How weight during pregnancy influences the association between pre-pregnancy body mass index and types of delivery and birth: a comparison of urban and rural areas.

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Abstract

Background: Women in study areas suffered from the problems of caesarean delivery (CD), low birth weight (LBW), and macrosomia.

Objective: To investigate how gestational weight gain (GWG) influences the effect of the pre-pregnancy body mass index (BMI) on the risks of CD, LBW, and macrosomia in urban and rural areas in a city of Iran.

Methods: We used 767 and 612 eligible subjects from the public health care centers in urban and rural areas respectively.

Results: The risk of CD increased from 74% to 2.62-fold in urban and from 62% to 2.15-fold in rural areas, and the risk of macrosomia increased from 58% to 2.35-fold in urban and from 47% to 96% in rural areas, among obese women compared to normal weight women who gained above median GWG. The risk of LBW increased from 38% to 92% in urban and from 49% to 97% in rural areas among lean women compared to normal weight women who gained below median GWG.

Conclusion: These findings strongly support the need to reform adequate pre-pregnancy weight and GWG against the risks of CD and macrosomia among overweight and obese women, and against the risk of LBW among lean women in both areas.

Keywords: Body mass index, gestational weight gain, caesarean delivery, low birth weight, macrosomia.

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Introduction

Over the past decades, pre-pregnancy BMI has been employed to assess the risk of pregnancy outcomes such as caesarean delivery (CD) and infant birth weight (IBW)[1-5]. Gestational weight gain (GWG) has also been referred to as a good means for evaluating the risks of CD and IBW[6-13]. Thus classifying women into the different pre-pregnancy BMI categories often raises the question whether the risks of CD and IBW are affected merely by pre-pregnancy BMI, or they might be influenced by GWG as well. While understanding the association effect of BMI and GWG has been controversial between the local health researchers in different nations[14-21], particularly in Iran[22-23], some studies investigated the combined effect of BMI and GWG on pregnancy outcomes in Western countries and countries in South and East Asia[16-20]. For instance, Nohr et al.[16] investigated that high BMI and high GWG are associated with the risk of CD in the Danish National Birth Cohort. Frederich et al.[17] showed that IBW is influenced by pre-pregnancy BMI and GWG on Seattle and Tacoma, Washington women. Thorsdottir et al.[18] revealed that women with normal BMI (19.5–25.5 kg/m^2) who gained weight within the Institute of Medicine (IMO) guidelines of 11.5–16 kg experienced fewer delivery complications than those who gained >20 kg for the Icelandic women. Merchant et al[19] showed that lean women (BMI<19.8 kg/m^2) who gained<12.5 kg had lower IBW compared to those who gained>12.5 kg among Pakistani women.[20] showed that pre-pregnancy BMI and total GWG were jointly associated with the risks of CD, LBW, and macrosomia in China.

Increased rates of CD, LBW, and macrosomia have been recently observed in Iran[24-30]. A few studies have been carried out in Iran, but to the best of our knowledge, none of them has succeeded in investigating the association between the risks of CD, LBW and macrosomia and pre-pregnancy BMI by looking at the effect of weight during pregnancy[29-30].Therefore, this study sought to explore the following research questions among pregnant

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women in two areas of the North East of Iran: (1) What are the differences in GWG within the IOM guidelines recommendation across pre-pregnancy BMI categories among women in urban and rural areas? (2) What are the differences in the rates of CD, LBW, and macrosomia among women in urban and rural areas? (3) How and in which direction the association between pre-pregnancy BMI and GWG affect the risks of CD, LBW, and macrosomia in urban and rural areas? Findings from this study may contribute to our understanding of the link between pre-pregnancy BMI and weight during pregnancy. These findings may also extend existing literature by providing information that underscores the need to reform pre-pregnancy weight and weight during pregnancy against the risk of CD, LBW, and macrosomia among women in urban and rural areas.

Methods

Study area and data

The study area is the city of Gorgan which is located in the NorthEast of Iran. This study randomly selected 767 and 612 singleton term pregnancies that referred at ≤10 weeks of gestation to one of 6 and 4 public health care centers respectively in urban and rural areas. Eligible participants were women who followed the prenatal care of the public health center and planned to deliver at the hospital which they were referred to by the physician. The expected dates of delivery were between April 2011 and July 2012. Women were interviewed by trained health workers. Maternal information such as weight in early pregnancy, height, gestational age, parity, pre-term, history of abortion and stillbirth, smoking, alcohol, drug addiction, and chronic disease were recorded using a standard questionnaire. Gestational age was determined using the self-reported date of last menstrual period (LMP) and confirmed by earliest ultrasound, when available, or by physician's best LMP estimate. Pre-pregnancy maternal weight was self-reported or was measured in the first trimester (or at the first prenatal care visit). Note that women with chronic diseases and with complications of pregnancy (health problems that occur during pregnancy or had before pregnancy) such as gestational diabetes, pre-eclampsia, anemia, depression (n=47 in urban, n=29 in rural) were excluded from the study, because this may affect the combined effect of GWG and BMI on CD and IBW. In addition, women with twin gestation (n=31 in urban, n=24 in rural) and women either whose weight in early pregnancy or in the first trimester (or at first prenatal care visit) were not available (n=34 in urban, n=19 in rural) were excluded from the study. Women also claimed to be non-smokers, non-drinkers, and non-drug users. The permission for collecting the data in this study was approved by Golestan University of Medical Sciences.

Treatments and outcomes

Pre-pregnancy BMI (pre-pregnancy weight in kilograms divided by height in meters squared) and GWG (the difference between pre-pregnancy weight and weight before delivery) were considered as treatments. Women were categorized into 4 BMI classes based on WHO: BMI<19.9 (lean), BMI=19.9-25 (normal weight), BMI=25-30 (overweight), and BMI≥30 (obese) 15 (Figure1). In line with IOM guidelines[14], GWG across BMI categories are 12.5-18 kg for lean women; 11.5-16 kg for normal weight women; 7-11.5 kg for overweight women; and ≤7 kg for obese women. In fact, GWG were generally categorized into three groups across BMI categories: below, within, and above guidelines. For instance, lean women with GWG<12.5 is below, with 12.5≤GWG≤18 is within, and with GWG>18 is above guidelines. To avoid collapsing the latter categorization and increasing the cell number in our analysis, we categorized GWG into two groups: ≤median; and >median (Figure 1). Pregnancy outcomes were unplanned CD (1=if CD, 0=if not) as a dichotomous variable, and IBW (kg) which was grouped LBW (<2.5 kg), normal birth weight (2.5-4 kg), and macrosomia (> 4 kg). IBW was a categorical variable with three levels where normal birth weight was considered as the reference group.

Statistical model

To incorporate the correlation within women and the variation among women, we fitted the logistic mixed-effect model with random intercept and random slope for health care center levels in urban and rural areas by adjusting the measured characteristics of the mothers and their infants. Specifically, the random intercept was 1 and the random slope was the levels of health centers (level 1 for urban health centers, 2 for rural health centers). Because our participants were under the prenatal care of two public health care centers in urban and rural areas with different levels of medical facilities such as having connoisseur specialists and trainers, technological resources, providing comprehensive care. These are accepted between the local health care physicians in the study areas that the health care centers in urban areas were at the high quality levels

of care[31]. Then unobserved heterogeneity of care was likely to be present between women in two areas. Thus, we used the following logistic mixed-effect model;

Logit {P (Y=1)} =ψ0+ψ1X+Wθ+ Z β+

where Y is pregnancy outcome, X is treatment, W is characteristics of the mothers and their infants, and Z is the health care center levels for urban and rural areas. Note that in the above model ψ1 is the effect of the treatment, θ is the vector parameter of the effect of W, β is the vector parameter of the random intercept and random slope, and ε is error term. We first estimated the effect of BMI on the risks of CD, LBW, and macrosomia by ignoring the association between BMI and GWG compared to women with normal weight as the reference group. Next, we took into account the association between BMI and GWG to estimate the combined effect of BMI and GWG on the risks of CD, LBW, and macrosomia. The latter was performed by constructing eight-level combined categories of BMI (four groups) and GWG (two groups). To answer how and in which direction the association between pre-pregnancy BMI and GWG affect, we established two reference groups. The first reference group was normal weight women with GWG>median, and the second reference group was normal weight women with GWG≤ median. We further adjusted the measured characteristics of the mothers and their infants listed in the previous section as the confounder factors. Adjusted risk ratio (RR) and its 95% confidence interval (CI) were obtained. Statistical analysis was performed using R-3.2.2 software throughout.

Results

In total, 1,195 singleton pregnancies remained from 6 and 4 public health centers in urban and rural areas respectively. Table 1 presents maternal and infant demographic characteristics.

Out of 655 subjects in urban areas, 10.08% were lean, 32.52% were normal weight, 39.69% were overweight,

Table 1 : Pre-pregnancy body mass index, gestational weight gain, the characteristics of the mothers and their infants, urban and rural areas, Gorgan, Iran, April 2011-July 2012.

	Urban (n=655)	Rural (n=540)	P value
BMI (kg/m^2)			
Mean ± SD*	25.93±4.65	27.37±5.09	<0.001
lean (%)	10.08	5.56	0.006
normal weight (%)	32.52	31.48	0.730
overweight (%)	39.69	34.81	0.990
obese (%)	17.71	28.15	0.001
GWG (kg)			
Mean ± SD*	12.17±4.38	10.93±4.57	<0.001
≤median (%)	57.40	60.50	0.780
>median (%)	42.60	39.50	0.780
Age (years)			
mean ± SD*	25.89±4.94	25.08±5.80	0.010
<20 (%)	8.40	16.85	<0.001
20-30 (%)	70.23	63.98	<0.001
30-40 (%)	20.30	18.37	<0.001
≥40 (%)	1.07	0.80	<0.010
Parity (%)			
0	55.50	41.30	<0.001
1	28.09	39.35	<0.001
2	11.21	11.67	0.100
≥3	5.20	8.68	<0.001
Preterm (%)	12.90	10.02	0.010
Abortion (%)	5.04	2.96	0.010
Stillbirth (%)	0.03	0.003	0.007
Infant sex (%)	b=51	b=55	0.57
	g=49	g=45	0.63

**SD=Standard deviation*
b=boy; g=girl

and 17.71% were obese. Out of 540 subjects in rural areas, 5.56% were lean, 31.48% were normal weight, 34.81% were overweight, and 28.15% were obese. Median GWG in urban and rural areas were 12.5 (kg) and 11.5 (kg) respectively, and 57.4% (42.6%) of women gained weight ≤12.5 (>12.5) in urban areas, and 60.5% (39.5%) of women gained weight ≤11.5 (>11.5) in rural areas (Figure 1).

On the average, age was 25.89± 4.94 and 25.08± 5.80 years; BMI was 25.93 ±4.65 and 27.37 ±5.09 kg/m^2; and

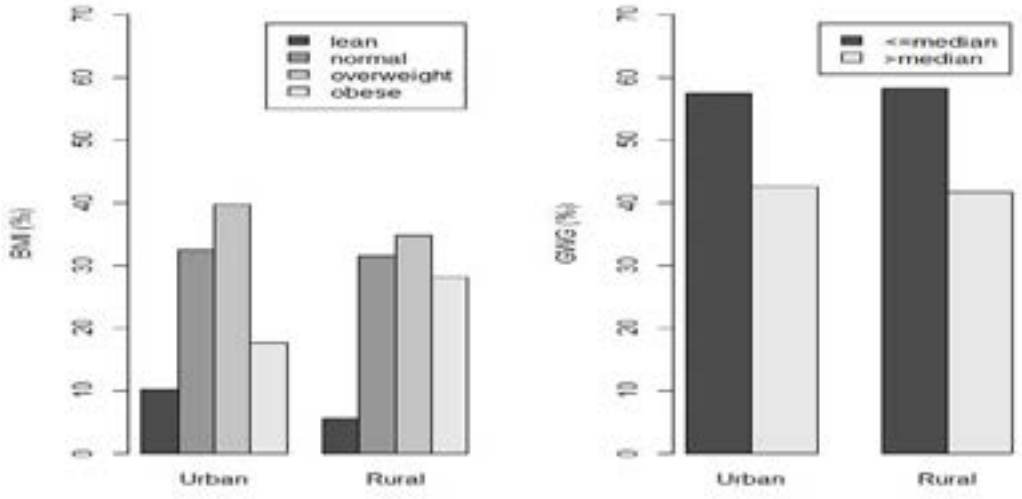

Figure 1: The distributions of the pre-pregnancy body mass index and gestational weight gain categories, urban and rural areas, Gorgan, Iran, April 2011-July 2012.

GWG was12.17 ±4.38 and 10.93 ±4.57 kg, respectively in urban and rural areas (Mean ±SD). We observed lean, normal weight, overweight, and obese women in rural areas were slightly younger, more likely to be multiparous, were less likely to have an abortion, were less likely to have preterm, and were less likely to have a stillbirth as compared to urban women with the same BMI. Further, we evaluated compliance with the IOM guidelines across BMI categories to develop GWG guidelines for optimal CD and IBW. Table 2 shows 37.89% of lean women, 29.11% of normal weight women, 37.69% of overweight women, and 36.21% of obese women were within the IOM guidelines for GWG recommendation in urban areas. While 40% of lean women, 36.47% of normal weight women, 39.89% of overweight women, and 45.39% of obese women were within the IOM guidelines for GWG recommendation in rural areas.

These implied that more women in all four BMI categories had not adhered to their IOM recommendation for

GWG in both areas. Further, the two groups of women in urban and rural areas in ≤median and >median of GWG were comparable. This is because the GWG median in urban and rural areas were 12.5 (kg) and 11.5 (kg) respectively, and also the percentage of the women in both areas with GWG ≤median and with GWG>median were not significantly different (Table 1). We compared these two groups as the independent samples by using Chi-square test. Our analysis also showed that BMI and GWG were positively associated with CD, LBW, and macrosomia in urban and rural areas after adjusting for the mothers and their infant's characteristics.

Identification of correlation and partial correlation

We investigated the correlation between BMI and GWG, and conditional on IBW. The results showed that the correlation between BMI and GWG was -0.11 and -0.14 in urban and rural areas respectively. This implied that BMI and GWG were significantly inversely correlated in both areas. Our analysis also showed that BMI was independently associated with IBW in both areas (R = 0.56, p.value= 0.001 in urban; R = 0.51, p.value= 0.001 in rural), and GWG was also independently associated with IBW in both areas (R = 0.32, p.value= 0.002 in urban; R = 0.28, p.value= 0.004 in rural). Further, to identify how GWG affects the correlation between BMI and IBW, we obtained the partial correlation between BMI and GWG conditional on IBW adjusted by W (the characteristics of the mothers and their infants). The partial correlation is a measure of the strength and direction of a linear relation between BMI and IBW whilst controlling for the effect of GWG on IBW adjusted by W. Specifically, the partial correlation between BMI and GWG conditional on LBW was obtained by 0.33, p.value= 0.004 in urban and 0.39, p.value= 0.002 in rural areas. The partial correlation between BMI and GWG conditional on macrosomia GWG was obtained by 0.54, p.value= 0.001 in urban and 0.51, p.value= 0.001 in rural areas. We imply that the correlation between IBW and BMI was increasingly influenced by GWG. The partial correlation between BMI GWG conditional on CD was performed by non-parametric test due to CD is a binary variable. We observed that CD was also increased by increasing BMI and GWG categories.

Therefore, we obtained the effect of pre-pregnancy BMI effect on CD, LBW, and macrosomia by ignoring the partial correlations between BMI and GWG by fitting the logistic mixed-effect model. We, in fact, considered GWG as the confounding factor in our statistical analysis here. Results in Table 3 show that overweight and obese women were at approximately a 52% (RR=1.52, 95% CI; 1.06, 2.17) and a 74% (RR=1.74, 95% CI; 1.18, 2.55) respectively higher risk to have CD compared to the normal weight women in urban areas, alternatively these groups of women were at approximately a 49% (OR=1.49, 95% CI; 1.04, 2.13) and a 62% (RR= 1.62, 95% CI; 1.22, 2.15) respectively higher risk to have CD compared to the normal weight women in rural areas. Moreover, lean women experienced a 58% reduction risk of CD in urban areas. Further, overweight and obese women were at approximately a 40% (RR=1.40, 95% CI; 1.03, 1.19) and a 58% (RR=1.58, 95% CI; 1.16, 2.18) respectively higher risk of macrosomia compared to the normal weight women in urban areas, while these groups of women in rural areas were at approximately a 35% (RR=1.35, 95% CI; 1.02, 1.77) and a 47% (RR=1.47, 95% CI; 1.10, 1.95) respectively higher risk of macrosomia compared to the normal weight women. Different results were observed for LBW. Lean women were at approximately a 38% (RR=1.38, 95% CI; 1.04, 1.83) and a 49% (RR=1.49, 95% CI; 1.08, 2.05) higher risk of LBW compared to the normal weight women in urban and rural areas respectively.

Combined effect of BMI and GWG

By identifying the partial correlations, we took into ac-

Table 3: Adjusted risk ratio and its 95% CI of caesarean delivery, low birth weight, and macrosomia according to the pre-pregnancy body mass index categories, urban and rural areas, Gorgan, Iran, April 2011-July 2012.

Treatment	Area	CD	LBW	Macrosomia
Lean	Urban	0.42 (0.24, 0.75)*	1.38 (1.04, 1.83)*	0.44 (0.10, 1.94)
	Rural	0.75 (0.35, 1.61)	1.49 (1.08, 2.05)*	0.52 (0.12, 2.25)
Normal weight	Urban	Reference	Reference	Reference
	Rural			
Overweight	Urban	1.52 (1.06, 2.17)*	0.85 (0.44, 1.64)	1.40 (1.03, 1.19)*
	Rural	1.49 (1.04, 2.13)*	0.89 (0.42,1.88)	1.35 (1.02, 1.77)*
Obese	Urban	1.74 (1.18, 2.55)*	0.67 (0.26,1.73)	1.58 (1.16, 2.18)*
	Rural	1.62 (1.22, 2.15)*	0.59 (0.21, 1.66)	1.47 (1.10, 1.96)*

** Significant P.value <0.05*

count the association between GWG and BMI. Results in Table 4 show that overweight women those who gained ≤12.5 kg experienced a 55% increased risk of CD in urban areas, while there was not a significant risk of CD in overweight women those who gained ≤11.5 kg in rural areas as compared to the first reference group. Moreover, overweight women those who gained>12.5 kg in urban and those who gained >11.5 kg in rural areas experienced a 92% and a 78% increased risk of CD in urban and rural areas respectively as compared to the first reference group. Further, obese women those who gained ≤12.5 kg in urban areas and those who gained≤11.5 kg in rural areas experienced 2.17-fold and 70% increased risk of CD as compared to the first reference group in urban and rural areas respectively; while obese women those who gained>12.5 kg in urban and those who gained>11.5 kg in rural areas experienced 2.62-fold and 2.15-fold increased risk of CD in urban and rural areas respectively as compared to the first reference group.

These implied that risk of CD was increased for overweight and obese women in both areas when GWG

Table 4: Adjusted risk ratio and its 95% CI of caesarean delivery, low birth weight, and macrosomia according to the combined categories of the pre-pregnancy body mass index and the gestational weight gain, urban and rural areas, Gorgan, Iran, April 2011-July 2012.

Treatment	Area	CD	LBW	Macrosomia
Lean, ≤median	Urban	0.43 (0.19, 0.99)*	1.66 (0.73, 3.77)	0.65 (0.19, 2.22)
	Rural	0.82 (0.35, 1.94)	1.85 (0.91, 3.76)	0.32 (0.10 1.02)
Lean, >median	Urban	0.65 (0.28,1.51)	1.78 (0.89, 3.56)	0.86 (0.27, 2.73)
	Rural	0.92 (0.31,2.76)	1.88 (0.93, 3.80)	0.58 (0.20, 1.68)
Normal weight,	Urban	1.45 (0.84, 2.51)	1.89 (0.94, 3.76)	1.31 (0.74, 2.32)
≤median	Rural	1.25 (0.67,2.30)	1.90 (0.97, 3.80)	1.25 (0.69, 2.26)
Normal weight,	Urban	Reference	Reference	Reference
>median	Rural			
Overweight,	Urban	1.55 (1.20, 1.99)*	1.73 (0.88, 3.40)	1.79 (1.08, 2.97)*
≤median	Rural	1.36 (0.78, 2.37)	1.58 (0.57, 4.37)	1.55 (0.89, 2.65)
Overweight,	Urban	1.92 (1.34, 2.73)*	1.19 (0.45, 3.16)	1.91 (1.18, 3.10)*
>median	Rural	1.78 (1.16, 2.89)*	0.94 (0.31, 2.85)	1.70 (1.04, 2.78)*
Obese, ≤median	Urban	2.17 (1.24, 3.80)*	0.57 (0.18, 1.80)	2.08 (1.30, 3.32)* 1.89
	Rural	1.70 (1.03, 2.81)*	1.32 (0.44, 3.97)	(1.08, 3.30)*
Obese, >median	Urban	2.62 (1.69, 4.05)*	0.63 (0.40, 0.99)*	2.35 (1.46, 3.78)*
	Rural	2.15 (1.27, 3.67)*	0.48 (0.12, 1.92)	1.96 (1.21, 3.17)*
Lean, ≤median	Urban	0.52 (0.23, 0.96)*	1.92 (1.08,	0.58 (0.23, 1.46)
	Rural	0.49 (0.25, 0.97)*	3.38)* 1.97 (1.21, 3.21)*	0.48 (0.16, 1.44)
Lean, >median	Urban	0.67 (0.31, 1.45)	1.82 (1.25, 2.65)*	0.67 (0.22, 2.04)
	Rural	0.74 (0.24, 2.24)	1.94 (1.35, 2.79)*	0.59 (0.21, 1.64)
Normal weight,	Urban	Reference	Reference	Reference
≤median	Rural			
Normal weight,	Urban	0.69 (0.40, 1.20)	0.99 (0.52, 1.87)	1.77 (0.97, 3.23)
>median	Rural	0.80 (0.43, 1.48)	0.87 (0.31, 2.44)	1.74 (0.98, 3.09)
Overweight,	Urban	1.41 (0.66, 2.99)	0.81 (0.36, 1.82)	1.91 (0.88, 4.50)
≤median	Rural	1.38 (0.82, 2.35)	0.93 (0.35, 2.47)	1.89 (0.99, 3.62)
Overweight,	Urban	1.79 (0.81, 3.95)	0.67 (0.24, 1.87)	1.91 (0.88, 4.50)
>median	Rural	1.77 (0.90, 3.48)	0.64 (0.27, 1.52)	1.89 (0.99, 3.62)
Obese, ≤median	Urban	1.85 (0.83, 4.12)	0.62 (0.26, 1.48)	1.91 (0.96, 3.80)
	Rural	1.69 (0.79, 3.16)	0.54 (0.25, 1.16)	1.94 (0.97, 3.88)
Obese, >median	Urban	2.00 (0.98, 4.08)	0.43 (0.12, 1.47)	1.97 (0.96, 4.04)
	Rural	1.87 (0.88, 3.96)	0.48 (0.10, 2.31)	1.87 (0.93, 3.76)

influence the effect of BMI. In addition, lean women those who gained ≤12.5 kg experienced a 57% reduction risk of CD in urban areas as compared to the first reference group. Further, overweight women those who gained≤12.5 kg experienced a 79% increased risk of macrosomia in urban areas, but no significant risk was observed for overweight women those who gained≤11.5 kg in rural areas as compared to the first reference group.

Moreover, overweight women those who gained >12.5 kg in urban areas, and those who gained >11.5 kg in rural areas experienced a 91% and a 70% increased risk of macrosomia in urban and rural areas respectively as compared to the first reference group. Obese women those who gained ≤12.5 kg in urban areas, and those who gained ≤11.5 kg in rural areas experienced 2.08-fold and a 89% increased risk of macrosomia in urban and rural areas respectively as compared to the first reference group, and also these groups of women those who gained>12.5 kg in urban areas, and those who gained>11.5 kg in rural areas experienced 2.35-fold and a 96% increased risk of

macrosomia in urban and rural areas respectively as compared to the first reference group. Here, GWG influenced the effect of BMI on the risks of CD and macrosomia.

This is because the partial correlation between BMI and GWG on the risks of CD and macrosomia were significantly increased by increasing BMI and GWG categories. When we switched to the second reference group, lean women those who gained ≤12.5 kg experienced a 48% and a 51% reduction risk of CD in urban and rural areas respectively. We observed no risk of delivering LBW infants by considering the first reference group, except obese women those who gained>12.5 kg experienced a 37% reduction risk of LBW in urban areas. We observed the risk of LBW by switching to the second reference group. This is because the partial correlation between BMI and GWG on the risks of LBW was significantly increased by decreasing BMI and GWG categories. Specifically, lean women those who gained ≤12.5 kg in urban areas, and those who gained ≤11.5 kg in rural areas experienced a 92% and a 97% increased risk of LBW in urban and rural areas respectively as compared to the second reference group. In addition, lean women those who gained >12.5 kg in urban, and those who gained >11.5 kg in rural areas experienced an 82% and a 94% increased risk of LBW in urban and rural areas respectively as compared to the second reference group.

Discussion

The purpose of this study was to investigate the association between the pre-pregnancy BMI and GWG among two groups of women under the two different levels of health care centers in two areas on the risks of CD and infant birth weight. Our study areas were urban and rural areas of a city in Iran which recently suffered from the problems of high rates of CD and infants with low (high) birth weights. The findings pertain to our three research questions. First, regarding GWG differences within the IOM guidelines recommendation across BMI, results showed that women in rural areas were totally more likely to be within the IOM guidelines for GWG recommendation than the women in urban areas (Table 2).

Then, we expected that women in rural areas would have experienced lower risks of CD, LBW, and macrosomia than women in urban areas. Second, regarding the unadjusted comparison of the rates of CD, LBW, and macrosomia, our results revealed that women in urban areas were more likely under the risks of CD and macrosomia, and women in rural areas were more likely under the risk of LBW (Table 3).

That is, in view of ignoring the association between BMI and GWG, our results in Table 3 revealed that overweight and obese women in urban areas were at approximately 6% and 19% risk and more likely to have CD compared to the same women in rural areas respectively. These groups of women in urban areas were at approximately 14% and 23% risk and more likely to deliver macrosomic infants compared to the same women in rural areas. This implied that the risks of CD and macrosomia among overweight and obese women in urban areas were more than the women with the same BMI categories in rural areas. In contrast, lean women in urban areas were at approximately 29% risk less likely to deliver an LBW infant compared to the same women in rural areas. To answer the third question, we investigated the effect of pre-pregnancy BMI on the risks of CD, LBW, and macrosomia in cases where the association between GWG and pre-pregnancy BMI is taken into account. This is because the partial correlation between pregnancy outcomes and BMI conditional on GWG were significant. This case has not yet been addressed in the previous studies in Iran and often has been ignored as a limitation of the study. Our interest in identifying this stemmed from the fact that BMI and GWG were positively associated with CD and IBW after adjusting for the mothers and their infant's characteristics in our analysis in both areas. When the association between GWG and pre-pregnancy BMI is taken into account, this study showed that the reference group (the direction of weight during pregnancy across weight in pre-pregnancy) in identifying the risks of CD, macrosomia, and LBW is important.

Different risk patterns of CD, macrosomia, and LBW were observed in both areas when the association between GWG (below and above median) and BMI (four categories) was taken into account (Table 4). We observe from Table 3 and 4 that the risk patterns of CD increased from 52% to 92% in urban areas and from 49% to 91% in rural areas among overweight women, and increased from 74% to 2.62-fold in urban areas and from 62% to 2.15-fold in rural areas among obese women. The risk patterns of macrosomia increased from 40% to 91% in urban areas and from 35% to 70% in rural areas among overweight women, and increased from 58% to 2.35-fold

in urban areas and from 47% to 96% in rural areas among obese women. These implied that the risk patterns of CD and macrosomia among overweight and obese women with above (below) median GWG in urban areas were more than the overweight and obese women with above (below) median GWG in rural areas. Note that, the latter results were observed among women who started pregnancy with overweight and obese and gained weight above (below) median GWG in comparison with women who started pregnancy with normal weight and gained weight above median GWG, and surprisingly no risks of CD and macrosomia were observed among these women compared with women started pregnancy with normal weight and gained weight below median GWG in both areas.

Further, the risk patterns of LBW increased from 38% to 92% in urban areas and from 49% to 97% in rural areas among lean women. This implied that the risk patterns of LBW among lean women with above (below) median GWG in urban areas were less than the lean women with above (below) median GWG in rural areas. Note that, the latter results were observed among women whose pregnancy started with lean and gained above (below) median GWG in comparison with women who started pregnancy with normal weight and gained weight below median GWG, and surprisingly no risk of LBW was observed among lean women compared with women who started pregnancy with normal weight and gained weight above median GWG in both areas. These issues support the need to reform adequate pre-pregnancy weight and weight during pregnancy against the risks of CD and macrosomia among overweight and obese women, and against the risk of LBW among lean women in both areas, particularly in rural areas in Northern Iran. Our findings are in agreement with previous studies[16-20]. The same as the previous studies[16-20], our results showed that the risks of CD and macrosomia occurred among overweight and obese women, and the risk of LBW occurred among lean women.

Nohr, et al.[16] found the significant risk of emergency CD occurred in overweight and obese women with high (16-19 kg) and very high (>20kg) GWG categories the Danish National Birth Cohort. Frederich et al.[17] showed that there was a significant risk of LBW among lean to average women who gained ≤15.9 (median GWG) kg in Seattle and Tacoma, Washington women. They have also found the significant risk of macrosomia among overweight and obese women who gained >15.9 kg. Merchant et al.[19] found that if a women started a pregnancy with BMI<19.8 kg/m^2 and gained <12.5 kg, the chance of her infant having a LBW is increased in Pakistani women. Moreover, Li et al.[20] evaluated women with both pre-pregnancy obesity and excessive GWG and they had 2.86 and 4.10 folds higher risks of CD and macrosomia respectively compared to women with normal pre-pregnancy BMI and adequate GWG among Tianjin women in Northern China. Further, our study subjects were younger than the subjects in Frederich et al.[17] and Li et al.[20], and a bit older than the subjects in Merchant et al.[19].Mean ±SD of maternal age was 32.40 ±5 years, 29.40 ±4.3 years, and 24.89 ±4.72 years, respectively in Frederich et al.[17] and Li et al.[20], and in Merchant et al.[19]. Further, in our study, the association between age and pre-pregnancy body mass index in urban and rural areas were 0.19 and 0.20 respectively. Age was a significant covariate in the mixed-effect model. Our finding also showed that the prevalence of LBW infant in rural areas was more than in urban areas, which is consistent with the previous findings[22,27]. One advantage of this study is using the logistic mixed-effect model which has been rarely used by previous studies. This model controlled unobservable heterogeneity between women in 6 and 4 different public health care centers. For instance, we observed no risk of macrosomia for overweight women in both urban and rural areas by using the ordinary logistic regression model, while we observed that overweight women experienced a 40% and 35% increased the risk of macrosomia in urban and rural areas in our analysis. Therefore, our results are more powerful and consistent than the obtained results by the ordinary logistic regression analysis.

Conclusion

The results may be generalizable to large sections of the women population in Northern areas of Iran. However, our findings strongly support the need to establish adequate pre-pregnancy weight and GWG against the risks of CD and macrosomia among overweight and obese women, and against the risk of LBW among lean women in both areas, particularly in rural areas in Northern Iran.

Limitation of the study

Alternatively, there were some limitations in this study. First, some maternal weights were not exactly measured in early pregnancy and we had to consider their weights at the first visit or at the first trimester or were self-reported.

Although BMI categories derived from the self-reported agreed for 91% of the women[16], the ideal time for measuring weight is exactly in pre-pregnancy[16,32]. Second, the considered health care centers were public, and this may cause the women with the low socio-economic levels to have been referred to these centers[24,27]. Although we have not measured the economic status of the subject in both areas, but there was evidence that women in rural areas were poorer than the urban areas in the economic and education status. The use of small sample size in establishing the treatment cells may also cause the interpretation of our results to be limited.

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Coflict of interest

None to declare

References

1. Khashan AS,Kenny LC. The effects of maternal body mass index on pregnancy outcome. *Eur J Epidemiol* 2009; 24: 697-705.

2.Cedergren MI. Maternal morbid obesity and the risk of adverse pregnancy outcome. Obstetrical and Gynecological Survey 2004; 59: 489-491.

3.Kabiru K, Raynor BD. Obstetric outcomes associated with increase in BMI categoryduring pregnancy. *American Journal of Obstetrics and Gynecology* 2004; 191: 928–932.

4. Young TK, Woodmansee B. Factors that are associated with cesarean delivery in a large private practice: the importance of prep-regnancy body mass index and weight gain. *Am J Obstet Gynecol* 2001; 187: 312-320.

5. Rosenberg TJ, Garbers S, Chavkin M, Chiasson MA.Pre-pregnancy weight and adverse perinatal outcomes in an ethnically diverse population. *J Obstet Gynecol* 2003; 102: 1022–1027.

6. Shrestha I, Sunuwar L, Bhandary S, Sharma P. Correlation between gestational weight gain and birth weight of the infants. *Nepal Med Coll J*. 2010; 12: 106-109.

7. Johnson JL, Farr SL, Dietz PM, et al. (2105). Trends in gestational weight gain: the Pregnancy Risk Assessment Monitoring System2000e2009. *American Journal of Obstetrics and Gynaecology* 2015; 212: 806.e1-8.

8. Tsukamoto H, Fukuoka H, Inoue K, Koyasu M, Nagai Y, Takimoto H. Restricting weight gain during pregnancy in Japan: A controversial factor in reducing perinatal complications. *European Journal of Obstetrics and Gynecology and Reproductive Biology* 2007; 133: 53-59.

9. Beaudrot ME, Elchert JA, DeFranco EA. Influence of gestational weight gain and BMI on cesarean delivery risk in adolescent. Journal of Perinatology2016; 36: 612-617.

10. Truong YN, Yee LM, Caughey AB,Cheng YW. Weight gain in pregnancy: does the Institute of Medicine have it right? *American Journal of Obstetrics and Gynecology* 2015; 212:362.e1–362.e8.

11. Crane JM, White J, Murphy P, Burrage L, Hutchens D. The effect of gestational weight gain by body mass index on maternal and neonatal outcomes. *Journal of Obstetrics and Gynaecology Canada* 2009; 31: 28-35.

12.Cedergren M. Effects of gestational weight gain and body mass index on obstetric outcome in Sweden. *Int J Gynaecol Obstet* 2006; 93: 269-274.

13. Chang MY, Kuo CH,Chiang KF. The effects of prepregnancy body mass index and gestational weight gain on neonatal birth weight in Taiwan. *International Journal of Nursing and Midwifery* 2010; 2: 28-34.

14. Institute of Medicine: National Research Council Committee to Reexamine IOM Pregnancy Weight Guidelines. Weight gain during pregnancy: reexamining the guidelines. Washington, DC: National Academies Press, National Academy of Sciences, 2009.

15. World Health Organization. Global status report on noncommunicable diseases 2014. World Health Organization, Geneva, 2014.

16. Nohr EA, Vaeth M, Baker JL, Srensen TI, Olsen J, Rasmussen KM. Combined associations of prepregnancy body mass index and gestational weight gain with the outcome of pregnancy. *Am J ClinNutr* 2008; 87: 1750-1759.

17. Frederick IO, Williams MA, Sales AE, Martin DP, Killien M. Prepregnancy body mass index, gestational weight gain, and other maternal characteristics in relation to infant birth weight. *Maternal Child Health J*. 2008; 12: 557-567.

18. Thorsdottir I, Torfadottir JE, Birgisdottir BE, Geirsson RT. Weight gain in women of normal weight before pregnancy: Complications in pregnancy or delivery and birth outcome. *Obstetrics and Gynecology* 2002; 99: 799–806.
19. Merchant SS, Momin IA, Sewani AA, Zuberi NF. Effect of pre-pregnancy body mass index and gestational weight gain on birth weight. *Journal of Pakistan Medicine Association* 1999; 49: 23-25.
20. Li N, Liu E, Guo J, Pan L, Li B, Wang P, Liu J, Wang Y, Liu G, Baccarelli AA, Hou L, Hu G.Maternal prepregnancy body mass index and gestational weight gain on pregnancy outcomes. *PLoS One* 2013; 8: e82310.
21. Chen Z, Du J, Shao L, Zheng L, Wu M, Ai M, Zhang Y. Prepregnancy body mass index, gestational weight gain, and pregnancy outcomes in China. *International Journal of Gynecology and Obstetrics* 2010; 109: 41-44.
22. Maddah M, Nikooyeh B. Urban and rural differences in pregnancy weight gain in Guilan, northern Iran. *Matern Child Health J* 2008; 12: 783-786.
23. Maddah M.Pregnancy weight gain in Iranian women attending in across sectional study of public health centers in Rasht. *Midwifery* 2005; 21: 365-370.
24.Yazdizadeh B, Nedjat S, Mohammad K, Rashidian A, Changizi N, Majdzadeh R. Cesarean section rate in Iran, multidimensional approaches for behavioral change of providers: a quantitative study. *BMC* Health Services Research 2011; 159: 1-14.
25.Maharlouei N, Moalaee M, Ajdari S, Zarei M, Lankarani KB. Caesarean delivery in south-western Iran: trends and determinants in a community based survey. *Med PrincPract*. 2013; 22: 184-188.
26. Sharifzadeh GR, Namakin K, Mehrjoofard H. An epidemiological study on infant mortality and factors affecting it in rural areas of Birjand, Iran. *Iran Journal of Pediatrics* 2008; 18: 335-342.
27. Jafari F, Eftekhar H, Pourreza A, MousaviJ. Socio-economic and medical determinants of low birth weight in Iran: 20 years after establishment of a primary health care network. Public Health 2010; 124: 153-158.
28. Hajian-Tilaki OK, Heydari B. Prevalence of obesity, central obesity and the associated factors in urban population aged 20-70 years, in the north of Iran: a population-based study and regression approach. The International Association for the Study of Obesity. *Obesity Reviews* 2006; 8: 3–10.
29. Pakniat H, Mohammadi F, Ranjkesh F.The impact of body mass index on pregnancy outcome. *Journal of Midwifery Reproductive Health* 2012; 3: 361-367.
30.Yekta Z, Ayatollahi H, Porali R,Farzin A. The effect of pre-pregnancy body mass index and gestational weight gain on pregnancy outcomes in urban care settings in Urmia-Iran. *BMC* Pregnancy and Child birth 2006; 6:doi: 10.1186/1471-2393-6-15.
31.Zarei A, Arab M, Froushani RA, Rashidian A, et al. Service quality of private hospitals: The Iranian patients' perspective BMC Health Services Research2012; 12:31. http://www. Biomed central.com/1472-6963/12/31.
32. Shin D, Chung H, Weatherspoon L, Song WO (2014) Validity of pre-pregnancy weight status estimated from self-reported height and weight. *Matern Child Health J* 2014; 18:1667–1674