CASE REPORT

Maternal obesity and its determinants: A neglected issue?

Nurul- Farehah S, Rohana AJ

Nurul- Farehah S, Rohana AJ. Maternal obesity and its determinants: A neglected issue?. *Malays Fam Physician.* 2020;15(2);34–42.

Keywords:
maternal obesity, obesity in pregnancy, determinants, modifiable associated factors, non-modifiable associated factors

Authors:

Rohana Abdul Jalil
(Corresponding author)
Ph.D
Department of Community Medicine
Universiti Sains Malaysia, Malaysia
Email: rohanajalil@usm.my

Nurul Farehah Shahrir
MBBS,MPH
Department of Community Medicine
Universiti Sains Malaysia, Malaysia

Abstract

Maternal obesity is a global public health concern that affects every aspect of maternity care. It affects the short-term and long-term health of the mother and her offspring. Obese pregnant mothers are at an increased risk of developing complications during antenatal, intrapartum, and postnatal periods. Maternal complications include gestational diabetes mellitus, hypertensive disorder in pregnancy, pre-eclampsia and eclampsia, increased rate of cesarean delivery, pulmonary embolism, and maternal mortality; fetal complications include congenital malformation, stillbirth, and macrosomia. Moreover, both mother and infant are at an increased risk of developing subsequent non-communicable diseases and cardiovascular problems later in life. Several factors are associated with the likelihood of maternal obesity, including sociodemographic characteristics, obstetric characteristics, knowledge, and perception of health-promoting behavior. Gaining a sound understanding of these factors is vital to reaching the targets of Sustainable Developmental Goal 3—to reduce global maternal mortality and end preventable deaths of children under 5 years of age—by 2030. It is essential to identify pregnant women who are at risk of maternal obesity in order to plan and implement effective and timely interventions for optimal pregnancy outcomes. Importantly, maternal obesity as a significant pregnancy risk factor is largely modifiable.

Introduction

Around the world, obesity has become a significant public health concern, and the prevalence of obesity is growing at an alarming rate.[1] This epidemic presents a substantial challenge for non-communicable disease (NCD) prevention.[2] Obesity is a complex, multifactorial disease involving interaction between genetic, hormonal, behavioral, socioeconomic, and environmental conditions; if not controlled, it can result in devastating morbidity and mortality.[3] Many countries have observed a rise in obesity following urbanization and industrialization over the last 30 years—some have seen obesity rates quadruple.[4]

Globally, obesity has nearly tripled since 1975. In 2016, the World Health Organization reported that more than 1.9 billion adults were overweight; among them, more than one-third were obese.

While the rate of obesity appears to be higher for women than for men[5], obesity is increasing in both developed and developing countries. However, in developed countries, the peak prevalence is trending toward younger people.[6]

In Malaysia, the prevalence of obesity rose by 4.4% between 2006 and 2015, from 26.2% to 30.6%.[7] In fact, the country has the highest prevalence of obesity in Southeast Asia (SEA). According to the 2015 National Health Morbidity Survey, the prevalence of obesity among adults was 30.6%. The rate was higher for women (33.6%) than for men (27.8%), and higher for married women (33.8%) than for single women (22.7%). Moreover, those who are ethnically Indian were found to have the highest prevalence of obesity (43.5%). The highest rate was seen in the state of Wilayah Persekutuan Putrajaya (43%).[7]

The purpose of this narrative review is to identify modifiable and non-modifiable risk factors for maternal obesity that are considered relevant in the development of guidelines concerning maternal obesity as well as interventions aimed at preventing obesity among pregnant women in Malaysia.

Methods

Through a narrative review, we examined the factors associated with maternal obesity. We discussed results from recent studies and the potential underlying mechanisms of the observed associations. The search keywords used include maternal obesity, obesity in pregnancy, determinants, modifiable associated factors, and non-modifiable associated factors.

Defining obesity in pregnancy

Obesity is defined as a condition characterized by excessive accumulation of fat in adipose tissue that may cause impairment to health.[8] One of the most commonly used indices of relative weight is the Body Mass Index (BMI), or body weight in kilograms divided by height in meters squared. The World Health Organization defines obesity as BMI ≥ 30 kg/m^2. However, Asian populations often see a lower BMI cut-off point, relative to Caucasian populations, for risk of complications. Few studies have been done on this difference, though some in Hong Kong[9] and Singapore[10] have shown an increasing prevalence of non-insulin dependent diabetes mellitus (NIDDM) and cardiovascular risk factors at cut-off points below 25 kg/m^2 for overweight and below 30 kg/m^2 for obesity.

In obstetric populations, the Royal College of Obstetricians and Gynaecologists defines maternal obesity as BMI ≥ 30 kg/m^2, similar to the general population. The National Institute for Health and Care Excellence (NICE) antenatal care guidelines recommend that maternal height and weight should be measured for BMI measurement in pregnant women by 10 weeks of gestation. In areas without the necessary equipment, self-reported height and weight can be used.[11] However, this method can often garner an overestimated height and an underestimated weight, especially in obese women, resulting in an inaccurate risk assessment for their pregnancy.[12] Regarding BMI cut-off points, a study in Singapore involving 8,843 mothers showed an increase in the prevalence of maternal obesity from 12.2% using the WHO cut-off points to 21.0% using the Asian BMI cut-off points.[13] However, the prevalence of adverse feto-maternal outcomes associated with maternal obesity did not change with lower BMI cut off points.

Obesity among women in the reproductive age group and pregnant mothers

The most recent national population survey in Malaysia revealed that obesity is more prevalent among women than among men.[7] A study found that 15.9% of women in the reproductive age group (20 - 49) were obese[14], meaning that these women of childbearing potential (WOCBP) would start pregnancy with maternal obesity.

In 2014, there were approximately 38.9 million overweight and obese pregnant women globally, with a higher rate in both upper- and middle-income countries, including Malaysia.[15] In India, the National Family Health Survey had shown a rise in the prevalence of maternal obesity over seven years, from 10.6% in 1999 to 14.8% in 2006. In Malaysia, according to the 2016 National Health Morbidity Survey, the prevalence of maternal obesity was 14.6% with the highest rates (69.2%) among those of advanced age (45–49), ethnic Malays (16.8%), and ethnic Indians (15.6%).[16] These findings have important implications for obstetric care, as maternal obesity is associated with a greater length of hospital stay.[17] It has been estimated that maternal obesity accounts for 2.8% of a country's total healthcare expenditure.[18]

Maternal and perinatal health

Maternal health refers to the health of women during pregnancy, childbirth, and the postpartum period.[19] According to the WHO, approximately 810 women died each day due to preventable causes related to pregnancy and childbirth in 2017. Globally, the five major direct causes of maternal morbidity and mortality include hemorrhage, infection, high blood pressure, unsafe abortion, and obstructed labor. In Malaysia, according to Confidential Enquiries into Maternal Death, the four leading causes of maternal death between 2009 and 2011 were associated medical conditions (31.2%), obstetric embolism (16.0%), hypertensive disorders in pregnancy (HDP) (15.8%), and postpartum hemorrhage (PPH) (11.6%). Three of these—obstetric embolism, hypertensive disorders in pregnancy, and postpartum hemorrhage—were associated with maternal obesity.[20,21] Furthermore, a cross-sectional study by the Malaysian National Obstetric Registry of data from 88,837 pregnant women showed that maternal overweight and obesity were associated with stillbirths (OR 1.2; 95% CI 1.0, 1.4), shoulder dystocia (OR 1.9 95% CI 1.2, 2.9), fetal macrosomia (OR 1.8; 95% CI 1.6, 2.0), and cesarean section (OR 1.9; 95% CI 1.8, 2.0). [22]

Determinants of maternal obesity

Sociodemographic and obstetric characteristics

Ramonienė et al.[23], Gaillard et al.[24], and Callaway et al.[17] have shown that older and multiparous women are at a higher risk of becoming obese. Similarly, Heslehurst et al.[25] found that advanced maternal age and multiparity were associated with maternal obesity after adjusting the confounders. Moreover, a prospective analysis of 2,923 non-obese women conducted by Rebholz et al. showed that the 5-year incidence of obesity was 11.3 per 100 multiparous women compared to

just 4.5 per 100 in nulliparous women.[26] However, this finding strayed from that in a study by Boudet-Berquier et al. which found that, among primiparous women, those between 25 and 29 were more likely to be obese than those between 30 and 34.[27]

Ying Pang et al. found that maternal obesity was far more common among Malay (21.5%) and Indian (17.2%) women than among Chinese (4.6%) women.[13] In contrast, some studies have shown that maternal obesity is associated with the minority group. In Queensland, Australia, the highest rate of delivery by overweight and obese mothers was found among indigenous women.[28] A study by Bahadoer et al. in Rotterdam involving 6,444 pregnant women found similar results, revealing a higher prevalence of maternal obesity among ethnic minority groups.[29] These racial/ethnic and nativity inequalities in the risk of maternal obesity were partially explained by living conditions, such as limited access to health-promoting environments like walkways, public transportation, and inexpensive healthy foods.[30] Ethnic differences may also be attributed to variance in genetic predisposition and developmental factors.[31] Interestingly, one study conducted in the UK involving 36,821 pregnant women argued that ethnicity was not associated with maternal obesity. However, the interpretation of this finding is limited since the numbers representing the non-Caucasian populations were relatively low.[11]

Low socioeconomic status has been linked to maternal obesity. A study in Middleborough, UK, of 36,821 pregnant women over 15 years found that pregnant mothers living in deprived areas (quintiles 1–3) were 2.5 times more likely to be obese than those living in the least deprived area (quintile 5).[11] This was consistent with Athukorala et al.[32] and Nohr et al.[33], who found that low household income was significantly associated with maternal obesity.

Several studies have shown that a low level of maternal education level was associated with an increased risk of obesity among pregnant women. A study of 54,022 pregnancies in Flanders showed that high pre-pregnancy BMI was significantly more prevalent among women with lower levels of education.[34] Moreover, a study of 36,821 women in the UK revealed that a longer schooling period significantly reduced the odds of becoming obese while pregnant.[11] Similar findings were seen in a study by Boudet-Berquier et al., in which pregnant women with a higher level of education or in professional workers were found to be less likely to be obese.[27] Other factors associated with high BMI among pregnant women include cigarette smoking and marital status.[24] Mkuu found that women who were married or living with a partner had a 73% higher risk of being overweight or obese.[35] In contrast, however, one study showed no significant association between marital status and maternal obesity.[36]

Antenatal and postpartum physical activities

Adiposity is the result of positive energy balance; the decline in energy expenditure is more than the intake of calories, leading to accelerated fat deposition. The Institute of Obstetricians and Gynaecologists of the Royal College of the Physicians of Ireland recommends that pregnant women get at least 30 minutes of daily exercise. Meanwhile, The Royal College of Obstetricians and Gynaecologists (RCOG) recommends that women avoid a sedentary lifestyle and get at least 150 minutes of moderate-intense activity per week throughout pregnancy. Physical activity and exercise have numerous benefits for pregnant women and their fetuses, including the prevention of excessive weight gain and postpartum weight retention.[37]

Restall et al. reported that women who reduced exercise levels by 14–16 weeks into their pregnancy were 50% more likely to develop excessive gestational weight gain (GWG); women with sedentary behaviors were more likely to gain weight to—based on Institute of Medicine (IOM) recommendations—an unhealthy extent, contributing to maternal obesity.[38] Nohr et al. reported that obese mothers were more likely to be physically inactive than normal-weight mothers.[33] A cross-sectional study of 491 overweight and obese women in North Carolina showed that nearly three-quarters of the respondents failed to meet the national physical activity recommendations during the postpartum period; women with a BMI ≥ 40 kg/m^2 spent more time doing sedentary activities than those with a lower BMI.[39]

Many pregnant women become more sedentary, especially after reaching their third trimester.[40] According to Pereira et al., there was a significant reduction of women's physical activity from the antenatal period to six months postpartum; the prevalence of insufficient physical activity (≤ 150 minutes per week of activity) increased from 12.6% prior to pregnancy to 21.7% during the postpartum period.[41] Caregiving duties, long working hours, limited knowledge of performing

physical activities, and concerns over pregnancy complications were among the barriers faced by pregnant women.[42]

Physical activity makes up 15–30% of total daily energy expenditure, meaning it is the most modifiable component. Involvement in purposeful exercise (both short- and long-term) has been proven to influence resting energy expenditure[43], consequently reducing the likelihood of maternal obesity. Furthermore, a randomized control trial among 82 pregnant women found that antenatal physical exercise among overweight pregnant women resulted in less weight gain throughout the entire pregnancy.[44]

Dietary intake during pregnancy and the postpartum period

A low healthy eating index (HEI) has been shown to be associated with overweight and obesity during pregnancy, as well as obesity prior to pregnancy.[45] There is some evidence to suggest that an overweight or obese woman is more likely to consume a poor-quality diet during pregnancy that worsens throughout the pregnancy and the postpartum period. A prospective observational study of 100 obese pregnant women found excessive intake of energy-dense processed foods with high fat and sugar content,[46] including crackers, cakes, preserves, confectionery, and savory snacks; creams, ice-cream, and chilled desserts; butter, spreading fats, and oils. Not only do these foods contribute to excessive weight gain during pregnancy and postpartum weight retention, but they also lack the essential micronutrients needed during pregnancy.[47]

Between 50% and 88% of overweight and obese pregnant women have poor compliance with dietary guidelines for the intake of cereals and legumes, carbohydrates, n-3 and n-6 fatty acids, dairy, fruits, and vegetables.[46,48] A study of 125 multi-ethnic women in the early-postpartum period showed that the dietary intake has low mean scores in fruits, total vegetables, and whole grains but had higher intake of sodium, saturated fats, and discretionary calories.[49] Oken et al. reported that every 0.5% increase in daily trans-fat intake resulted in a 1.3-times increase in the likelihood of retaining at least 5 kg weight in the postpartum period.[50] Similar results were found in Australia, where only 7% of respondents met vegetable-consumption recommendation and only 13% met fruit-consumption targets.[51]

Intake of excess energy above the requirement for a growing fetus is stored as part of the anabolic state of pregnancy, increasing body fat composition further with each pregnancy.[52] There are many barriers to healthy eating behaviors for underprivileged overweight and obese mothers, including low access to transportation, higher costs, low perceived self-efficacy, societal norms on food, low social support, and incorrect beliefs about the safe ways to manage weight gain during pregnancy.[53,54]

Interpregnancy interval

Birth spacing, pregnancy spacing, or inter-pregnancy interval is the period between delivery of the previous infant and conception of the present pregnancy. Studies are scarce on the relationship between spacing and maternal BMI outcomes. However, short spacing may increase the risk of maternal obesity due to the weight changes during the interval resulting from weight retained from pregnancy or gained postpartum.[55]

A retrospective cohort study of 38,178 women in Canada showed that short interpregnancy intervals were significantly associated with an increased risk of beginning the subsequent pregnancy obese (adjusted OR 1.61, 95% CI 1.05–2.45 for 0–5 months; adjusted OR 1.43, 95% CI 1.10–1.87 for 6–11 months).[56] However, more research is needed to have a good understanding of the impact of short spacing intervals on maternal obesity.

Pre-pregnancy BMI, excessive weight gain, and postpartum weight retention

Gestational weight gain (GWG) can be defined as the amount of weight gained between conception and before the birth of the infant. In 2009, the Institute of Medicine (IOM) released guidelines and recommendations for GWG based on pre-pregnancy BMI. These recommendations were released due to profound changes in population demographics—far more women were becoming pregnant while overweight or obese.

Pre-pregnancy BMI is the strongest predictor of GWG. A study of 4,619 African American and Caucasian women in Arkansas, US, revealed that overweight women were three times more likely than normal-weight women to exceed the IOM-recommended weight gain while obese women were four times more likely.[57] In Malaysia, a cross-sectional study of 180 pregnant women in the Batu Pahat district showed that women who were overweight or obese prior to being pregnant were seven times more likely than women with normal pre-pregnancy BMI to have an excessive

GWG rate (OR = 7.44, 95% CI = 2.07-26.66).[58] Similarly, a cross-sectional study of 422 pregnant women in a rural area of Gua Musang, Kelantan found that where pre-pregnancy overweight and obesity were significantly associated with excessive GWG.[59] Another cross-sectional study conducted in Selangor and Seremban found that the mean GWG rate for all pre-pregnancy BMI during the second and third trimesters was higher than the IOM recommendations; those with high pre-pregnancy body mass indices were two to three times more likely to have excessive GWG.[60]

In general, the more weight women gain during pregnancy, the more weight they retain following pregnancy. GWG is positively and significantly associated with postpartum weight retention regardless of pre-pregnancy BMI. A study by Baker et al. found that weight retention was between 0.30 and 0.40 kg (with attenuation) per 1 kg of gained weight and persisted for at least 18 months.[61] A separate study of 427 women in Atlanta revealed that the proportion of excessive weight gain was significantly higher among overweight and obese mothers; 52% of respondents retained more than 10 pounds one year postpartum.[62] This resulted in 36.1% of the women moving to a higher BMI category, making 68.5% of them overweight or obese one year postpartum. Similarly, a cross-sectional study of 83 pregnant women in Seremban, Malaysia found that 32.5% of women retained at least 4.5 kg six months postpartum; this retention was significantly associated with higher GWG during pregnancy.[63]

Hollis et al. highlighted the importance of adequate weight gain during pregnancy in order to minimize postpartum weight retention and prevent obesity in childbearing women.[64] They found that overweight (64.0%) and obese women (51.0%) were most likely to exceed the IOM GWG recommendations. Factors associated with postpartum weight retention include parity, socioeconomic status, marital status, race, GWG, breastfeeding, calorie intake, and physical activity.[65,66]

Breastfeeding practice

Theoretically, the energy expenditure of lactation is 2.62 MJ per day.[67] A biological rationale supports the hypothesis that breastfeeding promotes postpartum weight loss while a lack of breastfeeding contributes to weight retention and maternal obesity. A study of 2,571 women found that the odds of above-median postpartum weight retention among women who exclusively breastfed for six to nine months dropped by 37%; they dropped by 46% for those who exclusively breastfed for twelve months.

Furthermore, the odds of early lactation cessation have been shown to rise alongside a rise in BMI.[68] Obesity is an independent risk factor for not breastfeeding at the time of postpartum discharge from hospital,[69] which contributes to increasing BMI with each successive pregnancy. This is in line with the findings of a cohort study of 700 expectant mothers in Selangor, Malaysia, which showed that obese women were more likely to delay breastfeeding initiation and cease breastfeeding earlier. Additionally, after six months post-delivery, greater weight retention was found among mothers who formula-fed their offspring (5.69 kg) compared to those who breastfed (1.45 kg).[70] In another study by Janney et al.[71], weight loss was found to progress at slower rates when women ceased breastfeeding or switched from exclusive to non-exclusive breastfeeding. This could mean that breastfeeding protects against weight gain.[72] Moreover, a study involving 726 women revealed that, among obese mothers, those who exclusively breastfed retained less weight six-years postpartum (-8.0kg) than those who never breastfed.[73]

Gigante et al. reported that women who did not exclusively breastfeed or weaned at four months acquired higher fat mass and arm fat indices than those who exclusively breastfed.[74] A study by Dewey et al. found that formula-feeding mothers had gained triceps-skin-fold thickness while breastfeeding mothers acquired a net loss in this area (2.4 mm vs. -0.4 mm).[75] Thus, they concluded that exclusive breastfeeding for at least six months would enhance postpartum weight loss. This is in line with Endres et al., who found that women who met the recommendations from the American Academy of Pediatrics for six months of breastfeeding were significantly less likely to retain the weight gained during pregnancy twelve months postpartum.[65]

In contrast, He et al. found that the continuation of breastfeeding beyond six months had minimal or no influence on weight change due to the heterogeneity between studies in intensity, duration of breastfeeding, population under study (small sample size, loss to follow up), assessment of weight retention, assessment on breastfeeding practices, employed statistical analysis, and the presence of confounders such as gestational weight gain, physical activity, and pre-pregnancy BMI.[76]

Knowledge of pre-pregnancy BMI and gestational weight gain recommendation

Knowledge of pre-pregnancy weight status is associated with knowledge of GWG recommendations. Women who were aware of their pre-pregnancy weight status were twice as likely as those who were unaware of their pre-pregnancy weight status to know about the GWG recommendations.[77] Additionally, obese women tend to overestimate GWG recommendations. A longitudinal cohort study in San Francisco found that 24.1% of overweight women exceeded the IOM-guideline target weight gain limit while just 4.3% of normal-weight women did the same.[78] In another study, 74.0% of obese women underestimated their BMI category and 64.0% overestimated their recommended GWG.[79] Furthermore, women's knowledge of risks associated with excessive GWG and maternal obesity was poor; many reported incorrect beliefs about safe weight management in pregnancy.

Moreover, among both normal weight and overweight/obese women, those who misperceived their pre-pregnancy weight were more likely than those who knew their pre-pregnancy weight to exceed GWG recommendations.[80] Mehta-Lee et al. found that overweight/obese women who under-assessed their pre-pregnancy weight were 2.5 times more likely to gain weight than normal-weight women who accurately accessed their pre-pregnancy weight. Herring et al. found that the adjusted odds of excessive GWG were 2.0 (95% CI: 1.3, 3.0) in normal-weight over-assessors, 2.9 (95% CI: 2.2, 3.9) in overweight/obese accurate-assessors, and 7.6 (95% CI: 3.4, 17.0) in overweight/obese under-assessors compared to normal-weight accurate assessors.[81]

Existing guidelines in Malaysia

Comprehensive guidelines on the management of maternal obesity in primary care are essential to improve the quality of care. Currently, there are no such guidelines in Malaysia; the current national perinatal-care manual has no specific chapter on the management of obese mothers. Additionally, Malaysian obesity guidelines should be revised to include a section on managing obese women in the reproductive age group, as they carry distinctive risks and require specific attention. Maternal obesity should be considered in light of high-risk pregnancy. Enhancing the co-management of clinical care between primary and tertiary centers during the antenatal, intrapartum, and postnatal periods is crucial for obese mothers regardless of the presence of other comorbidities. Furthermore, in the Malaysian Perinatal Care Manual (2013), green color coding is used to indicate women with a pre-pregnancy weight ≥ 80 kg and BMI ≥ 27 kg/m^2 and is only stated as criteria for screening for gestational diabetes mellitus (GDM). Maternal obesity is currently coded under a green color tag, which is manageable at primary care facilities by medical officers and nurses. However, maternal obesity should also be included in the context of shared care with other disciplines, including specific guidelines on assisting in management at primary care facilities as well as at the tertiary level. One example of a guideline in the management of obesity on pregnancy is available in Australia and endorsed by the Queensland Clinical Guidelines Steering Committee. Furthermore, Confidential Enquiries into Maternal Deaths (CEMD) in Malaysia is lacking in terms of assessing maternal obesity as a determinant of maternal death relative to CEMD in the UK. As a result, the magnitude and severity of this issue cannot be appreciated.

Conclusion

The global emergence of "maternal obesity" as a major public health concern is supported by a vast body of research findings, including some in Malaysia. Maternal obesity is a high-risk phenomenon requiring both surveillance and intervention. Gaining insight into the association between maternal obesity and its contributing factors would enable the development of a more targeted behavioral-change intervention that could be implemented before, during, and after pregnancy, as most determinants are modifiable. This is an essential step in ensuring the end of all preventable causes of maternal and child mortality (SDG 3) and severing the intergenerational chain of non-communicable diseases (NCD) by adopting a life-course approach.

References

1. Friedrich MJ. Global obesity epidemic worsening. *JAMA*. 2017;318(7): 603.
2. Bassett MT, Perl S. Obesity: the public health challenge of our time. *Am J Public Health*. 2004;94(9): 1477.
3. Chan RSM, Woo J. Prevention of overweight and obesity: how effective is the current public health approach *Int J Environ Res Public Health*. 2010;7(3): 765–783.

4. Agha M, Agha R. The rising prevalence of obesity: part A: impact on public health. *Int J Surg Oncol*. 2017;2(9): e42.

5. Case A, Menendez A. Sex differences in obesity rates in poor countries: evidence from South Africa. *Econ Hum Biol*. 2009;7(3): 271–282.

6. Ng M, Fleming T, Robinson M, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet*. 2014;384(9945): 766–781.

7. Institute for Public Health. National health and morbidity survey. Malaysia Ministry of Health. 2015. Available from: http://www.moh.gov.my/moh/resources/nhmsreport2015vol2.pdf [Accessed 3rd May 2019].

8. World Health Organization. Obesity and Overweight. 2017. Available from: http://www.who.int/mediacentre/factsheets/fs311/en/ [Accessed 3rd May 2019].

9. Ko GTC, Chan JCN, Chow C-C, et al. Effects of obesity on the conversion from normal glucose tolerance to diabetes in Hong Kong Chinese. *Obes Res*. 2004;12(6): 889–895.

10. Deurenberg-Yap M, Schmidt G, van Staveren WA, et al. The paradox of low body mass index and high body fat percentage among Chinese, Malays and Indians in Singapore. *Int J Obes*. 2000;24(8): 1011-1017.

11. Heslehurst N, Ells L, Simpson H, et al. Trends in maternal obesity incidence rates, demographic predictors, and health inequalities in 36,821 women over a 15-year period. *BJOG*. 2007;114(2): 187–194.

12. Gorber SC, Tremblay M, Moher D, et al. A comparison of direct vs. self-report measures for assessing height, weight and body mass index: a systematic review. *Obes Rev*. 2007;8(4): 307–326.

13. Ying Pang S, Loy E, Tan L-K. Maternal obesity: prevalence, outcomes and evaluation of body mass index cut-off values in a multi-ethnic Asian obstetric population. *Journal of Obesity and Diabetics*. 2016;1(1): 1-9.

14. Sidik SM, Rampal L. The prevalence and factors associated with obesity among adult women in Selangor, Malaysia. *Asia Pac Fam Med*. 2009;8(1): 2.

15. Chen C, Xu X, Yan Y. Estimated global overweight and obesity burden in pregnant women based on panel data model. *PLoS ONE*. 2018;13(8): e0202183.

16. Institute for Public Health. National health and morbidity survey maternal and child health. Bangsar, Kuala Lumpur: Malaysia Ministry of Health. 2016.

17. Callaway LK, Prins JB, Chang AM, et al. The prevalence and impact of overweight and obesity in an Australian obstetric population. *Med J Aust*. 2006;184(2): 56–59.

18. Withrow D, Alter DA. The economic burden of obesity worldwide: a systematic review of the direct costs of obesity. *Obes Rev*. 2011;12(2): 131–41.

19. World Health Organization. Maternal and Perinatal Health. 2018. Available from: http://www.who.int/maternal_child_adolescent/topics/maternal/maternal_perinatal/en/ [Accessed 24th May 2019].

20. Leddy MA, Power ML, Schulkin J. The impact of maternal obesity on maternal and fetal health. *Rev Obstet Gynecol*. 2008;1(4): 170–178.

21. Simpson EL, Lawrenson RA, Nightingale AL, et al. Venous thromboembolism in pregnancy and the puerperium: incidence and additional risk factors from a London perinatal database. *BJOG*. 2001;108(1): 56–60.

22. Ganeshan M, Bujang MA, Soelar SA, et al. Importance of adopting BMI classifications using public health action points to delineate obstetric risk factors resulting in worsening obstetric outcomes among Asian population. *J Obstet Gynaecol India*. 2018;68(3): 173–178.

23. Ramonienė G, Maleckienė L, Nadišauskienė RJ, et al. Maternal obesity and obstetric outcomes in a tertiary referral center. *Medicina*. 2017;53(2): 109–113.

24. Gaillard R, Durmuş B, Hofman A, et al. Risk factors and outcomes of maternal obesity and excessive weight gain during pregnancy. *Obesity*. 2013;21(5): 1046–1055.

25. Heslehurst N, Lang R, Rankin J, et al. Obesity in pregnancy: a study of the impact of maternal obesity on NHS maternity services. *BJOG*. 2007;114(3): 334–342.

26. Rebholz SL, Jones T, Burke KT, et al. Multiparity leads to obesity and inflammation in mothers and obesity in male offspring. *Am J Physiol Endocrinol Metab*. 2012;302(4): E449–E457.

27. Boudet-Berquier J, Salanave B, Desenclos JC, et al. Sociodemographic factors and pregnancy outcomes associated with pre-pregnancy obesity: effect modification of parity in the nationwide Epifane birth-cohort. *BMC Pregnancy and Childbirth*. 2017;17: 273. Available from: doi:10.1186/s12884-017-1456-8.

28. Thrift AP, Callaway LK. The effect of obesity on pregnancy outcomes among Australian Indigenous and non-Indigenous women. *Med J Aust*. 2014;201(10): 592–595.

29. Bahadoer S, Gaillard R, Felix JF, et al. Ethnic disparities in maternal obesity and weight gain during pregnancy: the Generation R study. *Eur J Obstet Gynecol Reprod Biol*. 2015;193: 51–60.

30. Lovasi GS, Hutson MA, Guerra M, et al. Built environments and obesity in disadvantaged populations. *Epidemiol Rev*. 2009;31(1): 7–20.

31. Kumunyika SK. Obesity in minority populations: an epidemiologic assessment. *Obesity*. 1994;2(2): 166–182.

32. Athukorala C, Rumbold AR, Willson KJ, et al. The risk of adverse pregnancy outcomes in women who are overweight or obese. *BMC Pregnancy and Childbirth*. 2010;10(1): 56. Available from: doi:10.1186/1471-2393-10-56.

33. Nohr EA, Vaeth M, Baker JL, et al. Combined associations of prepregnancy body mass index and gestational weight gain with the outcome of pregnancy. *Am J Clin Nutr*. 2008;87(6): 1750–1759.

34. Bogaerts A. Obesity and pregnancy, an epidemiological and intervention study from a psychosocial perspective. Facts, Views & Vision in *ObGyn*. 2014;6(2): 81–95.

35. Mkuu RS. Prevalence and predictors of overweight and obesity among Kenyan women. *Prev Chronic Dis*. 2018;15:E44

36. McCall S, Nair M, Knight M. Factors associated with maternal mortality at advanced maternal age: a population-based case–control study. *BJOG*. 2017;124(8): 1225–1233.

37. Farpour-Lambert NJ, Ells LJ, Martinez de Tejada B, et al. Obesity and weight gain in pregnancy and postpartum: an evidence review of lifestyle interventions to inform maternal and child health policies. *Front Endocrinol*. 2018;9: 546.

38. Restall A, Taylor RS, Thompson J, et al. Risk factors for excessive gestational weight gain in a healthy, nulliparous cohort. *J Obes*. 2014;2014(3):1-9

39. Durham HA, Morey MC, Lovelady CA, et al. Postpartum physical activity in overweight and obese women. *J Phys Act Health*. 2011;8(7): 988–993.

40. Huberty JL, Buman MP, Leiferman JA, et al. Trajectories of objectively-measured physical activity and sedentary time over the course of pregnancy in women self- identified as inactive. *Prev Med Rep*. 2016;3: 353–360.

41. Pereira MA, Rifas-Shiman SL, Kleinman KP, et al. Predictors of change in physical activity during and after pregnancy: Project Viva. *Am J Prev Med*. 2007;32(4): 312–319.

42. Evenson KR, Moos M-K, Carrier K, et al. Perceived barriers to physical activity among pregnant women. *Matern Child Health J*. 2009;13(3): 364.

43. Poehlman ET. A review: exercise and its influence on resting energy metabolism in man. *Med Sci Sports Exerc*. 1989;21(5): 515–525.

44. Nascimento S, Surita F, Parpinelli M, et al. The effect of an antenatal physical exercise programme on maternal/perinatal outcomes and quality of life in overweight and obese pregnant women: a randomised clinical trial. *BJOG*. 2011;118(12): 1455–1463.

45. Tsigga M, Filis V, Hatzopoulou K, et al. Healthy Eating Index during pregnancy according to pre-gravid and gravid weight status. *Public Health Nutr*. 2011;14(2): 290–296.

46. Lindsay KL, Heneghan C, McNulty B, et al. Lifestyle and dietary habits of an obese pregnant cohort. *Matern Child Health J*. 2015;19(1): 25–32.

47. Pick ME, Edwards M, Moreau D, et al. Assessment of diet quality in pregnant women using the Healthy Eating Index. *J Am Diet Assoc*. 2005;105(2): 240–246.

48. Rodríguez-Bernal CL, Ramón R, Quiles J, et al. Dietary intake in pregnant women in a Spanish Mediterranean area: as good as it is supposed to be? *Public Health Nutr*. 2013;16(8): 1379–1389.

49. Shah BS, Freeland-Graves JH, Cahill JM, et al. Diet quality as measured by the Healthy Eating Index and the association with lipid profile in low-income women in early postpartum. *J Am Diet Assoc*. 2010;110(2): 274–279.

50. Oken E, Taveras EM, Popoola FA, et al. Television, walking, and diet: associations with postpartum weight retention. *Am J Prev Med*. 2007;32(4): 305–311.

51. Wen LM, Flood VM, Simpson JM, et al. Dietary behaviours during pregnancy: findings from first-time mothers in southwest Sydney, Australia. *Int J Behav Nutr Phys Act*. 2010;7(13):1-7

52. King JC. Physiology of pregnancy and nutrient metabolism. *Am J Clin Nutr*. 2000;71(5): 1218S–1225S.

53. Chang M-W, Nitzke S, Guilford E, et al. Motivators and barriers to healthful eating and physical activity among low-income overweight and obese mothers. *J Am Diet Assoc*. 2008;108(6): 1023–1028.

54. Haynes-Maslow L, Parsons SE, Wheeler SB, et al. A qualitative study of perceived barriers to fruit and vegetable consumption among low-income populations, North Carolina, 2011. *Prev Chronic Dis*. 2013;10 (3): E34.

55. Davis EM, Babineau DC, Wang X, et al. Short inter-pregnancy intervals, parity, excessive pregnancy weight gain and risk of maternal obesity. *Matern Child Health J*. 2014;18(3): 554–562.

56. Hanley GE, Hutcheon JA, Kinniburgh BA, et al. Interpregnancy interval and adverse pregnancy outcomes. *Obstet Gynecol*. 2017;129(3): 408–415.

57. Krukowski RA, Bursac Z, McGehee MA, et al. Exploring potential health disparities in excessive gestational weight gain. *J Womens Health*. 2013;22(6): 494–500.

58. Chee WF, Si YM, Siew CY. Factors associated with rates of gestational weight gain among pregnant women in Batu Pahat district of Johor state, Malaysia. *Malaysian Journal of Medicine and Health Sciences*. 2019; 15(1): 33–39.

59. Farhana MN, Rohana A, Alina TT. Excessive and inadequate gestational weight gain among Malaysian pregnant women in rural area: are there any associated factors? *Pakistan Journal of Nutrition*. 2015;14(12): 854.

60. Yong HY, Mohd Shariff Z, Koo SJ, et al. Pre-pregnancy body mass index, height and physical activity are associated with rate of gestational weight gain among Malaysian mothers. *J Obstet Gynaecol Res*. 2016;42(9): 1094–1101.

61. Baker JL, Gamborg M, Heitmann BL, et al. Breastfeeding reduces postpartum weight retention. Am J Clin Nutr. 2008;88(6): 1543–1551.

62. Gould Rothberg BE, Magriples U, Kershaw TS, et al. Gestational weight gain and subsequent postpartum weight loss among young, low-income, ethnic minority women. *Am J Obstet Gynecol*. 2011;204(1): 52.e1–52.e11.

63. Yaw YH, Shariff ZM, J binti Shahdan J. Pre-pregnancy BMI and gestational weight gain are associated with 6 months postpartum weight retention. *International Journal of Public Health and Clinical Sciences*. 2017;4(4): 112–25.

64. Hollis JL, Crozier SR, Inskip HM, et al. Modifiable risk factors of maternal postpartum weight retention: an analysis of their combined impact and potential opportunities for prevention. *Int J Obes*. 2017;41(7): 1091-1098.

65. Endres LK, Straub H, McKinney C, et al. Postpartum weight retention risk factors and relationship to obesity at 1 year. *Obstet Gynecol*. 2015;125(1): 144–152.

66. Zanotti J, Capp E, Wender MCO. Factors associated with postpartum weight retention in a Brazilian cohort. *Rev Bras Ginecol Obstet*. 2015;37(4): 164–171.

67. Butte NF, King JC. Energy requirements during pregnancy and lactation. *Public Health Nutr*. 2005;8(7a): 1010–1027.

68. Baker JL, Michaelsen KF, Sorensen TI, et al. High prepregnant body mass index is associated with early termination of full and any breastfeeding in Danish women. *Am J Clin Nutr*. 2007;86(2): 404–411.

69. Ramji N, Quinlan J, Murphy P, et al. The impact of maternal obesity on breastfeeding. *J Obstet Gynaecol Can*. 2016;38(8): 703–711.

70. Hamid A, Bariah S. A cohort study of maternal obesity and breastfeeding outcomes for Malay women in Selangor, Malaysia [dissertation]. Perth: Curtin University; 2016 [Accessed 24th May 2019]. Available from: https://pdfs.semanticscholar.org/6702/6592a423af5071ed386269836b98903bde32.pdf.

71. Janney CA, Zhang D, Sowers M. Lactation and weight retention. *Am J Clin Nutr.* 1997;66(5): 1116–1124.

72. Krause KM, Lovelady CA, Peterson BL, et al. Effect of breast-feeding on weight retention at 3 and 6 months postpartum: data from the North Carolina WIC Programme. *Public Health Nutr.* 2010;13(12): 2019–2026.

73. Sharma AJ, Dee DL, Harden SM. Adherence to breastfeeding guidelines and maternal weight 6 years after delivery. *Pediatrics*. 2014;134(1): S42–S49.

74. Gigante DP, Victora CG, Barros FC. Breastfeeding has a limited long-term effect on anthropometry and body composition of Brazilian mothers. *J Nutr*. 2001;131(1): 78–84.

75. Dewey KG, Heinig MJ, Nommsen LA. Maternal weight-loss patterns during prolonged lactation. *Am J Clin Nutr*. 1993;58(2): 162–166.

76. He X, Zhu M, Hu C, et al. Breast-feeding and postpartum weight retention: a systematic review and meta-analysis. *Public Health Nutr.* 2015;18(18): 3308–3316.

77. Ledoux T, Van Den Berg P, Leung P, et al. Factors associated with knowledge of personal gestational weight gain recommendations. *BMC Res Notes.* 2015;8: 349.

78. Stotland NE, Haas JS, Brawarsky P, et al. Body mass index, provider advice, and target gestational weight gain. *Obstet Gynecol.* 2005;105(3): 633–638.

79. Shub A, Huning EYS, Campbell KJ, et al. Pregnant women's knowledge of weight, weight gain, complications of obesity and weight management strategies in pregnancy. *BMC Res Notes*. 2013;6: 278.

80. Mehta-Lee SS, Lischewski Goel JL, Xu L, et al. Perception of weight status and its impact on gestational weight gain in an urban population. *Matern Child Health J*. 2013;17(10): 1931–1939.

81. Herring S, Oken E, Rd J, Rich-Edwards J, et al. Misperceived pre-pregnancy body weight status predicts excessive gestational weight gain: findings from a US cohort study. *BMC Pregnancy and Childbirth*. 2008;8(1): 54. Available from: doi:10.1186/1471-2393-8-54.