (GWG) is associated with pregnancy complications such as gestational diabetes mellitus (GDM) and preeclampsia [6–9]. To

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balance the benefits and risks for maternal weight before, during and after pregnancy, the Institute of Medicine (IOM) released GWG recommendations in 2009 based on the pre-pregnancy BMI [10]. Such guidelines have since been adopted by many countries worldwide. In Vietnam, a recent study reported that women with GWG below the IOM recommendations were 2.5 times more likely to give birth to a small-for-gestational-age infant when compared to those with normal GWG; however, the effect of GWG on postpartum weight retention (PPWR) remained unknown for Vietnamese women [11].

It has been suggested from a meta-analysis that GWG is related to PPWR [8]. In particular, women with excessive GWG have more PPWR than others with adequate GWG, while inadequate GWG is also inversely associated with PPWR [8]. A prospective study in the USA reported a significant association between pre-pregnancy BMI and weight retention at three months postpartum [12]. Nevertheless, the relationship between pre-pregnancy BMI and PPWR is still unclear [12–15]. Postpartum weight retention significantly contributes to women's weight trajectories and the onset of long-term obesity [16]. Apart from Malaysia [13,17], no other studies have investigated PPWR in relation to either pre-pregnancy BMI or GWG among Southeast Asian women. Compared with Japanese or non-Hispanic white mothers, Southeast Asian women with gestational diabetes mellitus or preeclampsia had an increased odds of adverse delivery outcomes (i.e. macrosomia, preterm or low birth weight) [18]. Besides, the majority of previous studies dichotomised PPWR using different cut-points [11,12,14,15,19], leading to potential misclassification of the outcome.

The present study examined the prospective association between pre-pregnancy BMI, GWG and 12-month PPWR using a large cohort of Vietnamese mothers [20]. We hypothesized that maternal pre-pregnancy BMI and/or GWG are associated with 12-month PPWR. Findings of the study will contribute towards the development of intervention strategies for postpartum obesity prevention and maternal weight management during and after pregnancy.

Materials and methods

Study design and participants

Details of the prospective cohort study design and recruitment procedure had been described elsewhere [20]. Briefly, 2248 pregnant women aged $\geq$18 years with a singleton pregnancy at 24–28 weeks of gestation were recruited from six participating hospitals in Hanoi, Haiphong and Ho Chi Minh City, Vietnam, and followed up between August 2015 and November 2017. Among them, 2030 women (90%) agreed to participate and signed the written informed consent form at the baseline interview. After delivery, they were followed up before hospital discharge, and then at 1, 3, 6 and 12 months postpartum, with a final response rate of 82% at 12 months. Follow-up surveys and weight measurements of the cohort were conducted at convenient places (mostly at the women's home) by trained interviewers. As shown in Fig. 1, after excluding participants with missing or implausible values for the main variables [21], n = 1666 women were available for the final analysis.

Study variables

Information on maternal demographic characteristics and lifestyle including age, employment, educational level, parity, pre-pregnancy weight, total energy intake and physical activity levels during pregnancy were obtained from the baseline face-to-face interview. Such self-reported data were verified against hospital medical records whenever feasible. Maternal height was measured using a stadiometer to the nearest 1 mm at the baseline interview. A validated food frequency questionnaire for Vietnamese adults was used to assess total energy intake during pregnancy [22]. Physical activity during pregnancy was quantified using the Vietnamese version of the Pregnancy Physical Activity Questionnaire [23]. Gestational diabetes status was ascertained using a 75 g oral glucose tolerance test administered between 24–28 weeks of gestation, and diagnosed in accordance to the International Association of Diabetes and Pregnancy Study Groups for gestational diabetes mellitus, with at least one glucose value above the following thresholds: fasting plasma glucose $\geq$5.1 mmol/L, 1-h plasma glucose $\geq$10.0 mmol/L, 2-h plasma glucose $\geq$8.5 mmol/L [24]. Postnatal information about gestational age (length of gestation), mode of delivery and pre-delivery weight was extracted from hospital medical records.

Pre-pregnancy BMI was calculated by dividing pre-pregnancy weight by the square of maternal height, and categorised according to the WHO criteria: underweight (<18.5 kg/m^2); normal (18.5–24.9 kg/m^2); overweight (25.0–29.9 kg/m^2); and obese ($\geq$30 kg/m^2) [25]. GWG was determined as the difference between pre-pregnancy weight and pre-delivery weight [19], and classified as being below (inadequate), within (adequate) or above (excessive) according to the 2009 IOM recommendations [10]. Maternal weight at 12-month postpartum was measured following the Anthropometry Procedures Manual of the U.S. National Health and Nutrition Examination Survey [26]. The continuous outcome variable PPWR (kg) was calculated by subtracting the (self-reported) pre-pregnancy weight from the 12-month postpartum measured weight [19].

Statistical analysis

Descriptive statistics were used to summarise the sample characteristics. Comparisons of pre-pregnancy BMI and GWG between subgroups of interest were conducted using Chi-square or Fisher's exact test (for independent categorical variables) or one-way ANOVA (for independent continuous variables). Associations between pre-pregnancy BMI, GWG and 12-month PPWR were examined using simple and multiple regression models. Covariates included in the models were selected with reference to the literature as plausible confounding factors: maternal age, education, employment status, parity, gestational diabetes mellitus, gestational age, mode of delivery, total energy intake and total physical activity level during pregnancy. The effect modification by pre-pregnancy BMI on the association between GWG and PPWR and vice versa (i.e., the interaction between pre-pregnancy BMI and GWG on PPWR) was assessed using a likelihood ratio test. We further carried out regression analyses by stratifying participants according to both pre-pregnancy BMI and GWG. A sensitivity analysis was further conducted after removing 62 (3.7%) participants who gave birth to low birthweight infants (<2500 g). All statistical analyses were performed using the STATA software version 15.1 [27].

Ethical statement

This study was approved by the Human Research Ethics Committee of Curtin University (approval no. HR32/2015) and the Human Research Ethics Committee of Hai Phong University of Medicine and Pharmacy (approval no. 05/HPUMPRB/2015). Participation was entirely voluntary and all participants signed the written informed consent form before their baseline interview.

Results

In the study population, 90% of participants were aged 34 years or younger, with mean age 27.46$\pm$5.23 years at the

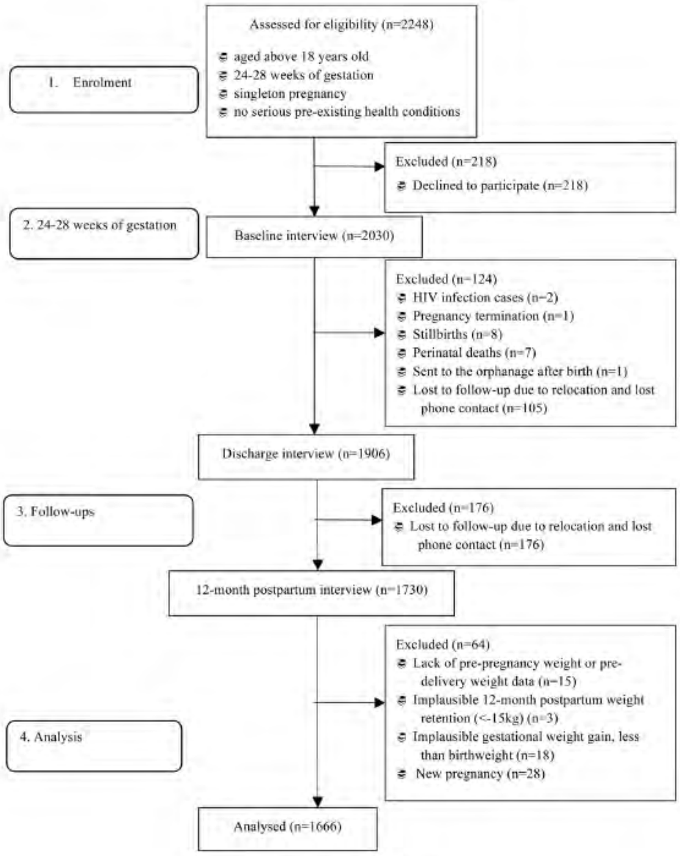

Fig. 1. Flow chart of participants.

baseline interview. About two-third of the participants attained high school education or above, and were employed (68.91%) and multiparous (61.10%). During pregnancy, the mean (±SD) total energy intake and total physical activity were 2123.31 (±742.03) Kcal/day and 124.77 (±57.24) MET-hour/week, respectively.

Before pregnancy, the mean (±SD) weight of the cohort was 48.41 (±6.26) kg. The prevalence of underweight and overweight/obese were 26.10% and 3.66%, respectively. During pregnancy, women gained 12.86 ± 3.99kg on average. Over one-third of them (n = 622, 37.33%) gained gestational weight inadequately, while 16.15% (n = 269) gained gestational weight excessively. At 12-month postpartum, participants weighed 51.04 ± 6.89 kg and retained 2.63 ± 3.80 kg on average. About a quarter of them (n = 433, 25.99%) retained 5 kg or more. As shown in Fig. 2, overweight women or those with obesity before pregnancy had the greatest proportion of excessive GWG (50.82%), whereas the lowest rate of excessive GWG (11.06%) was observed in pre-pregnancy underweight women. The bivariate analyses showed there was a statistical significant association between pre-pregnancy BMI and GWG (Tables 1 and 2). Furthermore, both pre-pregnancy BMI and GWG were found to be associated with maternal characteristics, including age, education, parity, mode of delivery and total energy intake during pregnancy (Tables 1 and 2). Individually pre-pregnancy BMI was associated with gestational diabetes mellitus (Table 1).

Table 3 presents the results of regression analyses, which suggest that both pre-pregnancy BMI and GWG were significantly associated with PPWR ($P < 0.001$) after accounting for the effects of covariates. The mean weight retention in underweight women before pregnancy (3.71 kg, 95% confidence interval (CI) 3.37–4.05) was significantly higher than that in those with normal pre-pregnancy weight (2.34 kg, 95% CI 2.13–2.54). In contrast, overweight women or those with obesity retained 1.83kg less weight on average than their normal pre-pregnancy weight counterparts. Moreover, we found positive association between GWG and PPWR. Women with excessive GWG retained significantly more weight (5.07 kg, 95% CI 4.63–5.50) on average at 12-month

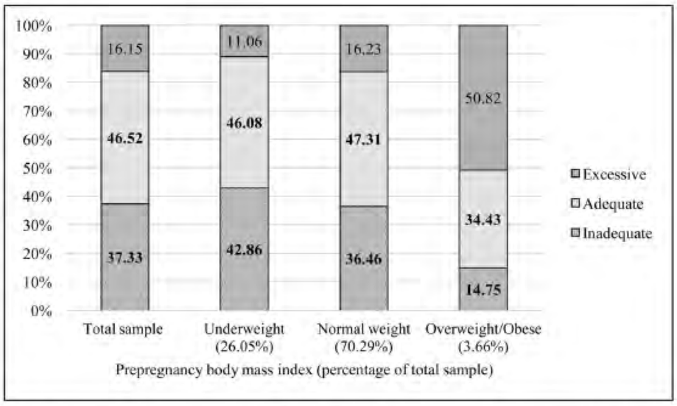

Fig. 2. Percentage of Vietnamese women (2015–2017, n = 1666) by pre-pregnancy BMI and gestational weight gain.

Table 1
Difference in proportions of pre-pregnancy BMI categories by sample characteristics (2015–2017, n = 1666).

Characteristics	Pre-pregnancy BMI[b]			p[a]
	Underweight n (%)	Normal n (%)	Overweight and obese n (%)	
Maternal age (years)				<0.001
<25	236 (54.38)	443 (37.83)	19 (31.15)	
25–34	175 (40.32)	590 (50.38)	29 (47.54)	
≥35	23 (5.30)	138 (11.78)	13 (21.31)	
Education				0.007
Secondary or lower	121 (27.88)	398 (33.99)	29 (47.54)	
High school	123 (28.34)	292 (24.94)	17 (27.87)	
College or above	190 (43.78)	481 (41.08)	15 (24.59)	
Employment status				0.762
Working	293 (67.51)	813 (69.43)	42 (68.85)	
Not working	141 (32.49)	358 (30.57)	19 (31.15)	
Parity				<0.001
First pregnancy	205 (47.24)	426 (36.38)	17 (27.87)	
Multiparous	229 (52.76)	745 (63.62)	44 (72.13)	
Gestational diabetes mellitus[c]				0.002
Yes	79 (18.29)	259 (22.17)	23 (37.70)	
No	353 (81.71)	909 (77.83)	38 (62.30)	
Mode of delivery				<0.001
Vaginal	312 (71.89)	691 (59.01)	23 (37.70)	
Caesarean	122 (28.11)	480 (40.99)	38 (62.30)	
Gestational age (weeks)				0.249
<37	16 (3.69)	48 (4.10)	5 (8.20)	
≥37	418 (96.31)	1123 (95.90)	56 (91.80)	
Gestational weight gain[e]				<0.001
Inadequate	186 (42.86)	427 (36.46)	9 (14.75)	
Adequate	200 (46.08)	554 (47.31)	21 (34.43)	
Excessive	48 (11.06)	190 (16.23)	31 (50.82)	
Total physical activities during pregnancy (MET-h/week)[d]	124.20 ± 55.89	124.53 ± 57.76	133.47 ± 57.12	0.502
Total energy intake during pregnancy (Kcal/day)[d]	2239.08 ± 717.99	2095.71 ± 746.45	1829.34 ± 703.10	<0.001

[a] Based on Chi-square or Fisher's exact test or ANOVA.
[b] The cut-off for overweight is 25 kg/m^2, recommended by World Health Organization.
[c] Missing data present.
[d] Continuous variables were presented as mean ± standard deviation.
[e] Categorised according to 2009 IOM recommendations.

postpartum, whereas women with inadequate GWG retained less weight (1.21 kg, 95% CI 0.93–1.49), when compared to mothers with adequate GWG (2.92 kg, 95% CI 2.67–3.17). There was no apparent interaction between GWG and pre-pregnancy BMI in relation to PPWR ($P = 0.724$). The adjusted estimated mean weight retention at 12-month postpartum stratified by GWG and pre-pregnancy BMI were presented in Table 4. After excluding low birthweight deliveries (n = 62), the associations of pre-pregnancy BMI and gestational weight gain with 12-month PPWR remained similar to those in the original full sample.

Discussion

The present study provides the first report on the relationship between pre-pregnancy BMI, GWG and PPWR in Vietnamese women. Consistent with our results, a review including most

Table 2
Difference in proportions of gestational weight gain categories by sample characteristics (2015-2017, n = 1666).

Characteristics	Gestational weight gain[e]			P[a]
	Inadequate n (%)	Adequate n (%)	Excessive n (%)	
Maternal age (years)				<0.001
<25	229 (36.82)	331 (42.71)	138 (51.30)	
25-34	315 (50.64)	371 (47.87)	108 (40.15)	
≥35	78 (12.54)	73 (9.42)	23 (8.55)	
Education				0.041
Secondary or lower	232 (37.30)	234 (30.19)	82 (30.48)	
High school	159 (25.56)	205 (26.45)	68 (25.28)	
College or above	231 (37.14)	336 (43.35)	119 (44.24)	
Employment status				0.706
Working	421 (67.68)	540 (69.68)	187 (69.52)	
Not working	201 (32.32)	235 (30.32)	82 (30.48)	
Pre-pregnancy BMI (kg/m^2)[b]				<0.001
Underweight (<18.5)	186 (29.90)	200 (25.81)	48 (17.84)	
Normal (18.5–<24.9)	427 (68.65)	554 (71.48)	190 (70.63)	
Overweight and obese (≥25)	9 (1.45)	21 (2.71)	31 (11.52)	
Parity				<0.001
First pregnancy	212 (34.08)	301 (38.84)	135 (50.19)	
Multiparous	410 (65.92)	474 (61.16)	134 (49.81)	
Gestational diabetes mellitus[c]				0.979
Yes	135 (21.77)	169 (21.86)	57 (21.27)	
No	485 (78.23)	604 (78.14)	211 (78.73)	
Mode of delivery				<0.001
Vaginal	424 (68.17)	463 (59.74)	139 (51.67)	
Caesarean	198 (31.83)	312 (40.26)	130 (48.33)	
Gestational age (weeks)				0.708
<37	29 (4.66)	30 (3.87)	10 (3.72)	
≥37	593 (95.34)	745 (96.13)	259 (96.28)	
Total physical activities during pregnancy (MET-h/week)[d]	124.10 ± 59.56	126.58 ± 56.64	121.10 ± 53.38	0.727
Total energy intake during pregnancy (Kcal/day)[d]	2071.86 ± 744.96	2146.14 ± 720.63	2176.50 ± 790.29	<0.001

[a] Based on Chi-square or Fisher's exact test or ANOVA.
[b] The cut-off for overweight is 25 kg/m^2, recommended by World Health Organization.
[c] Missing data present.
[d] Continuous variables were presented as mean ± standard deviation.
[e] Categorised according to 2009 IOM recommendations.

Table 3
Associations between pre-pregnancy BMI, gestational weight gain, and 12-month postpartum weight retention in Vietnamese women (2015-2017, n = 1666).

	n	%	Estimated regression coefficient				12-month postpartum weight retention (kg)			
			Crude		Adjusted		Crude		Adjusted	
			Coefficient	P	Coefficient	P	Mean	95% CI	Mean	95% CI
Pre-pregnancy BMI[a]				<0.001		<0.001				
Underweight	434	26.05	1.09	<0.001	1.37	<0.001	3.46	(3.11, 3.81)	3.71	(3.37, 4.05)
Normal	1171	70.29	Reference		Reference		2.37	(2.16, 2.59)	2.34	(2.13, 2.54)
Overweight/obese	61	3.66	−0.74	0.134	−1.83	<0.001	1.63	(0.69, 2.58)	0.51	(−0.40, 1.43)
Gestational weight gain[b]				<0.001		<0.001				
Inadequate	622	37.33	−1.61	<0.001	−1.71	<0.001	1.32	(1.04, 1.60)	1.21	(0.93, 1.49)
Adequate	775	46.52	Reference		Reference		2.93	(2.67, 3.18)	2.92	(2.67, 3.17)
Excessive	269	16.15	1.87	<0.001	2.15	<0.001	4.79	(4.36, 5.22)	5.07	(4.63, 5.50)

[a] Regression model was adjusted for maternal age, education, employment, gestational age, mode of delivery, parity, gestational diabetes mellitus, total energy intake during pregnancy, total physical activity during pregnancy and GWG.
[b] Regression model was adjusted for maternal age, education, employment, gestational age, mode of delivery, parity, gestational diabetes mellitus, total energy intake during pregnancy, total physical activity during pregnancy and pre-pregnancy BMI.

Table 4
Adjusted mean values[a] and 95% CIs of 12-month postpartum weight retention (kg) in Vietnamese women by gestational weight gain and pre-pregnancy BMI (2015–2017, n = 1666).

		Pre-pregnancy BMI		
		Underweight	Normal	Overweight/obese
Gestational weight gain	Inadequate	1.24 (0.96, 1.53)	1.28 (0.99, 1.57)	1.25 (0.96, 1.53)
	Adequate	2.91 (2.66, 3.16)	2.91 (2.66, 3.17)	2.89 (2.63, 3.14)
	Excessive	4.91 (4.48, 5.35)	4.80 (4.37, 5.24)	4.97 (4.53, 5.41)

[a] Regression model was adjusted for maternal age, education, employment, gestational age, mode of delivery, parity, gestational diabetes mellitus, total energy intake during pregnancy, total physical activity during pregnancy, and GWG by stratifying participants according to pre-pregnancy BMI.

studies from Asia showed an inverse association between pre-pregnancy BMI and PPWR [11]. Likewise, a recent USA study reported women with pre-pregnancy underweight status had increased odds of retaining moderate weight (1–10 lb) at 12 months postpartum (odds ratio 2.0, 95% CI 1.6–2.7) after adjusting for GWG and total physical activity [16]. However, a lack of association was found in a Chinese study and another study conducted in Australia [14,15], probably due to their smaller sample sizes. Our study showed the mean PPWR of underweight pregnant women was significantly higher than that of their normal or overweight counterparts. This finding suggests underweight pregnant women might be more lenient and persuaded to 'eat-for-two' in the Asian culture [28]. Retaining some postpartum weights among underweight women may have advantage in subsequent pregnancy outcomes, including the decreased risk of having intrauterine growth restriction and hypoglycaemia [29].

Our finding on a positive association between GWG and PPWR also concurs with previous studies in other Asian populations [19]. A meta-analysis confirmed that women with inadequate GWG retained 2.23 kg less weight than women with adequate GWG 1–9 years postpartum [8]. Similarly, our participants with inadequate GWG had 1.71 kg on average less weight retention than those with adequate GWG at 12 months postpartum. Moreover, a Canadian study showed that women who gained gestational weight excessively retained a mean postpartum weight of 5.0 kg (95% CI 4.9–5.2) [30] as did our study. Despite this, Canadian women with inadequate GWG retained less weight postpartum (0.4 kg) than our study participants (1.2 kg)[30]. Reasons for the difference are unclear, but may be attributed to restrictions on postpartum physical activity among Vietnamese mothers [31]. Alternatively, Vietnamese women with inadequate GWG may strive to consume a high-energy diet coupled with long sitting duration while engaging less in physical activity during the postpartum period, when they are typically on their 6-month maternity leave. While several studies have reported the impact of excessive GWG on delivery outcomes in Vietnam [11,32], it has been less recognised that retaining postpartum weight may be linked to subsequent obesity and associated comorbidities. Women with excessive GWG have been reported an increased risk of diabetes mellitus later through the mediation of PPWR and obesity [6]. In addition, a recent review found children whose mothers had been diagnosed with gestational diabetes mellitus (GDM) have an increased risk of type 2 diabetes and obesity [33]. Our finding on excessive PPWR among women with excessive GWG is consistent with the increasing trends towards overweight, as well as GDM and diabetes mellitus in Vietnam that have been noted in recent decades [34–36]. This implies the importance of including maternal weight management during childbearing period as a public health effort of preventing diabetes mellitus in Vietnam.

There are several strengths of our study, including the prospective cohort design with a large sample size and 12 months of follow-up. Our regression analyses have accounted for the effects of confounding factors including demographics, obstetrics and birth-related factors, as well as energy intake and energy expenditure (physical activity) during pregnancy which are prevalent in our study population. Furthermore, we have included sensitivity analysis to confirm the apparent associations in the presence of low birthweight infants. However, a major limitation concerns the self-reported pre-pregnancy weight, even though the maternal weight at 12 months was measured by our trained interviewers, which might lead to inaccuracy in the main study variables. A second limitation is the possibility of selection bias after excluding n = 364 women due to their missing or implausible weight values and lost to follow-up. These women had slightly lower education levels than our final participants, but were only 16% of the original sample. Nevertheless, our findings may be representative of the underlying population in Vietnam. Another limitation of our study is that we did not have data on other postpartum lifestyle factors that may influence maternal weight after delivery. On the other hand, further research studies are needed in Vietnam on the long term effects of weight gain in pregnancy and weight loss after pregnancy at different levels of pre-pregnancy BMI. This research should include long-term outcomes in terms of diabetes and other maternal and offspring complications, including maternal microbiome and subsequent offspring adiposity [37].

In summary, we found both pre-pregnancy BMI and GWG were significantly associated with PPWR in this large prospective cohort study of Vietnamese women. Being underweight before pregnancy and those who gained excessive weight during pregnancy experienced the largest weight retention one year after giving birth. Therefore, the pre-pregnancy BMI should be reviewed and examined by health professionals at the first antenatal visit. Interventions to prevent postpartum maternal obesity should also monitor and control the weight gain of women throughout pregnancy and after delivery.

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Conflict of interests

There is no conflict of interest for all authors.

Ethical statement

This study was approved by the Human Research Ethics Committee of Curtin University (approval no. HR32/2015) and the Human Research Ethics Committee of Hai Phong University of Medicine and Pharmacy (approval no. 05/HPUMPRB/2015). Participation was entirely voluntary and all participants signed the written informed consent form before their baseline interview.

CRediT authorship contribution statement

Anh Vo Van Ha: Methodology, Validation, Formal analysis, Investigation, Writing - original draft. **Yun Zhao:** Methodology, Validation, Formal analysis, Writing - review & editing, Supervision. **Ngoc Minh Pham:** Formal analysis, Writing - review & editing, Supervision. **Cong Luat Nguyen:** Validation, Investigation, Resources. **Phung Thi Hoang Nguyen:** Validation, Investigation, Data curation. **Tan Khac Chu:** Investigation, Data curation. **Hong Kim Tang:** Writing - review & editing. **Colin W. Binns:** Writing - review & editing, Supervision. **Andy H. Lee:** Writing - review & editing, Supervision, Project administration.

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4.2 Results for Objective 2

Objective 2:

To evaluate the role of physical activity during pregnancy on GWG in Vietnam.

The results addressing Objective 2 have been published in the following paper:

Ha, A. V. V., Zhao, Y., Pham, N. M., Nguyen, C. L., Nguyen, P. T. H., Chu, T. K., . . . Lee, A. H. (2019). Physical activity and sedentary behaviour during pregnancy are associated with gestational weight gain in Vietnamese women. *Asia Pacific Journal of Clinical Nutrition, 29*(1) http://dx.doi.org/10.6133/apjcn.201912/PP.0003

The permission of the journal is attached in Appendix D.

136 Objective 2 *Asia Pac J Clin Nutr 2020;29(1):136-143*

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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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.

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AUTHOR DISCLOSURES

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4.3 Results for Objective 3

Objective 3:

To ascertain the role of postpartum physical activity on weight retention within twelve months postpartum in Vietnam.

The results addressing Objective 3 have been published in the following paper:

Ha, A. V. V., Zhao, Y., Binns, C. W., Pham, N. M., Nguyen, P. T. H., Nguyen, C. L., . . . Lee, A. H. (2020). Postpartum Physical Activity and Weight Retention within One Year: A Prospective Cohort Study in Vietnam. *International Journal of Environmental Research and Public Health, 17*(3), 1105. Retrieved from https://www.mdpi.com/1660-4601/17/3/1105

The permission of the journal is attached in Appendix E.

Objective 3

International Journal of
Environmental Research and Public Health

MDPI

Article

Postpartum Physical Activity and Weight Retention within One Year: A Prospective Cohort Study in Vietnam

Anh Vo Van Ha [1,2], Yun Zhao [1], Colin W. Binns [1], Ngoc Minh Pham [1,3], Phung Thi Hoang Nguyen [1,4], Cong Luat Nguyen [5], Tan Khac Chu [1,6] and Andy H. Lee [1,*]

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Abstract: After delivery, mothers are encouraged to increase physical activity (PA) gradually to regulate body weight; however, data on PA in relation to postpartum weight retention remains scarce, particularly among Asian women. In a cohort of 1617 Vietnamese mothers, we investigated the prospective association between habitual PA exposures at 3-month postpartum and weight retention at 6-month and 12-month postpartum. Detailed information on PA intensity and domains was collected from participants using a validated instrument specifically for Vietnamese women. Linear regression analyses and a general linear model for the repeated weight retention measures were used to ascertain the apparent relationships. On average, the participants reported 3.6 (SD 3.9) and 2.6 (SD 3.8) kg weight loss at 6- and 12-month postpartum, respectively. Total and light-intensity PA were inversely associated with the postpartum weight retention (p for trend <0.05). Our findings highlight the importance of resuming PA in the early postpartum period as an appropriate weight management strategy.

Keywords: physical activity; pregnancy; body weight; postpartum weight retention; cohort study; Vietnam

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1. Introduction

Maternal overweight and obesity is a public health challenge and contributes to adverse health outcomes for both mother [1,2] and infant [3–5]. During the past decade, there has been a greater increase in average body mass index (BMI) among women in Southeast Asia (>1 kg/m^2) than those residing in higher-income Asian countries (<0.2 kg/m^2) [6]. A recent meta-analysis estimated that one in five women aged over 15 years was overweight in Southeast Asia, including Vietnam [7].

Excess postpartum weight retention has been linked to long-term maternal–infant outcomes, including metabolism changes in mothers, difficulties in breastfeeding initiation, and infant's microbiome [8]. Women who did not return to their pre-pregnancy weight and gained weight through one-year postpartum are at increased risk of obesity, insulin resistance, and metabolic syndrome at six-year postpartum [9]. Common risk factors of postpartum weight retention are related to pre-pregnancy and pregnancy periods, including pre-pregnancy BMI, gestational weight gain, and parity [10–12].

In 2015, the American College of Obstetricians and Gynecologists advocated physical activity (PA) in the postpartum period to maintain a healthy lifestyle and to manage a healthy weight [13] in mothers. Asian women weigh approximately two kilograms heavier on average at 6- to 12-month postpartum than their pre-pregnancy weight [14–17]. Since infant care occupies most of a new mother's time in the postpartum period [18], it remains a challenge for them to engage in sports or exercise programs.

Several studies have examined the relationship between postpartum PA and postpartum weight retention but mostly restricted to Caucasian populations [19]. For example, a study with a prospective cohort of 1213 Australian women reported walking 30 min or more per week in the postpartum period resulted in significant weight loss [20]. Another prospective cohort study of 908 women in the U.S.A. also reported an inverse association between daily 30-min walking and retaining five or more kilograms at 12-month postpartum [21]. These studies focused on the assessment of specific PA intensity (e.g., moderate level) and PA domain (such as sports or exercise) [20,21], while the impact of other intensity (e.g., light-intensity) or domain (e.g., occupational) of PA on postpartum weight retention remains unknown in Asian women [13].

There have been limited investigations on PA for the general population of Vietnam. Nevertheless, a previous study indicated that total PA was inversely associated with BMI, with the mean total PA for women being approximately 50% lower than the overall average, while three-quarters of the 14,706 participants reported engaging in none of the measurable sports/exercise activities [22]. For Vietnamese mothers, recent evidence has suggested that weight gain during pregnancy is related to postpartum weight retention [17]. However, no information is available concerning the role of PA during postpartum period in weight retention. Therefore, the present study aimed to fill the scientific gap by investigating the association between PA (intensity and domain) at 3-month postpartum and weight retention within one-year postpartum using a large cohort of women in Vietnam.

2. Methods

2.1. Study Design, Setting, and Participants

A multicenter prospective cohort study was conducted in Vietnam. Details of the study design, including sample size calculation and recruitment procedure, have been described elsewhere [23]. Briefly, a total of 2030 singleton pregnant women were recruited and followed up in three cities (Hanoi, Hai Phong, and Ho Chi minh City) between 2015 and 2017. Eligible women were ≥18 years old, living in the study locations, and not having a serious pre-existing health condition. Of the cohort, 1617 participants (79.7%) were successfully followed up to 12-month postpartum. The study was approved by the Curtin University Human Research Ethics Committee (HR32/2015) and the Hai Phong University of Medicine and Pharmacy Human Research Ethics Committee (No 05/HPUMPRB/2015).

2.2. Study Variables

The outcomes were weight retention at 6- and 12-month postpartum, calculated by subtracting the self-reported pre-pregnancy weight from the weight measured at 6- and 12-month postpartum, respectively.

The primary exposure variables were maternal PA during the first three months after giving birth. Such information was collected at 3-month postpartum using a validated Vietnamese version of the Pregnancy Physical Activity Questionnaire [24]. We measured 32 specified activities in four domains, namely, household/caregiving, occupational, sports/exercise, and transportation. The duration, frequency, and intensity of PA were calculated using the Compendium of Physical Activities and then converted to the metabolic equivalent of task hours per week (MET-hour/week). The sum of all activities across domains was defined as the total PA. Light-intensity PA, moderate-intensity PA, and vigorous-intensity PA were defined as 1.5 to <3 METs, 3 to 6 METs, and >6 METs, respectively. Light-intensity PA included activities related to household/caregiving, transportation, and occupational tasks. Moderate-intensity PA was derived from several activities pertaining to household/caregiving, transportation, sports/exercise, and occupational tasks. The variables of total PA, light-intensity, moderate-intensity, household/caregiving, and transportation were further categorized into tertiles (low, medium, and high levels) for subsequent regression analyses. Sports/exercise and occupational activities were dichotomized (yes/no) due to low participation in these activities. Vigorous-intensity PA was not included in the analyses because less than 2% of participants engaged in such high level of activity at 3-month postpartum.

Sociodemographic, pregnancy, and postnatal information was obtained from the interviews and medical records whenever available. These variables included maternal age (<25, 25–34, ≥35 years), education (secondary or lower, high school, college or above), formal employment (yes, no), parity (0, ≥1), mode of delivery (vaginal, Cesarean), and gestational age (<37, ≥37 weeks). Pre-pregnancy BMI and 12-month postpartum BMI were classified as underweight (<18.5 kg/m^2), normal (18.5–22.9 kg/m^2), and overweight and obese (≥23 kg/m^2) following the cut-offs from World Health Organization for Asian populations [25]. We measured total energy intake (Kcal/day) during pregnancy using a validated food frequency questionnaire for Vietnamese adults [26]. Total PA during pregnancy (MET-hour/week) was also quantified at the baseline interview. Gestational weight gain was calculated by subtracting each participant's self-reported pre-pregnancy weight from her pre-delivery weight, the latter being measured by midwives and documented in hospital medical records [17]. We then classified gestational weight gain as being below (inadequate), within (adequate), and above (excessive), according to the 2009 Institute of Medicine recommendations [27].

2.3. Statistical Analysis

Stata 15.1 [28] was used for all statistical analyses. We summarized the socio-demographic and postnatal characteristics of the maternal cohort using descriptive statistics and reported the mean weight retention at 6- and 12-month postpartum, and the mean PA exposures at 3-month postpartum. Comparisons between followed-up participants and dropouts were made using chi-square and *t*-tests.

Separate linear regression analyses were performed to assess the association between weight retention at the two time points and each of the 3-month postpartum PA exposures, namely, total PA, light-intensity PA, moderate-intensity PA, household/caregiving, occupational, sports/exercise, and transportation, accounting for potential confounding factors. These confounding factors were selected based on our literature review with a consideration of the available information in our study; they were maternal age [17,23,24], education [17,24], formal employment [17,24], parity [17,23], mode of delivery [24], pre-pregnancy BMI [17,24], energy intake during pregnancy and total PA during pregnancy [29], gestational age and gestational weight gain [17,24]. The linear regression results were presented in terms of estimated regression coefficients together with their 95% confidence intervals (CI).

The general linear model (GLM) with repeated measures provides analysis of variance when the outcome variable is measured at several time points for each subject. In view of our repeated weight retention measurements at 6- and 12-month postpartum, we further used the GLM with repeated measures to ascertain the relationship between weight retention and the PA exposures, adjusting for the same set of confounders as above. Results from fitting the GLM were presented as a forest plot using Stata's "coefplot" [30]. Tests for overall linear trends across PA levels were conducted in relation to postpartum weight retention, except for the dichotomous PA variables (sports/exercise and occupational).

PA exposures variables were examined both as continuous and categorical (tertiles) in all the above regression models. To assess the robustness of the associations between PA exposures and weight retentions, we furthermore carried out a subgroup analysis by pre-pregnancy BMI (only for the association between categorical total PA and weight retentions). The results of the subgroup analysis and those based on continuous were reported in a Supplementary file.

In order to meet the regression assumptions; the weight retention outcome variables were checked for normality. The homogeneity of variance of the regression residuals was also assessed for all models. Variance inflation factor (VIF) was used to assess the presence of multicollinearity among the independent variables in the regression analyses.

3. Results

The mean age of participants (n = 1617) at enrollment was 27.5 (SD 5.2) years. As shown in Table 1, the majority of women were formally employed, multiparous, and had a vaginal delivery with gestational age ≥ 37 weeks. Their mean pre-pregnancy BMI was 20.1 (SD 2.4) kg/m^2, and the mean gestational weight gain of the cohort was 12.9 (SD 4.0) kg. During pregnancy, total PA during pregnancy was 124.7 (SD 57.3) MET-hour/week, while total energy intake was 2120.8 (SD 746.8) Kcal/day on average (data not shown). There were no significant differences in maternal characteristics and pre-pregnancy BMI between the followed-up participants and dropouts.

Table 1. Characteristics of the maternal cohort of the examined women (n = 1617).

Characteristic	Distribution [a]	Weight Retention at 6-Month Postpartum (kg)	Weight Retention at 12-Month Postpartum (kg)
	3.1 ± 3.8	3.6 ± 3.9	2.6 ± 3.8
Age at enrollment (years)	27.5 ± 5.2		
<25	679 (42.0%)	3.8 ± 4.0	2.7 ± 4.0
25–34	769 (47.6%)	3.5 ± 3.7	2.6 ± 3.6
≥35	169 (10.4%)	3.6 ± 3.7	2.4 ± 3.5
Education			
Secondary or lower	536 (33.2%)	3.5 ± 3.9	2.7 ± 3.6
High school	416 (25.7%)	3.6 ± 3.8	2.6 ± 4.0
College or above	665 (41.1%)	3.8 ± 3.8	2.6 ± 3.7
Formal employment			
No	500 (30.9%)	3.9 ± 3.9	2.6 ± 3.7
Yes	1117 (69.1%)	3.5 ± 3.8	2.6 ± 3.8
Parity			
0	627 (38.8%)	3.7 ± 4.0	2.8 ± 4.1
≥1	990 (61.2%)	3.6 ± 3.8	2.5 ± 3.6
Pre-pregnancy BMI (kg/m^2) [b]	20.1 ± 2.4		
Underweight (<18.5)	421 (26.0%)	4.3 ± 3.4	3.4 ± 3.4
Normal (18.5–22.9)	1018 (63.0%)	3.6 ± 4.0	2.4 ± 3.8
Overweight and Obese (≥23.0)	178 (11.0%)	2.4 ± 3.9	2.1 ± 4.1
Mode of delivery			
Vaginal	992 (61.4%)	3.7 ± 3.9	2.5 ± 3.7
Caesarean section	625 (38.6%)	3.5 ± 3.8	2.7 ± 3.9
Gestational age (weeks)	38.9 ± 1.3		
<37	67 (4.1%)	2.4 ± 3.7	1.3 ± 3.5
≥37	1550 (95.9%)	3.7 ± 3.9	2.7 ± 3.8
Gestational weight gain (kg) [c]	12.9 ± 4.0		
Inadequate	597 (36.9%)	2.1 ± 3.3	1.3 ± 3.2
Adequate	755 (46.7%)	3.9 ± 3.6	2.9 ± 3.6
Excessive	265 (16.4%)	6.2 ± 4.2	4.8 ± 4.2

[a] Data are expressed as n (%) for categorical variables and mean ± SD for continuous variables; [b] Cut-offs from World Health Organization for Asian populations; [c] Categorized according to 2009 Institute of Medicine recommendations; MET, metabolic equivalent of task; SD, standard deviation.

The mean weight retention at 6-month was significantly higher than that at 12-month postpartum (1.0 kg; $p < 0.001$). At 6- and 12-month postpartum, 35.6% and 25.6% of the mothers retained 5 kg or more, respectively. The prevalence of overweight/obesity at 12-month postpartum (n = 351, 21.7%) was higher than that before pregnancy (n = 178, 11%).

Table 2 summarizes the PA exposures of the final cohort at 3-month postpartum. Their mean energy expenditure (total PA) was 150.9 (SD 50.1) MET-hour/week. It is evident that Vietnamese women seldom engaged in sports/exercise (n = 356, 21.9%) after delivery. On the other hand, they participated mostly in household/caregiving activities. Indeed, very few women (n = 124, 7.6%) returned to formal work within 3 months after giving birth.

Table 2. Physical activity of the examined women at 3-month postpartum (n = 1617).

Physical Activity (MET-Hour/Week)	Mean ± SD	Minimum	Maximum
Total	150.9 ± 50.1	26.6	375.1
Intensity			
Light	69.5 ± 31.6	8.2	214.0
Moderate	66.8 ± 27.6	0	253.8
Vigorous	0.03 ± 0.3	0	4.9
Domain			
Household/caregiving	130.5 ± 43.9	22.2	298.2
Transportation	7.4 ± 10.7	0	142.6
Sports/exercise	0.2 ± 0.6	0	10.7
Occupational	2.1 ± 9.4	0	111.3

MET, metabolic equivalent of task; SD, standard deviation.

Table 3 presents the results from linear regression analyses. All VIFs were <10, suggesting that multicollinearity was not a concern. Total PA and light-intensity PA were inversely associated with weight retention at both 6- and 12-month postpartum, though no significant associations were observed for moderate-intensity PA and subtypes (four domains) of PA.

Table 3. Linear regression analyses of postpartum weight retention in relation to physical activity exposures (n = 1617).

Physical Activity at 3-Month Postpartum (MET-hour/week)		Postpartum Weight Retention (kg) at			
		6-Month [a]		12-Month [a]	
	n (%)	Coefficient (95% CI)	*p*	Coefficient (95% CI)	*p*
Total physical activity		*p* trend = 0.023		*p* trend = 0.003	
Low (≤133.2)	550 (34.0%)	Reference		Reference	
Medium (>133.2 to ≤163.3)	562 (34.8%)	− 0.18 (− 0.59, 0.24)	0.257	− 0.06 (−0.48, 0.36)	0.570
High (>163.3)	505 (31.2%)	− 0.50 (− 0.94, − 0.07)	0.023	− 0.66 (− 1.09, − 0.23)	0.003
Light-intensity		*p* trend = 0.005		*p* trend = 0.015	
Low (≤56.8)	553 (34.2%)	Reference		Reference	
Medium (>56.8 to ≤80.7)	543 (33.6%)	− 0.21 (− 0.63, 0.21)	0.325	− 0.38 (− 0.80, 0.04)	0.076
High (>80.7)	521 (32.2%)	− 0.62 (− 1.05, − 0.18)	0.005	− 0.53 (− 0.96, − 0.10)	0.016
Moderate-intensity		*p* trend = 0.810		*p* trend = 0.557	
Low (≤59.6)	542 (33.5%)	Reference		Reference	
Medium (>59.6 to ≤71.3)	563 (34.8%)	0.13 (− 0.29, 0.56)	0.536	0.08 (− 0.34, 0.50)	0.723
High (>71.3)	512 (31.7%)	− 0.06 (− 0.48, 0.37)	0.801	− 0.13 (− 0.56, 0.30)	0.543
Household/caregiving		*p* trend = 0.117		*p* trend = 0.132	
Low (≤113.2)	541 (33.5%)	Reference		Reference	
Medium (>113.2 to ≤144.8)	553 (34.2%)	− 0.14 (− 0.57, 0.28)	0.500	− 0.15 (− 0.57, 0.27)	0.484
High (>144.8)	523 (32.3%)	− 0.34 (− 0.78, 0.09)	0.116	− 0.33 (− 0.76, 0.10)	0.131

Table 3. *Cont.*

Physical Activity at 3-Month Postpartum (MET-hour/week)		Postpartum Weight Retention (kg) at			
		6-Month [a]		12-Month [a]	
	n (%)	Coefficient (95% CI)	*p*	Coefficient (95% CI)	*p*
Transportation		*p* trend = 0.858		*p* trend = 0.957	
Low (≤3.6)	945 (58.4%)	Reference		Reference	
Medium (>3.6 to ≤7.6)	173 (10.7%)	− 0.11 (− 0.69, 0.46)	0.697	− 0.57 (− 1.14, 0.001)	0.050
High (>7.6)	499 (30.9%)	0.05 (− 0.34, 0.43)	0.818	0.06 (− 0.33, 0.44)	0.638
Occupational					
No	1500 (92.4%)	Reference		Reference	
Yes	124 (7.6%)	0.33 (− 0.33, 0.98)	0.327	0.57 (− 0.08, 1.22)	0.088
Sports/exercise					
No	1268 (78.1%)	Reference		Reference	
Yes	356 (21.9%)	− 0.22 (− 0.64, 0.20)	0.297	0.08 (− 0.34, 0.49)	0.722

[a] Separate linear regression models for each physical activity intensity and domain were adjusted for maternal age at enrolment, education, formal employment, parity, pre-pregnancy BMI, mode of delivery, gestational age, gestational weight gain, total energy intake during pregnancy, and total physical activity during pregnancy; CI, confidence interval; MET, metabolic equivalent of task.

Figure 1 displays graphically the results from fitting the GLM to the weight retention repeated measures, which confirms the above results from the separate regression analyses. Vietnamese mothers with high exposure levels of total PA and light-intensity PA experienced a significant reduction in weight retention, but not for engaging in moderate-intensity activities and other domains within one-year postpartum.

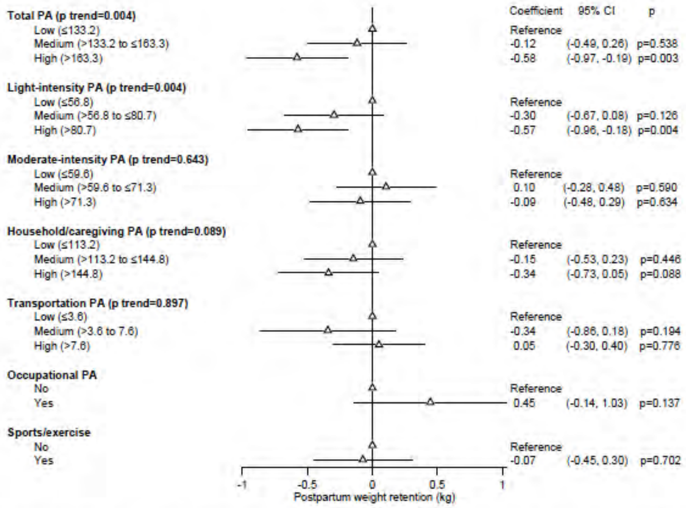

Figure 1. General linear model of one-year postpartum weight retention repeated measures in relation to physical activity at 3-month postpartum. GLM models for each physical activity intensity and domain were adjusted for maternal age at enrolment, education, formal employment, parity, pre-pregnancy BMI, mode of delivery, gestational age, gestational weight gain, total energy intake during pregnancy, and total physical activity during pregnancy; CI, confidence interval; MET, metabolic equivalent of task; PA, physical activity.

The results based on continuous PA exposures variables (see Table S1) are generally in line with those from categorical PA variables, particularly for light-intensity PA. The total PA was found to be inversely associated with weight retentions; however, the associations were only marginally statistically significant. Findings from the sub-group analysis are generally consistent with the findings based on the full sample, particularly for the pre-pregnancy normal weight and underweight groups, which constituted the majority of the examined women (normal weight: n = 1018, 63%; underweight: n = 421, 26%). For women with pre-pregnancy overweight and obesity (n = 178, 11%), total PA appeared to be positively associated with postpartum weight retention, albeit only 72 examined women with overweight and obesity (4.5%) engaged a high level of total PA (see Table S2).

4. Discussion

In this prospective cohort of 1617 Vietnamese women, the prevalence of overweight/obesity at 12-month postpartum was double that before pregnancy. This rate is similar to those in other regions. For example, a previous study of 302 African and Dominican women in the U.S.A. observed that 38% of participants were obese seven year after delivery, compared to 22.2% before pregnancy [31]. Another study in 810 Taiwanese women found a substantial increase in overweight and obesity from 18.3% (before pregnancy) to 27.6% (at 6-month postpartum) [32], though no comparable statistics have been reported in Southeast Asia.

The present study represented the first investigation of postpartum weight retention in relation to PA exposures in Vietnam, with comprehensive measurements of postpartum PA in both intensity and domain using a validated instrument for Vietnamese women. Overall, it is evident that a higher PA level (total and light-intensity PA) was associated with less weight retention at 6- to 12-month postpartum.

Our findings are generally consistent with those of previous studies in the postpartum period. A prospective cohort study of 420 Malaysian mothers suggested that increasing postpartum PA (walking, moderate-, and vigorous-intensity activities) could lead to less weight retention [33]. Similarly, another prospective cohort study of 1432 women in Sweden showed that mothers with higher levels of postpartum PA (a combination of occupational and leisure activities) lost more weight when compared to others who were inactive [34].

Light-intensity PA was found to be associated with weight retention within one-year postpartum. A prospective cohort study of 902 women in the U.S.A. similarly reported that walking at least 30 min daily (including sports/exercise and transportation) at 6-month postpartum could reduce weight retention at 12-month postpartum [21]. Although the underlying mechanism remains unclear, it has been suggested that changes in non-exercise activity thermogenesis (including energy expenditure in household/caregiving, transportation, and occupational tasks) may be related to the physiology of body weight regulation [35]. Despite the current PA guidelines recommending moderate-intensity PA in weight management [36], Asian women typically spend less time on moderate-to-vigorous PA during the postpartum period [37]. Nevertheless, our findings indicate that habitual light-intensity PA should be additionally recommended during the early postpartum period for their weight management [36].

We observed no significant associations between moderate-intensity PA, four PA domains, and postpartum weight retention, unlike findings from other countries [20,21,38]. Reasons for the discrepancy are unclear but may be attributed partly to the homogeneity of moderate-intensity PA among mothers engaged in the early postpartum period, that possibly leading to little or no apparent influence of moderate-intensity PA on postpartum weight retention in our study population. Furthermore, the effect of each PA domain on postpartum weight retention might not be discernible when considered separately. During the early postpartum period, Vietnamese mothers are commonly engaged in light-intensity activities (e.g., household/caregiving activities, walking slowly, and sitting), and the sum of such activities contributes substantially to the total PA. Another issue is the instrument used to quantify PA exposure. There has been no similar study in the literature that adopted the same questionnaire as ours to assess habitual PA among postpartum mothers in relation to weight retention.

The Vietnam Employment Law includes entitlement for eligible employees to have up to 6- month paid maternity leave. This policy may contribute to the low number of participants (7.6%) engaging in occupational activities at 3-month postpartum. The apparent lack of association between occupational PA and postpartum weight retention was consistent with a previous prospective cohort study of 550 mothers in the U.S.A. [39]. Furthermore, only a low proportion (21.9%) of Vietnamese women participated in any sports/exercise after giving birth, which may be attributed to busy motherhood for child caring and housework. Similarly, 70% of mothers in Hawaii stated that they were too busy to participate in sports/exercise activities during the postpartum period [40]. In our cohort, mothers who participated in sports/exercise appeared to have less, albeit statistically non-significant, postpartum weight retention. The apparent lack of association concerning sports/exercise and occupational PA was in line with the literature [16,39].

The results based on continuous PA variables further confirmed the inverse associations between PA and postpartum weight retention, particularly for light-intensity PA, which may be the most acceptable and suitable intensity for Asian women in the short-time period after delivery. The categorization of PA variables provided insights on how the specific tertile levels of PA were associated with postpartum weight retentions, which may be useful for implementing practical advice about PA and postpartum weight management.

The subgroup analysis by pre-pregnancy BMI suggested that the inverse association between total PA and postpartum weight retention retained consistently for women with pre-pregnancy normal weight and underweight, but not for those with overweight and obesity. It could be argued that these women were likely to incur an unhealthy lifestyle and perceived more barriers to change such unhealthy behaviors by themselves unless they participate in targeted interventions [41]. Nevertheless, the finding should be interpreted with care due to a very small proportion of women with pre-pregnancy overweight and obesity engaging a high total PA level (n = 72, 4.5%) in our sample.

Several strengths and limitations should be acknowledged. A major strength of our prospective cohort study was its large sample size. We also used a validated instrument for Vietnamese mothers to gather information on 32 habitual PA in four domains. Moreover, plausible confounding factors affecting postpartum weight retention had been accounted for in the regression analyses. Although postpartum weight was measured at two different time points, as in most other studies, postpartum weight retention was determined based on the self-reported pre-pregnancy weight. Nonetheless, there was a high level of concordance between self-reported and measured pre-pregnancy body weight [42,43]. Our participants were also recruited from mainly urban and peri-rural areas of three cities in Vietnam. Therefore, the findings cannot be extrapolated to the entire population of Vietnamese women. Given the limited information and available guidelines on the resumption of postpartum PA [19,44], further studies are needed to provide guidance and recommendations on exercise and PA level when women return to work after maternity leave.

5. Conclusions

It is essential that mothers resume PA to assist them in returning to a healthy weight in the early postpartum period. Our results suggested that the resumption of daily PA (total PA or light-intensity activities) is associated with less weight retention for Vietnamese mothers within one-year postpartum. Future research is recommended on ways to promote PA and exercise during the postpartum period. This should include studies of mothers who return to employment at 6-month postpartum.

Supplementary Materials: The following are available online at http://www.mdpi.com/1660-4601/17/3/1105/s1, Table S1: Linear regression analyses and GLM with repeated measures of postpartum weight retention in relation to physical activity exposures (n = 1617), Table S2: Sub-group analyses: Linear regression analyses and GLM of postpartum weight retention in relation to physical activity exposures (n = 1617).

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writing—review and editing, A.V.V.H., C.W.B, A.H.L., Y.Z., N.M.P., C.L.N., P.T.H.N. and T.K.C.; visualization, A.V.V.H., Y.Z., A.H.L., and N.M.P.; supervision, Y.Z., A.H.L., C.W.B. and N.M.P.; project administration, A.H.L. and C.W.B.; funding acquisition, A.H.L. All authors have read and agreed to the published version of the manuscript.

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4.4 Results for Objective 4

Objective 4:

To investigate the prevalence of postpartum low back pain and its relation to physical activity during pregnancy in Vietnam.

The results addressing Objective 4 have been published in the following paper:

Ha, V. V. A., Zhao, Y., Pham, M. N., Binns, C. W., Nguyen, C. L., Nguyen, P. T. H., … Lee, A. H. (2019). Physical Activity during Pregnancy and Postpartum Low Back Pain: A Prospective Cohort Study in Vietnam. *Asia Pacific Journal of Public Health*, *31*(8), 701–709. https://doi.org/10.1177/1010539519890148

The permission of the journal is attached in Appendix F.

Objective 4

Article

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Physical Activity During Pregnancy and Postpartum Low Back Pain: A Prospective Cohort Study in Vietnam

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Abstract

Low back pain (LBP) is a universal public health problem for all age groups, related to the upright stance of humans. Postpartum LBP is more common and can lead to limitations to women's daily activity. Knowledge about preventing postpartum LBP is limited, and the relationship between prenatal physical activity (PA) and LBP remains inconclusive. We conducted a prospective cohort study of 1807 singleton pregnant Vietnamese women to investigate the association between prenatal PA and postpartum LBP using logistic regression analyses. The prevalence of postpartum LBP was 12.3% (n = 222). Women reporting LBP spent more hours sitting per week. Relative to the lowest level of total PA, the highest level was associated with reduced odds of postpartum LBP (odds ratio = 0.55; 95% confidence interval = 0.38-0.80). Inverse associations with LBP were also observed for light intensity, moderate-to-vigorous intensity, household/caregiving, occupational, and transportation activities. Overall, prenatal PA was inversely associated with postpartum LBP in Vietnamese women.

Keywords

low back pain, physical activity, postpartum period, pregnancy, Vietnam

What We Already Know

- Low back pain is one of the most common human conditions.
- Low back pain is increased during pregnancy due to hormonal changes and increased strains due to pregnancy.
- There have been very few studies on prevention of low back pain in pregnancy, particularly in Asian populations.

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What This Article Adds

- This was a large cohort study in Vietnam (n = 1807), and 12.3% reported postpartum low back pain.
- Postpartum low back pain was observed to be inversely associated with total physical activity.
- The odds ratio for postpartum low back pain in women at the highest level of physical activity was 0.55 (95% confidence interval = 0.38-0.80) compared with the lowest level of physical activity.

Introduction

Low back pain (LBP) is a leading global cause of disability,[1] and it becomes even more common after giving birth.[2] Stresses in the sacroiliac joints and lumbosacral spine through weight gain, lordosis, and ligament laxity contribute to postpartum LBP.[3] Previous studies of Swedish women with postpartum LBP reported impairments to their daily activities, but they seldom sought health care assistance or treatment.[4,5] Several studies aimed to assess the treatment of LBP in the postpartum period; however, little prevention research has been undertaken in general populations and postpartum women.[5,6] For example, older Japanese women with their first pregnancy are a vulnerable group for postpartum LBP, but little research has been undertaken to prevent the problem.[6]

The 2018 Physical Activity (PA) Guidelines Advisory Committee Scientific Report supported PA during pregnancy, and stated that it is unlikely to be a risk to safe labor and delivery.[7] PA may result in changes in muscle physiology, which protects the spine.[8] Also, PA plays a role in an increase in endorphins, positive mood, and prevents avoidance of normal activities.[8] In general populations, a systematic review and meta-analysis of randomized controlled trials (RCTs) reported the protective effect of exercise against LBP.[9] The findings of another recent meta-analysis indicated that a variety of PA significantly reduces the severity of LBP during pregnancy, but evidence on the effect of PA in the prenatal period on postpartum LBP prevalence is limited.[10] In the studies included in this meta-analysis, the PA assessed in the prenatal period included ergonomic information, the ability to access to a physical therapist, stabilizing self-exercise, and supervised exercise program. Nilsson-Wikmar et al[11] studied three PA treatment groups of Sweden women with diagnosed LBP during pregnancy, including the first group with information about LBP and sacroiliac belt, the second group with the same treatment as in the first and a home exercise program, and the last group with the same as in the first and a clinic-based exercise program. However, they found no differences in pain among these groups during the postpartum period.[11] A Norwegian study compared supervised exercises following the current American Congress of Obstetricians and Gynecologists recommendations with no exercise among healthy nulliparous women and showed no differences between the two groups.[12] In fact, for many women, PA in the antenatal period includes not only exercises/sports but also daily activities (i.e. household and caregiving tasks, transportation, and occupational activities). Insufficient information on non-exercise PA at baseline has been described in the studies listed above. Furthermore, a low level of sports/exercise and the high levels of non-exercise PA, particularly occupational and household/caregiving activities in Asian women.[13] Thus, it is essential to document the effect of both exercises/sports and non-exercise PA in the antenatal period on postpartum LBP, particularly in Asian women.

This prospective cohort study aimed to determine the relationship between PA in the antenatal period and LBP during the first six months postpartum in Vietnamese women.

Methods

Study Design, Setting, and Participants

A multicentre prospective cohort study was conducted in Hanoi, Hai Phong, and Ho Chi Minh City of Vietnam. Details of the study design and recruitment procedure have previously been reported.[14]

In summary, the study included singleton pregnant women aged ≥18 years, who had provided signed informed consent, permanently living in the study locations, and not having a severe preexisting health condition, including cancer and ischemic heart disease. We recruited participants at antenatal hospitals, then interviewed, and followed up between August 2015 and November 2017. After hospital discharge, follow-up surveys were conducted at convenient places (mostly at the women's home) by trained interviewers. This study included information collected from the surveys at baseline (24-28 weeks of gestation), hospital discharge, and six months postpartum. We considered mothers who were unable to be contacted after three attempts as lost to follow-up.

Measurements

During interviews, information was cross-checked from medical records and maternal health books whenever possible. The binary outcome variable was the presence or absence of LBP during the six months postpartum period (i.e. from after hospital discharge until the interview at six months postpartum), which made it difficult to do her routine activities.[6] The respondents reported the presence or absence of LBP on a health problem checklist, following the previous practice.[15] To minimize the impact of information bias, the interviewers then asked mothers for details of their pain location to confirm the LBP, defined as pains at the lower back (lumbosacral spine). The frequency and duration of postpartum LBP were not recorded, due to the subjectivity and perception of women on LBP.

The validated Vietnamese version of the Pregnancy Physical Activity Questionnaire (PPAQ) was used to ascertain habitual PA during the past three months (i.e. second trimester) before the baseline interview.[16] The PPAQ measures time spent participating in 32 specified activities in five domains, namely household/caregiving, occupational, sports/exercise, transportation, and sedentary activity.[17] The duration, frequency, and intensity of participants' PA were calculated and expressed in terms of metabolic equivalent task hours per week (MET-h/wk), based on the PPAQ scoring mechanism and the Compendium of Physical Activities.[17] We then calculated total physical activity. The intensity was further classified as "light-intensity" activity (1.5 to <3 METs) and "moderate-to-vigorous-intensity" activity (≥3 METs).[17] Vigorous-intensity activity (>6 METs) was rare during pregnancy (n = 59; 2.9%) in our sample and was thus combined with the moderate-intensity category. Sedentary activities during pregnancy included watching television, sitting in front of a computer, reading, talking, riding a motorcycle, or driving a car/bus, and sitting at work or classes. Total sitting (hours per week) was the sum of all times devoted to these sedentary activities at home, work, and transportation. We divided each PA variable (i.e. total, light intensity, moderate-to-vigorous intensity, sitting, household/caregiving, sports/exercise, occupational, and transportation) into tertiles with the highest (third) tertile reflecting the highest level of activity.

Sociodemographic characteristics were recorded at the baseline interview (24-28 weeks of gestation), including maternal age (<25, 25-34, ≥35 years), formal employment ("yes": office-based staff, service, sales or manufacturing workers, and technicians; "no": housewives, freelancers, unskilled farmers or planters, unemployed), and education (secondary school or lower; high school; college or university). Information on current pregnancy, including prepregnancy body mass index (BMI), parity (first pregnancy and multiparous), total energy intake during pregnancy, gestational weight gain (in kg), gestational age (<37, ≥37 weeks), gestational diabetes mellitus (yes, no), mode of delivery (vaginal, caesarean), neonatal weight (in kg), and infant gender (male, female), were captured from medical records, at the baseline interview, or through the hospital discharge survey using structured questionnaires. Prepregnancy BMI was obtained using self-reported prepregnancy weight and measured height, and classified according to the World Health Organization criteria as "underweight" (<18.5 kg/m^2), "normal" (18.5-24.9 kg/m^2), and "overweight/obese" (≥25 kg/m^2).[18] Gestational weight gain was calculated by subtracting the predelivery weight from the prepregnancy weight. Participants were divided into three gestational weight gain groups ("inadequate", "adequate", and "excessive") by their prepregnancy BMI category, based on the recommendations from the Institute of Medicine.[19] Total energy intake (in kcal/day) during pregnancy was assessed using a validated food frequency questionnaire for Vietnamese adults.[20] Gestational diabetes mellitus was ascertained and diagnosed using a 75-gram oral glucose tolerance test administered between 24 and 28 weeks of gestation.[21]

Statistical Analyses

Descriptive statistics were used to summarize the sample characteristics and the prevalence of LBP during the first six months postpartum. Comparisons of LBP between subgroups of interest were made using χ^2 test for categorical covariates or one-way analysis of variance for continuous covariates. These covariates (Table 1) were selected from previous literature on LBP and the availability of such information in our study.[22,23] To ascertain the associations between LBP and PA exposures (i.e. total PA, sitting hours per week, light-intensity PA, moderate-to-vigorous–intensity PA, and PA domains), we adopted a two-stage analysis strategy. In stage 1, the bivariate associations between continuous PA variables and LBP were assessed through independent samples *t* tests. In stage 2, PA variables were categorized into tertiles. Multivariable logistic regression analyses were then undertaken, with the lowest tertile of each PA variable taken as the reference level. We included the covariates (maternal age, education, formal employment, parity, prepregnancy BMI, and gestational diabetes mellitus) in the final model using either the backward elimination method or according to a priori clinical relevance. Adjusted odds ratios (aORs) were presented with 95% confidence intervals (CIs), as well as tests for linear trend across tertiles of each PA variable. Participants and nonparticipants' demographic characteristics, including maternal age, prepregnancy BMI, and parity, were compared using χ^2 test. All statistical analyses were performed using the STATA software version 15.1.[24]

Ethical Approval

Ethical approval for the study was obtained from the Curtin University Human Research Ethics Committee (Approval No. HR32/2015) and the Hai Phong University of Medicine and Pharmacy Human Research Ethics Committee (Approval No. 05/HPUMPRB/2015).

Results

The study cohort comprised 2030 participants in the baseline interview. A final sample of 1807 women was available for statistical analyses at six months postpartum (the response rate was 89%). There were no significant differences between nonparticipants (ie, lost to follow-up) and participants (i.e. continued at six months postpartum) in terms of demographic characteristics, including age, prepregnancy BMI, and parity ($P > .05$).

The period prevalence of LBP was 12.3% (n = 222). Before pregnancy, the majority of women were employed (68.1%, n = 1230), multiparous (61.7%, n = 1115), having high school or above education (66.3%, n = 1198), and normal weight (69.9%, n = 1263). During pregnancy, 22.1% of women were diagnosed with gestational diabetes mellitus (n = 398) in the final sample.

In Table 1, it is apparent that women with older age, prepregnancy overweight/obesity, a lower level of education, and formal employment, as well as women diagnosed with gestational diabetes mellitus and underwent cesarean, were more likely to report postpartum LBP ($P < .05$). Table 2 compares PA exposures between women who reported LBP and those who did not. Women reporting postpartum LBP appeared to sit longer hours per week, and engaged in lower levels of PA, for total and across different intensities (light intensity and moderate-to-vigorous intensity) and domains (household/caregiving and transportation), when compared with their counterparts without postpartum LBP.

Table 1. Maternal Characteristics of Participants by Reported Low Back Pain Status During the Six Months Postpartum Period in Vietnamese Women (n = 1807).

	Total	Reported Postpartum LBP (n = 222)	
Variable	n (%)	n (%)	P^a
Maternal age (years)			
<25	756 (41.9)	58 (7.7)	<.001
25-34	866 (47.9)	126 (14.6)	
≥35	185 (10.2)	38 (20.5)	
Education			
Secondary school or lower	609 (33.7)	96 (15.8)	.002
High school	470 (26.0)	58 (12.3)	
College or above	728 (40.3)	68 (9.3)	
Formal employment			
No	577 (31.9)	55 (9.5)	.015
Yes	1230 (68.1)	167 (13.6)	
Prepregnancy BMI (kg/m^2)			
Underweight (<18)	469 (25.9)	37 (7.9)	<.001
Normal (18-24.9)	1263 (69.9)	162 (12.8)	
Overweight/obese (≥25)	75 (4.2)	23 (30.7)	
Parity			
First pregnancy	692 (38.3)	79 (11.4)	.375
Multiparous	1115 (61.7)	143 (12.8)	
Mode of delivery[b]			
Vaginal	1114 (61.8)	122 (11.0)	.026
Cesarean	690 (38.2)	100 (14.5)	
Gestational weight gain[b,c]			
Inadequate	687 (38.2)	75 (10.9)	.073
Adequate	826 (46.0)	100 (12.1)	
Excessive	284 (15.8)	46 (16.2)	
Gestational age (weeks)[b]			
<37	82 (4.6)	14 (17.1)	.179
≥37	1722 (95.4)	208 (12.1)	
Infant gender[b]			
Male	932 (51.7)	120 (12.9)	.446
Female	872 (48.3)	102 (11.7)	
Gestational diabetes mellitus[b]			
No	1403 (77.9)	145 (10.3)	<.001
Yes	398 (22.1)	76 (19.1)	
Total energy intake during pregnancy, mean ± SD, Kcal/day	2115.5 ± 739.6	2051.0 ± 704.9	.122
Neonatal weight, mean ± SD, kg	3.1 ± 0.4	3.2 ± 0.4	.773

Abbreviations: BMI, body mass index; LBP, low back pain; SD, standard deviation.
[a]Based on χ^2 test or one-way analysis of variance.
[b]Missing data present.
[c]Categorized according to the Institute of Medicine 2009 gestational weight gain report.

The results from multivariable logistic regression modeling (Table 3) confirm the findings from the univariate analysis. Relative to those in the lowest level (tertile), the pregnant women who engaged in higher levels of PA generally sustained reduced odds of postpartum LBP. In particular, we observed significant inverse associations with LBP for total PA, light-intensity, moderate- to vigorous-intensity PA, household/caregiving activities, and to a lesser extent, occupational PA and transportation PA.

Table 2. Physical Activity During Pregnancy by Reported Low Back Pain Status During the Six Months Postpartum Period in Vietnamese Women (n = 1807).

	Postpartum LBP		
	Not Reported (n = 1585)	Reported (n = 222)	
Physical Activity	Mean (SD)	Mean (SD)	P^a
Total physical activity (MET-h/wk)	127.1 (58.2)	109.3 (50.1)	<.001
Sitting (h/wk)	26.4 (14.3)	28.5 (13.5)	.036
Intensity (MET-h/wk)			
Light	58.9 (32.6)	52.1 (33.9)	.004
Moderate-to-vigorous	31.8 (33.6)	18.5 (22.8)	<.001
Domain (MET-h/wk)			
Household/caregiving	62.1 (42.1)	49.7 (37.4)	<.001
Occupational	32.1 (30.5)	28.7 (25.2)	.065
Sports/exercise	6.2 (9.2)	6.0 (11.5)	.811
Transportation	12.1 (13.7)	9.2 (11.0)	<.001

Abbreviations: LBP, low back pain; MET-h/wk, metabolic equivalent of task hours per week; SD, standard deviation.
[a]Based on independent-samples *t* test.

Discussion

Findings from the present study suggested that engaging in higher levels of PA in the antenatal period was associated with lower odds of LBP during the first six months postpartum. To our knowledge, this is the first cohort study assessing this association using a validated PA instrument for pregnant women in Asia. Approximately one in eight (12.3%) of the Vietnamese women experienced LBP during the six months postpartum period. No findings on postpartum LBP have been found in Vietnamese women for comparisons. The observed prevalence is lower than the rates reported in some European countries, including Sweden, the Netherlands, and Turkey.[22,25,26]

In the present study, we investigated the dose-response associations of both the intensity and the domains of PA with postpartum LBP. The number of hours spent per week in sitting was not significantly associated with LBP in our multivariable model. A previous study suggested the inclusion of both sitting time and postures when assessing the association between sitting and LBP.[27] Women might be limited in postures due to pregnancy, and this might warrant further investigation. For our participants, total PA, intensity-specific PA (light-intensity and moderate-to vigorous-intensity PA), and domain-specific PA (household/caregiving, occupational, and transportation activities) in the antenatal period were all inversely associated with the odds of reporting postpartum LBP. Our results were consistent with a meta-analysis (including three European-based RCTs), indicating that no association between sports/exercise in the antenatal period and odds of postpartum LBP.[10] In addition, our findings are moderately consistent with a longitudinal study in Canada, showing a negative dose-response association between gardening activities and odds of back pain.[28] This study also found a positive association between activity restriction and the odds of back pain.[28] The aforementioned findings supported our findings on PA levels and their associations with LBP. To date, we found no research examining the association between transportation activities and the odds of LBP. In the general population, PA has been reported to exhibit a U-shape relation with LBP, that is, too little or too much activity may result in back pain.[29] However, there are few reports in the literature of PA in the antenatal period and postpartum LBP, and none from Asia. A study in Sweden reported that a history of heavy work before pregnancy was associated with LBP during the 12 months postpartum period.[25] However, another recent study in the Swedish population found no association between the six months postpartum LBP and PA before pregnancy.[22,25] It should be borne in mind that both the duration and intensity of leisure activity, sports, or other PA are expected to decrease throughout

Table 3. Associations Between Physical Activity During Pregnancy and Reported Low Back Pain During the Six Months Postpartum Period in Vietnamese Women (n = 1807).

	Postpartum LBP			
	Not Reported (n = 1585)	Reported (n = 222)		
Physical Activity	n (%)	n (%)	aOR[a]	95% CI
Total physical activity (MET-h/wk)		*P* trend = .002		
First tertile (9.98 to <92.64)	489 (83.9)	94 (16.1)	1.00	Reference
Second tertile (92.64 to <142.05)	534 (88.4)	70 (11.6)	0.70	(0.50-0.99)
Third tertile (142.05 to 362.78)	562 (90.7)	58 (9.3)	0.55	(0.38-0.80)
Sitting (hours/week)		*P* trend = .168		
First tertile (1.75 to <23.84)	561 (90.0)	62 (10.0)	1.00	Reference
Second tertile (23.84 to <46.86)	501 (85.9)	82 (14.1)	1.43	(0.99-2.07)
Third tertile (46.86 to 110.08)	523 (87.1)	78 (12.9)	1.32	(0.90-1.96)
Intensity (MET-h/wk)				
Light		*P* trend = .005		
First tertile (0 to <38.33)	493 (83.8)	95 (16.2)	1.00	Reference
Second tertile (38.33 to <68.72)	544 (89.3)	65 (10.7)	0.65	(0.46-0.93)
Third tertile (68.72 to 170.8)	548 (89.8)	62 (10.2)	0.60	(0.42-0.87)
Moderate-to-vigorous		*P* trend < .001		
First tertile (0 to <10.90)	517 (82.2)	112 (17.8)	1.00	Reference
Second tertile (10.90 to <31.05)	479 (88.1)	65 (11.9)	0.68	(0.49-0.97)
Third tertile (31.05 to 203.53)	589 (92.9)	45 (7.1)	0.40	(0.27-0.59)
Domain (MET-h/wk)				
Household/caregiving		*P* trend = .013		
First tertile (0 to <34.97)	481 (83.8)	93 (16.2)	1.00	Reference
Second tertile (34.97 to <67.50)	546 (88.8)	69 (11.2)	0.67	(0.47-0.95)
Third tertile (67.50 to 231)	558 (90.3)	60 (9.7)	0.63	(0.43-0.92)
Occupational		*P* trend = .006		
First tertile (0 to <9.28)	526 (87.2)	77 (12.8)	1.00	Reference
Second tertile (9.28 to <39.51)	515 (85.7)	86 (14.3)	0.86	(0.59-1.25)
Third tertile (39.51 to 176.23)	544 (90.2)	59 (9.8)	0.57	(0.38-0.86)
Sports/exercise		*P* trend = .260		
First tertile (0 to <2.06)	698 (84.8)	125 (15.2)	1.00	Reference
Second tertile (2.06 to <5.99)	559 (91.9)	49 (8.1)	0.59	(0.41-0.85)
Third tertile (5.99 to 81.38)	328 (87.2)	48 (12.8)	0.91	(0.63-1.32)
Transportation		*P* trend < .001		
First tertile (0 to <5.17)	517 (84.5)	95 (15.5)	1.00	Reference
Second tertile (5.17 to <12.85)	535 (87.3)	78 (12.7)	0.80	(0.57-1.13)
Third tertile (12.85 to 170.63)	533 (91.6)	49 (8.4)	0.49	(0.33-0.71)

Abbreviations: aOR, adjusted odds ratio; CI, confidence interval; LBP, low back pain; MET-h/wk, metabolic equivalent of task hours per week.
[a]The final model included maternal age, formal employment, education, parity, prepregnancy body mass index, and gestational diabetes mellitus.

pregnancy until three months postpartum.[30] Therefore, PA during pregnancy could serve as a protective factor against postpartum LBP than PA before pregnancy.

The present cohort study has several strengths. First, the data were prospectively collected from a large sample of women. Second, a comprehensive range of PA intensities and domains was measured using the validated PPAQ for Vietnamese pregnant women. Third, all plausible confounding factors from the literature have been accounted for in the statistical analysis. Notwithstanding these strengths, some limitations should be considered when interpreting the results of the study. The participants were recruited from urban and peri-urban cities in

Vietnam, and thus might not be representative of the entire population without the coverage of rural and remote areas. We were unable to establish causation in this prospective cohort study; hence, our findings support continued research, especially RCTs. Although we assessed pregnancy PA at 24 to 28 weeks of gestation, the self-reported questionnaire might not be able to capture the actual energy expenditure accurately.[16] Also, the data collectors were unable to conduct clinical examinations on LBP at mothers' private accommodation. Therefore, the LBP outcome was subjective according to the personal perception of mothers on health problems experienced after childbirth. Future studies should include more assessments of postpartum LBP over time regarding the duration and severity.

Conclusions

Relative to the lowest level of total PA, the highest PA level was associated with reduced odds of postpartum LBP (aOR = 0.55; 95% CI = 0.38-0.80; *P* trend = .002). The present study suggests that PA during the antenatal period may play a protective role against the development of LBP after childbirth. The finding has important implications for health care professionals to recommend and encourage pregnant women to participate in a variety of PA with different intensities and not to restrict activities without medical precautions during early pregnancy. Further research is needed to better understand the causal effect of PA in the antenatal period and postpartum LBP.

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Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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4.5 Results for Objective 5

Objective 5:

To determine the prevalence of periconceptional folic acid supplementation in Vietnam and ascertain the maternal characteristics associated with folic acid use.

The results addressing Objective 5 have been published in the following paper:

Ha, V. V. A., Zhao, Y., Binns, W. C., Pham, M. N., Nguyen, L. C., Nguyen, T. P., . . . Lee, H. A. (2019). Low Prevalence of Folic Acid Supplementation during Pregnancy: A Multicenter Study in Vietnam. *Nutrients, 11*(10). http://dx.doi.org/10.3390/nu11102347

The permission of the journal is attached in Appendix E.

Objective 5

nutrients

MDPI

Article

Low Prevalence of Folic Acid Supplementation during Pregnancy: A Multicenter Study in Vietnam

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Abstract: Periconceptional folic acid (FA) supplementation is recommended to prevent neural tube defects (NTDs), but little information is known about its use in Vietnam. It is important that FA supplements start to be taken when planning a pregnancy and continued through the first trimester to prevent NTDs, as the neural tube closes in the first month of pregnancy. However, FA supplementation in Vietnam is usually recommended to commence from the first antenatal visit, which is usually at 16 weeks, and very few women take FA before their first visit. This multicenter study aimed to determine the prevalence of FA supplement use and associated maternal characteristics in Vietnam. FA supplementation was assessed in 2030 singleton pregnant women between 2015 and 2016. In total, 654 (32.2%) women reported taking either supplements containing FA alone or multivitamins containing FA, and 505 (24.9%) reported correctly taking supplements containing FA alone. Women who were aged 30 years or over, had low education levels, had formal employment, and whose current pregnancy was first or unplanned were less likely to supplement with FA. Education programs are needed to encourage FA supplementation when contemplating pregnancy.

Keywords: folic acid; folate; pregnancy; dietary supplement; Vietnam

1. Introduction

Folate has a vital role in periods of rapid cell division and growth, especially during pregnancy [1]. It is difficult to measure folate intake from food because it exists in multiple forms of polyglutamates, which have varying levels of bioactivity and can easily be destroyed by sunlight, cooking and storage processes [2]. Folic acid (FA) is the synthetic form of folate that is used in supplements and food fortification. FA only contains the monoglutamate form, which is more biologically active than polyglutamates and is more efficient for preventing adverse health effects due to folate deficiency [2].

Folate deficiency is one of the most common micronutrient deficiencies during pregnancy, as the demand for folate is increased due to fetal growth and development. This can occur if the mother's dietary intake of folate is inadequate during pregnancy [3–6]. The cells' ability to methylate important compounds, including DNA, proteins and lipids, may be compromised by folate deficiency, leading to impaired cellular function [7]. The impairment of DNA synthesis or methylation reactions can adversely affect genomic responses (e.g., impaired gene expression, genomic instability and DNA damage), possibly preventing the proper closure of the neural tube [8]. Intervention studies have demonstrated the protective effects of FA supplementation against some types of neural tube defects (NTDs) [9–11] and congenital heart defects [12,13]. In order to prevent NTDs, the World Health Organization (WHO) recommends periconceptional folic acid supplementation, i.e., that all women take a daily supplement of 400 μg FA from the moment they plan to conceive until 12 weeks of gestation [14]. Following confirmation by the Medical Research Council Vitamin Study in 1991, most Western countries have recommended FA supplementation [15–17]. In Vietnam, the latest national guidelines on nutrition for pregnant women (in accordance with the Decision 776/2017-QD-BYT) were issued in 2017, which recommend supplementation with a daily dose of 400 μg FA during pregnancy. However, it is recommended that health professionals start the prescription of FA supplements to pregnant women at their first antenatal visit [18], which, on average, is at four months of pregnancy [19], i.e., later than the date recommended by the WHO [14].

Congenital anomalies that can be prevented by FA supplementation continue to be one of the top three causes of neonatal mortality in Vietnam [20]. The prevalence of anencephaly (a type of NTD) was estimated at 3.6 per 10,000 live births in Vietnam in 2010, which is higher than the corresponding data in the USA (1.9–2.3 per 10,000 live births during 1995–2011) and Thailand (0.8 per 10,000 live births during 2001–2012) [21,22]. The prevalence of NTDs declined slightly from 62.1 per 100,000 live births to 61.7 per 100,000 live births during the past 10 years (from 2007 to 2017), but was still higher than the corresponding rates in Singapore (12.4 per 100,000 live births) and Cambodia (45.3 per 100,000 live births) in 2017 [23]. The awareness of the importance of FA prior to conception and during early pregnancy is low, and little information is available on the coverage of supplementation with FA during this period [24–27]. Studies that reported the coverage of FA supplementation were not able to assess the frequency and duration of supplementation. In addition, no health promotion programs have been focused on FA supplementation to prevent NTDs at national and community level in Vietnam [28].

Previous studies have shown the relationships between some maternal characteristics and FA supplementation; however, to date, very few studies have been conducted in Asian countries [29–32]. For examples, the authors noted that maternal age, parity, and a planned pregnancy are associated with FA supplementation [30,32]. A randomized controlled trial in Vietnam reported several factors associated with the use of prenatal micronutrient supplements by pregnant women [26]. However, the study was conducted in only one rural province. Information on FA supplementation following the WHO recommendations in large-scale studies of Vietnamese pregnant women is lacking.

The objective of this multicenter study was to determine the prevalence of correct FA supplementation among Vietnamese pregnant women and to ascertain the maternal characteristics associated with FA use. The findings of this study are important to ensure that FA supplementation is conducted in accordance with the WHO recommendations and to update or develop national nutrition strategies on promoting FA supplementation during pregnancy, and thereby to reduce the burden of NTDs in Vietnam.

2. Materials and Methods

Details of the study design and recruitment procedure have been described elsewhere [33]. This study collected data at the first (baseline) interview (undertaken between August 2015 and July 2016) from a multicenter cohort study conducted in Hanoi, Hai Phong and Ho Chi Minh City. Among the 2248 eligible pregnant women recruited from six participating hospitals, 218 (9.7%) women declined to participate due to time constraints or planned relocation after delivery, and 2030 women (a response rate of 90.3%) agreed to participate and gave their informed consent. The inclusion criteria were as follows: (1) permanent residents in the study locations; (2) ≥18 years of age; (3) singleton pregnancy; and (4) able to read the information sheet and sign the consent form. The latter condition was not invoked, because there is almost universal literacy in Vietnam. Women with serious pre-existing health conditions such as cancer or ischemic heart disease were excluded after consultation with their medical doctors. This study was approved by the Human Research Ethics Committees of Curtin University, Australia (HR32/2015) and Hai Phong University of Medicine and Pharmacy, Vietnam (No. 05/HPUMPRB/2015). Confidentiality was assured and written informed consent was obtained from all participants.

Trained interviewers collected information on dietary supplementation via a validated Food Frequency Questionnaire at the baseline interview [4,34]. Upon receiving a positive response to the question "Have you ever taken FA/multivitamin supplements during this pregnancy?", further consumption details were solicited in terms of frequency (times per day/week/month), quantity (number of tablets taken each time) and duration (number of months/weeks/days taken during pregnancy) of supplementation. The information was cross-checked against their pregnancy health books and medical records whenever possible and subsequently reconfirmed with the participants if any discrepancy was found.

Given that the multivitamin supplements available in Vietnam contain FA, the first binary outcome variable of our study was defined as the correct use of either supplements containing FA alone or multivitamins containing FA (1 = correct use, 0 = incorrect use). The second binary outcome variable was defined as the correct use of supplements containing FA alone (1 = correct use, 0 = incorrect use). We did not intentionally assess the amount of FA taken, though prenatal supplements provided to pregnant women are required to provide at least 600 µg of FA daily (Circular No.43/2014/TT-BYT) [35]. In the Vietnamese market, common commercial prenatal supplements contain approximately 400 µg FA [36,37]. Therefore, for both outcomes, "correct use" in this study was defined as the daily use of a supplement containing 400 µg (or more) FA and commencement of supplementation from the time when the pregnancy was planned until 12 weeks of gestation (periconceptional period), following the WHO recommendations [14]. The "incorrect use" group included participants who never consumed FA from supplements, those who did not take the tablets on a daily basis, and those who took the tablets for a shorter duration than that recommended by the WHO.

Information on maternal characteristics was also obtained during the baseline interview, including age (<25, 25–29, and ≥30 years), formal employment (yes = office-based staff, service, sales or manufacturing workers and technicians; no = housewives, freelancers, unskilled farmers or planters, unemployed), education level (secondary school or lower; high school; college or university), parity (nulliparous; multiparous), pre-pregnancy weight, and whether or not the current pregnancy was planned (yes; no). Maternal height was measured using a stadiometer to the nearest 1 mm. The pre-pregnancy body mass index (BMI) value was then calculated using the self-reported pre-pregnancy weight and height, and classified according to the WHO criteria for Asian populations [38] as underweight (<18.5 kg/m^2), normal (18.5–22.9 kg/m^2), or overweight/obese (≥23 kg/m^2).

Descriptive statistics were used to summarize the maternal characteristics and estimate the prevalence of correctly taking (1) either supplements containing FA alone or multivitamins containing FA, and (2) supplements containing FA alone at a daily dose of 400 µg (or more). We then performed univariate (for each independent variable) and multivariable logistic regression analyses to separately determine the associations between the maternal characteristics and either of the two outcome variables. All independent variables considered in the full regression models (maternal age, education level, formal employment, pre-pregnancy BMI, parity, and planned pregnancy) were based on the available information and with reference to the literature as plausible factors affecting FA use [39–45]. The results are presented as crude (unadjusted), and adjusted odds ratios (ORs) with 95% confidence intervals (CIs). All statistical analyses were performed using Stata version 15.1 [46].

3. Results

The mean age of the 2030 women included in this study was 27.6 years (Standard Deviation (SD) = 5.3), and over one-third (35.6%) of women only attended secondary school or had a lower level of education. In addition, a total of 1393 women (68.6%) were formally employed. For 789 women (38.9%), it was their first pregnancy, and 601 women (29.7%) stated that they had not planned their current pregnancy. Before pregnancy, the prevalence of underweight and overweight/obese was 26.1% and 12.7%, respectively.

There were 522 (25.7%) Vietnamese pregnant women who took supplements containing FA alone, while 675 (33.2%) took either supplements containing FA alone or multivitamins containing FA when the pregnancy was planned until 12 weeks of gestation. Overall, 654 (32.2%) pregnant women reported correct use of either supplements containing FA alone or multivitamins containing FA, while 505 (24.9%) reported correct use of supplements containing FA alone during the periconceptional period (Table 1). Notably, 50 mothers (2.5%) never took any such dietary supplements from the time when the pregnancy was planned until 12 weeks of gestation.

Table 1. Periconceptional supplementation with folic acid (FA), Vietnam 2015–2016 (n = 2030).

Intakes	Either Supplements Containing FA Alone or Multivitamins Containing FA			Supplements Containing FA Alone		
	n (%)			*n* (%)		
Frequency	Daily	Non-daily	Did not use	Daily	Non-dail	Did not use
	1912 (94.2)	68 (3.3)	50 (2.5)	1702 (83.8)	67 (3.3)	261 (12.9)
Duration (when the pregnancy was planned)	Until 12 weeks of gestation	<12 weeks of gestation	Did not use	Until 12 weeks of gestation	<12 weeks of gestation	Did not use
	675 (33.2)	1305 (64.3)	50 (2.5)	522 (25.7)	1247 (61.4)	261 (12.9)
Correct use of FA	Correct use [1]	Incorrect use [2]		Correct use [1]	Incorrect use [2]	
	654 (32.2)	1376 (67.8)		505 (24.9)	1525 (75.1)	

FA = folic acid. [1] Includes daily users of supplements containing 400 µg (or more) FA who started supplementation when the pregnancy was planned and continued until 12 weeks of gestation. [2] Includes participants who never consumed FA from the supplements, who did not take the tablets on a daily basis, and who took the tablets for a shorter duration than that recommended by the WHO [14].

Tables 2 and 3 show the results of the univariate and multivariable logistic regression analyses. Inverse associations were evident between both correct supplement use outcomes and maternal age ≥30 years, secondary school, or a lower level of education, and nulliparous or unplanned pregnancy. Attending high school and having formal employment were only significantly associated with reduced odds of correctly taking supplements containing FA alone or multivitamins containing FA.

Table 2. Maternal characteristics associated with the correct use of supplements containing folic acid alone during the periconceptional period in Vietnam, 2015–2016 (n = 2030).

Characteristic	Correct Use [4] (n = 505) n (%)	OR (95% CI) [5]	p	OR (95% CI) [1,6]	p
Maternal age (years)					
<25	181 (35.8)	1		1	
25–29	188 (37.2)	0.90 (0.71, 1.14)	0.400	0.82 (0.63, 1.06)	0.128
≥30	136 (27.0)	0.63 (0.49, 0.82)	<0.001	0.57 (0.42, 0.76)	<0.001
Education level					
Secondary school or lower	133 (26.3)	0.60 (0.47, 0.77)	<0.001	0.61 (0.47, 0.79)	<0.001
High school	159 (31.5)	1.16 (0.91, 1.48)	0.226	1.11 (0.87, 1.43)	0.402
College or university	213 (42.2)	1		1	
Formal employment					
No	466 (30.6)	1		1	
Yes	1059 (69.4)	0.86 (0.69, 1.06)	0.166	0.81 (0.65, 1.02)	0.072

Table 2. *Cont.*

Characteristic	Correct Use [4] (*n* = 505) *n* (%)	OR (95% CI) [5]	*p*	OR (95% CI) [1,6]	*p*
Pre-pregnancy BMI (kg/m^2) [2]					
Underweight (<18)	139 (27.5)	1.05 (0.84, 1.33)	0.654	1.00 (0.79, 1.27)	0.984
Normal (18–22.9)	314 (62.2)	1		1	
Overweight/obese (≥23)	52 (10.3)	0.75 (0.54, 1.04)	0.083	0.87 (0.62, 1.22)	0.420
Parity					
Nulliparous	182 (36.0)	0.85 (0.69, 1.05)	0.133	0.62 (0.48, 0.78)	<0.001
Multiparous	323 (64.0)	1		1	
Planned pregnancy [3]					
No	113 (22.4)	0.61 (0.48, 0.77)	<0.001	0.60 (0.47, 0.76)	<0.001
Yes	392 (77.6)	1		1	

OR = Odds ratio. CI = confidence interval. BMI = body mass index. [1] From the full logistic regression model, which included maternal age, education level, formal employment, pre-pregnancy BMI, parity, and planned pregnancy. [2] Based on the cut-off for the Asian population [34]. [3] Missing data presents. [4] Includes the daily users of supplements containing 400 μg (or more) folic acid who started supplementation when the pregnancy was planned and continued until 12 weeks of gestation [14]. [5] Crude odds ratio. [6] Adjusted odds ratio.

Table 3. Maternal characteristics associated with the correct use of either supplements containing folic acid alone or multivitamins containing folic acid during the periconceptional period in Vietnam, 2015–2016 (*n* = 2030).

Characteristic	Correct Use [4] (*n* = 654) *n* (%)	OR (95% CI) [5]	*p*	OR (95% CI) [1,6]	*p*
Maternal age (years)					
<25	222 (33.9)	1		1	
25–29	259 (39.6)	1.07 (0.85, 1.33)	0.572	0.96 (0.75, 1.22)	0.720
≥30	173 (26.5)	0.64 (0.50, 0.81)	<0.001	0.63 (0.48, 0.83)	0.001
Education level					
Secondary school or lower	155 (23.7)	0.40 (0.32, 0.51)	<0.001	0.41 (0.32, 0.52)	<0.001
High school	183 (28.0)	0.79 (0.63, 0.99)	0.045	0.77 (0.61, 0.98)	0.032
College or university	316 (48.3)	1		1	
Formal employment					
No	217 (33.2)	1		1	
Yes	437 (66.8)	0.88 (0.72, 1.08)	0.228	0.76 (0.62, 0.94)	0.012
Pre-pregnancy BMI (kg/m^2) [2]					
Underweight (<18)	177 (27.1)	1.00 (0.81, 1.24)	0.997	0.94 (0.76, 1.18)	0.619
Normal (18–22.9)	416 (63.6)	1		1	
Overweight/obese (≥23)	61 (9.3)	0.62 (0.45, 0.84)	0.002	0.76 (0.55, 1.05)	0.093
Parity					
Nulliparous	250 (38.2)	0.96 (0.79, 1.16)	0.683	0.67 (0.54, 0.84)	0.001
Multiparous	404 (61.8)	1		1	
Planned pregnancy [3]					
No	149 (22.8)	0.60 (0.49, 0.75)	<0.001	0.62 (0.50, 0.77)	<0.001
Yes	505 (77.2)	1		1	

OR = Odds ratio. CI = confidence interval. BMI = body mass index. [1] From the full logistic regression analysis, which included maternal age, education level, formal employment, pre-pregnancy BMI, parity, and planned pregnancy. [2] Based on the cut-off for the Asian population [38]. [3] Missing data presents. [4] Includes the daily users of supplements containing 400 μg (or more) folic acid who started supplementation when the pregnancy was planned and continued until 12 weeks of gestation [14]. [5] Crude odds ratio. [6] Adjusted odds ratio.

4. Discussion

This is the first observational study to report the prevalence of correct FA supplementation as recommended by the WHO in Vietnamese women. It also provides an insight into the association between maternal characteristics and the correct supplemental intake of periconceptional FA as recommended by the WHO. Despite the WHO recommendations that women take a daily FA supplement from the time when the pregnancy was planned until 12 weeks of gestation, only 32.2% of women (*n* = 654) reported taking either supplements containing FA alone or multivitamins containing FA, and one in four women (24.9%, *n* = 505) reported taking supplements containing FA alone at a daily dose of 400 µg (or more), and started when the pregnancy was planned and continued until 12 weeks of gestation. These findings suggest that FA supplementation in accordance with the WHO recommendations remains a major challenge in Vietnam. Our findings on the low prevalence of correct FA supplementation (or high prevalence of incorrect FA supplementation) suggests that the Vietnam national guidelines on nutrition for pregnant women need to be adjusted according to the WHO recommendations, with an emphasis on correct timing (from when planning to conceive), correct amount (400 µg daily), and sufficient duration (12 weeks of gestation) of FA supplement use.

The observed prevalence of correct FA supplementation was lower than the results reported in China (67.7%), but higher than those reported in some high-income countries in Asia, such as Japan (20.5%) and Korea (10.3%) [30,32,44]. Compared with some Western countries, the prevalence of correct FA supplementation found in our study was lower than that found in Ireland (43.9%) between 2009 and 2013 but was comparable to corresponding data in New Zealand collected in 2010 (33.3%) [42,47]. The differences in FA supplementation prevalence among countries might result from variations in policy promotion and practical implementations.

Our study found that an education level of secondary school or lower education was associated with lower odds of correct FA supplementation. This finding is consistent with other studies in the literature, which reported that women with higher education levels were more likely to correctly take FA-containing supplements than those with low education level [31,39,40,48,49], and were at higher risk for severe maternal/infant outcomes [50]. Mothers with lower education levels may lack awareness, knowledge, and confidence regarding the WHO recommendations for FA supplementation. They might be unaware of the benefits of FA to the healthy fetal growth and development, and the potential susceptibility to, and severity of NTDs caused by folate deficiency [27]. Our study also showed that Vietnamese women aged 30 years or over were less likely to comply with the WHO recommendation, contrary to previous observations in Japan, the Netherlands, and Norway [32,39,47]. Reasons for the discrepancy may include a lack of awareness of older Vietnamese women concerning the role of FA in reducing the risk of NTDs, and their belief that dietary intake alone is sufficient to prevent the defect.

Studies in developed countries have shown that unskilled or semi-skilled manual workers or those without paid employment are less likely to consume FA from supplements [41,47,51]. Our study showed that Vietnamese women in formal employment were associated with lower odds of correctly taking either supplements containing FA alone or multivitamins containing FA as recommended by the WHO. In Vietnam, married women are expected to work, take care of children and other family (and family-in-law) members, and do housework [52]. It is thus plausible that they are more likely to forget or skip prescribed supplementation during pregnancy if they have a formal employment that is often full-time with a fixed work schedule [27]. The group with formal employment may be difficult to reach in community-based health promotion programs due to their tight schedules. Our findings suggest that workplace-based campaigns might be a more appropriate way to access to women in these latter groups.

If the current pregnancy was the first pregnancy or was unplanned, women might not be aware of the need for FA supplementation during pregnancy. Most Vietnamese women began supplementation only after becoming pregnant [27]. Likewise, our study found that women undergoing their first pregnancy and those with an unplanned pregnancy were associated with lower likelihoods of correctly taking FA-containing supplements. In view of the declining fertility rate in Vietnam from 3.6 to 2.0 births per woman during 1990–2017 [53], it is important to give greater attention to Vietnamese primigravida as well as women who have just married regarding the correct use of FA-containing supplements, because they may account for a large number of pregnancies in Vietnam in the near future.

Antenatal care services play an important role in promoting and implementing the correct use of FA-containing supplements. However, in Vietnam, only approximately 4% of women aged 15–49 years with a live birth within the past two years attended the first antenatal care visit during the first trimester [19] and very few mothers attend these services until the second trimester [54]. Additionally, health professionals may not be fully aware of FA recommendations in Vietnam [55]. Both a lack of antenatal care attendance and lack of full awareness in health professionals contribute to the low prevalence of correct FA supplementation during the periconceptional period. A randomized controlled trial on prenatal micronutrient supplements indicated a positive relationship between the number of community health worker visits and adherence to prenatal supplementation in Vietnam [26]. These findings suggest that the support of community health services may improve the prevalence of correct FA supplementation recommended by the WHO.

Due to the absence of a national birth defect surveillance system, there is a lack of complete information on NTDs that could be used to advocate for interventions on FA supplementation [56,57]. The Vietnam National Nutrition Strategy for 2011–2020 does not mention the promotion of FA supplementation [28]. As a result, Vietnamese women may not be aware of the critical role of FA during pregnancy and may therefore not adhere to FA prescriptions [27]. Indeed, the recent national guidelines on nutrition for pregnant women recommend FA supplementation; however, the supplementation is only recommended to commence from the first antenatal care visit [18], which is commonly at approximately 16 weeks of pregnancy in Vietnam [19]. Given that women do not typically plan their pregnancy and attend antenatal care later in gestation, women of reproductive age should be targeted in programs promoting FA supplementation. In addition, health communication through multiple media platforms may be tailored to motivate the imperative of FA supplementation and improve the utilization of antenatal health care services, particularly in women who were found to be less likely to supplement FA correctly in this study.

Our study was strengthened by its multicenter cohort design, relatively large representative sample size and high response rate (90%). Another notable strength is that we examined the details of the use of FA in pregnant Vietnamese women using two separate outcome variables, namely either the correct use of either supplements containing FA alone or multivitamins containing FA, and the correct use of supplements containing FA alone, in both bivariate and multivariable logistic regression analyses. There are several limitations to be considered when interpreting the results of this study. Regional effect was not assessed, because the sample size of one region was relatively small to enable a valid comparison between study regions. The present study recruited pregnant women who sought prenatal care at public hospitals but not those attending private health clinics. Little information is available concerning the contribution of private health facilities or private practitioners to reproductive health in Vietnam [54]. The brands of supplements were not assessed in detail, but we listed the most common brands during the interview. Finally, we did not evaluate FA intake from fortified food. Voluntary wheat flour fortification with FA has been promoted since 2003, but few products are available on sale. Rice is the staple food in Vietnam, yet its fortification remains difficult to implement in practice.

5. Conclusions

The prevalence of correct FA supplementation during pregnancy was found to be low in Vietnam. Less than one-third of women reported taking either supplements containing FA alone or multivitamins containing FA, in accordance with the WHO recommendations. Based on our findings, greater attention should be focused on mothers who are aged thirty years or over, have only attained an education level of secondary school or lower, are formally employed, and having their first pregnancy, together with promote pregnancy planning in couples. The results suggest that more campaigns promoting FA supplementation might help raise the consciousness and awareness of the importance of FA, especially in these vulnerable subgroups of women. In order to ensure the correctness of FA use among all Vietnamese women, the timing of FA supplementation commencement in preventing NTDs should be emphasized to a greater extent as part of these health campaigns.

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Chapter 5. General Discussion and Limitations

This thesis aimed to gain more insight into maternal weight changes (pre-pregnancy BMI, GWG, and postpartum weight retention), physical health (low back pain), physical activity from pregnancy to postpartum, and dietary supplementation in Vietnamese mothers within twelve months postpartum. In this chapter, the main findings, unusual findings, and study limitations are discussed, from a public health implication perspective.

5.1 Summary of Key Findings and Discussions

In line with its research objectives, this thesis firstly assessed the associations of pre-pregnancy BMI, and/or gestational weight gain (GWG) with postpartum weight retention. Second, we studied the relationship between physical activity during pregnancy and GWG. Third, we investigated the relationship between postpartum physical activity and postpartum weight retention. Fourth, we ascertained the association of physical activity during pregnancy with postpartum low back pain. Lastly, we studied the prevalence of periconceptional folic acid supplementation and maternal characteristics associated with folic acid use.

The key findings are summarised and discussed as below.

1. Associations of pre-pregnancy BMI and GWG with postpartum weight retention (Objective 1)

Overall, pre-pregnancy BMI and GWG were found as two significant factors influencing weight retention at twelve months postpartum. However, no interaction between pre-pregnancy BMI and GWG was observed in this study. Underweight women before pregnancy retained higher weight on average at twelve months postpartum than women with normal weight or overweight/obesity before pregnancy. This result suggests that women who are underweight before pregnancy might be more persuaded to 'eat-for-two' with a little consideration for their GWG limits. Women with excessive GWG (following the 2009 IOM recommendations) retained higher weight at twelve months postpartum on average than those with adequate GWG or inadequate GWG. The findings support the work of previous studies in other Asian countries, including Malaysia and China (Fadzil et al., 2018; X. He et al., 2014). It implies the importance of setting GWG limits to prevent the onset of obesity after childbirth in Vietnamese women.

2. Relationship between physical activity during pregnancy and GWG (Objective 2)

This thesis found that physical activity during pregnancy (i.e., high levels of moderate-to-vigorous intensity, household or caregiving, and occupational activities) was a protective factor of high GWG, and longer sitting time was associated with higher GWG. A theoretical risk, which too much physical activity could cause too little GWG, was not observed in our study and is unlikely ever a real-world risk (Collings et al., 2020). The findings on the relationship between prenatal physical activity and GWG were in line with several studies in China and the USA (Jiang et al., 2012; Kraschnewski et al., 2013; Xiang et al., 2019). Another study of only Hispanic women in the USA, however, did not observe the relationship between physical activity during pregnancy and GWG, except for occupational activities. This inconsistency may be due to the differences in study population characteristics, including education, age, and ethnicity. Given that sitting and household or caregiving are dominant in Asian women's routine, promoting physical activity integrated with the supportive role of household or caregiving is an essential aspect of interventions on appropriate GWG in Vietnam. The result also suggests that developing interventions on GWG in Vietnam needs to target both the reduction of sitting time and the increase of other physical activity at the same time.

3. Relationship between postpartum physical activity and weight retention within twelve months postpartum (Objective 3)

This thesis revealed that both higher level of total and light-intensity physical activity at three months postpartum were associated with lower weight retention within twelve months postpartum. In accordance with our present results, a previous study in Malaysia also reported the significant association of postpartum physical activity with postpartum weight retention (Fadzil et al., 2018). During the early postpartum months, women seldom reported participating in sports/exercise and occupational activities in Vietnam (probably due to six-month maternity leave). Asian women typically spend less time on moderate-to-vigorous-intensity physical activity in the postpartum period compared with other ethnic groups (Richardsen et al., 2016). Our results suggest that postpartum weight can be managed by participating in habitual light-intensity physical activity in the early postpartum period. The effects of moderate-intensity physical activity and the four physical activity domains (i.e. household/caregiving, transportation, occupational physical activity, and sports/exercise) on one-year postpartum weight retention were not observed by our study, unlike findings obtained from other Western countries previously (Ng et al., 2014; Oken et al., 2007; Østbye, Peterson, Krause, Swamy, & Lovelady, 2011).

4. Prevalence of postpartum low back pain and its association with physical activity during pregnancy in Vietnam (Objective 4).

This study provides evidence that higher levels of total physical activity and various intensities and domains during pregnancy are associated with a lower risk of low back pain in the early postpartum months. Our findings are moderately consistent with those previously reported in general populations (Kopec et al., 2004; R. Shiri & Falah-Hassani, 2017). A study in Sweden indicated the positive relationship between having a history of heavy work before pregnancy and twelve-month postpartum low back pain (Ostgaard & Andersson, 1992). However, up to our best knowledge, no similar reports on the association of prenatal physical activity and postpartum low back pain have been found in Asia. Physical activity during pregnancy has been recommended for the prevention of adverse maternal and infant outcomes (Dipietro et al., 2019; Domenjoz, Kayser, & Boulvain, 2014; Kraschnewski et al., 2013). Prenatal physical activity may be at lower levels, compared to that prior to pregnancy (Coll et al., 2016). Therefore, more work will need to be done to determine the protective role of physical activity during pregnancy on postpartum low back pain, particularly in Asian populations. From an objective point of view, continued research should include more assessments of low back pain throughout postpartum months regarding its duration and severity.

5. Prevalence of folic acid supplementation in the periconceptional period and maternal factors associated with folic acid use (Objective 5).

The notably low percentage of women taking folic acid supplementation in the periconceptional period in this cohort of Vietnamese women is concerning. This low rate was in line with those observed in other Asian studies. There was also evidence to suggest the less likelihood of supplement folic acid among women aged 30 years or over, having low educational levels, or having formal employment. Additionally, women whose current pregnancy was first or unplanned were less likely to take folic acid supplements, following the WHO recommendations. These findings accord with earlier observations in other Asian and Western countries. These results may have significant implications for a need of more campaigns on periconceptional folic acid supplementation in Vietnam, especially in these vulnerable subgroups of women. The new results obtained from the additional regression analyses, which removed 601 (29.7%) women who did not plan for their current pregnancy, were still in line with the original results based on the full sample.

5.2 Study Limitations

This study has several limitations:

The generalisability of the results of this thesis is subject to certain limitations. First, our study participants were predominantly from urban and semi-urban areas. Second, the study did not include pregnant women in private health facilities and general practitioners. Compared to those giving birth at public facilities, more women stay at least 3 days at private facilities for delivery (75% private versus 70.4% public) (General Statistics Office and UNICEF, 2015). Caesarean deliveries are more prevalent at private hospitals (45%) than public hospitals (32.6%) (General Statistics Office and UNICEF, 2015). These data suggest that different maternal characteristics between public and private facilities in Vietnam. However, information on reproductive health services provision in the private sector, including the characteristics of Vietnamese women using such services, is not available, probably owing to the low proportion of women giving birth at private health facilities (3.9%), in comparison with their counterparts at public health facilities (89.7%) (General Statistics Office and UNICEF, 2015).

Data on physical activity and dietary intake were self-reported, although the instruments used had been validated for Vietnamese and information were collected by face-to-face interviews. Self-reported pre-pregnancy weight might also lead to a lack of accuracy. However, a high level of concordance between measured weight and self-reported pre-pregnancy weight has been shown, particularly in examining their associations with several pregnancy outcomes (Bannon et al., 2017; Han, Abrams, Sridhar, Xu, & Hedderson, 2016).

As part of cohort study disadvantages, the associations we observed might be distorted by confounding effects (Sedgwick, 2013). Although potential confounders with reference to the literature were adjusted in our multivariable regression analyses, maternal diet in the postpartum period was not included in the analyses because the data was not available. Furthermore, the sample size of one studied region was relatively small to assess regional effect.

Furthermore, information on prenatal physical activity and dietary intake were only interviewed in the middle months of pregnancy. It has been unknown if the respondents had changed their levels of physical activity or dietary intake in the later months of pregnancy.

Lastly, the brands of dietary supplements were not investigated in details in the analysis. However, the interviewers listed common brands during the interviews with participated women. We were also unable to evaluate folic acid intake from fortified food because fortified products are limited, and folic acid fortification policy is voluntary (Dijkhuizen, Wieringa, Soekarjo, Van, & Laillou, 2013). Besides, folic acid intake was not measured during the preconception period, making it difficult to address folic acid supplementation in relation to pregnancy planning.

Chapter 6. Conclusion and Recommendations

6.1 Conclusion

This thesis addresses the five objectives, as stated in Chapter 1, Section 1.3. Its findings contribute to the body of knowledge on maternal weight changes from pregnancy to one-year postpartum in Vietnamese women. In addition, its results support the protective role of prenatal and postnatal physical activity against the occurrence or likelihood of maternal health issues, including excessive gestational weight gain (GWG), postpartum weight retention and obesity, and low back pain. This thesis, furthermore, reported a low prevalence of periconceptional folic acid supplementation in this studied cohort and explored several maternal characteristics associated with the low supplementation. In summary, these findings will be beneficial for developing and implementing guidelines for public health professionals working for the mother-infant dyad in Vietnamese population with a potential to be extended to other Asian populations.

6.2 Recommendations

6.2.1 Future Practice

In Vietnam, marriage registration is maintained by the People’s Committee at wards or communes where the hokhau (residential confirmation book) of either bride or groom is kept. The People’s Committees in wards or communes are also responsible for administrating communal health centres, which operate national health programs at ward/commune level. Therefore, women who register for marriage certificate at the councils, can be informed about sufficient folic acid supplementation during the periconceptional period. This early information may help prevent neural tube defects in babies. In addition, it is necessary to refer women to community health care centres for further recommendations or guidelines regarding better control of preconception weight and GWG. These referrals for services will require effectiveness assessments as they necessitate strong collaboration and supports from many stakeholders.

Healthcare professionals should follow the 2009 IOM guidelines and promote healthy GWG based on women's pre-pregnancy BMI categories (following the 2009 IOM recommendations) and continue to encourage folic acid supplementation in the periconceptional period.

It has been revealed by the thesis that prenatal and postnatal physical activity subtypes can contribute to controlling maternal weight during pregnancy and in the postpartum period. Healthcare providers should promote the benefits of physical activity during pregnancy and in the postpartum period in relation to controlling appropriate GWG, maintaining healthy postpartum weight retention, and preventing the occurrence of postpartum low back pain, aiming to improve women's awareness of these benefits and to encourage them maintaining physical activity during pregnancy and continuing in postpartum period.

6.2.2 Future Research

Based on the scope of this thesis and its limitations, further research is recommended to provide better understanding to the benefits of controlling appropriate GWG and postpartum weight retention, participating in physical activity, and periconceptional folic acid supplementation on mother and offspring health:

- The present study investigated maternal health and weight together with their associated factors by following mothers from pregnancy until twelve months postpartum. Further cohort studies with longer follow-up periods (e.g., from getting married or planning pregnancy until two years) are suggested to gain a better understanding to the impacts of factors associated with maternal health, particularly those modifiable factors.
- The present thesis only measured maternal participations in physical activity at three months postpartum. Future studies are recommended to repeatedly measure maternal participation in physical activity at different time points after childbirth (e.g., when returning to work) with corresponding weight retention. Such studies can be used to determine if maternity leave can contribute to changes in postpartum physical activity and then postpartum weight retention.
- Future studies should recruit women in both rural and urban areas. It is important to examine if urban women differ from rural women in terms of

physical activity, weight gain during pregnancy, postpartum weight retention, and periconceptional folic acid supplementation.

- Information on women utilising private maternal care services has been scarce in Vietnam; therefore, future research should strive to obtain data related to service utilisation and consumer behaviours in private health facilities. Studies that include pregnant women utilising both public and private health facilities would allow researchers to determine differences in maternal health outcomes between these two sectors.
- Future studies that address the role of postpartum diet on maternal health are needed, given that maternal diet in the postpartum period has been suggested as one of the factors associate with energy balance.
- Clinical measures of postpartum low back pain and psychometric assessment of mothers' perception on their health problems after childbirth should be further undertaken to assess the association between maternal participation on physical activity and low back pain in the postpartum period.
- This study indicated the protective role of physical activity during pregnancy on low back pain after delivery. We recommend more studies on physical activity in the postpartum period, which would provide insights of the time-varying effect (during pregnancy and in the postpartum period) of physical activity on low back pain after delivery and assist to develop evidence-based interventions on improving maternal physical health in Vietnam.
- Randomised controlled trials can demonstrate the impacts of physical activity during pregnancy and in the postpartum period on GWG, postpartum weight retention and maternal health (including low back pain).
- It is important to continue the investigation of folic acid supplementation in the periconceptional period among women with different backgrounds and characteristics in Vietnam in order to assess the effectiveness of health programs promoting this supplementation and modify these programs swiftly if necessary.

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Appendix A. Ethical Approvals

Memorandum

To	Prof Andy H Lee, Public Health
From	Professor Peter O'Leary, Chair Human Research Ethics Committee
Subject	Protocol Approval Application 4873
Date	15 December 2014
Copy	Prof Colin W Binns, Public Health Dr Li Tang, Public Health Dr Cat Van Duong, Public Health

Thank you for your application submitted to the Human Research Ethics Comr "*Maternal lifestyle and nutritional status in relation to pregnancy and child he prospective cohort study in Vietnam*". Your application has been reviewed by the conditions detailed below:

1. Please simplify the language used in the participant information translation.
2. Amend your participant information sheet and consent form to a use of de-identified data.
3. Data storage needs to be stored on the Curtin University R: drive
4. Provide copies of letters of approval from hospitals granting acce records.

Please do not commence your research until your response to the above co clearance has been granted by the Human Research Ethics Committee.

Please note the following:

- Reference Number: **4873.** *Please quote this number in any future co.*
- The following standard statement **must be** included in the informatio
  This study has been approved by the Curtin University Human Resear HRxxxx). The Committee is comprised of members of the public, ac carers. If needed, verification of approval can be obtained either by Research Ethics Committee, c/- Office of Research and Developme Perth 6845 or by telephoning 9266 9223 or by emailing hrec@curtin.ec
- It is the policy of the HREC to conduct random audits on a percentage o be conducted at any time after the project starts. In cases where the HRE adverse events, or where participants may be especially vulnerable, the H to provide an outcomes report, including information on follow-up of part

Yours sincerely

Professor Peter O'Leary
Chair Human Research Ethics Committee

MINISTRY OF HEALTH **HAIPHONG UNIVERSITY OF MEDICINE AND PHARMACY**	**SOCIALIST REPUBLIC OF VIETNAM** **Independence-Freedom-Happiness**

No: 05 /HPUMPRB
Issue: Approval of HPUMPRB

CERTIFICATE OF APPROVAL

Basing on the Decision No. 580A/QD-YHP on June 22nd 2012 by The Rector of Haiphong Medical University on the foundation of the HPMU Review Board and secretariat for reviewing the ethical issues in Bio-medical researches;

Basing on the Decision No. 2153/2013/QĐ-TTg on November 11th 2013 by Prime Minister on rename of Haiphong Medical University to Haiphong University of Medicine and Pharmacy.

Basing on the Agreed Minutes (enclosured) of the Haiphong University of Medicine and Pharmacy Review Board (HPUMPRB) and the ratification and assessment committee on August 20th 2015.

HAIPHONG UNIVERSITY OF MEDICINE AND PHARMACY
REVIEW BOARD (HPMURB)
IN BIO-MEDICAL RESEARCH

approves the ethical issues of the following research proposal:

- Research title: ***Maternal lifestyle and nutritional status in relation to pregancy and child health outcomes: A multi-centre prospective cohort study in Viet Nam***
- Principal Investigators: ***Prof. AnDy Lee***
  Chu Khac Tan, MD
  Nguyen Cong Luat, MD
  Nguyen Hoang Phung, MD
  Ha Vo Van Anh, MD
- Research Institution: ***Curtin University, Australiaa***
- Site for research: Vietnam
- Research Period: From August 2015 to December 2017

Date of approval: August 25th, 2015

IRB Chair **Haiphong University** **of Medicine and Pharmacy**	**Rector** **Haiphong University** **of Medicine and Pharmacy**
Assoc.Prof. Tran Quang Phuc, M.D, PhD	**Prof. Pham Van Thuc, M.D, PhD**

Appendix B. Declaration of Authorship

18 May 2020,

To Whom It May Concern:

I, A/Professor Yun Zhao, contributed as a main supervisor of PhD candidate Vo Van Anh Ha. I had ongoing close involvement with the research, including contribution to the study design, data analysis, discussion of the findings, and tentative papers, revising the manuscripts, and giving comments to improve the following publications. As a co-author, I endorse that this level of contribution by the candidate indicated below is appropriate:

Vo Van Anh Ha conceived the study design and research objectives in consultation with YZ, AHL, CWB, and NMP, implemented data collection, statistical analysis, interpreted the findings, wrote the first drafts of the following manuscripts, and made revisions using input from all authors.

Ha, A. V. V., Zhao, Y., Pham, N. M., Nguyen, C. L., Nguyen, P. T. H., Chu, T. K., Tang, H. K., Binns, C. W., Lee, A. H. (2019). Postpartum weight retention in relation to gestational weight gain and pre-pregnancy body mass index: A prospective cohort study in Vietnam. *Obesity Research & Clinical Practice, 13*(2), 143-149. http://dx.doi.org/https://doi.org/10.1016/j.orcp.2019.02.001

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Ha, A. V. V., Zhao, Y., Binns, C. W., Pham, N. M., Nguyen, C. L., Nguyen, P. T. H., Chu, T. K., Lee, H. A. (2019). Low Prevalence of Folic Acid Supplementation during Pregnancy: A Multicenter Study in Vietnam. *Nutrients 11*(10) http://dx.doi.org/10.3390/nu11102347

A/Professor Yun Zhao (Signature of Co-author).

Vo Van Anh Ha (Signature of Candidate)

18 May 2020,

To Whom It May Concern:

I, Professor Andy H. Lee, contributed as an associate supervisor of PhD candidate Vo Van Anh Ha. I had ongoing close involvement with the research, including contribution to the study design, data analysis, discussion of the findings, and tentative papers, revising the manuscripts, and giving comments to improve the following publications. As a co-author, I endorse that this level of contribution by the candidate indicated below is appropriate:

Vo Van Anh Ha conceived the study design and research objectives in consultation with YZ, AHL, CWB, and NMP, implemented data collection, statistical analysis, interpreted the findings, wrote the first drafts of the following manuscripts, and made revisions using input from all authors.

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Professor Andy H. Lee (Signature of Co-author)

Vo Van Anh Ha (Signature of Candidate)

18 May 2020,

To Whom It May Concern

I, Professor Colin W. Binns, contributed as an associate supervisor of PhD candidate Vo Van Anh Ha. I had ongoing close involvement with the research, including contribution to the study design, data analysis, discussion of the findings, and tentative papers, revising the manuscripts, and giving comments to improve the following publications. As a co-author, I endorse that this level of contribution by the candidate indicated below is appropriate:

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John Curtin Distinguished Professor Colin W. Binns (Signature of Co-author)

18 May 2020,

To Whom It May Concern

I, Dr. Ngoc Minh Pham, contributed as an associate supervisor of PhD candidate Vo Van Anh Ha. I had ongoing close involvement with the research, including contribution to the discussion of the findings, and tentative papers, revising the manuscripts, and giving comments to improve the following publications. As a co-author, I endorse that this level of contribution by the candidate indicated below is appropriate:

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Dr. Ngoc Minh Pham (Signature of Co-author)

Vo Van Anh Ha (Signature of Candidate)

18 May 2020

To Whom It May Concern:

I, Phung Thi Hoang Nguyen, provided advice on the study design and instruments, implemented data collection, and commended draft manuscripts of the following publications. As a co-author, I endorse that this level of contribution by the candidate indicated below is appropriate:

Vo Van Anh Ha conceived the study design and research objectives in consultation with YZ, AHL, CWB, and NMP, implemented data collection, statistical analysis, interpreted the findings, wrote the first drafts of the following manuscripts, and made revisions using input from all authors.

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Phung Thi Hoang Nguyen (Signature of Co-author)

Vo Van Anh Ha (Signature of Candidate)

18 May 2020,

To Whom It May Concern

I, A/Professor Kim Hong Tang, provided advice on data collection, and commended the draft manuscript of the following publication. As a co-author, I endorse that this level of contribution by the candidate indicated below is appropriate:

Vo Van Anh Ha conceived the study design and research objectives in consultation with YZ, AHL, CWB, and NMP, implemented data collection, statistical analysis, interpreted the findings, wrote the first draft of the following manuscript, and made revisions using input from all authors.

Ha, A. V. V., Zhao, Y., Pham, N. M., Nguyen, C. L., Nguyen, P. T. H., Chu, T. K., Tang, H. K., Binns, C. W., Lee, A. H. (2019). Postpartum weight retention in relation to gestational weight gain and pre-pregnancy body mass index: A prospective cohort study in Vietnam. *Obesity Research & Clinical Practice, 13*(2), 143-149. http://dx.doi.org/https://doi.org/10.1016/j.orcp.2019.02.001

A/Professor. Kim Hong Tang (Signature of Co-author).

Vo Van Anh Ha (Signature of Candidate)

18 May 2020

To Whom It May Concern:

I, Tan Khac Chu, provided advice on the study design and instruments, implemented data collection, and commended draft manuscripts of the following publications. As a co-author, I endorse that this level of contribution by the candidate indicated below is appropriate:

Vo Van Anh Ha conceived the study design and research objectives in consultation with YZ, AHL, CWB, and NMP, implemented data collection, statistical analysis, interpreted the findings, wrote the first drafts of the following manuscripts, and made revisions using input from all authors.

Ha, A. V. V., Zhao, Y., Pham, N. M., Nguyen, C. L., Nguyen, P. T. H., Chu, T. K., Tang, H. K., Binns, C. W., Lee, A. H. (2019). Postpartum weight retention in relation to gestational weight gain and pre-pregnancy body mass index: A prospective cohort study in Vietnam. *Obesity Research & Clinical Practice, 13*(2), 143-149. http://dx.doi.org/https://doi.org/10.1016/j.orcp.2019.02.001

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Tan Khac Chu (Signature of Co-author)

Vo Van Anh Ha (Signature of Candidate)

18 May 2020

To Whom It May Concern:

I, Dr. Cong Luat Nguyen, provided advice on the study design and instruments, implemented data collection, and commended draft manuscripts of the following publications. As a co-author, I endorse that this level of contribution by the candidate indicated below is appropriate:

Vo Van Anh Ha conceived the study design and research objectives in consultation with YZ, AHL, CWB, and NMP, implemented data collection, statistical analysis, interpreted the findings, wrote the first drafts of the following manuscripts, and made revisions using input from all authors.

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Dr. Cong Luat Nguyen (Signature of Co-author)

Vo Van Anh Ha (Signature of Candidate)

Appendix C. Permission from Publisher – Elsevier

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Postpartum weight retention in relation to gestational weight gain and pre-pregnancy body mass index: A prospective cohort study in Vietnam

Author: Anh Vo Van Ha,Yun Zhao,Ngoc Minh Pham,Cong Luat Nguyen,Phung Thi Hoang Nguyen,Tan Khac Chu,Hong Kim Tang,Colin W. Binns,Andy H. Lee

Publication: Obesity Research & Clinical Practice

Publisher: Elsevier

Date: March–April 2019

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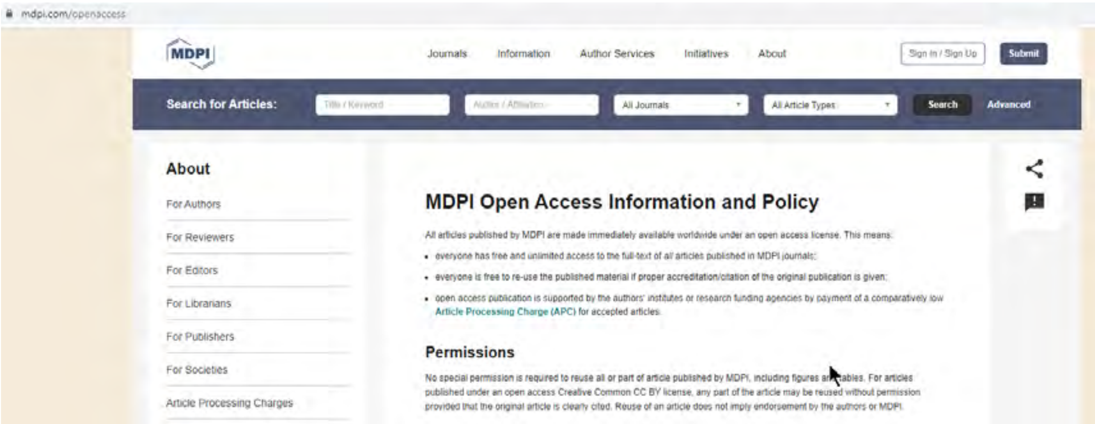

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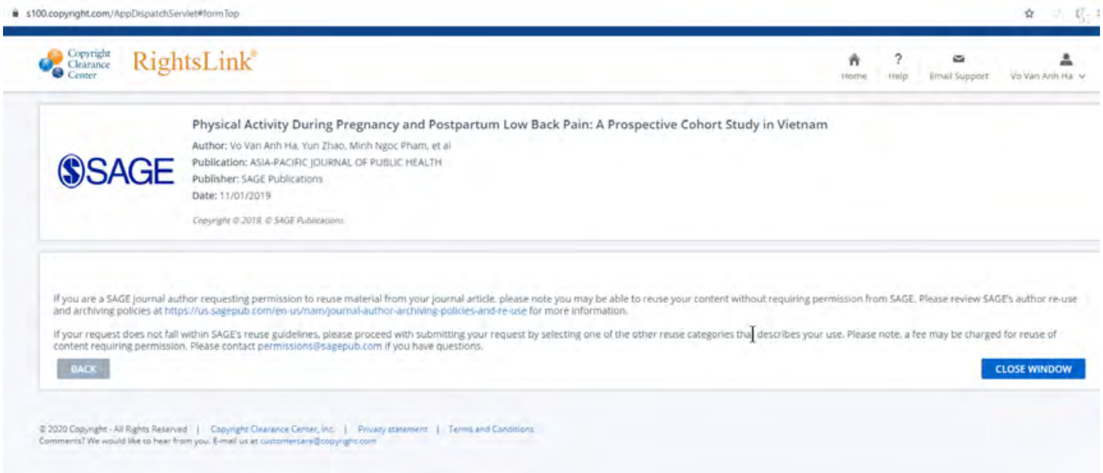
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Physical Activity During Pregnancy and Postpartum Low Back Pain: A Prospective Cohort Study in Vietnam

Author: Vo Van Anh Ha, Yun Zhao, Minh Ngoc Pham, et al

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Appendix G. Questionnaires

G1. Baseline Questionnaire (English version)

A1. Date of interview: ______/_____/_____(DD/MM/YYYY)

A2. Interviewer's name: ____

A3. Mother's name: ____

A4. Mother's address: ____

A5. Mother's phone number: ____

A6. Husband's name: ____

A7. Husband's phone number: _____________________________________

A8. Duration of pregnancy _____________weeks

DEMOGRAPHIC INFORMATION

No.	Questions	Answers
B1.	What is your age (years)?	……/……/……(DD/MM/YYYY) (_________ years)
B2.	What is your marital status?	1. Never married 2. Married 3. Widowed /Divorced/Separated
B3.	What is your main occupation? (Tick only one, do not read the list)	1. Farmer 2. Worker 3. Office staff 4. Housewife 5. Other (please specify): …………
B4.	What is your highest level of education you have completed?	1. No schooling 2. Primary school 3. Secondary school 4. High school 5. College or vocational school 6. University or higher

A. ANTHROPOMETRICS

No.	Questions	Answers
C1.	Mother's height?	_ _ _ . _ cm
C2.	Mother's weight?	_ _ _ . _ kg

B. MATERNAL HISTORY

No.	Questions	Answers
C1.	What was your weight before this pregnancy?	_ _ _ . _ kg
C2.	What was your weight at the first antenatal visit?	_ _ _ . _ kg (at _ _ weeks of gestation)
C3.	What was the date of your last menstrual period (if remembered)	_________/_______/_________(DD/MM/YYYY)
C4.	What is the date you are expected to give birth(if known)?	_________/_______/_________(DD/MM/YYYY)
C 5.	How many children do you have, except for this current pregnancy?	1. None 2. Yes → Please specify…………………
C 6	Was this current pregnancy planned	1. No 2. Yes
C 7.	Do you have hypertension before this pregnancy?	1. No 2. Yes → 2a: Systolic …………mmHg 2b: Diastolic = ……….mmHg 9. Unknown
C 8.	Have you ever been diagnosed with gestational diabetes mellitus in this pregnancy?	1. No 2. Yes
C 9.	Have you ever had a stillbirth in your previous pregnancy?	1. No 2. Yes
C 10.	Have you ever had preeclampsia in your previous pregnancy?	1. No 2. Yes
C 11.	Have you ever had preterm birth in your previous pregnancy?	1. No 2. Yes
C 12.	Have you ever had macrosomia (>4000 g) in your previous pregnancy and childbirth?	1. No 2. Yes
C 13.	Have you ever had abortion in your previous pregnancy?	1. No 2. Yes
C 14.	Have you ever had a caesarean section in your previous pregnancy?	1. No 2. Yes
C 15.	Do you have a history of polycystic ovary syndrome?	1. No 2. Yes
C 16.	Do you have a history of renal disease?	1. No 2. Yes
C 17.	Do you have a history of other chronic diseases?	1. No 2. Yes → Please specify: …………………

E. PHYSICAL ACTIVITY (during pregnancy)

It is very important that you recall your physical activity. There are no right or wrong answers. We just want to know what activities you have spent during the previous 3 months and their frequencies.

During the previous 3 months, when you are NOT at work, how often do you usually spend:

E1. Preparing meals (cook, set table, wash dishes) None ..... 1 Less than 1/2 hour per day ..... 2 1/2 to almost 1 hour per day ..... 3 1 to almost 2 hours per day ..... 4 2 to almost 3 hours per day ..... 5 3 or more hours per day 6	E2. Dressing, bathing, feeding children while you are sitting None ..... 1 Less than 1/2 hour per day ..... 2 1/2 to almost 1 hour per day ..... 3 1 to almost 2 hours per day ..... 4 2 to almost 3 hours per day ..... 5 3 or more hours per day 6
E3. Dressing, bathing, feeding children while you are standing None ..... 1 Less than 1/2 hour per day ..... 2 1/2 to almost 1 hour per day ..... 3 1 to almost 2 hours per day ..... 4 2 to almost 3 hours per day ..... 5 3 or more hours per day 6	E4. Playing with children while you are sitting or standing None ..... 1 Less than 1/2 hour per day ..... 2 1/2 to almost 1 hour per day ..... 3 1 to almost 2 hours per day ..... 4 2 to almost 3 hours per day ..... 5 3 or more hours per day 6
E5. Playing with children while you are walking or running None ..... 1 Less than 1/2 hour per day ..... 2 1/2 to almost 1 hour per day ..... 3 1 to almost 2 hours per day ..... 4 2 to almost 3 hours per day ..... 5 3 or more hours per day 6	E6. Carrying children None ..... 1 Less than 1/2 hour per day ..... 2 1/2 to almost 1 hour per day ..... 3 1 to almost 2 hours per day ..... 4 2 to almost 3 hours per day ..... 5 3 or more hours per day 6
E7. Taking care of an older adult None ..... 1 Less than 1/2 hour per day ..... 2 1/2 to almost 1 hour per day ..... 3 1 to almost 2 hours per day ..... 4 2 to almost 3 hours per day ..... 5 3 or more hours per day 6	E8. Sitting and using a computer or writing, while not at work None ..... 1 Less than 1/2 hour per day ..... 2 1/2 to almost 1 hour per day ..... 3 1 to almost 2 hours per day ..... 4 2 to almost 3 hours per day ..... 5 3 or more hours per day 6

E9. Watching TV or a video None ....1 Less than 1/2 hour per day......................2 1/2 to almost 2 hour per day ....3 2 to almost 4 hours per day.....................4 4 to almost 6 hours per day ....5 6 or more hours per day 6	E10. Sitting and reading, talking, or on the phone, while not at work None ....1 Less than 1/2 hour per day......................2 1/2 to almost 2 hour per day ....3 2 to almost 4 hours per day.....................4 4 to almost 6 hours per day.....................5 6 or more hours per day 6
E11. Playing with pets None ....1 Less than 1/2 hour per day......................2 1/2 to almost 1 hour per day ....3 1 to almost 2 hours per day.....................4 2 to almost 3 hours per day ....5 3 or more hours per day 6	E12. Light cleaning (make beds, laundry, iron, put things away) None ....1 Less than 1/2 hour per day......................2 1/2 to almost 1 hour per day ....3 1 to almost 2 hours per day.....................4 2 to almost 3 hours per day.....................5 3 or more hours per day 6
E13. Shopping (for food, clothes, or other items) None ....1 Less than 1/2 hour per day......................2 1/2 to almost 1 hour per day ....3 1 to almost 2 hours per day.....................4 2 to almost 3 hours per day ....5 3 or more hours per day 6	E14. Heavier cleaning (vacuum, mop, sweep, wash windows) None ....1 Less than 1/2 hour per week ....2 1/2 to almost 1 hour per week.................3 1 to almost 2 hours per week ....4 2 to almost 3 hours per week..................5 3 or more hours per week 6
E15. Mowing lawn using a walking mower, raking, gardening None ....1 Less than 1/2 hour per week ....2 1/2 to almost 1 hour per week.................3 1 to almost 2 hours per week ....4 2 to almost 3 hours per week..................5 3 or more hours per week 6	

Going Places…

During last 3 months, how often do you usually spend:

E16. Walking slowly to go to places (such as to the bus, work, visiting) NOT for fun or exercise None ....1 Less than 1/2 hour per day.....................2 1/2 to almost 1 hour per day ....3 1 to almost 2 hours per day....................4 2 to almost 3 hours per day ....5 3 or more hours per day 6	E17. Walking quickly to go to places (such as to the bus, work, visiting), NOT for fun or exercise None ....1 Less than 1/2 hour per day.....................2 1/2 to almost 1 hour per day ....3 1 to almost 2 hours per day....................4 2 to almost 3 hours per day....................5 3 or more hours per day 6
E18. Riding a bicycle to go places (such as the bus, work, or school) NOT for fun or exercise None ....1 Less than 1/2 hour per day.....................2 1/2 to almost 1 hour per day ....3 1 to almost 2 hours per day....................4 2 to almost 3 hours per day ....5 3 or more hours per day 6	E19. Driving or riding in a motorbike or bus None ....1 Less than 1/2 hour per day.....................2 1/2 to almost 1 hour per day ....3 1 to almost 2 hours per day....................4 2 to almost 3 hours per day....................5 3 or more hours per day 6

For Fun or Exercise…

During the previous 3 months, how often do you usually spend:

E20. Walking slowly for fun or exercise None ....1 Less than 1/2 hour per week..................2 1/2 to almost 1 hour per week................3 1 to almost 2 hours per week ....4 2 to almost 3 hours per week.................5 3 or more hours per week 6	E21. Walking more quickly for fun or exercise None ....1 Less than 1/2 hour per week ....2 1/2 to almost 1 hour per week................3 1 to almost 2 hours per week ....4 2 to almost 3 hours per week.................5 3 or more hours per week 6
E22. Walking quickly up hills for fun or exercise None ....1 Less than 1/2 hour per week..................2 1/2 to almost 1 hour per week................3 1 to almost 2 hours per week 4	E23. Jogging None ....1 Less than 1/2 hour per week ....2 1/2 to almost 1 hour per week................3 1 to almost 2 hours per week 4

2 to almost 3 hours per week..................5 3 or more hours per week.......................6	2 to almost 3 hours per week..................5 3 or more hours per week.......................6
E24. Prenatal exercise class None ....1 Less than 1/2 hour per week...................2 1/2 to almost 1 hour per week.................3 1 to almost 2 hours per week ....4 2 to almost 3 hours per week..................5 3 or more hours per week.......................6	E25. Swimming None ....1 Less than 1/2 hour per week...................2 1/2 to almost 1 hour per week.................3 1 to almost 2 hours per week ....4 2 to almost 3 hours per week..................5 3 or more hours per week.......................6
E26. Dancing None ....1 Less than 1/2 hour per week...................2 1/2 to almost 1 hour per week.................3 1 to almost 2 hours per week ....4 2 to almost 3 hours per week..................5 3 or more hours per week.......................6	E27. ____________________ Name of Activity None ....1 Less than 1/2 hour per week...................2 1/2 to almost 1 hour per week.................3 1 to almost 2 hours per week ....4 2 to almost 3 hours per week..................5 3 or more hours per week.......................6

Please fill out the following section if you are a casual, part-time, full-time employee, or a volunteer, or a student. If you are out of work, or unable to work, you do not need to complete this section.

At work…… During the previous 3 months, how often do you usually spend:

E28. Sitting at work or in class None ....1 Less than 1/2 hour per day ....2 1/2 to almost 2 hour per day ....3 2 to almost 4 hours per day..................4 4 to almost 6 hours per day ....5 6 or more hours per day 6	E29. Standing or slowly walking at work while carrying things (≥4.5 kg) None ....1 Less than 1/2 hour per day...................2 1/2 to almost 2 hour per day ....3 2 to almost 4 hours per day..................4 4 to almost 6 hours per day ....5 6 or more hours per day 6
E30. Standing or slowly walking at work not carrying anything None ....1 Less than 1/2 hour per day ....2 1/2 to almost 2 hour per day ....3 2 to almost 4 hours per day..................4 4 to almost 6 hours per day ....5 6 or more hours per day 6	E31. Walking quickly at work while carrying things (≥4.5 kg) None ....1 Less than 1/2 hour per day...................2 1/2 to almost 2 hour per day ....3 2 to almost 4 hours per day..................4 4 to almost 6 hours per day ....5 6 or more hours per day 6
E32. Walking quickly at work not carrying anything None ....1 Less than 1/2 hour per day ....2 1/2 to almost 2 hour per day ....3 2 to almost 4 hours per day..................4 4 to almost 6 hours per day ....5 6 or more hours per day 6	

F. FOOD FREQUENCY QUESTIONNAIRE

General dietary habit – *please recall your diet since you became pregnant*

No	Questions	Answer
G1.	Are you on a special diet listed below now?	0 [ ] No 1 [ ] Vegetarian 2 [ ] Low fat 3 [ ] Low salt 4 [ ] Other: ………………………
G2.	Do you have 3 meals per day regularly?	0 [ ] Regular 1 [ ] Often regular 2 [ ] Sometime regular 3 [ ] Almost irregular
G3.	Your eating habit *Eating breakfast:* 1 [ ] daily 2 [ ] frequently *Eating takeaway food or eating out:* 1 [ ] daily 2 [ ] frequently *Eating snacks (Biscuits…):* 1 [ ] daily 2 [ ] frequently *Eating sweet food (candy, congee…*): 1 [ ] daily 2 [ ] frequently	 3 [ ] occasionally 4 [ ] never 3 [ ] occasionally 4 [ ] never 3 [ ] occasionally 4 [ ] never 3 [ ] occasionally 4 [ ] never
G4.	Did you or any of your family members feel your food was salty?	0 [ ] never 1 [ ] sometimes 2 [ ] usual
G5.	When you eat meat, did you trim off all the fat?	0 [ ] never 1 [ ] sometimes 2 [ ] usual
G6.	When you ate chicken, did you eat the skin	0 [ ] never 1 [ ] sometimes 2 [ ] usual
G7.	How often do you eat the following types of food? *(How many times per Month/Week/Day?)* *Fried food:* *Smoked food:* *Cured food:* *Grilled food:*	 .... times/[ ]**M** [ ]**W** [ ]**D** .... times/[ ]**M** [ ]**W** [ ]**D** .... times/[ ]**M** [ ]**W** [ ]**D** .... times/[ ]**M** [ ]**W** [ ]**D**
G8.	How often do you use vegetable cooking oil?	.... times/[ ]**M** [ ] [ ]**D**
G9.	How often do you use pork lard?	.... times/[ ]**M** [ ]**W** [ ]**D**
G10.	When you eat, how often do you use the following seasonings? *Fish sauce:* *Salt:*	 .... times/[ ]**M** [ ]**W** [ ]**D** .... times/[ ]**M** [ ]**W** [ ]**D**

No	Questions	Answer
	Soybean sauce: *Tomato sauce:*	.... times/[ ]**M** [ ]**W** [ ]**D** .... times/[ ]**M** [ ]**W** [ ]**D**
G11.	*Since you became pregnant, have you changed your diet habit*	1 [ ] No 2 [ ] Yes
G12.	*If yes, please specify:* *- How you have changed: ……………………………………………………………………….* *- The reasons for this change: ……………………………………………………………….*	

Consumption of beverage: How often/what amount of/ how do you drink the following beverage? – Please tell us about your dietary habits since you became pregnant.

No	Beverage	Frequency Per **M**onth/**W**eek/**D**ay	Unit (PS: portion size)	Quantity/ each time (PS)	For how many months ?
G13.	Beer	____times/[ ]**M** [ ]**W** [ ]**D**	*300 ml cup **(A)***		
G14	Home-made rice wine	____times/[ ]**M** [ ]**W** [ ]**D**	*30 ml cup **(B)***		
G15.	Home-made herbal rice wine	____times/[ ]**M** [ ]**W** [ ]**D**	*30 ml cup **(B)***		
G16.	Strong bottled liquor (≥ 39% alcohol, e.g., vodka)	____times/[ ]**M** [ ]**W** [ ]**D**	*30 ml cup **(B)***		
G17.	Light bottled liquor (≤ 29% alcohol, e.g., small bottle vodka)	____times/[ ]**M** [ ]**W** [ ]**D**	*30 ml cup **(B)***		
G18.	Red wine	____times/[ ]**M** [ ]**W** [ ]**D**	*100 ml cup **(C)***		
G19.	White wine	____times/[ ]**M** [ ]**W** [ ]**D**	*100 ml cup **(C)***		
G20.	Since you became pregnant, have you changed your drinking habit for any type of liquor above?			0 [ ] No 1 [ ] Yes	
If yes, please tell us the reasons for that change?					
G21.	Green tea (dried)	____times/[ ]**M** [ ]**W** [ ]**D**	*100 ml cup **(D)***		
G22.	Green tea leaves	____times/[ ]**M** [ ]**W** [ ]**D**	*200 ml cup **(E)***		
G23.	Black tea	____times/[ ]**M** [ ]**W** [ ]**D**	*100 ml cup **(D)***		
G24.	Oolong tea	____times/[ ]**M** [ ]**W** [ ]**D**	*100 ml cup **(D)***		
G25.	Since you became pregnant, have you changed your drinking habit for any type of tea above?			0 [ ] No 1 [ ] Yes	
If yes, please tell us the reasons for that change?					

No	Beverage	Frequency Per **M**onth/**W**eek/**D**ay	Unit (PS: portion size)	Quantity/ each time (PS)	For how many months?
G26.	Black coffee	______times/[ ]**M** [ ]**W** [ ]**D**	*150 ml cup* ***(F)***		
G27.	Instant coffee	______times/[ ]**M** [ ]**W** [ ]**D**	*Bag 5g spoon* ***(H)***	*…….. bag …….. spoon*	
G28.	Milk coffee	______times/[ ]**M** [ ]**W** [ ]**D**	*150ml cup* ***(G)***		
G29.	Since you became pregnant, have you changed your drinking habit for any type of coffee above?			0 [ ] No 1 [ ] Yes	
	If yes, please tell us the reasons for that change?				
G30.	Water	________________times/day	*250 ml cup*	____________cup	
G31.	Soy milk	______times/[ ]**M** [ ]**W** [ ]**D**	*250 ml cup*	____________cup	
G32.	Lemon juice	______times/[ ]**M** [ ]**W** [ ]**D**	*250 ml cup*	____________cup	
G33.	Orange juice	______times/[ ]**M** [ ]**W** [ ]**D**	*250 ml cup*	____________cup	
G34.	Coconut water	______times/[ ]**M** [ ]**W** [ ]**D**	*250 ml cup*	____________cup	
G35.	Fruit smoothies	______times/[ ]**M** [ ]**W** [ ]**D**	*250 ml cup*	____________cup	
G36.	*What type of fruits did you drink the most?*	1 [ ] mango 2 [ ] guava 3 [ ] watermelon 4 [ ] avocado 5 [ ] custard apple	6 [ ] papaya 7 [ ] Pineapple 8 [ ] sapodilla 9 [ ] Other:		
G37.	Soft drink (coke, Pepsi…)	______times/[ ]**M** [ ]**W** [ ]**D**	*250ml cup*	____________cup	
G38.	*What type of soft drinks did you drink the most?*	1 [ ] Coca cola 2 [ ] Pepsi 3 [ ] Fanta	4 [ ] Nestea 5 [ ] Iced tea 6 [ ] Other canned soft drink		
G39.	Did you add sugar into your drinks, such as tea, coffee, or orange juice? *If yes, how many spoons (5g) did you add?*		0 [ ] No 1 [ ] Yes, ... spoons		

Consumption of soybean products

How often do you eat soybean products?

No	Food item	Frequency (per month/week/day)	Unit (PS)	Quantity/meal (0.5 PS, 1 PS, 1.5 PS)
G40.	Fried tofu	____times/[ ]**M** [ ]**W** [ ]**D**	Piece (**I**)	PS
G41.	Raw tofu	____times/[ ]**M** [ ]**W** [ ]**D**	Piece (**I**)	PS
G42.	Soybean curd with sweet syrup	____times/[ ]**M** [ ]**W** [ ]**D**	Small bowl (**J**)	PS

Consumption of vegetables and fruit

How often/what amount of/ how do you eat vegetables/fruit?

No.	Food item	Frequency (per month/week/day)	Unit (PS)	Quantity/meal? (½ PS, 1 PS, 1.5 PS...)
G43.	Tomato	____times/[ ]**M** [ ]**W** [ ]**D**	Whole	PS
G44.	Bean sprout	____times/[ ]**M** [ ]**W** [ ]**D**	Small bowl (**L**)	PS
G45.	Amaranth, Jute potherb	____times/[ ]**M** [ ]**W** [ ]**D**	Small bowl (**L**)	PS
G46.	Water spinach	____times/[ ]**M** [ ]**W** [ ]**D**	Small bowl (**L**)	PS
G47.	Mustard green, Chinese cabbage	____times/[ ]**M** [ ]**W** [ ]**D**	Small bowl (**L**)	PS
G48.	Malabar nightshade	____times/[ ]**M** [ ]**W** [ ]**D**	Small bowl (**L**)	PS
G49.	Crown-daisy	____times/[ ]**M** [ ]**W** [ ]**D**	Small bowl (**L**)	PS
G50.	Chinese leek	____times/[ ]**M** [ ]**W** [ ]**D**	Small bowl (**L**)	PS
G51.	Cabbage	____times/[ ]**M** [ ]**W** [ ]**D**	Small bowl (**L**)	PS
G52.	French bean	____times/[ ]**M** [ ]**W** [ ]**D**	Small bowl (**L**)	PS
G53.	Pumpkin	____times/[ ]**M** [ ]**W** [ ]**D**	Small bowl (**L**)	PS
G54.	Gourd	____times/[ ]**M** [ ]**W** [ ]**D**	Small bowl (**L**)	PS
G55.	Cucumber	____times/[ ]**M** [ ]**W** [ ]**D**	Small bowl (**L**)	PS
G56.	Broccoli	____times/[ ]**M** [ ]**W** [ ]**D**	Small bowl (**L**)	PS
G57.	Cauliflower	____times/[ ]**M** [ ]**W** [ ]**D**	Small bowl (**L**)	PS
G58.	Chinese yam	____times/[ ]**M** [ ]**W** [ ]**D**	Small bowl (**L**)	PS
G59.	Ash gourd, wax gourd	____times/[ ]**M** [ ]**W** [ ]**D**	Small bowl (**L**)	PS
G60.	Bitter melon	____times/[ ]**M** [ ]**W** [ ]**D**	Small bowl (**M**)	PS
G61.	Capsicum	____times/[ ]**M** [ ]**W** [ ]**D**	Small bowl (**N**)	PS
G62.	Carrot	____times/[ ]**M** [ ]**W** [ ]**D**	Whole (**O**)	PS
G63.	White potato	____times/[ ]**M** [ ]**W** [ ]**D**	Whole (**O**)	PS
G64.	Sweet potato	____times/[ ]**M** [ ]**W** [ ]**D**	Whole (**P**)	PS
G65.	Luffa	____times/[ ]**M** [ ]**W** [ ]**D**	Small bowl (**L**)	PS
G66.	Mushroom	____times/[ ]**M** [ ]**W** [ ]**D**	Gram	gr

G67.	Dragon fruit	_____times/[ ]**M** [ ]**W** [ ]**D**	Whole	PS
G68.	Banana	_____times/[ ]**M** [ ]**W** [ ]**D**	Whole	PS
G69.	Papaya	_____times/[ ]**M** [ ]**W** [ ]**D**	Piece 20 x 4 cm (**Q**)	PS
G70.	Pomelo	_____times/[ ]**M** [ ]**W** [ ]**D**	Piece (**R**)	PS
G71.	Longan	_____times/ [ ]**M** [ ]**W** [ ]**D**	Kg	kg
G72.	Orange	_____times/ [ ]**M** [ ]**W** [ ]**D**	Whole	PS
G73.	Watermelon	_____times/ [ ]**M** [ ]**W** [ ]**D**	Piece 100 g (**S**)	PS
G74.	Pear	_____times/ [ ]**M** [ ]**W** [ ]**D**	Whole	PS
G75.	Grape	_____times/ [ ]**M** [ ]**W** [ ]**D**	Kg	kg
G76.	Guava	_____times/ [ ]**M** [ ]**W** [ ]**D**	Whole	PS
G77.	Apple	_____times/ [ ]**M** [ ]**W** [ ]**D**	Whole	PS
G78.	Lychee	_____times/ [ ]**M** [ ]**W** [ ]**D**	Kg	kg
G79.	Mangoes	_____times/ [ ]**M** [ ]**W** [ ]**D**	Whole	PS
G80.	Durian	_____times/ [ ]**M** [ ]**W** [ ]**D**	Piece (**T**)	PS

Consumption of sweet varieties - *How often/what amount of/ how do you eat sweet varieties?*

No	**Food item**	**Frequency** (per month/week/day)	**Unit**	**Quantity/meal?** (½ PS, 1 PS, 1.5 PS...)
G81.	Sweet soup (made of glutinous rice and bean, corn…)	__________times/[ ]**M** [ ] **W** [ ] **D**	250 ml cup (**U**)	PS
G82.	Please choose 3 types that you eat the most?		1 [ ] Glutinous soup with taro 2 [ ] Glutinous soup with corn 3 [ ] Glutinous soup with mung beans 4 [ ] Glutinous soup with black beans 5 [ ] Glutinous soup with white beans 6 [ ] Mix glutinous soup with beans 7 [ ] Other: …………….	
G83.	Sweet cakes	_________times/ [ ]**M** [ ] **W** [ ] **D**	Piece (**V**)	PS
G84.	Biscuits	_________times/ [ ]**M** [ ] **W** [ ] **D**	Piece	PS

Consumption of bread and rice varieties - *How often/what amount of/ how do you eat the following items?*

No	Food item	Frequency (per month/week/day)	Unit	Quantity/meal? (½ PS, 1PS, 1.5PS...)
G85.	French type bread (either plain or with meat)	_____times/ [ ]**M** [ ]**W** [ ]**D**	Load (**W**)	PS
G86.	Sliced bread (either plain or with meat)	_____times/ [ ]**M** [ ]**W** [ ]**D**	Slice	PS
G87.	Rice-based noodles	_____times/ [ ]**M** [ ]**W** [ ]**D**	Large bowl (**X**)	PS
G88.	Instant noodle	_____times/ [ ]**M** [ ]**W** [ ]**D**	Bag	PS
G89.	Plain rice (at home)	_____times/ [ ]**M** [ ]**W** [ ]**D**	Small bowl	PS
G90.	Rice comes in a serving (a plate of fried rice, broken rice…) when eating outside	_____times/ [ ]**M** [ ]**W** [ ]**D**	Plate	PS
G91.	Glutinous rice (either plain, with bean, or salted)	_____times/ [ ]**M** [ ]**W** [ ]**D**	Small bowl	PS
G92.	Rice porridge	_____times/ [ ]**M** [ ]**W** [ ]**D**	Large bowl (KK)	PS

Consumption of meat- *How often/what amount of/how do you eat?*

No	Food item	Frequency (per month/week/day)	Unit (PS)	Quantity/meal? (½ PS, 1 PS,1.5 PS...)
G93.	Pork lean	_____times/ [ ]**M** [ ]**W** [ ]**D**	Small piece (**Y**)	PS
G94.	Pork medium fat	_____times/ [ ]**M** [ ]**W** [ ]**D**	Small piece (**Z**)	PS
G95.	Pork rib	_____times/ [ ]**M** [ ]**W** [ ]**D**	Small piece (**AA**)	PS
G96.	Pork lower leg	_____times/ [ ]**M** [ ]**W** [ ]**D**	Small piece (**BB**)	PS
G97.	Pork steak	_____times/ [ ]**M** [ ]**W** [ ]**D**	Piece 60 g (**CC**)	PS
G98.	Beef	_____times/ [ ]**M** [ ]**W** [ ]**D**	Small bowl (**DD**)	PS
G99.	Chicken	_____times/ [ ]**M** [ ]**W** [ ]**D**	Small piece (**EE**)	PS
G100.	Pigeon	_____times/ [ ]**M** [ ]**W** [ ]**D**	Small piece (**FF**)	PS
G101.	Duck	_____times/ [ ]**M** [ ]**W** [ ]**D**	Small piece (**FF**)	PS
G102.	Pork heart	_____times/ [ ]**M** [ ]**W** [ ]**D**	gram	gr
G103.	Pork liver	_____times/ [ ]**M** [ ]**W** [ ]**D**	gram	gr
G104	Pork kidney	_____times/ [ ]**M** [ ]**W** [ ]**D**	gram	gr
G105.	Poultry offal	_____times/ [ ]**M** [ ]**W** [ ]**D**	gram	gr

Consumption of fish, egg, and milk- *How often/what amount of/how do you eat?*

No	Food item	Frequency (per month/week/day)	Unit (PS)	Quantity/meal? (½ PS, 1 PS, 1.5 PS...)
G106.	Sea fish (Mackerel, tuna...)	______times/ [ ]**M** [ ]**W** [ ]**D**	Piece 70 g (**GG**)	PS
G107.	*Please check two types of sea fish that you eat the most often?*		1 [] Mackerel 2 [] Tuna 3 [] Mullet 4 [] other, specify…………………	
G108.	Freshwater fish (Tilapia...)	____times/ [ ]**M** [ ]**W** []**D**	Piece 50 g (**HH**)	PS
G109.	*Please check two types of freshwater fish that you eat the most often?*		1 [ ] Tilapia 2 [ ] Snakehead 3 [ ] Carp 4 [ ] Chub 5 [ ] Other, specify…………………	
G110.	Shrimp	_________times/[ ]**M** [ ]**W** [ ]**D**	Whole (**II**)	PS
G111.	Squid/octopus	_________times/[ ]**M** [ ]**W** [ ]**D**	Piece (**JJ**)	PS
G112.	Snails, scallops	_________times/[ ]**M** [ ]**W** [ ]**D**	Small bowl	PS
Egg				
G113.	Chicken egg		Whole	PS
G114.	Duck egg		Whole	PS
Preserved food				
G115.	Pickle vegetable & garlic	_________times/[ ]**M** [ ]**W** [ ]**D**	gram	gr
G116.	Fermented soy product	_________times/[ ]**M** [ ]**W** [ ]**D**	gram	gr
G117.	Salted fish	_________times/[ ]**M** [ ]**W** [ ]**D**	gram	gr
G118.	Preserved meat (sausage…)	_________times/[ ]**M** [ ]**W** [ ]**D**	gram	gr
Milk				
G119.	Cow whole milk	_________times/[ ]**M** [ ]**W** [ ]**D**	Cup 250 ml	PS
G120.	Soya milk	_________times/[ ]**M** [ ]**W** [ ]**D**	Cup 250 ml	PS
G121	Milk powder, whole	_________times/[ ]**M** [ ]**W** [ ]**D**	5 g spoon (**H**)	PS
G122.	Yogurt	_________times/[ ]**M** [ ]**W** [ ]**D**	Box	PS
G123.	Condensed milk	_________times/[ ]**M** [ ]**W** [ ]**D**	ml (**C**)	PS

Dietary supplements - *How often/what amount of/how did you use?*

No.	Item	**Frequency** (per month/week/day)	Unit	Quantity/ time (unit)	Days/ Weeks/ Months of use
G124.	Multivitamin	________times/[ ]**M** [ ]**W** [ ]**D**	Tablet		
G125.	Vitamin A	________times/[ ]**M** [ ]**W** [ ]**D**	Tablet		
G126.	Vitamin C	________times/[ ]**M** [ ]**W** [ ]**D**	Tablet		
G127.	Vitamin E	________times/[ ]**M** [ ]**W** [ ]**D**	Tablet		
G128.	Riboflavin (Vitamin B6)	________times/[ ]**M** [ ]**W** [ ]**D**	Tablet		
G129.	Vitamin D	________times/[ ]**M** [ ]**W** [ ]**D**	Tablet		
G130.	Acid Folic	________times/[ ]**M** [ ]**W** [ ]**D**	Tablet		
G131.	Calcium	________times/[ ]**M** [ ]**W** [ ]**D**	Tablet		
G132.	Selenium	________times/[ ]**M** [ ]**W** [ ]**D**	Tablet		
G133.	Iron	________times/[ ]**M** [ ]**W** [ ]**D**	Tablet		
G134.	Zinc	________times/[ ]**M** [ ]**W** [ ]**D**	Tablet		
G135.	Iodine	________times/[ ]**M** [ ]**W** [ ]**D**	Tablet		
G136.	DHA	________times/[ ]**M** [ ]**W** [ ]**D**	Tablet		
G137.	Fish oil	________times/[ ]**M** [ ]**W** [ ]**D**	Tablet		
G138.	Ginseng	________times/[ ]**M** [ ]**W** [ ]**D**			

G2. Discharge Questionnaire (English version)

A. PARTICIPANT'S IDENTIFICATION

A1. Date of interview: ______/______/______(DD/MM/YYYY)

A2. Interviewer's name: ____

A3. Mother's name: ____

A4. Mother's address: ____

A5. Mother's phone number: ____

A6. Husband's name: ____

A7. Husband's phone number: ______________________________________

B. INFORMATION ON PREGNANCY OUTCOMES

No.	Questions	Answers
B1.	When was your baby born?	_______/_______/_______ (DD/MM/YYYY)
B2.	What is your baby's gender?	1. Male 2. Female
B3.	Infant weight at delivery (gram)	__ __ __ __ gram
B4.	Which method did you give birth to?	1. Vaginal delivery 2. Caesarean section
B5.	Maternal weight just before giving birth	__ __ . __ kg

G3. Three-Month Postpartum Questionnaire (English version)

A. PARTICIPANT'S IDENTIFICATION

A1. Date of interview: ______/______/______(DD/MM/YYYY)

A2. Interviewer's name: ____

A3. Mother's name: ____

A4. Mother's address: ____

A5. Mother's phone number: ______________________________________

A6. Husband's name: ____

A7. Husband's phone number: ______________________________________

B. ANTHROPOMETRICS

No.	Questions	Answers
C2.	Mother's weight?	_ _ _ . _ kg

C. PHYSICAL ACTIVITY

It is very important that you recall your physical activity. There are no right or wrong answers. We just want to know what activities you have spent within 3 months postpartum and their frequencies.

During the previous 3 months, when you are NOT at work, how often do you usually spend:

E1. Preparing meals (cook, set table, wash dishes) None .... 1 Less than 1/2 hour per day .... 2 1/2 to almost 1 hour per day................... 3 1 to almost 2 hours per day .... 4 2 to almost 3 hours per day.................... 5 3 or more hours per day......................... 6	E2. Dressing, bathing, feeding children while you are <u>sitting</u> None .... 1 Less than 1/2 hour per day .... 2 1/2 to almost 1 hour per day................... 3 1 to almost 2 hours per day .... 4 2 to almost 3 hours per day.................... 5 3 or more hours per day 6
E3. Dressing, bathing, feeding children while you are <u>standing</u> None .... 1 Less than 1/2 hour per day .... 2 1/2 to almost 1 hour per day................... 3 1 to almost 2 hours per day .... 4 2 to almost 3 hours per day.................... 5 3 or more hours per day 6	E4. Playing with children while you are <u>sitting or standing</u> None .... 1 Less than 1/2 hour per day .... 2 1/2 to almost 1 hour per day................... 3 1 to almost 2 hours per day .... 4 2 to almost 3 hours per day.................... 5 3 or more hours per day........................... 6
E5. Playing with children while you are <u>walking</u> <u>or running</u> None .... 1 Less than 1/2 hour per day .... 2 1/2 to almost 1 hour per day................... 3 1 to almost 2 hours per day .... 4 2 to almost 3 hours per day.................... 5 3 or more hours per day......................... 6	E6. Carrying children None .... 1 Less than 1/2 hour per day .... 2 1/2 to almost 1 hour per day................... 3 1 to almost 2 hours per day .... 4 2 to almost 3 hours per day.................... 5 3 or more hours per day 6
E7. Taking care of an older adult None .... 1 Less than 1/2 hour per day .... 2 1/2 to almost 1 hour per day................... 3 1 to almost 2 hours per day .... 4 2 to almost 3 hours per day.................... 5 3 or more hours per day 6	E8. Sitting and using a computer or writing, while <u>not</u> at work None .... 1 Less than 1/2 hour per day .... 2 1/2 to almost 1 hour per day................... 3 1 to almost 2 hours per day .... 4 2 to almost 3 hours per day.................... 5 3 or more hours per day 6
E9. Watching TV or a video None .... 1 Less than 1/2 hour per day .... 2 1/2 to almost 2 hour per day................... 3 2 to almost 4 hours per day .... 4 4 to almost 6 hours per day.................... 5 6 or more hours per day 6	E10. Sitting and reading, talking, or on the phone, while <u>not</u> at work None .... 1 Less than 1/2 hour per day .... 2 1/2 to almost 2 hour per day................... 3 2 to almost 4 hours per day .... 4 4 to almost 6 hours per day.................... 5 6 or more hours per day 6

E11. Playing with pets

None 1
Less than 1/2 hour per day..................... 2
1/2 to almost 1 hour per day................... 3
1 to almost 2 hours per day 4
2 to almost 3 hours per day.................... 5
3 or more hours per day 6

E12. Light cleaning (make beds, laundry, iron, put things away)

None 1
Less than 1/2 hour per day 2
1/2 to almost 1 hour per day................... 3
1 to almost 2 hours per day 4
2 to almost 3 hours per day.................... 5
3 or more hours per day 6

E13. Shopping (for food, clothes, or other items)

None 1
Less than 1/2 hour per day..................... 2
1/2 to almost 1 hour per day................... 3
1 to almost 2 hours per day 4
2 to almost 3 hours per day.................... 5
3 or more hours per day 6

E14. Heavier cleaning (vacuum, mop, sweep, wash windows)

None 1
Less than 1/2 hour per week................... 2
1/2 to almost 1 hour per week 3
1 to almost 2 hours per week.................. 4
2 to almost 3 hours per week 5
3 or more hours per week 6

E15. Mowing lawn using a walking mower, raking, gardening

None 1
Less than 1/2 hour per week 2
1/2 to almost 1 hour per week................ 3
1 to almost 2 hours per week 4
2 to almost 3 hours per week................. 5
3 or more hours per week 6

Going Places…

During last 3 months, how often do you usually spend:

E16. Walking <u>slowly</u> to go to places (such as to the bus, work, visiting) <u>NOT</u> for fun or exercise

None 1
Less than 1/2 hour per day..................... 2
1/2 to almost 1 hour per day................... 3
1 to almost 2 hours per day 4
2 to almost 3 hours per day.................... 5
3 or more hours per day 6

E17. Walking <u>quickly</u> to go to places (such as to the bus, work, visiting), <u>NOT</u> for fun or exercise

None 1
Less than 1/2 hour per day 2
1/2 to almost 1 hour per day................... 3
1 to almost 2 hours per day 4
2 to almost 3 hours per day.................... 5
3 or more hours per day 6

E18. Riding a bicycle to go places (such as the bus, work, or school) <u>NOT</u> for fun or exercise

None 1
Less than 1/2 hour per day..................... 2
1/2 to almost 1 hour per day................... 3
1 to almost 2 hours per day 4
2 to almost 3 hours per day.................... 5
3 or more hours per day 6

E19. Driving or riding in a motorbike or bus

None 1
Less than 1/2 hour per day 2
1/2 to almost 1 hour per day................... 3
1 to almost 2 hours per day 4
2 to almost 3 hours per day.................... 5
3 or more hours per day 6

For Fun or Exercise…

During the previous 3 months, how often do you usually spend:

E20. Walking <u>slowly</u> for fun or exercise None ....1 Less than 1/2 hour per week ....2 1/2 to almost 1 hour per week.................3 1 to almost 2 hours per week ....4 2 to almost 3 hours per week..................5 3 or more hours per week 6	E21. Walking more <u>quickly</u> for fun or exercise None ....1 Less than 1/2 hour per week ....2 1/2 to almost 1 hour per week.................3 1 to almost 2 hours per week ....4 2 to almost 3 hours per week..................5 3 or more hours per week 6
E22. Walking <u>quickly up hills</u> for fun or exercise None ....1 Less than 1/2 hour per week ....2 1/2 to almost 1 hour per week.................3 1 to almost 2 hours per week ....4 2 to almost 3 hours per week..................5 3 or more hours per week 6	E23. Jogging None ....1 Less than 1/2 hour per week ....2 1/2 to almost 1 hour per week.................3 1 to almost 2 hours per week ....4 2 to almost 3 hours per week..................5 3 or more hours per week 6
E24. Exercise class/session None ....1 Less than 1/2 hour per week ....2 1/2 to almost 1 hour per week.................3 1 to almost 2 hours per week ....4 2 to almost 3 hours per week..................5 3 or more hours per week 6	E25. Swimming None ....1 Less than 1/2 hour per week ....2 1/2 to almost 1 hour per week.................3 1 to almost 2 hours per week ....4 2 to almost 3 hours per week..................5 3 or more hours per week 6
E26. Dancing None ....1 Less than 1/2 hour per week ....2 1/2 to almost 1 hour per week.................3 1 to almost 2 hours per week ....4 2 to almost 3 hours per week..................5 3 or more hours per week 6	E27. ____________________ Name of Activity None ....1 Less than 1/2 hour per week ....2 1/2 to almost 1 hour per week.................3 1 to almost 2 hours per week ....4 2 to almost 3 hours per week..................5 3 or more hours per week 6

Please fill out the following section if you are a casual, part-time, full-time employee, or a volunteer, or a student. If you are out of work, or unable to work, you do not need to complete this section.

At work…… During the previous 3 months, how often do you usually spend:

E28. Sitting at work or in class None ....1 Less than 1/2 hour per day ....2 1/2 to almost 2 hour per day ....3 2 to almost 4 hours per day..................4 4 to almost 6 hours per day ....5 6 or more hours per day 6	E29. Standing or slowly walking at work while carrying things (≥4.5 kg) None ....1 Less than 1/2 hour per day...................2 1/2 to almost 2 hour per day ....3 2 to almost 4 hours per day..................4 4 to almost 6 hours per day ....5 6 or more hours per day 6
E30. Standing or slowly walking at work not carrying anything None ....1 Less than 1/2 hour per day ....2 1/2 to almost 2 hour per day ....3 2 to almost 4 hours per day..................4 4 to almost 6 hours per day ....5 6 or more hours per day 6	E31. Walking quickly at work while carrying things (≥4.5 kg) None ....1 Less than 1/2 hour per day...................2 1/2 to almost 2 hour per day ....3 2 to almost 4 hours per day..................4 4 to almost 6 hours per day ....5 6 or more hours per day 6
E32. Walking quickly at work not carrying anything None ....1 Less than 1/2 hour per day ....2 1/2 to almost 2 hour per day ....3 2 to almost 4 hours per day..................4 4 to almost 6 hours per day ....5 6 or more hours per day 6	

G4. Six-Month Postpartum Questionnaire (English version)

A. PARTICIPANT'S IDENTIFICATION

A1. Date of interview: ______/______/______(DD/MM/YYYY)

A2. Interviewer's name: ____

A3. Mother's name: ____

A4. Mother's address: ____

A5. Mother's phone number: ____

A6. Husband's name: ____

A7. Husband's phone number: ____

B. ANTHROPOMETRICS

No.	Questions	Answers
B1.	Mother's weight?	_ _ _ . _ kg

C. MOTHER – HEALTH

C1. Have you ever experienced low back pain that you feel too ill to do normal duties during the first 6 months postpartum?

No ------------- 0 *If you choose NO, move to question C2*

Yes ------------ 1

For the interviewer's confirmation:

C2. If the mother says YES, ask her to show the position of her experienced pain and tick it here.

No ------------- 0

Yes ------------ 1

G5. Twelve-Month Postpartum Questionnaire (English version)

A. PARTICIPANT'S IDENTIFICATION

A1. Date of interview: ______/______/______(DD/MM/YYYY)

A2. Interviewer's name: ____

A3. Mother's name: ____

A4. Mother's address: ____

A5. Mother's phone number: ____

A6. Husband's name: ____

A7. Husband's phone number: ____

B. ANTHROPOMETRICS

No.	Questions	Answers
B1.	Mother's weight?	_ _ _ . _ kg

Appendix H. Information Sheet for Participants

Project title: Maternal lifestyle and nutritional status in relation to pregnancy and child health outcomes: A multi-centre prospective cohort study in Vietnam.

The School of Public Health at Curtin University is studying the associations among maternal lifestyle and nutritional status with pregnancy and child health outcomes in Vietnam. This research has been approved by the Curtin University Human Research Ethics Committee (No. HR32/2015) and the Haiphong University of Medicine and Pharmacy Review Board (No. 05/HPUMPRB).

We would like to invite you to participate in our study. There will be six interviews at antenatal, delivery, 1, 3, 6, and 12 months postpartum. It will take you 30-40 minutes for each interview to answer some questions related to your lifestyle, dietary intakes, attitude, and practice in feeding and breastfeeding your new baby, antenatal and postnatal depression, and well-being postpartum. These questions are insensitive and there are no interventions in both you and your baby.

Your participation in this research is completely voluntary. You can refuse any specific question that you are uncertain or find it difficult to answer. You are totally free to withdraw from the study at any time without negative consequences. The information you provided will be kept strictly confidential, and your identity will remain anonymous. Only aggregated and de-identified data from all respondents will be analysed and reported. Your participation has a vital role in supporting our study's success and improving maternal and child health in a resource-limited setting like Vietnam.

If you have any concern or questions about this study, please contact the following project staff:

Vo Van Anh Ha, PhD Candidate, Curtin University

Telephone number:

Email Address: vovananh.ha@postgrad.curtin.edu.au

Thank you very much for taking your time and consideration.

Appendix I. Informed Consent Forms

Project title: Maternal lifestyle and nutritional status in relation to pregnancy and child health outcomes: A multi-centre prospective cohort study in Vietnam.

(You are invited to participate in this study. Please read the information document carefully and ask any questions you wish. Do not sign this informed consent form unless you fully understand the nature of the study and the commitment you may need to make over the next two years.)

I, ……………………………………………….……………., have read and understood the Information letter given to me. I understand the purpose, participant's risks and rights, and requirements of the study. I fully understand that my participation is voluntary, and I am free to withdraw from the study at any time without any negative consequences. I have also been given the opportunity to ask questions about the study. Data gained in this study may be published with de-identified personal information. Therefore, I agree to participate in the study.

Signature of participant: ___________________________

Full name of participant: ____

Date: ______/______/__________

Signature of witness: ___________________________

Full name of witness: ____

Date: ______/______/__________