ASSESSMENT OF WEIGHT GAIN AND ITS ASSOCIATION WITH DIETARY INTAKE, PHYSICAL ACTIVITIES AND SOCIODEMOGRAPHIC FACTORS AMONG PREGNANT WOMEN IN BACHOK DISTRICT, KELANTAN

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by

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TABLE OF CONTENT

Page

ACKNOWLEDGEMENT ii
TABLE OF CONTENT iv
LIST OF TABLES vii
LIST OF FIGURES viii
LIST OF SYMBOLS AND ABBREVIATIONS ix
ABSTRAK x
ABSTRACT xii
CHAPTER 1 INTRODUCTION 1
1.1 Background 1
1.2 Rationales 3
1.3 Objectives 4
1.3.1 General objective 4
1.3.2 Specific objectives 4
1.4 Research questions 4
1.5 Conceptual framework 5
1.6 Significance of study 5
1.7 Definition of terms 7
CHAPTER 2 LITERATURE REVIEW 8
2.1 Gestational weight gain 8
2.2 Prepregnancy Body Mass Index (BMI) 13
2.3 Sociodemographic factors 18
2.3.1 Maternal age 18
2.3.2 Educational level 19
2.4 Skinfold measurements 21
2.5 Dietary assessment 22
2.5.1 Nutrient intake 22
2.5.2 Dietary diversity 24
2.6 Physical activity 26
CHAPTER 3 MATERIALS AND METHODS 28
3.1 Background of the study 28
3.2 Study design 28
3.3 Reference population 28

3.4 Source population 28
3.5 Target population 29
3.5.1 Inclusion criteria 29
3.5.2 Exclusion criteria 29
3.6 Sampling frame 29
3.7 Sampling method 30
3.8 Sample size 30
3.9 Data collection 33
3.9.1 Questionnaire 34
3.9.2 Anthropometric measurements 37
3.9.2 (a) Anthropometric measurements 37
(i) Height 37
(ii) Prepregnancy weight 37
(iii) Weight during third trimester 38
(iv) Prepregnancy body mass index 38
(v) Gestational weight gain 39
(vi) Mid-upper arm circumference 39
(vii) Maternal triceps skinfold thickness 40
3.9.2 (b) Infant measurement 40
3.9.3 Dietary assessment 40
3.9.3 (a) 24-hour dietary recall 40
3.9.3 (b) Dietary diversity questionnaire 41
3.9.4 Physical activity questionnaire 42
3.10 Statistical analysis 44
3.10.1 Multinomial logistic Regression 44
3.11 Ethical issues 48
CHAPTER 4 RESULTS 50
4.1 Maternal sociodemographic characteristics 50
4.2 Maternal nutritional status 53
4.3 Maternal obstetric and clinical characteristics 55
4.4 Infant characteristics 55
4.5 Maternal dietary intake profiles 57
4.6 Maternal dietary intake profiles and prepregnancy BMI categories 58
4.7 Dietary diversity score 58
4.8 Physical activity level 62

4.9 Associated factors of maternal gestational weight gain 62
CHAPTER 5 DISCUSSION 66
5.1 Prepregnancy body mass index and gestational weight gain 66
5.2 Dietary assessment 71
5.2.1 Nutrient intake 71
5.2.2 Dietary diversity score 73
5.3 Physical activity level 74
5.4 Gestational weight gain and infant's characteristics 75
5.5 Associated factors of gestational weight gain in pregnant women 76
5.5.1 Gestational weight gain and sociodemographic factors 76
5.5.2 Association of gestational weight gain and nutritional status of pregnant women 77
CHAPTER 6 CONCLUSION 80
REFERENCES 83

APPENDICES

Appendix A Ethical Approval Letter from the Human Research Ethics Committee of Universiti Sains Malaysia

Appendix B Ethical Approval Letter from the Medical Research Ethics Committee of Ministry of Health, Malaysia

Appendix C Written Informed Consent

Appendix D Questionnaires

LIST OF TABLES

Page

Table 2.1: New recommendations for total and rate of weight gain during pregnancy, by prepregnancy body mass index 8

Table 3.1: Sample size calculations for specific objectives 31

Table 3.2: Dietary diversity score 42

Table 3.3: GPAQ guidelines for category of physical activity 43

Table 4.1: Sociodemographic characteristics of pregnant women (n=211) 51

Table 4.1: Continued 52

Table 4.2: Nutritional status among pregnant women (n=211) 54

Table 4.3: Obstetric and clinical characteristics of pregnant women (n=211) 56

Table 4.4: Characteristics of infant (n=211) 57

Table 4.5: Dietary intake and percentage of intake among different age groups of pregnant women (n=211) 59

Table 4.6: Energy and macronutrients intake according to prepregnancy body mass index categories of pregnant women (n=211) 60

Table 4.7: Dietary diversity score for different food groups of pregnant women (n=211) 61

Table 4.8: Physical activity level of pregnant women (n=211) 62

Table 4.9: Overall fit of two logit functions (n=211) 63

Table 4.9.1: Associated factors of inadequate and excessive weight gain compared to adequate weight gain during pregnancy. 64

LIST OF FIGURES

Page

Figure 1.1: Conceptual framework of the study 6
Figure 3.1: Flow chart of the study 36
Figure 3.2: Flow chart of steps for multinomial logistic regression 49

LIST OF SYMBOLS AND ABBREVIATIONS

BMI	Body mass index
CI	Confidence interval
GDM	Gestational diabetes mellitus
GPAQ	Global Physical Activity Questionnaire
GWG	Gestational weight gain
IOM	Institute of Medicine
IQR	Interquartile range
LBW	Low birth weight
LGA	Large-for-gestational age
MANS	Malaysian Adult Nutrition Survey
METs	Metabolic equivalents
MUAC	Mid-upper arm circumference
PIH	Pregnancy induced hypertension
RNI	Recommended Nutrient Intakes
SD	Standard deviation
SGA	Small-for-gestational age
USDA	U.S. Department of Agriculture
WHO	World Health Organization

PENILAIAN PERTAMBAHAN BERAT BADAN DAN PERKAITANNYA DENGAN PENGAMBILAN MAKANAN, AKTIVITI FIZIKAL DAN CIRI-CIRI SOSIODEMOGRAFI DALAM KALANGAN WANITA MENGANDUNG DI DAERAH BACHOK, KELANTAN

ABSTRAK

Kehamilan adalah masa yang unik di mana terdapat perubahan dinamik secara fisiologi terhadap ibu mengandung untuk menampung pertumbuhan bayi. Pertambahan berat badan semasa mengandung adalah penting untuk perkembangan bayi yang sihat dan juga untuk mengurangkan kadar komplikasi yang tidak diingini terhadap ibu mengandung and bayi. Kajian ini bertujuan untuk menilai faktor-faktor yang berkaitan dengan berat badan semasa mengandung dalam kalangan ibu mengandung pada trimester ketiga di Daerah Bachok, Kelantan. Seramai 211 orang ibu mengandung pada trimester ketiga yang berumur 19-49 tahun dengan kehamilan singleton telah dipilih dari klinik-klinik kesihatan di Daerah Bachok untuk dimasukkan dalam kajian ini dan diikuti dengan kajian susulan selepas bersalin. Ciri-ciri sosiodemografi ibu mengandung, pengambilan makanan, tahap aktiviti fizikal dan ukuran antropometri telah dikumpulkan melalui temubual seorang-dengan-seorang. Analisa regresi logistik multinomial telah digunakan untuk mengenal pasti faktor-faktor yang berkaitan dengan pertambahan berat badan semasa mengandung. Keputusan kajian menunjukkan bahawa ibu mengandung yang lebih berumur (30-49) dikaitkan dengan 2.57 kali ganda (95% CI 1.27, 5.19) untuk memperoleh kekurangan pertambahan berat badan semasa mengandung, manakala ibu mengandung dengan

berat badan berlebihan dan obes berada pada 72.2% (95% CI 0.10, 0.75) dan 72.9% (95% CI 0.08, 0.97), lebih rendah kejadian untuk kekurangan berat badan semasa mengandung masing-masing. Di samping itu, saiz isi rumah yang lebih besar (≥ 6) dikaitkan dengan 59.6% (95% CI 0.18, 0.89) peluang lebih rendah untuk mendapat berat badan yang berlebihan. Walau bagaimanapun, ibu mengandung dengan lilitan lengan pertengahan atas ≥ 27cm dikaitkan dengan 7.13 kali ganda (95% CI 1.60, 31.68) peluang yang lebih tinggi untuk memperoleh berat badan semasa mengandung yang berlebihan. Kesimpulannya, umur ibu mengandung, saiz isi rumah, indeks jisim badan sebelum mengandung dan ukuran lilitan lengan pertengahan atas dikaitkan dengan rapat dengan pertambahan berat badan semasa mengandung. Kaunseling untuk pertambahan berat badan yang disyorkan sewaktu mengandung berserta dengan pengambilan makanan yang sihat dan tahap aktiviti fizikal yang disarankan akan memperoleh penambahan berat badan sewaktu mengandung yang sewajarnya serta dapat mengurangkan komplikasi ibu mengandung dan juga bayi.

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ABSTRACT

Pregnancy is a unique period where there is a dynamic change of physiological phenomenon of a pregnant woman to accommodate the fetus development. Appropriate gestational weight gain during pregnancy is crucial for healthy development of fetus and also to reduce the incidence of adverse maternal and neonatal outcomes. This study aimed to assess the associated factors of gestational weight gain among third trimester pregnant women in Bachok District, Kelantan. Pregnant women in their third trimester were recruited from government healthcare clinic in Bachok District and were followed-up after delivery. A total of 211 pregnant women aged 19-49 years with singleton pregnancy were included in the study. Maternal sociodemographic characteristics, dietary intake, physical activity level and anthropometric measurements were collected through face-to-face interview. Multinomial logistic regression analysis was performed to identify the associated factors of gestational weight gain during pregnancy. Findings showed that higher maternal age (30-49) was associated with 2.57 times (95% CI 1.27, 5.19) to develop inadequate gestational weight gain, while overweight and obese pregnant women were at 72.2% (95% CI 0.10, 0.75) and 72.9% (95% CI 0.08, 0.97), respectively lower incidence of developing inadequate gestational weight gain. In the other hand, higher household size (≥ 6) was associated with 59.6% (95% CI 0.18,

0.89) lower chance of developing excessive weight gain. However, pregnant women with mid-upper arm circumference ≥ 27cm were associated with 7.13 times (95% CI 1.60, 31.68) greater chance to develop excessive gestational weight gain. In conclusion, maternal age, household size, prepregnancy body mass index and mid-upper arm circumference measurement were significantly associated with gestational weight gain. Proper counseling on recommended weight gain during pregnancy as well as healthy dietary intake and recommended physical activity may lead to an appropriate gestational weight gain within recommendations and reduce the complication of maternal and neonatal outcomes.

CHAPTER 1

INTRODUCTION

1.1 Background

According to World Health Organization (WHO), in 2008, there are more than 1.4 billion overweight adults worldwide. Out of them, nearly 300 million women were in the obese category (WHO, 2014). Overweight and obesity individuals have increased risk for serious diet-related chronic diseases, such as type 2 diabetes, cardiovascular disease, hypertension and stroke, and certain forms of cancer. In the case of pregnancy, overweight or obese women will enter pregnant phase with higher body mass index (BMI) which further lead to childhood obesity (Whitaker, 2004). Childhood obesity has become one of the most serious public health challenges currently (WHO, 2017).

Overweight and obese women will enter their pregnancy with higher BMI. Compared to pregnant women who had a normal BMI, overweight and obese pregnant women were more likely to gain weight above the 2009 Institute of Medicine (IOM) recommendations (Restall *et al.*, 2014). Excessive gestational weight gain (GWG) during pregnancy was associated with increased risk for pregnancy-induced hypertension (PIH), cesarean delivery (Li *et al.*, 2013), preterm birth and macrosomia infant (Liu *et al.*, 2015).

According to the 2010 report of Centers for Disease Control and Prevention's (CDC's) Pregnancy Nutrition Surveillance, prevalence of prepregnancy BMI was 4.5% underweight, 42.1% normal weight, 26.0% overweight and 27.4% obese

(Dalenius *et al.*, 2012). Pregnant women who were in the category of low prepregnancy BMI were more likely to have weight gain below the IOM recommendations (Brawarsky *et al.*, 2005). Underweight pregnant women with low weight gain during pregnancy were at increased risk for low birth weight (LBW) infants (Tsai *et al.*, 2012). In brief, pregnant women who have GWG less than recommendation have higher risk of infants with LBW.

Nutritional status of a pregnant woman at preconception and throughout the pregnancy is important. The nutritional status of a pregnant mother will influence the health of a newborn infant. Complications during pregnancy such as hypertension, gestational diabetes and preeclampsia were more commonly seen in overweight and obese women during late pregnancy (Nohr *et al.*, 2008). Obese pregnant mothers were at an increased risk for macrosomia infant, whereas underweight pregnant mothers increased the likelihood of preterm birth. Preeclampsia, chronic diabetes and hypertension which might due to overweight during pregnancy also increased the risk for preterm birth (Rosenberg *et al.*, 2005). According to Quigley *et al.* (2012), preterm birth children have an increased risk of poorer educational achievement at the age of five compared to children born with full term.

Besides preterm birth, underweight pregnant women also increased the likelihood of 72% in miscarriage at the first trimester of pregnancy. However, the risk of miscarriage was reduced by approximately 50% if the underweight pregnant women took vitamin supplements especially folic acid, iron and multivitamin. The consumption of fruits and vegetables in daily dietary intake were also found to be halved the risk of miscarriage (Maconochie *et al.*, 2007).

Gestational weight gain is the amount of the weight gained during pregnancy and it is a unique and natural way that supports the functions of growth and development of the infants. Gestational weight gain is an important indicator as it has direct impact on the health of the mothers, and the development of their offspring. Evidences supported that there is an association between excessive GWG and increased infant birth weight and also association between inadequate GWG and LBW. In 2009, Institute of Medicine had published the revised guidelines for GWG which aim to optimize the outcomes of the pregnant mothers as well as their infants (IOM, 2009).

1.2 Rationales

Currently, information on weight gain during pregnancy is lacking in Malaysia. As weight gain during pregnancy will have influence on the mothers and infants, studies need to be done to explore the nutritional status of pregnant women on whether there are more overweight or underweight pregnant women during pregnancy as well as their GWG throughout the pregnancy in order to be able to provide nutritional support for those who are in needs.

This study is important to determine the association of gestational weight gain and sociodemographic factors, dietary intake and physical activity level among pregnant women in Bachok District, Kelantan. Hence, enable further intervention study to be carried out in the near future in the hope of reducing the incidence of pregnancy-related complications in pregnant women and improve birth outcomes.

1.3 Objectives

1.3.1 General objective

To determine the association between gestational weight gain and sociodemographic factors, dietary intake and physical activity level among pregnant women in Bachok District, Kelantan.

1.3.2 Specific objectives

1. To evaluate prepregnancy body mass index and gestational weight gain of pregnant women in Bachok District, Kelantan.
2. To evaluate the nutrient intake and dietary diversity score of pregnant women in Bachok District, Kelantan.
3. To assess the level of physical activity of pregnant women in Bachok District, Kelantan.
4. To identify associated factors of gestational weight gain among pregnant women in Bachok District, Kelantan.

1.4 Research questions

Is there any association between sociodemographic factors, dietary intake and physical activity level against gestational weight gain of pregnant women in Bachok District, Kelantan?

Hypotheses Alternative (H_α)

There is an association between sociodemographic factors, dietary intake and physical activity level against gestational weight gain of pregnant women in Bachok District, Kelantan.

1.5 Conceptual framework

A conceptual framework of the association between GWG and its associated factors and birth outcomes was shown in Figure 1.1. The conceptual framework illustrates the associated factors of GWG such as sociodemographic factors (age, educational level, household size, employment status, and household income), anthropometric measurements (prepregnancy BMI and mid-upper arm circumference (MUAC)), obstetric and clinical factors (primigravida, parity, gestational age at delivery, GDM, PIH and anemia), dietary intake (nutrient intake and dietary diversity score) and physical activity level that may have resulted in adverse birth outcomes by excessive or inadequate GWG.

For outcomes resulted by excessive GWG, there was an increased in neonatal intensive care unit (NICU) admission, stillbirth, macrosomia infant or childhood obesity. On the other hand, inadequate GWG increased the odds of preterm birth, LBW, full term LBW or fetal growth restriction.

1.6 Significance of study

This study will provide baseline data on nutritional status of the pregnant women and also prevalence of pregnancy-related complications in rural area of Bachok District, Kelantan. This study is important to identify sociodemographic factors, anthropometric measurements, obstetric and clinical factors, dietary intake and physical activity level in influencing gestational weight gain of the pregnant women in Bachok District, Kelantan. Hence, enable further intervention study to be carried out in the near future.

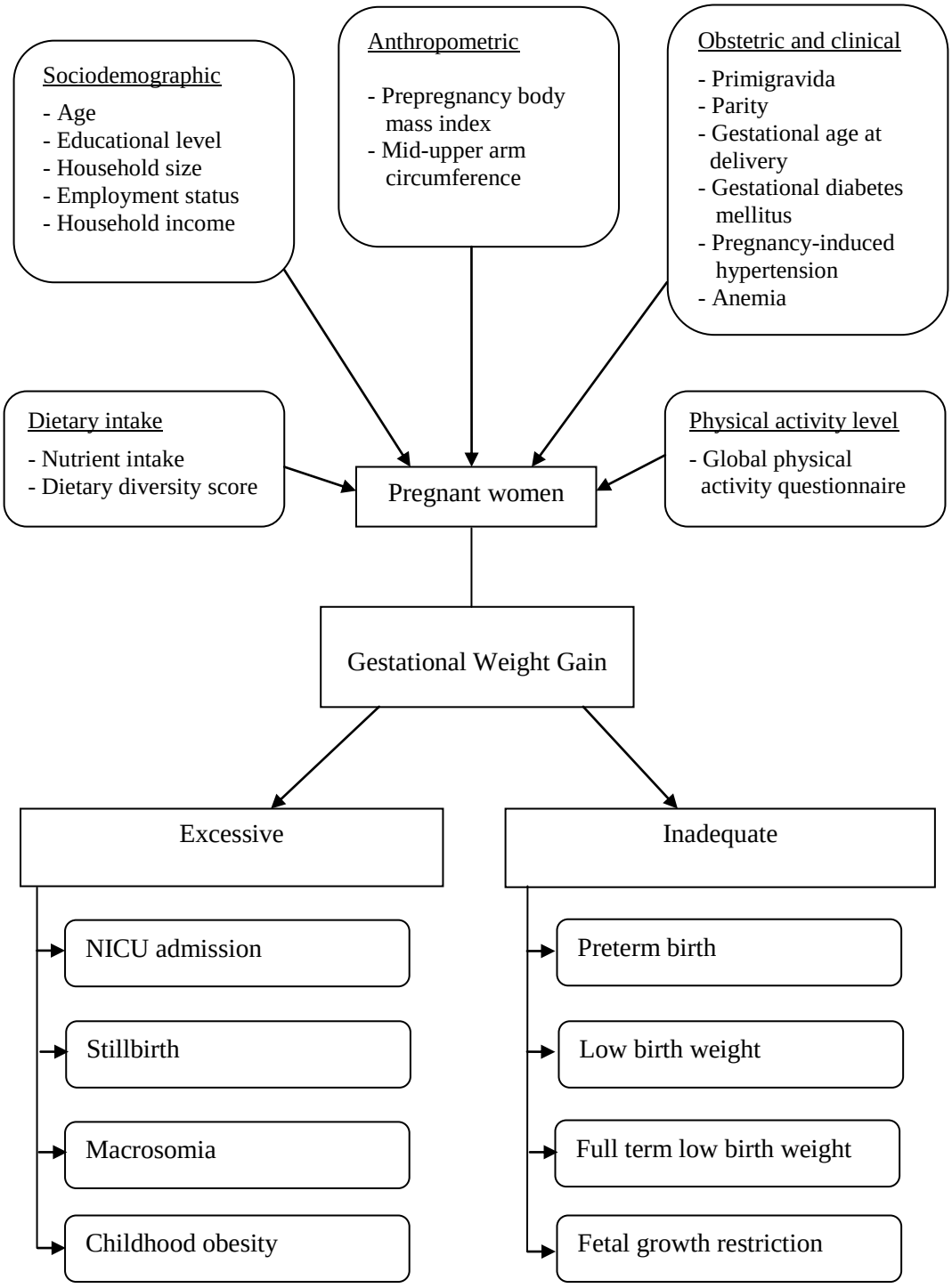

Figure 1.1: Conceptual framework of the study

1.7 Definition of terms

Third trimester – the last trimester during pregnancy and it is start from week 28 until the end of the pregnancy

Gestational weight gain – the difference between the weight measured at the last visit before delivery and the prepregnancy weight reported by the pregnant mother

Macrosomia – infant's birth weight which is above 4000 grams

Low birth weight – infant's birth weight which is less than 2500 grams

Preterm delivery – infant who is born before 37 weeks of pregnancy

Term delivery – infant who is born after 37 weeks of pregnancy

Large-for-gestational age (LGA) – infants's birth weight equal or more than 90^{th} percentile for gestational age

Small-for-gestational age (SGA) – infant's birth weight less than 10^{th} percentile for gestational age

CHAPTER 2

LITERATURE REVIEW

2.1 Gestational weight gain

Pregnancy is a unique period where there is a dynamic change of the biological phenomenon of a pregnant mother which requires sufficient nutrients intake for the nourishment of the fetus. As the fetus is fully dependant on the pregnant mother to provide the necessary nutrients for a healthy growth and development, adequate and well-balanced diet is required to ensure sufficient energy intake with adequate weight gain to support the increased nutrients needs. Adequate weight gain is important to ensure a healthy nutritional status of the pregnant mother and sufficient energy intake for the continuous growth of the fetus. Hence, the gestational weight gain (GWG) guidelines (Table 2.1) were published by the Institute of Medicine (IOM) (2009) to educate the public on the recommended weight gain during pregnancy to prevent pregnancy-related complications.

Table 2.1: New recommendations for total and rate of weight gain during pregnancy, by prepregnancy body mass index

Prepregnancy BMI	BMI* (kg/m^2) (WHO)	Total Weight Gain Range (kg)	Rates of Weight Gain* 2nd and 3rd Trimester (Mean Range in kg/wk)
Underweight	<18.5	12.5-18	0.51 (0.44-0.58)
Normal weight	18.5-24.9	11.5-16	0.42 (0.35-0.50)
Overweight	25.0-29.9	7.0-11.5	0.28 (0.23-0.33)
Obese (includes all classes)	≥30.0	5-9	0.22 (0.17-0.27)

*Calculations assume a 0.5-2 kg (1.1-4.4 lbs) weight gain in the first trimester (based on Siega-Riz et al., 1994; Abrams et al., 1995; Carmichael et al., 1997)

(IOM, 2009)

During pregnancy, weight gain is necessary for a healthy pregnancy as the weight gained is not solely from the fetus and energy intake but also from the weight of the placenta, uterus, and amniotic fluid. Hence, pregnant women were advised to follow the IOM recommendation of weight gain during pregnancy to ensure a healthy weight gain. However, study shown that 47.2% of pregnant women gained more than the recommended weight gain and 20.9% gained less than the recommended weight gain (Deputy *et al.*, 2015).

Maternal excessive GWG was associated with increased risk of pregnancy-induced hypertension (PIH), caesarean delivery, and a decreased risk of preterm delivery (Li *et al.*, 2013). Pregnant women with PIH were more likely to develop edema as compared to pregnant women who were normotensive (Li *et al.*, 2013) and were more likely to have induction of labour, preterm birth and caesarean delivery (Abalos *et al.*, 2014; Jayaraman *et al.*, 2016). Besides that, results obtained from a study conducted at Beijing Friendship Hospital, China reported that weight gain during pregnancy above the IOM recommendations increased the incidence of caesarean section, preterm delivery, preeclampsia and macrosomia in newborn, however reduced the incidence for gestational diabetes mellitus (GDM) (Liu *et al.*, 2015). There were 60% of pregnant women who gained weight above the IOM recommendations reported to have caesarean delivery (Rodrigues *et al.*, 2010) and it was associated with the adverse infant outcome (Reis *et al.*, 2014).

In a study by Tsai *et al.* (2012), GWG greater than 18kg was significantly increased the risk for preeclampsia and a cesarean delivery regardless of the maternal prepregnancy BMI. It was noticed that preeclampsia increased the risk of

cardiovascular disease later in life (McDonald *et al.*, 2008). Although preeclampsia also affects a variety of organ in human body, however, the greatest impact was on heart and vital organ such as renal, liver and brain (Lin *et al.*, 2015). Furthermore, preeclampsia also have some impact on infant such as stillbirths, low birth weight, low Apgar score at birth (Abalos *et al.*, 2014) and neonatal intensive care unit admission (Jayaraman *et al.*, 2016).

Besides that, GWG of women above the IOM recommendations were two times higher chance to deliver large-for-gestaional age (LGA) infants compared to women who gained within the recommendations (Munim and Maheen, 2012). Excessive GWG was found to be associated with increased infant birth weight and incidence of macrosomia (Costa *et al.*, 2012). Similarly, study by Li *et al.* (2013) found that maternal excessive GWG compared with adequate GWG was associated with increased risk of infant macrosomia, however decreased the risk of low birth weight (LBW). There were 23.5% of macrosomic infants observed in pregnant women with excessive GWG compared to only 4.5% in women with inadequate weight gain (Rodrigues *et al.*, 2010). Moreover, higher total GWG was significantly associated with higher risk for LGA (Heude *et al.*, 2012).

In addition, excessive maternal weight gain during pregnancy was significantly associated with higher risk of overweight in children (Moreira *et al.*, 2007; Beyerlein *et al.*, 2012; Guo *et al.*, 2015). A study shown that excessive weight gain during pregnancy was associated with 48% greater odds of overweight in children at the age of seven (Wrotniak *et al.*, 2008). A prospective cohort study in China found that the risk of overweight in children was doubled in overweight or

obese women with excessive GWG (Guo *et al.*, 2015). Excessive GWG increased the risk of childhood overweight as well as childhood abdominal adiposity (Ensenauer *et al.*, 2013). Moreover, greater maternal GWG increased the adiposity of children at the age of three (Oken *et al.*, 2007).

According to Schack-Nielsen *et al.* (2010), increased in childhood BMI was associated with higher GWG and this phenomenon will continue through adulthood with a greater risk of obesity in adults. It is believed that excessive GWG may have some effect on maternal intrauterine development which further resulting in childhood overweight. The possible explanation might be due to fetal hyperinsulinism. Fetal hyperinsulism as a result from overstimulation of fetal pancreatic ß cells caused by excessive GWG and hyperglycemia resulting in higher birth weight, impaired glucose tolerance and obesity in adolescence (Wrotniak *et al.*, 2008).

These overweight children will subsequently increased the risk of being overweight (Ahmad *et al.*, 2010) and possess higher risk of coronary heart diseases during adulthood (Baker *et al.*, 2007). The possible reason of overweight children have increased risk of being overweight during adult may be due to genetic and environmental factors as the children shared the same gene and living in the same environment as their overweight or obese mothers (Oken *et al.*, 2007; Guo *et al.*, 2015). However, genetic predisposition was non-modifiable, thus environmental modification may be essential in reducing the prevalence of overweight children as weight loss in children is more successful than in adults over the long-term (Ahmad *et al.*, 2010).

On the other hand, maternal GWG less than recommended guidelines also increased the risk for maternal and neonatal complications (Choi *et al.,* 2011). Maternal inadequate GWG was associated with an increased risk of preterm delivery (Li *et al.,* 2013). However, inadequate GWG of obese diabetic mothers were associated with lower mean of infant birth weight, lower incidence of cesarean delivery and pregnancy-related hypertensive disorders (Kurnit *et al.,* 2016).

Recently, researchers from China found that inadequate GWG significantly increased the risk for LBW and preterm birth (Wen and Lv, 2015). Higher incidence of GDM and SGA were also reported as pregnant women had inadequate GWG (Liu *et al.,* 2015). Mothers who gained weight within the Institute of Medicine's (IOM) BMI-specific guidelines have lower occurrence of neonatal complications (Margerison Zilko *et al.*, 2010) as greater odds of infant death were found to be associated with inadequate GWG (Davis and Hofferth, 2012). Hence, adequate weight gain is important during pregnancy to avoid the negative pregnancy outcomes.

A study showed that prevalence of SGA infants was two-fold lower in underweight mothers with appropriate GWG as compared to underweight mothers with inadequate GWG (Jeric *et al.*, 2013). Another study found that underweight women were more likely to deliver LBW infants and a minimum weight gain of 8.5 kg is needed to prevent LBW (Munim and Maheen, 2012). Besides that, prepregnancy BMI is also important as it indicates the range of weight gain a pregnant woman should gain during her pregnancy. Weight gain during pregnancy decreased as the maternal prepregnancy BMI increased (Heude *et al.*, 2012; Liu *et*

al., 2015). Prepregnancy BMI and GWG are correlated in order to have a healthy pregnancy. Healthcare professional should provide proper counseling on recommended GWG to the pregnant women as following correct advice on total GWG according to the prepregnancy BMI of the pregnant women were three times more likely to achieved for appropriate GWG (Cohen and Koski, 2013).

2.2 Prepregnancy Body Mass Index (BMI)

Prepregnancy BMI is crucial for a pregnant woman as it is not only to determine how much weight a pregnant woman should gain but also to avoid maternal and neonatal complications such as GDM, preeclampsia, preterm birth, cesarean delivery, SGA and macrosomia. Evidence shown that obese women were at higher risk of getting GDM as 19% of obese women were diagnosed with GDM while only 4% in women with normal prepregnancy BMI. The risk for GDM increased with increasing prepregnancy BMI and it was significant for overweight and obese pregnant women (Heude *et al.*, 2012). Similarly, study by Liu *et al.* (2015) found that overweight or obese pregnant women had higher incidence of cesarean section, preterm delivery, GDM, preeclampsia and SGA, while underweight pregnant women had a lower incidence of GDM and macrosomia.

According to Boney *et al.*(2005) mothers with diabetes mellitus have higher risk to give birth to LGA infants. These infants will later develop significant risk of metabolic syndrome during childhood. A study at the Tianjin Women's and Children's Health Center found that overweight and obese GDM pregnant women together with excessive GWG were associated with increased incidence for LGA and

macrosomia infants. These infants were at increased risk of childhood overweight at the age of 1-5 years old (Leng *et al.,* 2015).

Besides diabetic mothers, infants born to mothers with prepregnancy obesity and excessive GWG had increased four folds risk of macrosomia, compared with those children born to mothers with both prepregnancy normal weight and adequate GWG (Li *et al.,* 2013). This indicated that overweight or obese pregnant women increased the likelihood of delivered LGA or macrosomia infants with or without GDM. Even in the absence of GDM, maternal obesity is associated with higher glucose concentration which contributed to intrauterine hormonal environment similar to metabolic syndrome, characterized by hyperglycemia and insulin resistance and further lead to greater diffusion of glucose and resulting in fetal hyperglycemia and stimulate deposition of glycogen and fat (O'brien *et al.,* 2017). This subsequently resulted in LGA or macrosomia infant.

Overweight women were 1.58 times higher odds of delivered LGA infants compared to normal weight mothers (Munim and Maheen, 2012). Moreover, obese mothers were twice more likely to deliver LGA infants compared to those non-obese mothers. Children who were born LGA had higher chance to become obese preschoolers later in their life (Whitaker, 2004). However, increased in prepregnancy BMI and maternal weight gain in the other hand, were significantly decreased the risk for small-for-gestational age (SGA) (Boney *et al.*, 2005).

Higher prepregnancy BMI compared to normal significantly increased the chance of preterm birth, GDM, preeclampsia, cesarean delivery and increased infant

birth weight (Tsai *et al.*, 2012). Study by Li *et al.* (2013) obtained similar results where maternal prepregnancy BMI was positively associated with the risk of cesarean delivery, GDM, PIH and preterm delivery. The odds for preterm birth were 1.53 times higher in overweight women as compared to normal BMI women (Munim and Maheen, 2012). Pregnant women with a high BMI group ($\geq$24kg/m^2) and low GWG were also at an increased risk for preterm birth (Tsai *et al.*, 2012).

Overweight and obese pregnant women were at an increased likelihood of excessive GWG compared to normal weight women (Schlaff *et al.*, 2014). Study showed that, prepregnancy overweight and obesity were risk factors associated with excessive GWG (Wells *et al.*, 2006). Pregnant women with high prepregnancy BMI were more likely to have high GWG (Ebrahimi *et al.*, 2015). Furthermore, Prepregnancy obese women with excessive GWG or adequate GWG had increased the risk of GDM, PIH, and caesarean delivery by two to seven folds compared with normal prepregnancy BMI and adequate GWG women (Li *et al.*, 2013). Recent study found that regardless of the adequacy of GWG, the risk of gestational hypertension, GDM and LGA infants increased with pregnant women who were obese, whereas preterm delivery and SGA infants increased with pregnant women who were underweight (Shin and Song, 2015).

The odds of childhood obesity increased as the maternal prepregnancy BMI increased (Whitaker, 2004). A study found that maternal overweight and obesity were associated with childhood obesity at the age of five and obese pregnant women were 2.9 times more likely to have obese children (Janjua *et al.*, 2012). High maternal prepregnancy BMI was associated with an increasing risk of obesity in the

infant during adulthood (Schack-Nielsen *et al.*, 2010). Study found that infants of normal BMI mothers had lower fat mass and higher fat free mass compared to infants of overweight or obese mothers (Hull *et al.*, 2008).

Children of obese pregnant women were associated with lower cognitive development scores during early childhood (Casas *et al.*, 2013). Children born to underweight or extremely obese mothers were significantly higher risk of delayed mental development compared to children of normal weight mothers (Hinkle *et al.*, 2012). A population-based, case-control study involving 1004 children found that obese women were 67% higher risk of having children with autism spectrum disorder and two-folds more likely to have children with developmental delay (Krakowiak *et al.*, 2012).

A prospective pregnancy cohort study from Sweden, Denmark and Finland shown that overweight or obese pregnant women were associated with increased risk of having school-age children with attention deficit hyperactivity disorder (ADHD) symptom compared to children born to normal weight mothers (Rodriguez *et al.*, 2008). The mechanism underlying this association was unknown. However, there are a few possibilities that suggested this association between maternal BMI and ADHD symptoms. It is believed that the association was related to genetics, perceived stress, complications during pregnancy or delivery, environmental factors and micronutrients or leptin level (Rodriguez *et al.*, 2008).

Other evidence has found that women who entered their pregnancy obese are more likely to have a child affected by a structural defect such as spina bifida, as

well as heart defects, anorectal atresia, hypospadias, limb reduction defects, diaphragmatic hernia, and omphalocele. Overweight pregnant women too increased the risk significantly for heart defects, hypospadias, and omphalocele (Waller *et al.*, 2007).

Besides that, maternal obesity was positively related to more than doubled risk for stillbirth and neonatal death (Kristensen *et al.*, 2005). High BMI increased the risk of maternal morbidity whereas incidence of complications of the infant affected by low maternal BMI (Murakami *et al.*, 2005). Pregnant mothers who had a low prepregnancy BMI were most likely to have inadequate weight gain during pregnancy compared to mothers who had a normal prepregnancy BMI (Brawarsky *et al.*, 2005), whereas overweight and obese women have high tendency to gain excess weight during pregnancy compared to women with normal BMI (Crane *et al.*, 2009).

Prepregnancy underweight group were more likely to have gestational anemia but less likely to have PIH and preeclampsia compared to prepregnancy normal weight group (Fujiwara *et al.*, 2014). Underweight women with low GWG increased the risk for LBW, whereas higher birth weight was found in underweight and normal weight women with GWG greater than 14kg (Tsai *et al.*, 2012). The incidences of spontaneous preterm birth and SGA were significantly higher in prepregnancy underweight pregnant women than in normal weight (Fujiwara *et al.*, 2014). However, with a gain of 9.0 kg or more GWG, underweight pregnant women did not show a significantly increased risk of SGA birth (Harita *et al.*, 2012).

Hence, having a normal BMI before conception is important to have a healthy pregnancy and prevent any negative pregnancy outcomes. However, weight gain within the IOM recommendations was equally important as a study showed that GWG with either below or above the IOM recommendations increased the risk for childhood overweight or obesity, and this was especially stronger among normal prepregnancy BMI group (Sridhar *et al.*, 2014). This indicated that pregnant women should have normal prepregnancy BMI and gain within the IOM recommendations to prevent childhood obesity in their offsprings.

2.3 Sociodemographic factors

2.3.1 Maternal age

Age of the pregnant women was found to be significant risk factors of maternal and neonatal complications. A retrospective cohort study done at three hospitals at United Kingdom found that advanced maternal age was associated with increased incidence of miscarriage, GDM, preeclampsia and cesarean section in mothers; while SGA in infants (Khalil *et al.*, 2013). Besides that, a population-based cross-sectional study in Victoria, Australia found a very strong association of maternal age and GDM where, women over the age of 35 years had approximately 6 times the risk of developing GDM compared to women aged less than 20 years and this incidence was most evident among Asian women (Carolan *et al.*, 2012).

Furthermore, a matched case-control study conducted in Universiti Kebangsaan Malaysia Medical Centre (UKMMC) found that maternal age was significantly associated with LBW in infants. The pregnant women with younger age were at increased risk of having LBW infants. This may be due to the poor eating

pattern which resulted in maternal nutrition depletion of the younger age pregnant women (Sutan *et al.,* 2014). Likewise, maternal age was also shown a significant association with GWG. A study performed at KK Women's and Children's Hospital, Singapore reported that maternal age less than 20 years were associated with increased risk of inadequate GWG, meanwhile maternal age greater than 30 years were at decreased risk of excessive GWG (Koh *et al.,* 2013).

2.3.2 Educational level

A few studies showed that educational level of pregnant women were significantly associated with GWG. A retrospective cohort study involving 2586 pregnant women from Shenyang Province, China shown that lower GWG was found in pregnant women with less than 12 years of education (Chen *et al.,* 2010). Adversely, an observational cohort study of pregnant women in rural area of Vietnam found that maternal tertiary education was significantly increased the rate of GWG (Hanieh *et al.,* 2014). Study by Changamire *et al.* (2014) discovered that a higher weight gain of 244 grams per month was observed in pregnant women with more than 12 years of education compared to those with less than 5 years of education. Furthermore, study showed that higher education level of equal or more than 4 years had higher gestational weight gain compared to those with less than 4 years of education level. This may suggest that the education level might be a marker of food access in the population (Konno *et al.,* 2007).

On the other hand, a prospective prebirth cohort study demonstrated a lower educational level in pregnant women with excessive GWG (Jedrychowski *et al.,* 2011). In addition, lower education women with a normal prepregnancy BMI were at

greater risk of excessive GWG (Holowko *et al.*, 2014). This might be due to the association between educational level and nutritional knowledge of pregnant women and subsequently affects their dietary habits, thus resulted in excessive GWG.

A study conducted among Malay pregnant women to determine the nutritional knowledge and nutritional status of pregnant women found that educational level was significantly associated with nutritional knowledge score (Abdul Manaf *et al.*, 2014). Another study on maternal nutritional knowledge on iron rich foods and supplements observed that the nutritional knowledge was significantly higher in the group of pregnant women with higher education level (Mohannad *et al.*, 2012). This may due to pregnant women with higher educational level may have more knowledge and better understanding when provided with nutrition information (Abdul Manaf *et al.*, 2014). As a result, their nutritional knowledge was higher compared to those who had lower educational status. This may lead to a better nutritional status during pregnancy as pregnant women who had a better access to nutrition information had been shown to have associated with good dietary practices (Alemayehu and Tesema, 2015).

On the other hand, a lower educational level may lead to lower nutritional knowledge and subsequently increases the consumption of unhealthy diet, thus affect the weight gain of pregnant women. A study conducted in Korea demonstrated that nutritional knowledge was negatively associated with bad eating habit (Kim, 2009). Similarly, study by Fowles (2002) showed that the pregnant women who lack of nutritional knowledge had unhealthy dietary intake during pregnancy where they had high intake of fried and processed food. As a result, they did not gain weight

according to the IOM recommendation. These evidences showed that poor nutritional knowledge may result in unhealthy dietary intake which further led to undesired GWG.

Besides that, a population-based prospective cohort study enrolled the pregnant women during early pregnancy in Rotterdam, the Netherlands showed a significant association of low maternal educational level and increased risk of maternal overweight and obesity (Gaillard *et al.*, 2013). Evidences showed that educational level of pregnant women possess a significant risk factor for maternal overweight or obesity and GWG.

2.4 Skinfold measurements

Currently, there is no consensus on how to identify a pregnant woman with acute malnutrition and in particularly which cut-off value should be used. MUAC was identified as the preferential tool as it is relatively strong association with LBW (Ververs *et al.*, 2013). MUAC is commonly used to assess the nutritional status of children for acute malnutrition and wasting. Besides that, MUAC is also used in adolescents and adults, including pregnant women to determine their nutritional status and eligibility for nutritional support (Ververs *et al.*, 2013). The advantages of MUAC were simple to use and inexpensive equipment to be carried around especially for community-based assessment where facilities were limited.

Studies suggested that there were significant correlation of maternal MUAC with maternal health and infants outcomes. Study by Charles *et al* (2010) showed that pregnant women with MUAC less than 25cm were at increased risk of anemia

during pregnancy. A study in Brazil found that maternal MUAC was positively correlated to birth weight. The study suggested that maternal MUAC was a potential indicator of maternal nutritional status and it could be used as an alternative indicator, together with other anthropometric measurements to determine pregnant women at risk of adverse pregnancy outcomes (Ricalde *et al.*, 1998).

Similarly, the Breastfeeding, Antiretrovirals, and Nutrition (BAN) Study involving 1005 HIV-infected women from Lilongwe, Malawi found that maternal MUAC was a strong predictor for infant birth weight. The study reported that as with 1cm increased in maternal MUAC, infant birth weight was increased by approximately 32g (Ramlal *et al.*, 2012). In addition, increased in maternal MUAC was strongly associated with decreased odds of LBW in infants (Ramlal *et al.*, 2012). Moreover, an observational cohort study on pregnant women was conducted in Kersa Demographic Surveillance and Health Research Center, Ethiopia demonstrated that maternal MUAC less than 23cm was significantly associated with increased rate of LBW (Assefa *et al.*, 2012)

2.5 Dietary assessment

2.5.1 Nutrient intake

An earlier study revealed that low energy intake was observed in pregnant women with high prepregnancy BMI (Bergmann *et al.*, 1997). As the BMI of the mother increased, the diet quality of the mother decreased (Laraia *et al.*, 2007). Dietary intake high in red and processed meat, potatoes and high-fat dairy, and low in fruits and vegetables were associated with increased risk for SGA infant (Knudsen *et al.*, 2008). This not only will affect the nutritional status of the mother but also the

infant. A study conducted in the Netherlands involving 6956 pregnant women found that higher total energy, carbohydrate, protein and fat intake were significantly increased the incidences of excessive GWG (Gaillard *et al.*, 2013).

According to a study conducted by Changamire *et al.* (2014), higher rate of weight gain in third trimester was observed with greater total energy intake during pregnancy. A large prospective cohort study in the Danish National Birth Cohort (DNBC), Denmark found that there was a significant reduced in GWG of pregnant women who had a high protein-to-carbohydrate ratio. The association was found to be driven more by reducing in carbohydrate intake, especially added sugar. The study observed that dietary intake of pregnant women with higher protein intake gained less weight during pregnancy compared to pregnant women who consume less protein. Pregnant women who replaced their carbohydrate intake with protein gained significantly 13grams less per gestational week. Interestingly, findings from the study showed that dietary protein intake less than 12 percent of energy was associated with increased of GWG in pregnant women, however, protein intake more than 20 percent reduced the incidence (Maslova *et al.*, 2015). Similar findings were obtained from a prospective study in sub-Saharan, Africa where replacing energy from fat and carbohydrate with protein were significantly reduced the rate of weight gain during pregnancy (Changamire *et al.*, 2014).

Evidences suggested that higher protein intake as compared to fat and carbohydrate intake may reduce the incidence of excessive weight gain during pregnancy. Higher total energy and macronutrients intake were associated with higher risk of excessive GWG (Gaillard *et al.*, 2013). Similarly, study found that

total caloric intake was directly associated with excessive GWG, however, vegetarian diet in early pregnancy showed inverse association toward excessive GWG (Stuebe *et al.*, 2009). Besides that, study also shown that intake of caloric beverages, snacks, fish and bread was associated with higher odds for excessive GWG (Bärebring *et al.*, 2016). Higher consumption of foods with added sugars such as sweets and cakes were also strongly associated with greater GWG (Renault *et al.*, 2015). A strong relationship between dietary intake and risk for GDM was reported, where high added sugar and organ meats, while low in fruits, vegetables and seafood intake were significantly associated with increased risks for GDM (Shin *et al.*, 2015).

Besides dietary intake, a low glycemic index was also found to be associated with weight gain during pregnancy. A randomized controlled trial of low glycemic index dietary intervention study was conducted at National Maternity Hospital (NMH) in Dublin, Ireland observed a significant reduced of maternal glycemic index after a low glycemic index dietary intervention in early pregnancy was done in pregnant mothers who were having macrosomic infants previously. Dietary consumption of fiber, wholegrain breads and cereals were significantly increased, while high energy beverages, white breads and refined cereals were reduced. In addition, pregnant mothers who received the low glycemic index dietary counseling were more likely to gained weight within the IOM recommendations throughout the pregnancy (McGowan *et al.*, 2013).

2.5.2 Dietary diversity

According to the Food and Agriculture Organization of the United Nations (FAO), with the USAID's Food and Nutrition Technical Assistance Project (FANTA),