



The relationship between body mass index and sleep in women with risk factors for gestational diabetes mellitus

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Abstract

Background: Both obesity and sleep disorders are common among women during pregnancy. Although prior research has identified a relationship between obesity and sleep disorders, those findings are from women later in pregnancy.

Objective: To explore the relationships between self-reported sleep duration, insufficient sleep and snoring with body mass index (BMI) among multiethnic women at risk of gestational diabetes mellitus (GDM) in early pregnancy.

Pamela Acosta Reyes, Jincy Immanuel and David Simmons contributed equally to this work.

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Methods: Cross-sectional study of baseline data from women at risk of GDM enrolled in the Treatment of BOoking Gestational diabetes Mellitus (TOBOGM) multicentre trial across 12 Australian/Austrian sites. Participants completed a questionnaire before 20 weeks' gestation to evaluate sleep. BMI <25 kg/m² served as the reference group in multivariable logistic regression.

Results: Among the 2865 women included, the prevalence of overweight and obesity classes I-III was 28%, 19%, 11% and 12%, respectively. There was no relationship between sleep duration and BMI. The risk of insufficient sleep >5 days/month was higher in class II and class III obesity (1.38 (1.03–1.85) and 1.34 (1.01–1.80), respectively), and the risk of snoring increased as BMI increased (1.59 (1.25–2.02), 2.68 (2.07–3.48), 4.35 (3.21–5.88) to 4.96 (3.65–6.74), respectively).

Conclusions: Obesity is associated with insufficient sleep among pregnant women at risk of GDM. Snoring is more prevalent with increasing BMI.

KEYWORDS

GDM, obesity, pregnancy, sleep, snore

1 | INTRODUCTION

The most common metabolic disorder in pregnant women is diabetes, which complicates 1 in 6 (16.8%) pregnancies, with gestational diabetes mellitus (GDM) making up 86% of the total.¹ Obesity during pregnancy is the major risk factor for GDM,² and there is a greater risk of preeclampsia, caesarean section and maternal morbidity when obesity and GDM occur together than separately.³

Many women develop sleep disturbances during pregnancy,^{4,5} particularly in late pregnancy.⁶ These include difficulty falling asleep, frequent night waking and restless sleep by the end of pregnancy.⁷ Pregnant women experience a decrease in restorative deep sleep as early as weeks 11 and 12 of gestation,⁸ and only 54% of pregnant women sleep for at least 8 h uninterrupted in the last trimester.⁹ Many factors contribute to sleep disturbance during pregnancy.^{9–11} Excess gestational weight gain is experienced by 64% of women who are overweight or obese and is associated with decreased sleep hours and sleep quality during the late stages of pregnancy.^{12,13}

Obesity has been linked with a high risk of sleep disturbance.^{14,15} Some studies have revealed a bidirectional relationship between obesity and sleep quality.¹⁶ Sleep disturbances interfere with endocrine pathways that regulate energy balance, stimulating weight gain and obesity.¹⁷ Some studies,^{18,19} but not others,^{20,21} have suggested that weight reduction has a positive impact on obstructive sleep apnea (OSA) outside of pregnancy.²² One study suggested that awareness of basic nutrition and customized diet plans are associated with improved sleep and reduced snoring.²³ The occurrence of sleep-disordered breathing is higher during pregnancy compared with non-pregnant individuals,²⁴ yet few intervention studies have been reported.^{25,26} A recent meta-analysis²⁷ showed an increased risk of snoring, short sleep duration and poor sleep quality among pregnant women with high BMI; however, most of the studies included were conducted late in gestation.

Therefore, a cross-sectional study was conducted, using data from a large multicentre randomized control trial (RCT), among pregnant women at risk of GDM at an early stage of pregnancy. The aims of this study were to compare the amount of sleep, insufficient sleep and self-reported snoring in different BMI groups within a multiethnic cohort of pregnant women at risk of GDM participating in the TOBOGM study.²⁸ Limited nutritional data were collected, and BMI was therefore used as a proxy for all its contributing factors.

2 | METHODS

A cross-sectional cohort study of women at baseline enrolled in the TOBOGM multicentre RCT was performed. This trial is investigating the benefits and adverse effects of the early treatment of GDM diagnosed before 20 weeks' gestation according to the International Association of the Diabetes and Pregnancy Study Groups (IADPSG) criteria.^{28,29} Women at risk of GDM recruited prior to the coronavirus (COVID19) pandemic to TOBOGM from the antenatal clinics of the participating hospitals between June 2017 and March 2020 were included. Women were eligible if they were aged ≥18 years, were carrying a singleton pregnancy between 4 and 19⁺⁶ weeks' gestation, had a risk factor (e.g., being overweight or obese, advanced maternal age, multiparous, family history of type 2 diabetes mellitus, non-European descent) for GDM and had provided written informed consent.²⁹ Women with pre-existing diabetes, with overt diabetes or fasting blood glucose ≥6.1 mmol/L, or with major medical disorders were excluded. All enrolled women completed a booking demographic questionnaire that included the ethnicity that the participant identified with, and medical and obstetric history. Height and weight were extracted from medical records. After calculation, BMI was categorized into five groups: <25.0 kg/m², overweight (25.0–29.9 kg/m²), obesity class I (30.0–34.9 kg/m²), obesity class II

(35.0–39.9 kg/m²), and obesity class III (≥ 40.0 kg/m²), based on the World Health Organization (WHO) classification.³⁰

Ethnicity was divided into two main groups (European (of European descent) and non-European) for the statistical analysis due to the lower number of participants in any one non-European group.

Sleep parameters were collected at recruitment using a written questionnaire adapted from the Pittsburgh Sleep Quality Index (PSQI) questionnaire³¹ by shortening to reduce participant questionnaire burden. Sleep duration, insufficient sleep and snoring were assessed, using the following questions: “How many hours do you sleep per 24 h on average?”, “How many days in the last month have you had the feeling of insufficient sleep?”, and “How many days per week do you snore/are you told you snore?”, respectively.

The main outcomes of the study among pregnant women in early pregnancy were decreased sleep duration less than 8 h per day (selected to allow dichotomization of the variable around the median), insufficient sleep more than 5 days per month (selected as the population median) and the presence of snoring. Blood glucose results, GDM status and pregnancy outcomes were kept separate from the baseline dataset in accordance with the blinded nature of the trial and were not included in this study. The study was approved by the South Western Sydney Local Health District Ethics committee (reference 15/LPOOL/551). In Austria, the study was approved by the Ethics committee of the Medical University of Vienna (1337/2016). The study was registered with the Australian New Zealand Clinical Trial Registry (ACTRN12616000924459).

2.1 | Statistical analysis

Categorical variables have been described using frequencies and percentages, and continuous variables by means and standard deviations. Maternal characteristics between BMI groups have been compared, using one-way analysis of variance (ANOVA) for continuous variables and the Pearson's χ^2 test for binary data. Multivariable logistic regression models were performed to evaluate the relationship between BMI categories and sleep parameters, adjusting for potential confounders, including age, ethnicity, smoking, employment status, gestational age, parity, married/living together, alcohol consumption before pregnancy, and family history of diabetes. All statistical analyses were conducted using SPSS software (IBM SPSS Statistics, Version 25.0). All tests were two-tailed and a p -value < 0.05 was considered significant.

3 | RESULTS

3.1 | Comparisons of maternal characteristics between BMI groups

Of the 2897 women enrolled in the timeframe of this sub-study, 2865 had a BMI recorded before 20 weeks' gestation and were therefore included in the analysis. The mean age of the women was

31.3 \pm 5.1 years. The mean BMI was 29.9 \pm 7.6 kg/m² at booking (between 4 and 19⁺⁶ weeks' gestation). The majority had a European (37.7%), Middle Eastern (7.9%) or South Asian (26.9%) background (Table 1). The prevalence of overweight was 28.1% ($n = 806$) and the overall prevalence of obesity was 41.5% ($n = 1202$) (class I obesity, 18.7% ($n = 537$), class II obesity, 11.4% ($n = 326$), and class III obesity 11.8% ($n = 339$)). The women reported sleeping 7.8 \pm 1.4 h per day and 7.8 \pm 8.9 days of insufficient sleep per month (median 5 days). The reported prevalence of snoring was 36.6%.

Table 1 shows the comparison of baseline and sleep characteristics between BMI groups. The characteristics of the BMI groups differed significantly, except for gestation at booking and prior GDM status. The proportion of women sleeping fewer than 8 h a day varied across groups, with higher prevalence (44.4%) among the class III obesity group ($p = 0.02$). The proportions of women reporting insufficient sleep more than 5 days per month increased across the BMI range from 37.9% to 43.8%, 51.4%, and 54.0% in overweight to class I, class II, and class III obesity, respectively ($p < 0.001$). The trend was similar for snoring (31.4%, 42.6%, 53.4%, and 55.0% respectively, $p < 0.001$).

3.2 | Association between BMI categories and sleep parameters according to ethnic group

European women were more likely than non-European women to report sleeping < 8 h and experience > 5 days/month of insufficient sleep among women with BMI < 25.0 kg/m². Within high BMI groups, there were no differences in sleep duration and snoring comparing women of European and non-European descent, but European women had a higher rate of experiencing insufficient sleep > 5 days per month in all overweight and obese BMI groups (Table 2).

3.3 | Risk of developing sleep disorders among different BMI groups

Table 3 shows the risk of sleep disturbances in each BMI group. There was not an association between the control group and higher BMI. Class II and III obesity were associated with increased risk of insufficient sleep (aOR (95% CI) 1.38(1.03–1.85), and 1.34 (1.01–1.80)), respectively. The risk of snoring increased with an increased BMI and persisted after adjusting for potential confounders, including full-time employment (as long working hours can cause sleep disturbances) (Table 3).

4 | DISCUSSION

This study identified a strong positive relationship between BMI category and indices of sleep disturbance early in pregnancy in a large multiethnic cohort of pregnant women at risk of GDM. Findings, after adjusting for relevant confounders, suggest an increased risk of

TABLE 1 Comparisons of maternal characteristics among BMI groups.

Characteristics	All		<25 kg/m ²		25.0–29.9 kg/m ²		30.0–34.9 kg/m ²		35.0–39.9 kg/m ²		≥40.0 kg/m ²		p value
	N	Mean ± SD/ n (%)	N	Mean ± SD/ n (%)	N	Mean ± SD/ n (%)	N	Mean ± SD/ n (%)	N	Mean ± SD/ n (%)	N	Mean ± SD/ n (%)	
Age (years)	2865	31.3 ± 5.1	857	31.7 ± 4.9	806	31.8 ± 5.1	537	31.2 ± 5.4	326	30.6 ± 5.1	339	30.3 ± 4.9	<0.001
Height (cm)	2865	162.8 ± 6.9	857	162.0 ± 6.7	806	161.4 ± 6.6	537	163.4 ± 6.8	326	164.4 ± 7.1	339	165.5 ± 6.4	<0.001
Booking weight (kg)	2865	79.7 ± 22.7	857	58.7 ± 6.8	806	71.1 ± 7.0	537	86.1 ± 8.5	326	100.7 ± 9.2	339	123.3 ± 15.0	<0.001
Self-reported pre-pregnancy weight (kg)	2839	76.7 ± 22.5	853	56.6 ± 8.0	795	68.0 ± 7.7	535	83.1 ± 9.8	322	97.4 ± 10.7	334	118.8 ± 16.0	<0.001
Gestation at booking (weeks)	2865	14.7 ± 2.5	857	14.7 ± 2.5	806	14.7 ± 2.5	537	14.8 ± 2.5	326	14.8 ± 2.3	339	14.8 ± 2.4	0.88
Ethnicity	2857		854		804		536		325		338		
European		1097 (37.7)		203 (23.8)		225 (28.0)		243 (45.3)		188 (57.8)		220 (65.1)	<0.001
Middle Eastern		227 (7.9)		56 (24.7)		81 (35.7)		40(17.6)		26 (11.4)		20 (8.8)	
South Asian		769 (26.9)		304 (39.5)		298 (38.7)		116 (15.0)		28 (3.6)		11 (1.4)	
Southeast Asian/ East Asian		425 (14.8)		241 (28.2)		123 (15.3)		43 (8.0)		12 (3.7)		6 (1.8)	
Other		374 (13.1)		50 (5.9)		78 (9.7)		94 (17.5)		71 (21.8)		81 (24.0)	
Married/living together	2842	2665 (93.8)	849	816 (96.1)	800	764 (95.5)	532	494 (92.9)	324	300 (92.6)	337	291 (86.4)	<0.001
Working full-time	2865	1063 (37.1)	857	324 (37.8)	806	320 (39.7)	537	194 (36.1)	326	130 (39.9)	339	95 (28.0)	0.003
Working part-time	2865	699 (24.4)	857	241 (28.1)	806	183 (22.7)	537	124 (23.1)	326	74 (22.7)	339	77 (22.7)	0.056
Gravidity	2865	2.6 ± 1.7	857	2.3 ± 1.5	806	2.6 ± 1.7	537	2.9 ± 1.9	326	2.7 ± 1.6	339	2.9 ± 1.8	<0.001
Parity	2865	1.0 ± 1.1	857	0.8 ± 1.0	805	1.0 ± 1.1	537	1.2 ± 1.2	326	1.0 ± 1.1	339	1.2 ± 1.2	<0.001
Current smoking	2713	144 (5.3)	826	28 (3.4)	765	32 (4.2)	504	30 (6.0)	301	18 (6.0)	317	36 (11.4)	<0.001
Alcohol consumption before pregnancy	2679	1068 (39.9)	816	291 (35.7)	754	275 (36.5)	498	220 (44.2)	297	132 (44.4)	314	150 (47.8)	<0.001
Prior GDM	2044	432 (21.1)	532	115 (21.6)	601	129 (21.5)	405	90 (22.2)	243	37 (15.2)	263	61 (23.2)	0.19
Family history of diabetes	2704	1193 (44.1)	819	351 (42.9)	763	393 (51.5)	502	214 (42.6)	300	119 (39.7)	320	116 (36.3)	<0.001
Self-reported PCOS	2854	518 (18.1)	853	129 (15.1)	802	138 (17.2)	534	104 (19.5)	326	75 (23.0)	339	72 (21.2)	0.003
Sleep characteristics													
Less than 8 h of sleep per day	2682	1062 (39.6)	819	297 (36.3)	761	287 (37.7)	498	217 (43.6)	293	123 (42.0)	311	138 (44.4)	0.02
Insufficient sleep more than 5 days/month	2608	1084 (41.6)	787	278 (35.3)	742	281 (37.9)	489	214 (43.8)	290	149 (51.4)	300	162 (54.0)	<0.001
Snoring	2540	921 (36.3)	765	175 (22.9)	704	221 (31.4)	479	204 (42.6)	290	155 (53.4)	302	166 (55.0)	<0.001

Abbreviations: BMI, body mass index; GDM, Gestational diabetes mellitus; PCOS, Polycystic ovary syndrome.

TABLE 3 Adjusted and unadjusted risk of developing sleep disorders among different BMI groups.

Self-reported sleep parameters	Unadjusted OR (95% CI), <i>p</i> value				Adjusted OR (95% CI), <i>p</i> value			
	25.0–29.9 kg/m ² N = 806	30.0–34.9 kg/m ² N = 537	35.0–39.9 kg/m ² N = 326	≥40.0 kg/m ² N = 339	25.0–29.9 kg/m ² N = 806	30.0–34.9 kg/m ² N = 537	35.0–39.9 kg/m ² N = 326	≥40.0 kg/m ² N = 339
Less than 8 h of sleep per day	1.06 (0.87–1.31), 0.55	1.36 (1.08–1.70), 0.008	1.27 (0.97–1.67), 0.08	1.40 (1.07–1.83), 0.01	1.03 (0.83–1.27), 0.80	1.26 (0.99–1.60), 0.06	1.16 (0.87–1.55), 0.31	1.26 (0.95–1.68), 0.11
Insufficient sleep more than 5 days/month	1.12 (0.91–1.38), 0.30	1.42 (1.13–1.80), 0.003	1.94 (1.47–2.54), <0.001	2.15 (1.64–2.82), <0.001	1.02 (0.82–1.27), 0.89	1.12 (0.87–1.43), 0.38	1.38 (1.03–1.85), 0.03	1.34 (1.001–1.80), 0.049
Snoring	1.54 (1.22–1.95), <0.001	2.50 (1.95–3.20), <0.001	3.87 (2.91–5.15), <0.001	4.12 (3.10–5.46), <0.001	1.59 (1.25–2.02), <0.001	2.68 (2.07–3.48), <0.001	4.35 (3.21–5.88), <0.001	4.96 (3.65–6.74), <0.001

Note: Reference group = BMI <25 kg/m²; Results were adjusted for age, ethnicity as European/non-European descent, smoking, gestation at booking, parity, full-time employment, married/living together, alcohol consumption before pregnancy, and family history of diabetes.

at booking to reduce the presence of sleep disorders, minimize maternal and fetal consequences and improve the quality of life.^{40,41} Healthcare professionals should advise and guide pregnant women with high BMI in early pregnancy. Their recommendations should include a healthy diet, exercise and sleep hygiene habits as preventive.^{39,42,43}

The strengths of this study are the large sample size and the use of extensive and accurate data from different locations and ethnic groups in the multivariable analysis to prevent potential confounding bias. The multiethnic nature of the cohort also made it possible to analyze the differences more broadly.

A major limitation is that there was no assessment of the relationship between sleep and obesity was direct or related to the food choices and limited physical activity associated with obesity. This is an important area for future research. Further limitations include sleep parameters being self-reported through a questionnaire survey conducted at booking rather than being objectively measured. This may have led to an overestimation of the occurrence of sleep disorders, with resultant recall or social desirability bias.⁴⁴ Also, the questionnaires did not use any validated sleep assessment index, such as the PSQI scale,³¹ which measures the quality and patterns of sleep in adults. The questionnaire was based on some of the questions of the PSQI questionnaire and the Berlin questionnaire.⁴⁵ Further studies using more accurate measures of sleep-disordered breathing, such as the use of actigraphy that measures sleep duration and disruption, would be useful to minimize possible bias. Additionally, this study focused only on early pregnancy data; it remains unclear whether the relationship between BMI and sleep varies late in pregnancy. Finally, this study used a selected cohort of women at risk of GDM, so the results may not be generalizable to a wider population. Limited nutritional data were collected, and BMI was therefore used as a proxy for all its contributing factors.

In conclusion, this study in a large multiethnic cohort of pregnant women at risk of GDM revealed a significant relationship between severe obesity and sleep parameters, such as insufficient sleep and

snoring. Women of both European and non-European ethnicities were largely similar, except for a higher rate of experiencing insufficient sleep >5 days per month among European women. Further research is required to support the findings, investigate changes across different stages of pregnancy and ascertain the role of diet in sleep disturbances.

AUTHOR CONTRIBUTIONS

Pamela Acosta Reyes and Jincy Immanuel performed statistical analysis, interpreted the data, and drafted the manuscript. David Simmons conceived the TOBOGM project and this analysis, and together with JI supervised PAR, interpreted the data, reviewed, and edited the draft and provided critical input to the manuscript. All authors read and approved the final manuscript. DS is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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CONFLICT OF INTEREST STATEMENT

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

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REFERENCES

- Lapolla A, Metzger BE. In: Lapolla, Metzger BE, eds. *Gestational diabetes: a decade after the HAPO study*. Karger; 2020.
- Ahmadzadeh Sani T, Peyman N, Esmaili H. The relationship between obesity and complications during pregnancy and childbirth in Dargaz: a cross sectional study. *J N Khorasan Univ Med Sci*. 2017;8(3):383-393. <https://doi.org/10.18869/acadpub.jnkums.8.3.383>
- HuetBeucher G, Rod A, Morello R, Dreyfus M. Joint impact of gestational diabetes and obesity on perinatal outcomes. *J Gynecol Obst Human Rep*. 2018;47(9):469-476. <https://doi.org/10.1016/j.jogoh.2018.08.003>
- Zhu B, Shi C, Park CG, Reutrakul S. Sleep quality and gestational diabetes in pregnant women: a systematic review and meta-analysis. *Sleep Med*. 2020;67:47-55. <https://doi.org/10.1016/j.sleep.2019.11.1246>
- Lu Q, Zhang X, Wang Y, et al. Sleep disturbances during pregnancy and adverse maternal and fetal outcomes: a systematic review and meta-analysis. *Sleep Med Rev*. 2021;58:101436. <https://doi.org/10.1016/j.smrv.2021.101436>
- Mong JA, Cusmano DM. Sex differences in sleep: impact of biological sex and sex steroids. *Phil Trans Biol Sci*. 2016;371(1688):20150110. <https://doi.org/10.1098/rstb.2015.0110>
- Mindell JA, Jacobson BJ. Sleep disturbances during pregnancy. *J Obstet Gynecol Neonatal Nurs*. 2000;29(6):590-597. <https://doi.org/10.1111/j.1552-6909.2000.tb02072.x>
- Lee KA, Zaffke ME, McEnany G. Parity and sleep patterns during and after pregnancy. *Obstet and Gynecol*. 2000;95(1):14-18. [https://doi.org/10.1016/s0029-7844\(99\)00486-x](https://doi.org/10.1016/s0029-7844(99)00486-x)
- Kryger MH, Lee KA, Wolfson AR. Summary of Findings; 2007. https://www.sleepfoundation.org/wp-content/uploads/2018/10/Summary_Of_Findings-FINAL.pdf
- Malfertheiner SF, Malfertheiner MV, Kropf S, Costa SD, Malfertheiner P. A prospective longitudinal cohort study: evolution of GERD symptoms during the course of pregnancy. *BMC Gastroenterol*. 2012;12(1):131. <https://doi.org/10.1186/1471-230x-12-131>
- Garbaza C, Hackethal S, Riccardi S, et al. Polysomnographic features of pregnancy: a systematic review. *Sleep Med Rev*. 2020;50:101249. <https://doi.org/10.1016/j.smrv.2019.101249>
- Brown SD, Hedderson MM, Ehrlich SF, et al. Gestational weight gain and optimal wellness (GLOW): rationale and methods for a randomized controlled trial of a lifestyle intervention among pregnant women with overweight or obesity. *BMC Pregnancy Childbirth*. 2019;19(1):1-12. <https://doi.org/10.1186/s12884-019-2293-8>
- Gay CL, Richoux SE, Beebe KR, Lee KA. Sleep disruption and duration in late pregnancy is associated with excess gestational weight gain among overweight and obese women. *Birth-Iss Perinat C*. 2017;44(2):173-180. <https://doi.org/10.1111/birt.12277>
- Hill C, Lipsky LM, Betts GM, Siega-Riz AM, Nansel TR. A prospective study of the relationship of sleep quality and duration with gestational weight gain and fat gain. *J Wom Health*. 2021;30(3):405-411. <https://doi.org/10.1089/jwh.2020.8306>
- Rice JR, Larrabure-Torrealla GT, Fernandez MAL, et al. High risk for obstructive sleep apnea and other sleep disorders among overweight and obese pregnant women. *BMC Pregnancy Childbirth*. 2015;15(1):1-8. <https://doi.org/10.1186/s12884-015-0633-x>
- Krupp K, Wilcox M, Srinivas A, Srinivas V, Madhivanan P, Bastida E. Snoring is associated with obesity among middle aged Slum-dwelling women in Mysore, India. *Lung India*. 2020;37(3):210-219. https://doi.org/10.4103/lungindia.lungindia_515_19
- Motivala SJ, Tomiyama AJ, Ziegler M, Khandrika S, Irwin MR. Nocturnal levels of ghrelin and leptin and sleep in chronic insomnia. *Psychoneuroendocrinology*. 2009;34(4):540-545. <https://doi.org/10.1016/j.psyneuen.2008.10.016>
- DobrosielskiPatilSchwartzBandeem-Roche DASARK, Stewart KJ. Effects of exercise and weight loss in older adults with obstructive sleep apnea. *Med Sci Sports Exerc*. 2015;47(1):20-26. <https://doi.org/10.1249/mss.0000000000000387>
- Andersen IG, Holm J-C, Homøe P. Impact of weight-loss management on children and adolescents with obesity and obstructive sleep apnea. *Int J Pediatr Otorhinolaryngol*. 2019;123:57-62. <https://doi.org/10.1016/j.ijporl.2019.04.031>
- JoostenHamilton GS, Naughton MT. Impact of weight loss management in OSA. *Chest*. 2017;152(1):194-203. <https://doi.org/10.1016/j.chest.2017.01.027>
- Carter R, Watenpaugh DE. Obesity and obstructive sleep apnea: or is it OSA and obesity? *Pathophysiology*. 2008;15(2):71-77. <https://doi.org/10.1016/j.pathophys.2008.04.009>
- Peppard PE, et al. Longitudinal study of moderate weight change and sleep-disordered breathing. *JAMA*. 2000;284(23):3015-3021. <https://doi.org/10.1001/jama.284.23.3015>
- Sahni N, Arora K, Bansal S, Reddy G, Malhotra S, Virk R. Impact of lifestyle modifications on snoring and mild sleep apnea patients. *J Laryngol and Otol*. 2021;135(10):892-896. <https://doi.org/10.1017/S0022215121002139>
- Ayyar L, Shaib F, Guntupalli K. Sleep-disordered breathing in pregnancy. *Sleep Med Clin*. 2018;13(3):349-357. <https://doi.org/10.1016/j.jsmc.2018.04.005>
- Dominguez JE, Street L, Louis J. Management of obstructive sleep apnea in pregnancy. *Obstet Gynecol Clin N Am*. 2018;45(2):233-247. <https://doi.org/10.1016/j.jogc.2018.01.001>
- Miller MA, Mehta N, Clark-Bilodeau C, Bourjeily G. Sleep pharmacotherapy for common sleep disorders in pregnancy and lactation. *Chest*. 2020;157(1):184-197. <https://doi.org/10.1016/j.chest.2019.09.026>
- Lau Y, Cheng LJ, Chee DGH, et al. High body mass index and sleep problems during pregnancy: a meta-analysis and meta-regression of observational studies. *J Sleep Res*. 2021;31(1):e13443. <https://doi.org/10.1111/jsr.13443>
- Simmons D, Hague WM, Teede HJ, et al. Hyperglycaemia in early pregnancy: the Treatment of Booking Gestational diabetes Mellitus (TOBOGM) study. A randomised controlled trial. *Med J Aust*. 2018;209(9):405-406. <https://doi.org/10.5694/mja17.01129>
- IADPSG Consensus Panel. International association of diabetes and pregnancy study groups recommendations on the diagnosis and classification of hyperglycemia in pregnancy. *Diabetes Care*. 2010;33(3):676-682. <https://doi.org/10.2337/dc09-1848>
- Weir CB, Jan A. *BMI Classification Percentile and Cut Off Points*. StatPearls Publishing; 2020.
- Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index - a new instrument for psychiatric practice and research. *Psychiatr Res*. 1989;28(2):193-213. [https://doi.org/10.1016/0165-1781\(89\)90047-4](https://doi.org/10.1016/0165-1781(89)90047-4)
- Conlon RPK, Wang B, Germeroth LJ, Cheng Y, Buysse DJ, Levine MD. Demographic, pregnancy-related, and health-related factors in association with changes in sleep among pregnant women with overweight or obesity. *Int J. Behav. Med*. 2020;28(2):200-206. <https://doi.org/10.1007/s12529-020-09887-4>
- KimKeenan BT, Jackson N, Chan EL, et al. Tongue fat and its relationship to obstructive sleep apnea. *Sleep (New York, N.Y.)*. 2014;37(10):1639-U227. <https://doi.org/10.5665/sleep.4072>
- Nicoli F, Prete A, Citro F, et al. Short sleep duration and risk of gestational diabetes. *Gynecol Endocrinol*. 2022;38(8):672-675. <https://doi.org/10.1080/09513590.2022.2089105>

35. Castellucci B, Barrea L, Laudisio D, et al. Improving sleep disturbances in obesity by nutritional strategies: review of current evidence and practical guide. *Int J Food Sci Nutr*. 2021;72(5):579-591. <https://doi.org/10.1080/09637486.2020.1851659>
36. KaurSaxena N, Zhu Z. Effect of Asian BMI on risk of chronic disease progression: a Singapore perspective. *Proc Singapore Healthc*. 2018; 27(4):270-276. <https://doi.org/10.1177/2010105818779400>
37. Lagadec N, Steinecker M, Kapassi A, et al. Factors influencing the quality of life of pregnant women: a systematic review. *BMC Pregnancy Childbirth*. 2018;18(1):455. <https://doi.org/10.1186/s12884-018-2087-4>
38. Fattah C, Farah N, Barry SC, O'Connor NO, Stuart B, Turner MJ. Maternal weight and body composition in the first trimester of pregnancy. *Acta Obstet Gynecol Scand*. 2010;89(7):952-955. <https://doi.org/10.3109/00016341003801706>
39. World Health Organization. *WHO Recommendations on Antenatal Care for a Positive Pregnancy Experience*. World Health Organization; 2016.
40. Mindell JA, Cook RA, Nikolovski J. Sleep patterns and sleep disturbances across pregnancy. *Sleep Med*. 2015;16(4):483-488. <https://doi.org/10.1016/j.sleep.2014.12.006>
41. Facco FL, Kramer J, Ho KH, Zee PC, Grobman WA. Sleep disturbances in pregnancy. *Obstet and Gynecol*. 2010;115(1):77-83. <https://doi.org/10.1097/aog.0b013e3181c4f8ec>
42. Ferraro ZM, et al. *The Potential Value of Sleep Hygiene for a Healthy Pregnancy: A Brief Review*. ISRN family medicine; 2014:928293-928297.
43. St-Onge M-P, Roberts A, Shechter A, Choudhury AR. Fiber and saturated fat are associated with sleep arousals and slow wave sleep. *J Clin Sleep Med*. 2016;12(1):19-24. <https://doi.org/10.5664/jcsm.5384>
44. Ko HS, Kim MY, Kim YH, et al. Obstructive sleep apnea screening and perinatal outcomes in Korean pregnant women. *Arch Gynecol Obstet*. 2013;287(3):429-433. <https://doi.org/10.1007/s00404-012-2602-1>
45. Tan A, Yin JD, Tan LW, van Dam RM, Cheung YY, Lee CH. Using the Berlin questionnaire to predict obstructive sleep apnea in the general population. *J Clin Sleep Med*. 2017;13(3):427-432. <https://doi.org/10.5664/jcsm.6496>

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