ORIGINAL ARTICLE

Sleep Science

Does sleep influence weight gain during pregnancy? A prospective study

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ABSTRACT

Objective: The focus of this study was to evaluate the associations between subjective sleep quality and duration and weight gain during pregnancy. **Methods:** A prospective and longitudinal study was conducted with 63 pregnant women. Pregnant women were evaluated at the first, second and third trimester for subjective sleep quality (Pittsburgh Sleep Quality Index [PSQI]) and anthropometric variables for body mass index [BMI] calculation. The sleep quality was grouped per cluster, identifying those individuals who maintained, improved or worsened their sleep quality, based on the PSQI classifications. Generalized estimating equations (GEE) were used to examine the association between sleep and BMI over the pregnancy period. **Results:** An effect of the interaction between time of pregnancy and clusters of sleep quality was observed on the BMI ($p<0.05$), which indicates that pregnant women who improved subjective sleep quality during pregnancy gained more weight from the second to third trimester, while those that worsened the subjective sleep quality gained more weight during the first to second trimester. Sleep duration was not associated with weight gain. However, pregnant women who maintained the same BMI category over the pregnancy period increased their sleep duration from the first to third trimester, while those that increased the BMI category slept the same amount of time during this period (median=1.0 [0.0–2.0] and median=0.0 [-2.0–1.0], respectively, $p=0.039$). **Conclusions:** The authors concluded that a worse subjective sleep quality seems to lead to an inadequate weight gain distribution during the period of pregnancy.

Keywords: Weight Gain; Pregnancy; Sleep; Body Mass Index.

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INTRODUCTION

The prevalence of overweight during pregnancy has been on the increase in the last few decades in Brazil, with rates ranging from 25 to 52%[1,2]. This fact is worrying, given that weight gain is seen as an important indicator for the overall prognosis of the pregnancy[3,4]. In this regard, evidence shows that excessive weight gain associated with initial overweight and obesity tend toward an increase in the risk of gestational diabetes mellitus[5,6], type 2 diabetes mellitus after pregnancy[7,8], glucose intolerance[9], hypertensive disorder in pregnancy[6,10], depression11 and caesarean delivery[6,12]. Health problems concerning the offspring are also reported in the literature, such as macrosomia[6,13], congenital malformation[14,15] and, over the long term, metabolic syndrome[16] along with the risk of cardio-metabolic factors[17].

The U.S. Institute of Medicine[18] (IOM) emphasizes that weight gain during pregnancy depend on BMI before pregnancy, as follows: women who are underweight before pregnancy (BMI of less than 18.5) should gain between 12.5 and 18 kilograms during pregnancy; women who are of normal weight before pregnancy (BMI of between 18.5 and 24.9) should gain between 11.5 and 16 kilograms; women who are overweight before pregnancy (BMI of between 25 and 29.9) should gain between 7 and 11.5 kilograms; and women who are obese before pregnancy (BMI greater than 30) should gain between 5 and 9 kilograms[18].

According to IOM, it is also important to consider that the pattern of weight gain changes throughout the gestation period. In this sense, women should gain less weight in the first trimester, in a period representing mainly the deposition of maternal fat, and the largest weight gain should occur in the third trimester of pregnancy[18], when the highest fetal weight gain occurs[19]. Studies have shown that failing to meet this standard and gaining excess weight in the first trimester of pregnancy is associated with an increased risk of overweight / obesity in children aged 2 years to 4 years[20] and maternal obesity in the future[18].

It is known that poor sleep quality is a common complaint during pregnancy due to the multiple physical, hormonal and physiological alterations[21-23]. However, the studies do not bring necessarily convergent results in this field. In this context, the occurrence, magnitude and frequency of these disorders are very heterogeneous among pregnant women[24-26]. In general, there is an increase in sleep time, daytime sleepiness and insomnia in the first trimester of pregnancy, but a decrease in overall sleep quality[27,28], to nocturnal urinary frequency and heartburn[25]. During the second trimester, increased levels of estrogen and progesterone may cause edema of the upper airway mucosa and predispose women, especially obese pregnant women, to snoring and the development of obstructive sleep apnea[29].

Other studies, however, found that most pregnant women reported decreased sleep quality and increased nighttime wakefulness, especially in the third trimester[21,22,30]. In this regard, between 82 and 98% of the women report waking during the night in the final week of pregnancy[21,31], and 64% to 86% report problems concerning sleep quality over the whole period of their pregnancy[32]. In relation to daytime sleepiness, Guilleminault et al.[30] found that in 277 women, 37.45% reported daytime sleepiness to a varying degree at six weeks of pregnancy. This however, increased to 52% of the women in the seventh month of pregnancy.

The relationship between changes in sleep pattern and weight gain has been widely reported in the literature[33], but poorly investigated in pregnant women. Studies conducted with a non-pregnant population have demonstrated that a short sleep duration can lead to obesity[34-37], which seems to happen due to a metabolic change capable of altering the secretion of hormones related to the control of food intake, such as ghrelin and leptin[38,39]. One of the few studies concerning this theme that was performed in pregnant women used a cross-sectional model and showed that the mean hours of sleep was identified as a modifiable behavioural correlation to excessive gain of gestational weight[40]. New studies in this area are necessary to provide us with an important understanding of the role of sleep in weight gain during pregnancy.

In light of this, the hypothesis of this study is that a shorter sleep time and a worse sleep quality can be related to a worse weight gain pattern during pregnancy. The focus of this study was to evaluate the influence of sleep duration and sleep quality on the increase of the BMI during pregnancy.

MATERIALS AND METHODS

Participants and Ethics

A prospective and longitudinal study was conducted in antenatal clinics in the public health service in the city of Uberlândia, Minas Gerais, Brazil. The criteria for inclusion were pregnant women of a single fetus, who had their first prenatal consultation at the l low-risk health clinic of the public health service until the 12th week of pregnancy. Thus, women with gestational age greater than 12 weeks were not included in the study. The exclusion criteria were pregnant women younger than 18 years old, individuals who were underweight (BMI<18.5 kg/m^2)[41] and those that presented previous diseases or developed some type of disease over the pregnancy period.

A total of 142 pregnant women were contacted in their first trimester and 63 completed all the evaluations (Figure 1). These women were evaluated in the first, second and third trimester and had follow-ups until term and delivery, which aimed at checking the outcome of the pregnancy (data not shown). The evaluations were performed between October 2015 and December 2016.

The pregnant women had the option to leave the study at any time and all signed the provided full, written informed consent. The study was conducted in accordance with the Declaration of Helsinki and the protocol was approved by the Ethics Committee of the Federal University of Uberlândia (CAAE: 43473015.4.0000.5152/2015).

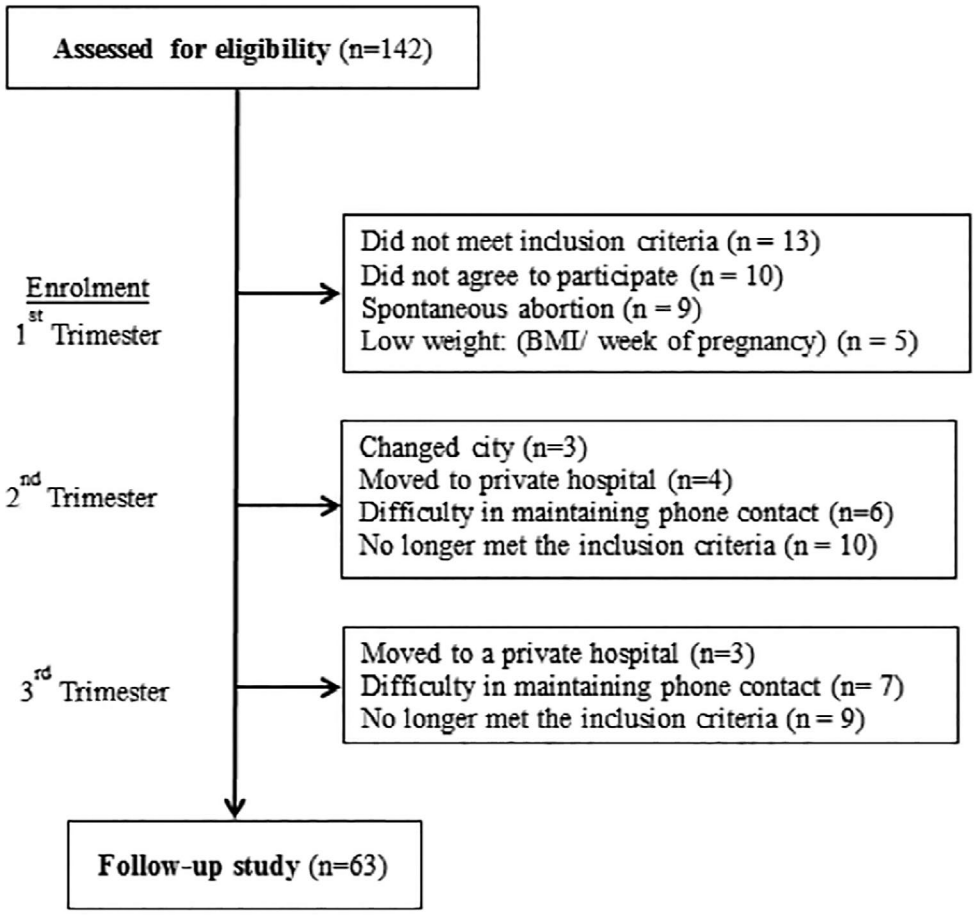

Figure 1. Diagram reporting the number of pregnant women at each stage of the study. Diagram reporting number of pregnant women both approached and recruited during the study in the public health care service of the city of Uberlandia, Minas Gerais, Brazil, 2015–2016 (n=63).

METHODS

A questionnaire was used to evaluate socio-demographic aspects and marital status in the first trimester.

Evaluations of physical activity, as well as information regarding tobacco and alcohol consumption, anthropometric variables, physical activity, food intake and sleep duration and quality were performed in the first (≤12 weeks of pregnancy), second (20th to 26th week) and third trimester (30th to 37th week).

Anthropometric variables

Weight was measured with a scale to an accuracy of 0.1 kg (Welmy®, São Paulo, Brazil). Height was measured to an accuracy of 0.1 cm using a stadiometer fixed to the wall (Welmy®). The height of the pregnant woman was measured only in the first evaluation and used over all other trimesters. Pre-pregnancy BMI (kg/m²) was calculated and the pregnant was classified according to the BMI classification by the World Health Organization (WHO)[41]: underweight (<18.50 kg/m²), normal weight (18.50-24.99 kg/m²), overweight (25.00-29.99 kg/m²) and obese (30.00-39.99 kg/m²). The current weight was measured over the three evaluations and the BMI was classified in accordance with the curve from Atalah Samur et al.[42] for the gestational age, according to the recommendations by WHO[41].

Food intake

Food intake was determined using three 24-hour recalls in non-successive days, including a weekend day, with one being performed in person and the others by telephone, a technique already used in previous studies[43,44]. These data were used for characterization of pregnant women and adjustments over the analyses.

Sleep duration and sleep quality

For the sleep quality evaluation, the PSQI was used[45], translated into Portuguese, and has been used by other investigators in Brazil[46]. The PSQI is an instrument widely used to measure the subjective sleep quality during the last month of pregnancy and has been validated in populations of pregnant women in previous studies[47,48]. The PSQI includes 19 Items that are categorized into seven clinically derived components and are analysed from instructions based on scores for each of the components, varying between zero and three points, which include: sleep duration; disturbances during sleep; sleep latency; dysfunction during the day due to sleepiness; efficiency of sleep; overall sleep quality; and need medication to sleep. The maximum score for this instrument is 21 points, where scores of 0 to 4: good quality sleep, 5 to 10: poor quality sleep, and > 10 presence of sleep disorder.

Sample size calculation

The determination of the sample size was done using the G Power software, version 3.1[49], based on F-test ANOVA which repeated measurements with an effect size f of 0.25, an alpha level of 0.05, 95% power and four clusters and three measurements (gestational trimester). Thus, a total sample of 65 pregnant women was required at final follow-up.

Statistical analysis

The Kolmogorov–Smirnov test was initially performed. Descriptive statistics were used to summarize participant sociodemographics, lifestyle, food intake, anthropometrics and sleep duration and sleep quality. Weight gain was expressed from the increase in BMI over pregnancy, through the adoption of 1.0 as the weight in the first trimester. Categorical variables were presented using percentages/ frequencies and continuous variables were presented using median/ interquartile interval or means/ standard deviations.

The individual pattern of women in relation to BMI was analysed, identifying those who maintained or increased the BMI categories recommended by WHO[41]. Based on the classifications of each pregnant woman at the first and third trimester, all were grouped into two clusters of BMI. These clusters were 'Constant', individuals who maintained the same classification for BMI at the first and third trimester; and 'Ascending', individuals who showed an ascending curve and changed/ increased to a higher BMI category in the third trimester. The Delta difference between sleep duration from the third to the first trimester was calculated. The Mann–Whitney U test was used for comparing the delta according to the BMI clusters.

The sleep duration of each woman in the study was analysed and characterized as normal sleep (>7h) or short sleep (≤7h)[50] over the three quarters in order that variations over the period could be analysed. The sleep quality was grouped per cluster, identifying those individuals who maintained, improved or worsened their sleep quality, based on the PSQI classifications[45] over the three trimesters. These clusters were 'good before/ good after', for the study individuals with maintained a good sleep quality in the first and third trimesters; 'good before/ poor after', for those that presented a deterioration in sleep quality; 'poor before/ good after', for those that showed improvement in their sleep quality; 'poor before/ poor after', for those women in the study who presented a poor sleep quality in the two analysed times. The second cluster (good before/ poor after) was considered better than the third (poor before/ good after) because the first trimester is considered as a very important period for fetal development and poor sleep quality in this period could be thought to interfere with development[18].

Generalized estimating equations (GEE) were used to examine the association between clusters of sleep quality or duration and BMI over the pregnancy period (at the first, second and third trimester) adjusting for age, physical activity level, education, initial BMI, previous sleep disturbances (PSQI>10) and usual energy intake. An interaction effect between the clusters of sleep quality or duration and pregnancy period was also included in the model. The GEE logistic regression model accounts for correlations among the within-subject outcome variables of BMI gain across the pregnancy period and provides consistent estimates of the parameters and standard errors using robust estimators. The adjustment method used for multiple comparisons was the Sequential Sidak. Analyses were performed using SPSS 20 software and a p-value ≤ 0.05 was considered as significant.

RESULTS

Socio-demographic data, such as lifestyle, food intake, anthropometric and subjective sleep quality and duration are presented in Table 1. Most of the pregnant women were married or lived with a partner (79.4%), presented secondary incomplete/ complete education level (71.5%), had a normal pre-pregnancy BMI (60.3%) and a poor PSQI global sleep quality (62%). In addition, food intake pattern seems to be minimally adequate for the stage of life (Table 1).

In Figure 2, the delta of sleep duration (hours; third–first trimester) according to the BMI clusters is presented. One notes that pregnant women who maintained the same BMI category over the pregnancy period increased their sleep duration from the first to third trimester, while those that increased the BMI category slept the same amount of time during this period (median = 1.0 [0.0–2.0] and median = 0.0 [-2.0–1.0], respectively, p=0.039).

Table 2 presents the average estimates for the BMI according to the pregnancy period and sleep duration (≤7 and>7) over the three trimesters. No effect of sleep duration was observed in BMI. As expected, a significant effect of time of pregnancy (p<0.005) was observed on the BMI. For pregnancy with a normal or short sleep duration, significant differences between the first and second trimester and between the first and third trimester were found (p<0.005).

Table 3 shows the estimated averages for BMI according to the sleep quality clusters using the PSQI over the three trimesters of pregnancy. Despite the fact that no effect of sleep quality was observed in the BMI, an effect of time of pregnancy (p<0.05) and of interaction effect between time of pregnancy and clusters of sleep quality were observed on the BMI (p<0.05). The effect of interaction between time of pregnancy and clusters of sleep quality indicates that pregnant women with higher-quality sleep (two first clusters) gain more weight from the second to third trimester, while those with the worst-quality sleep (two last clusters) gain more weight during the first to second trimester. Regarding the effect of time of pregnancy on the BMI, a significant weight gain was observed in the following clusters/ times: for pregnant women from the cluster 'good before/ good after' from the first to the third trimester (1.00±0.00 *versus* 1.11±0.07, p<0.005); for those pregnant women from the cluster 'good before/ poor after' from the first to second and third trimester (1.00±0.00 *versus* 1.09±0.13 and 1.00±0.00 *versus* 1.11±0.17, respectively, p<0.005); for pregnant women from the cluster 'poor before/ good after' from the first to the second and third trimester

Table 1. Socio-demographic data, lifestyle, food intake, anthropometry and subjective sleep quality and duration of pregnant women in the first trimester (n=63).

Variables	First Trimester Mean ± SD or Median [interquartile range] or n (%)
Age, years	27.14±5.730
Menarche age*	12.00 [11.0–13.00]
Marital status	
Married or Living with companion	50 (79.4%)
Single	13 (20.6%)
Education level	
Primary incomplete/complete	3 (4.8%)
Secondary incomplete/complete	45 (71.5%)
Higher incomplete/complete	15 (23.7%)
Participated in physical activity	14 (22.2%)
Smoker	11 (17.5%)
Consumes alcohol	6 (9.5%)
Food intake	
Energy (kcal)	1562.84±688.17
Carbohydrates (g)	200.04±82.01
Protein (g)	63.56±32.81
Lipids (g)	51.85 [37.72–73.77]
Anthropometric variables:	
Height (m)	1.64±0.06
Pre-pregnancy weight (kg)	65.00 [59.00–73.00]
Pre-pregnancy BMI (kg/m^2)	23.90 [21.70–26.10]
Normal weight	38 (60.3%)
Overweight:	17 (27%)
Obese	8 (12.7%)
Weight - first trimester (kg)	66.80 [60.00–75.00]
BMI - first trimester (kg/m^2)	25.26±4.39
Underweight	8 (12.7%)
Normal weight	27 (42.9%)
Overweight	18 (28.6%)
Obese Subjective sleep quality and duration	10 (15.9%)
PSQI‡ global sleep quality score (0–21)	7.00 [4.00–9.00]
Good (0–4)	17 (27%)
Poor (5–10)	39 (62%)
Sleep disorder (>10)	7 (11%)
Bedtime weekday (h:min)	23:06 [22:00–23:00]
Bedtime weekend (h:min)**	23:50 [23:50–24:00]
Wake time weekday (h:min)	7:00 [6:00–8:00]
Wake time weekend (h:min)**	8:50 [8:00–9:50]
Median for sleep per week (h:min)	8:30 [7:17–9:33]

Note: Values are presented as mean and SD (standard deviation) for normally distributed data or as median [interquartile range] for not normal distributed data or n (%).
§BMI: Body mass index
‡PSQI = Pittsburgh Sleep Quality Index
*Missing: 3; **Missing: 1.

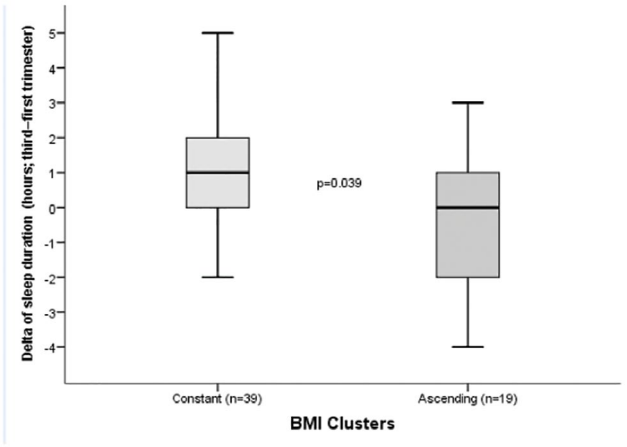

Figure 2. Delta of sleep duration (hours; third–first trimester) according to the BMI clusters (n=58; 4 outliers were excluded). 'Constant', individuals who maintained the same classification for BMI at the first and third trimester (median=1.0 [0.0–2.0]); and 'Ascending', individuals who showed an ascending curve and changed/ increased to a higher BMI category in the third trimester (median = 0.0 [-2.0–1.0]). The Mann–Whitney test was performed for comparing the Delta according to the BMI clusters, p=0.039.

(1.00±0.00 *versus* 1.10±0.16, p<0.005 and 1.00±0.00 *versus* 1.07±0.007, p<0.005, respectively); and for the individuals from the cluster 'poor before/ poor after' from the first to the second and third semester (1.00±0.00 *versus* 1.10±0.009, p<0.005 and 1.00±0.00 *versus* 1.08±0.006, p<0.005, respectively).

The median for the women's age at the moment of delivery was 39 weeks [38–40] and the median for the weight of new borns was 3.09kg [2.87–3.45]. Thirty-four of the pregnant women (62%) had Caesarean section (analysis performed with 55 expectant mothers; data not shown in the tables).

DISCUSSION

The present study evaluated the association between sleep duration and quality and the increase in BMI during pregnancy. An effect of interaction between time of pregnancy and sleep quality was observed on the BMI, indicating that women who improved sleep quality during pregnancy gained more weight from the second to third trimester, while those that worsened the sleep quality gained more weight during the first to second trimester. Furthermore, it was found that pregnant women who maintained their BMI category as 'Constant' during pregnancy increased their sleep duration from the first to the third trimester, while those that increased the BMI category slept the same time between these periods.

These results indicate that a poor sleep quality over the pregnancy period as a whole, negatively impacts the weight gain distribution, and consequently the BMI. These results should be seen as worrying, due to the negative effects of inadequate weight gain on the outcome of pregnancy[4,6,10,11]. Such findings partially confirm our initial hypothesis –that the worse sleep quality, but not the least duration–, is related to an inadequate

Table 2. Estimated measurements of the body mass index according to sleep duration (≤7 and >7) over the three gestational trimesters (n=63).

	Normal sleep >7 h (n=53)			Short sleep ≤7 h (n=10)			Effect	Df	*p*-value
	1stT	2ndT	3rdT	1stT	2ndT	3rdT			
BMI	1.00±0.00[a]	1.10±0.008[b]	1.08±0.006[b]	1.00±0.00[a]	1.08±0.14[b]	1.07±0.009[b]	Time	1	<0.005
							Sleep	2	0.117
							Time *Sleep duration	2	0.27

Adjusted to age, participation in physical exercise and daily calorie intake. **p* values calculated by generalized estimating equation (GEE). $p<0.05$ was considered significant. DF=degree of freedom. Bold values are statistically significant. BMI= body mass index. 1stT - first trimester; 2ndT - second trimester; 3rdT - third trimester.

Table 3. Estimated measurements for the body mass index according to sleep quality over the three gestational trimesters (n=63).

	Good before/ good after (n=3)			Good before/ poor after (n=14)			Poor before/ good after (n=10)			Poor before/ poor after (n=36)			Effect	Df	*p*-value
	1stT	2ndT	3rdT	1stT	2ndT	3rdT	1stT	2ndT	3rdT	1stT	2ndT	3rdT	Time	2	<0.005
BMI Mean/ DP	1.0 ± 0.00[a]	1.07 ± 0.46[a]	1.11 ± 0.07[b]	1.00 ± 0.00[a]	1.09 ± 0.13[b]	1.11 ± 0.17[b]	1.00 ± 0.00[a]	1.10 ± 0.16[b]	1.07 ± 0.007[b]	1.00 ± 0.00[a]	1.10 ± 0.009[b]	1.08 ± 0.006[b]	Sleep	3	0.707
													Time *Sleep quality	6	<0.005

Adjusted to age, participation in physical exercise and daily energy intake. **p* values calculated by generalized estimating equation (GEE). $p < 0.05$ was considered significant. DF=degree of freedom. Bold values are statistically significant. BMI: body mass index. Clusters: 'good before/ good after', pregnant women that maintained good sleep quality from the first to the third trimester; 'good before/ poor after', those pregnant women whose sleep quality worsened from the first to the third trimester; 'poor before/ good after', pregnant women who improved in sleep quality from the first to the third trimester; 'poor before/ poor after', those women who maintained a poor sleep quality in the first and the third trimester. 1stT - first trimester; 2ndT - second trimester and 3rdT - third trimester.

pattern in the increase of BMI during pregnancy. This is found to be a relevant topic that remains under explored in the literature, and which reinforces the importance of standard follow-ups for sleep duration and quality in pregnant women in the search for adequate mother and foetus health.

The main finding of the present study was the association between weight gain and the sleep quality analysed by GEE analysis. Interestingly, the period of sleep duration did not show any effect on BMI, but only the interaction between the pregnancy period and sleep quality. This fact suggests that the sleep quality interferes in the BMI over the pregnancy period. These data are relevant since the sleep quality is evaluated in a broad sense by the PSQI tool, which not only evaluates the sleep duration, but also sleep disturbances, latency, efficiency, daytime sleepiness, the need for medication and the global sleep quality[45]. In the present study, it was found that two clusters from the PSQI indicating better sleep quality ('good before/ good after' and 'good before/ poor after') demonstrate that weight gain is less from the first to the second trimester, and increases from the second to the third trimester. This standard of weight gain is seen as ideal, given that in the first 12 weeks of gestation the development of the foetus should take place, whereby a low weight gain is noted on the part of both mother and foetus[18]. On the other hand, in the second half of the pregnancy period one hopes for a higher weight gain, aimed at providing the necessary weight to the foetus, besides the weight gain due to fluid retention, amniotic fluid, the increased blood volume and the accumulation of body fat as an extra energy deposit[18].

In the present study, since the first two clusters in the PSQI indicating worst sleep pattern showed an inverted pattern of BMI increase in relation to the last two clusters, it is reasonable to suppose that a worse quality of sleep leads to a higher fat gain in the initial stage of pregnancy. This is because the maternal weight gain is seen as an important indicator for the overall prognosis of the pregnancy[3,4] and that a better quality of sleep leads to a weight gain that presents a more physiological pattern[18], that is, a greater weight gain between the last trimesters of gestation, since it is when there is a more pronounced growth of the fetus. Studies that evaluate changes in body composition throughout pregnancy are necessary to confirm these assumptions.

Other studies with women in pregnancy[40,51-53] have shown controversy in the relationship of sleep duration and weight gain. Gay et al.[54] found that 60% of the 128 pregnant women evaluated in their study had excess gestational weight gain, which was associated with poorer perceived sleep quality, but was unrelated to objective measures of sleep duration and sleep disruption. Authors also found that excess weight gain was associated with shorter sleep duration and more sleep disruption, but only among women who were overweight before pregnancy.

A cross-sectional study of Althuizen et al.[40], which evaluated 144 pregnant women, found that the average number of hours slept was identified as a modifiable behavioural correlation in terms of excessive gestational weight gain. The study by Knight et al.[52] analysed the sleeping habits during the third trimester of pregnancy in a cohort, and found that those that sleep less than 7 hours per night had a higher percentage of total weight gain in the first trimester (23.6% *versus* 14.2%, $p=0.03$). Contrary to the findings of the above cited studies, Restall et al.[53] found that women during pregnancy that slept for ten hours a day or more were nearly twice as likely to suffer from excessive weight, when compared to those women that reported sleeping less than 8 hours per night. However, due to the fact all the

studies cited above had evaluated sleep duration at a singular moment[53] - in general at the end of pregnancy[40,52] - direct comparisons with the present study are difficult.

The present study evaluated the dynamic changes to the sleep quality and duration over the gestational process and its influence on weight gain, which can be considered as a strength, when considering the modifications to sleep during each trimester of pregnancy and their implications[20,22]. Abeysena and Jayawardana's study[51] (n=710) - to the best of our knowledge, the only longitudinal study that associated sleep with weight gain - found that sleep duration <8 h/ day during the second, third or both trimesters was a risk factor toward inadequate weight gain (OR 1.60, 95% CI 1.05, 2.46). Besides the methodological differences from the present study - they did not compare the dynamic changes during the gestational process, but considered short sleep in only one of the trimesters (8h/ day) - these data are contrary to the present study, which demonstrates the importance of performing more research in the area.

An interesting result found in the present study was the higher median delta for sleep duration from the third to the first trimester in the BMI category 'Constant' (p=0.039) in relation to the group that changed/ increased in the BMI category. These results show that the group that gained weight excessively seemed to sleep for the same period at the beginning and end of gestation (median=0.0 [-2.0–1.0]), while the group that maintained their initial nutritional status, slept around one hour more at the end of pregnancy in relation to the beginning (median=1.0 [0.0–2.0]). We suggest that the increase in sleep duration seems to be a factor that avoids excessive weight gain in these women during pregnancy. This could be due to the fact that a shorter duration of sleep is characterized by an increase in food consumption[55-58]. In this sense, a study has pointed out that a longer time awake is also an opportunity to perform more meals[55] and that several neuroendocrine and metabolic functions can be triggered due to sleep restriction, such as reduction of leptin levels and increased levels of ghrelin[39,59]. Together, these responses can increase appetite and, consequently, food intake and weight gain[60].

Previous studies that accompanied the sleep quality at each gestational trimester show divergent findings[51]. The researchers Neau et al.[21] found a reduction of 40 minutes for the last trimester, when compared to the first; these authors, however, did not evaluate its relationship with weight gain. In general, evidence that evaluated the sleep duration and quality of women during pregnancy has demonstrated that this can both improve[61] and worsen[21,23] from the first to the third trimester. However, these studies did not evaluate its relationship to weight gain. Another aspect that may influence the BMI is the progesterone levels, since this hormone is associated with increased sleepiness. In this sense, Diemert et al.[62] investigated the association between maternal factors - endocrine and anthropometric indices - throughout all trimesters of pregnancy. Authors found that an increased BMI was associated with an increased risk for pregnancy complications. Also, maternal 1st trimester BMI showed a significant inverse correlation to progesterone levels throughout gestation (p<0.0001 in the 1st and 2nd, p=0.01 in the 3rd trimester). This inverse association between maternal BMI and progesterone levels was confined to overweight women.

There are some limitations to our study. First, some evaluations were done using questionnaires, which are subjective and dependent on the motivation and memory of the subjects. Studies using objective measures of sleep - such as polysomnography and actigraphy - allow for greater understanding of the dynamics of the architecture of sleep when dealing with weight gain. Second, it was not possible to standardize the same week of the evaluation in each quarter. Considering that the third trimester is the period of greatest weight gain, the number of gestational weeks and, consequently, the weight gain among pregnant women may have varied during this period. Lastly, the patients were not evaluated for the presence or absence of apnea, which supposedly could interfere in the metabolic diseases and in the weight gain.

We conclude that a better sleep quality seems to lead to a better distribution of weight during pregnancy. Future studies should confirm such findings, which can thus justify the monitoring of sleep duration and quality during pregnancy as measures for preventing an inadequate pattern of weight gain during this period.

Ethical Committee Permission: The study was conducted in accordance with the Declaration of Helsinki and the protocol was approved by the Ethics Committee of the Federal University of Uberlândia (CAAE: 43473015.4.0000.5152/2015). Informed consent was obtained from all individual participants included in the study.

Conflict of Interest Statement: On behalf of all authors, the corresponding author states that there is no conflict of interest.

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