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Influence of Gestational Weight Gain on Baby's Birth Weight in Addis Ababa, Central Ethiopia: a Prospective Cohort Study

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Abstract

Background: Gestational weight gain (GWG) is an important indicator of fetal wellbeing during pregnancy. Inadequate or excessive GWG could have undesirable effects on birth weight. However, information regarding the influence of GWG on birth weight is lacking from the Ethiopian setting.

Objective: The aim of this study was to determine the influence of GWG and other maternal related factors on birth-weight in Addis Ababa, Ethiopia.

Design and methods: A prospective cohort study was conducted among pregnant women who received perinatal care in health centres in Addis Ababa, from January to September 2019. Data were collected using a structured questionnaire and medical record reviews. We conducted multivariable linear regression analysis to determine the independent effect of gestational weight on birth weight.

Results: Of the 395 women enrolled in the study, the outcome of pregnancy was available for 329 (83.3%) of the participants. The mean birth weight was 3130 (standard deviation, 509) g. The proportion of low-birth weight (<2500g) was 7.5% (95% CI: 4.8% to 11.0%). Babies born to underweight women were 155g (95% CI: 2 to 309g, p=0.047) lighter than infants born to normal weight women. Similarly, babies whose mothers gained inadequate weight were 246g (95% CI: 112 to 379g, p<0.001) lighter compared to those who gained adequate weight. Moreover, infants whose mothers had a previous history of abortion or miscarriages or developed gestational hypertension in the current pregnancy were 144g (95% CI: 2 to 287g, p=0.047) and 317g (95% CI: 77 to 556g, p=0.010) lighter, respectively, compared to those whose mothers had not.

Conclusions: Pre-pregnancy weight, GWG, having had previous history of abortion or miscarriages, and developing gestational hypertension during a current pregnancy was independently associated with birth weight. Pregnancy related weight management should be actively promoted through intensive counselling during routine antenatal care contacts.

Key words: Pre-pregnancy weight; Gestational weight gain; Birth weight; Pregnancy outcomes

Strengths and limitations of this study

- ✓ We prospectively followed weight of the women inorder to assess GWG and its influence on birth weight.
- ✓ The IOM GWG recommendations are the recommendations of high-income countries, may not be suitable in low-income settings such as Ethiopia.
- ✓ We measured pre-pregnancy BMI before or at 16 weeks of gestation, at which time there may already have been an increase or decrease of gestational weight.
- ✓ This study was conducted in the capital city of Ethiopia in the public health facilities; the situation in other parts of the country and private health facilities may be different.

Introduction

Gestational weight gain (GWG) is attributable to pregnancy related changes that women experience such as the increase in size of the uterus and the developing fetus, placenta, amniotic fluid, an increase in breast size, extracellular fluid and blood volume. The American Institute of Medicine (IOM) has published recommendations for GWG of 12.5 to 18 kg for underweight

women; 11.5 to 16 kg for normal weight women, 7 to 11 kg for overweight women and 5 to 9 kg for obese women.[1]

GWG is a powerful indicator of maternal [2] and fetal [1] nutrition during pregnancy. Adequate GWG supports the growth and development of the fetus.[3] Both extremes, excessive or inadequate GWG, could result in undesirable pregnancy outcomes.[4-7] Excessive GWG is associated with pre-eclampsia,[8-10] caesarean birth,[8 10 11] macrosomia, large for gestation age and high birth weight.[7] On the other hand, inadequate weight gain is associated with intrauterine growth restriction,[12] low for gestational age, pre-term birth,[13-15] and low birth weight.[6 7]

Birth weight is one of the most important health indices in the growth, development and future survival of a newborn baby.[16] Birth weight is high if it is >4000 g [17] or low if it is <2500g.[18] Low birth weight (LBW) is a proxy measure of intrauterine malnutrition. Intrauterine malnutrition has life-long consequences for the fetus.[19] Identifying the influence of GWG on birth weight at the local level is importance to provide an appropriate nutrition intervention during the pregnancy to reduce the risk of intrauterine malnutrition, and to improve GWG and birth weight outcome. This could help to break the vicious intergenerational cycle of malnutrition. [20]

Factors influencing birth weight have been reported as including but not limited to, maternal characteristics such as maternal age,[21] pre-pregnancy body mass index (BMI)[22], nutritional status, smoking,[23 24] and physical activity.[25-27] Factors related to the amount of growth and weight gain during pregnancy, and overall health of the mother and the fetus [28 29] also affect the amount of birth weight. While there are a number of studies on factors affecting birth weight

in Ethiopia, the influence of GWG on birth weight is not well understood in this setting. This study aimed to determine the influence of GWG and other maternal related factors on birth weight in Addis Ababa, a central Ethiopian population.

Methods

Study design

We conducted a prospective cohort study, recruiting women who were pregnant between January 2019 and September 2019.

Sample size determination

We calculated the sample size using Open Epi Version 2.3 uaing double proportion formula. The assumptions for the sample size calculation were alpha value 0.05; power 80%; exposed to non-exposed ratio 1:2 (proportion of adequate GWG = 28% (exposure); and proportion of inadequate GWG = 69% (non-exposure))[30]; proportion of LBW among women who gained adequate gestational weight =1.7%; proportion of LBW among women who gained inadequate gestational weight =17.5%, [21] loss to follow-up =20%. The required sample was 189 (exposed =63, and control =126). However, since this study was part of another large study, we recruited a sample size of 395.

Participants

Pregnant women who came to maternal health centres before or at 16 weeks gestation for antenatal care were invited to participate and those who agreed were recruited. We limited

eligibility to women with a singleton pregnancy and no co-morbidities such as diabetes and hypertension.

Measurements

We used structured questionnaires with trained interviewers and face-to-face semi-structured interviews. The questionnaires collected information on socio-demographic characteristics, previous history of abortion (termination of pregrnancy before the 28th week of gestation), low birth weight and stillbirth, pregnancy intention (planned/unplanned), gravidity, food security and dietary diversity, physical activity, intimate partner violence, and depression related symptoms. Data collectors measured baseline weight and height of the women, and mid-upper arm circumference. Women's medical records were also reviewed both during baseline data collection and after birth to collect data such as gestational age (ultrasound result), blood pressure, level of haemoglobin, random blood sugar result, weight at the 4th antenatal care visit, mode of birth, episiotomy, birth weight, and sex of the baby. Women were followed from prior to or at their 16th week of gestation until they gave birth to assess their gestational weight gain and the baby's birth weight. Sixteen women (5.2%) gave birth in a rural location and we were unable to access the birth records. For these women, the birth weight information was ascertained through a phone call to the mother.

We calculated GWG by subtracting women's baseline weight from their weight at the 4th antenatal care visit. The adequacy of GWG (inadequate, adequate or excessive) was determined using the IOM criteria. Birth weight was analysed as a categorical and continuous variable. Birth weight was classified as <2.5 kg (low birth weight), 2.5 kg to 3.9 kg (normal birth weight), ≥4.0 kg (macrosomia). The primary outcome variable in this study was birth weight. However,

other pregnancy outcome variables such as the occurrence of pre-eclampsia, modes of birth, episiotomy, and birth outcomes (live birth, miscarriage, stillbirth or intra-uterine fetal death) were also considered as outcome variables.

We assessed the household food insecurity using the Household Food Insecurity Access Scale (HFIAS) [31] and the dietary diversity of the women was assessed using the minimum dietary diversity-women (MDD-W) tool.[32] Women's physical activity level was measured using the International Physical Activity Questionnaire (IPAQ-long form).[33] Perinatal depression symptoms were measured using the Edinburgh postnatal depression scale (EPDS),[34] and intimate partner violence was measured using a questionnaire used by the World Health Organization (WHO) multi-country study on women's health and domestic violence. [35]

Statistical analysis

We double entered into CSPro version 7.1. We exported data to STATA (version14, Stata Corp, 2015) for cleaning and analysis. Descriptive statistics including frequencies, means, and standard deviations were computed to describe the data. The influence of GWG on birth weight was assessed using a linear regression model. The assumptions for linear regression were checked. Scatter plots showed that observations were linear. Multi collinearity was checked using the variance inflation factor (VIF). The mean VIF value was 1.46. The VIF value for each predictor variable was < 3, which showed that there was no multi-collinearity among variables.

We performed multivariable linear regression analysis to determine the independent effect of gestational weight gain on birth weight, adjusting for other potential factors (educational status,

average household monthly income, and previous history of abortion (termination of pregrnancy before the 28th week of gestation), consuming meat or chicken in the last 24 hours, pre-pregnancy weight, maternal haemoglobin level, occurrence of pre-eclampsia and sex of the baby).

Results

Of the 395 women enrolled in the study, the outcome of the pregnancy was available for 329 (83.3%) of the participants. Eight of the 329 pregnancies ended in early pregnancy loss/ miscarriage; two ended in stillbirths and one an intra-uterine fetal death; the remaining were live births (Figure 1).

The mean age of the women was 25.3 (standard deviation, 3.9) years. As shown in Table 1, half of the participants 199 (50.4%) were multigravida, of which 40.7% had previous history of abortion or miscarriage; 4.5% had previous history of stillbirth; and 3.3% had previous history of LBW. Twenty one (5.8%) developed gestational hypertension during their current pregnancy. Eighty two percent (82%) gave birth via spontaneous vaginal birth (SVD), with 47.5% associated with episiotomy. The majority of infants had normal birth weight (89.6%) and 7.5% had low birth weight. Twelve babies (3.9%) were born pre-term (Table 1).

As shown in Table 2, 85.6% of women who gained inadequate gestational weight gave birth vaginally, while 74.4% of women who gained adequate gestational weight gave birth vaginally; 9.3% of women who gained inadequate gestational weight gave birth to LBW babies, while 4.5% of women who gained adequate gestational weight gave birth to LBW babies. Four percent of the women who gained inadequate gestational weight developed pre-eclampsia

while 11% and 6% of women who gained adequate and excess gestational weight, respectively, developed pre-eclampsia (Table 2).

Table 1: Pregnancy and pregnancy outcome related data of the study participants, Addis Ababa, Ethiopia, 2021

Variable	Frequency	Percentage
Gravidity (395)		
Primi gravida	196	49.6
Gravida 2	115	29.1
Gravida 3	54	13.7
gravida 4 and above	30	7.6
Inter–pregnancy interval (192)		
Less than 23 months	53	27.6
Greater or equal to 23 months	139	72.4
Previous history of abortion or miscarriages (199)		
Yes	81	40.7
No	118	59.3
Previous history of stillbirth (198)		
Yes	9	4.5
No	189	95.5
Mode of birth (314)		
Spontaneous vaginal birth	257	81.8
Caesarean section	57	18.2
Episiotomy (255)		
Yes	121	47.5
No	134	52.5
Sex of the baby		
Male	146	46.6
Female	167	53.4
Gestational hypertension		
Yes	21	5.8
No	338	94.2
Birth Weight		
Low birth weight	23	7.5
Normal birth weight	276	89.6
Macrosomia	9	2.9
Pre-term birth		
Yes	12	3.9
No	296	96.1

Table 2: Association between gestational weight gain and pregnancy outcomes, Addis Ababa, Ethiopia, 2021

Variables	Gestational weight gain			P-value for χ^2 test
	Inadequate GWG n (%)	Adequate GWG n (%)	Excess GWG n (%)	
Gestational hypertension (357)				
Yes	9 (3.8)	11 (11.0)	1 (5.9)	0.035
No	231(96.2)	89 (89.0)	16 (94.1)	
Total	240 (100)	100 (100)	17 (100)	
Mode of birth (313)				
Spontaneous vaginal delivery	179 (85.6)	67 (74.4)	11 (78.6)	0.064
Caesarean section	30 (35.4)	23 (25.5)	3 (21.4)	
Total	209 (100)	90 (100)	14 (100)	
Episiotomy (255)				
Yes	84 (47.5)	32 (47.8)	5 (45.5)	
No	93 (52.5)	35 (52.2)	6 (55.5)	0.990
Total	177 (100)	67 (100)	11 (100)	
Birth weight (307)				
LBW	19 (9.3)	4 (4.5)	0 (0.0)	
Normal birth weight	183 (89.7)	78 (87.6)	14 (100)	0.008
Macrosomia	2 (1.0)	7 (7.9)	0 (0.0)	
Total	204(100)	89(100)	14(100)	
Sex of the baby (312)				
Male	98 (46.9)	40 (44.9)	8 (57.1)	0.696
Female	111 (53.1)	49 (55.1)	6 (42.9)	
Total	209 (100)	87(100)	14(100)	
Pre-term baby (270)				
Yes	9 (5.1)	3 (3.9)	0 (0)	0.651
No	169 (94.9)	74 (96.1)	14 (100)	
Total	178 (100)	77(100)	14 (100)	

The mean birth weight was 3.13 kg with standard deviation (SD) of 0.51 kg. It was 3.04 (SD = 0.49) kg among women who gained inadequate gestational weight; 3.30 (SD = 0.52) kg among women who gained adequate gestational weight; and 3.25 (SD =0.53) among women who gained excessive gestational weight; 3.02 (SD =0.46) among underweight women; and 3.14 (SD=0.53) among normal weight women. The proportion of LBW was 10.3% (95% CI: 4.0 % to 21.2%) among underweight women while it was 6.7% (95% CI: 3.6% to 11.2%) among normal weight women. Similarly, 27.8% women who developed gestational hypertension gave birth to LBW babies while only 5.7% women who did not develop gestational hypertension gave birth to LBW babies; 12.7% women with low MUAC (<23cm) gave to LBW babies compared to women with high MUAC (6.5%) (Table 3).

Table 2: Birth weight in relation to different factors in women of Addis Ababa, Ethiopia, 2021

Variable	LBW, n (%)	Normal birth weight, n (%)	Macrosomia, N (%)	Mean birth weight (standard deviation) (kg)
Women's age category				
< 20 years	1 (7.1)	13 (92.9)	0 (0.0)	2.96 (0.50)
20 to 29 years	18 (7.3)	220 (89.4)	8 (3.3)	3.13 (0.51)
≥30 years	4 (8.3)	43 (89.6)	1 (2.1)	3.14 (0.53)
Marital status				
Married	22 (7.4)	267 (89.9)	8 (2.7)	3.13 (0.51)
Single	1 (9.1)	9 (81.8)	1 (9.1)	3.15 (0.46)
Educational status				
No formal education	2 (8.0)	23 (92.0)	0 (0.0)	3.17 (0.49)
Primary	12 (9.7)	111(89.5)	1 (0.8)	3.01(0.48)
Secondary	8 (9.0)	75 (84.3)	6 (6.7)	3.15 (0.58)
Tertiary	1 (1.4)	67 (95.7)	2 (2.9)	3.23 (0.45)
Occupational Status				
House duty	14 (9.2)	133 (87.5)	5 (3.3)	3.07 (0.54)
Employee	4 (4.0)	95 (94.0)	2 (2.0)	3.19 (0.44)
Merchant	2 (6.1)	29 (87.8)	2 (6.1)	3.26(0.55)
Others*	3 (13.4)	19 (86.4)	0(0.0)	3.00(0.47)
Average monthly income				
< $200 USD	18 (9.1)	176 (88.9)	4 (2.0)	3.10 (0.52)
≥ $200 USD	4 (4.6)	79 (91.9)	3 (3.5)	3.18 (0.47)
Pregnancy intention				
Intended	22 (8.0)	246 (89.5)	7 (2.5)	3.12 (0.51)
Unintended	1 (3.4)	26 (89.7)	2 (6.9)	3.22 (0.48)
Gravidity				
Primi gravida	9 (6.2)	132 (91.0)	4 (2.8)	3.11 (0.50)
Multigravida	14 (8.6)	144 (88.3)	5 (3.1)	3.14 (0.52)
Time gap between pregnancy				
< 23 months	4 (9.8)	37 (90.2)	0 (0.0)	3.09 (0.51)
≥ 23 months	10 (8.6)	101 (87.1)	5 (4.3)	3.16 (0.53)
Dietary Diversity				
Low dietary diversity	1 (1.9)	50 (96.2)	1 (1.9)	3.09 (0.49)
High dietary diversity	22 (8.6)	226 (88.3)	8 (3.1)	3.13 (0.52)
Physical Activity				
Low	13 (9.0)	127 (88.2)	4 (2.8)	3.10 (0.50)
Moderate	7 (5.5)	115 (90.6)	5 (3.9)	3.15 (0.52)
High	3 (8.1)	34 (91.9)	0 (0.0)	3.15 (0.53)
MUAC**				
Low MUAC	7 (12.7)	46 (83.6)	2 (3.7)	3.02 (0.53)
High MUAC	16 (6.5)	223 (90.6)	7 (2.9)	3.15 (0.50)
Pre-pregnancy weight				
Underweight	6 (10.3)	52 (89.7)	0 (0.0)	3.02 (0.46)
Normal weight	13 (6.7)	173 (89.2)	8 (4.1)	3.14 (0.53)
Overweight or obese	4 (7.1)	51 (91.1)	1 (1.8)	3.14 (0.50)
Gestational hypertension				
Yes	5 (27.8)	12 (66.7)	1 (5.5)	2.93 (0.69)
No	16 (5.7)	257 (91.8)	7 (2.5)	3.14 (0.49)
Intimate partners violence				
Yes	2 (3.5)	53 (93.0)	2 (3.5)	3.13 (0.50)
No	21(8.4)	223 (88.8)	7 (2.8)	3.12 (0.51)
Food insecurity				
Food secure	19 (7.1)	239 (89.9)	8 (3.0)	3.12 (0.50)
Food insecure	4 (10.5)	33 (86.8)	1 (2.6)	3.12 (0.58)
Perinatal depression				
Yes	3 (9.1)	29 (87.9)	1 (3.0)	3.14 (0.51)
No	20 (7.3)	247 (89.8)	8 (2.9)	3.05 (0.49)

*students, daily laborer, farmer; ** MUAC = Mid Upper Arm Circumference

Predictors of infants' birth weight

The bivariable and multivariable linear regression models (Table 4) indicate that maternal educational status, average household monthly income, previous history of abortion, consuming meat or chicken in the last 24 hours, pre-pregnancy weight, GWG, maternal level of haemoglobin at baseline data collection, occurrence of gestational hypertension and sex of the baby were included into multivariable linear regression analysis. Of these variables, previous history of abortions or miscarriages, occurrence of gestational hypertension, pre-pregnancy weight and GWG were significantly associated with infants' birth weight at p-value <0.05.

The ß–coefficient showed that infants born to underweight women were 155 g (95% CI: 2 to 309 g, p=0.047) lighter than infants born to normal weight women. Similarly, infants whose mothers had inadequate weight gain were 246 g (95% CI: 112 to 379, p<0.001) lighter compared to those who gained adequate weight. In the same vein, infants whose mothers had previous history of abortion or miscarriages and developed gestational hypertension during current pregnancy were 144 g (95% CI: 2 to 286 g, p=0.047) and 317 g (95% CI 77 to 556 g, p = 0.010) respectively lighter compared to those whose mothers had not.

Maternal age, educational status, monthly income, haemoglobin level, pregnancy intention, gravidity, dietary diversity, food insecurity, physical activity, intimate partners' violence, and perinatal depression were not significantly associated with birth weight.

Table 3: Bivariate and multivariable linear regression analysis for predictors of birth weight (in gram) in Addis Ababa, Ethiopia 2021

Variable	Bivariate regression			Multivariable regression		
	Crude-ß	95%CI	P-value	Adjusted-ß	95%CI	P-value
Women's age			0.446			
< 20 years	-176.0	-451.7 to 99.7	0.210	---	---	---
20 to 29 years	Ref					
≥30 years	6.0	-151.9 to 164.7	0.936	---	---	---
Educational status			0.065			
No formal education	- -57.6	-289.6 to 174.5	0.626	-73.3	- 321.5 to 174.8	0.561
Primary	-194.8	-343.7 to -45.9	0.010	-143.5	- 304.5 to 17.6	0.081
Secondary	-84.1	-243.2 to 74.9	0.299	-53.5	-221.1 to 113.6	0.528
Tertiary	Ref			Ref		
Average monthly income			0.190			
< 5000 ETB	-177.9	-372.5 to 16.6	0.073	- 111.9	-321.3 to 97.5	0.294
5000 to 10000 ETB	-175.9	-396.4 o 44.4	0.117	-165.5	-390.7 to 59.8	0.149
≥10000 ETB	Ref			Ref		
Pregnancy intention			0.294			
Intended	Ref					
Unintended	104.8	-91.4 to 301.1	0.294	---	---	---
Previous history of abortion or miscarriages			0.119			
Yes	-109.7	-247.8 to 28.5	0.119	- 144.2	-286.5 to -2.0	0.047
No	Ref			Ref		
Gravidity	15.9	-36.6 to 68.4	0.552			
Dietary Diversity			0.600			
Low dietary diversity	Ref					
High dietary diversity	-40.7	-193.4 to 112.0	0.600	---	---	---
Physical Activity			0.641			
Low	-51.7	-236.9 to 133.4	0.583	---	---	---
Moderate	4.1	-183.6 to 191.8	0.966	---	---	---
High	Ref					
Consuming meat or chicken in the last 24 hours			0.085			
Yes	111.4	-15.4 to 238.2	0.085	122.6	10.7 to 255.9	0.071
No	Ref			Ref		
Pre-pregnancy weight			0.173			
Underweight	-114.9	-264.7 to 34.8	0.132	-155.3	-308.6 to -2.1	0.047
Normal weight	Ref			Ref		
Overweight or obese	57.2	-94.5 to 209.0	0.458	1.1	- 165.8 to 168.1	0.990
Gestational hypertension			0.076			
Yes	-216.7	-455.9 to 22.5	0.076	-316.8	-556.2 to -77.2	0.010
No	Ref			Ref		
GWG			<0.001			
Inadequate	-252.9	-377.4 to -128.4	<0.001	-245.8	-379.3 to -112.4	<0.001
Adequate	Ref			Ref		
Excessive	47.8	-329.5 to 233.9	0.739	-54.2	-354.0 to 245.4	0.722
Sex of the baby			0.198			
Male	Ref			Ref		
Female	-75.0	-189.0 to 39.0	0.198	-110.8	-226.9 to 5.2	0.061
Maternal haemoglobin	-41.0	-81.2 to -0.9	0.045	-30.9	-71.7 to 9.8	0.137
Intimate partners violence			0.906			
Yes	8.8	-138.6 to 156.2	0.906	---	---	---
No	Ref					
Food insecurity			0.924			
Food secure	Ref					
Food insecure	-8.4	-183.5 to 166.6	0.924	---	---	---
Perinatal depression			0.355			
Yes	-86.9	-271.8 to 97.8	0.355	---	---	---
No	Ref					

Discussion

The overall mean birth weight was 3130 (SD, 509) g. The proportion of LBW was 7.5% (95% CI: 4.8 % to 11.0%). It was 9.3% (95% CI: 5.7% to 14.2%) of women who gained inadequate gestational weight gave birth to LBW babies while 4.5% (95% CI: 1.2 % to 11.1%) of women who gained adequate gestational weight gave birth to LBW babies. In addition, women's pre-pregnancy weight, GWG, having had previous history of abortion, occurrence gestational hypertension were the significant predictors of birth weight.

The proportion babies born with low birth weight (7.5%) was lower than the findings from the nationwide study using the 2016 Ethiopia Demographic Health Survey data, which was 13.2% (95% CI:10.7% to 15.7 %),[36] and a meta-analysis conducted in 2018 in Ethiopia (pooled BW data from 1995 to 2017), which was 17.3% (95% CI: 14.1% to 20.4 %).[37] Studies conducted in different parts of the country reported that factors such as maternal educational,[36] employment status, income and maternal age [37] are significantly associated with baby's birth weight. However, these factors were not associated with birth weight in our study.

In our study, infants born to underweight women were 155g lighter than infants born to normal weight women. The proportion of LBW was higher (10%) among underweight women compared to that of normal weight women (6.7%). Our study confirmed most prior reports that women's pre-pregnancy weight is associated with birth weight. [7 21 22 38] Maternal undernutrition, which is characterised by low pre-pregnancy weight and inadequate gestational weight gain, can negatively influence fetal growth that could lead to lower birth weight.

Gestational weight gain was found to have a significant influence on birth weight. Based on our study, infants whose mothers gained inadequate gestational weight were significantly lighter than infants of mothers who gained adequate weight. Moreover, 9.3% of women who gained inadequate gestational weight gave birth to LBW babies compared to babies of women who gained adequate gestational weight (4.5%). Other studies in similar settings also reported that LBW was more common among women who gained inadequate gestational weight than among women who gained adequate weight.[21 39] While there is strong need for extra nutritional intake during pregnancy, more than a quarter of pregnant women (27.3%) in Addis Ababa restrict their food intake to avoid weight gain .[40] This is mostly due to perceived severity of birth complications as a result of large for gestational age babies will make the birth more difficult and leads to caesarean birth.[41 42] Decreased nutrient intake due to poor dietary practices together with socio-economic and environmental factors could affect fetal growth, which also leads to lower birth weight.[43] Poor nutritional status among pregnant women may be associated with reduced placental size, which may lead to a reduction of nutrient transfer to the fetus from the placenta. Furthermore, low nutritional status of mothers might reduce serum concentrations of hormones such as estrogen and leptin, which could result in impairement of the fetal growth.[37] Nutritional counselling during pregnancy may improve women's feeding behaviour and hence, their nutritional status which may help mothers to decrease the risk of delivering LBW babies.[44 45]

We found that the birth weight of newborns whose mothers had previous history of abortions or miscarriages were significantly lower than those whose mothers had no history of abortions or miscarriages, an average decrease of 144g. This could be due to forty percent (40%) of multigravida women had previous history of abortions or miscarriages; 22% of these women experienced abortions or miscarriages at least two times. This would indicate that reproductive health and family planning use of women and their partners is low. A study conducted by the

DKT Ethiopia (a non-profit organisation that promotes family planning), in 2018, on 880 women who recived post-abortion care showed that 83.4% of aborted pregnancies were unplanned; and 91.6% of the women intentionally aborted their pregnancy.[46] This would suggest that the Ethiopian government needs to improve access to information and knowledge of reproductive choices and access to family planning services for both men and women.

Consistent with other studies, [47-50] our study showed gestational hypertension was significantly associated with lower infant birth weights. Infants born to mothers with gestational hypertension were 317 g lighter than infants born to mothers without gestational hypertension. Similarly, 27.8% of women with gestational hypertension gave birth to LBW babies while 5.7% of women without gestational hypertension gave birth to LBW babies. Although the relationship between gestational hypertension and an optimal intrauterine environment requires further exploration, some studies indicated that gestational hypertension is related to placental blood flow,[51 52] which affects fetal development including birth weight.

In our study, nearly a half of the women (47.5%) who gave birth through spontaneous vaginal birth had an episiotomy. The prevalence of episiotomy in Ethiopian was much higher than the recommended level by the WHO, which is 10%.[53] Another study from southern Ethiopia reported that the prevalence of episotomy was 68%.[54] According to the 2016 Ethiopian emergency obstetric and newborn care assessment report, 9% of primary postpartum hemorrhage and 8% of maternal sepsis are attributed to episiotomy.[55] The reasons for this high prevalence of episotomy in Ethiopian setting may be due to the liberal use of episiotomy among care providers or other maternal related factors such as high prevalence of female genital mutilation. This may need further investigation.

Conclusion

We found that GWG was significantly associated with infants' birth weight. Infants whose mothers gained inadequate gestational weight were significantly lighter than the infants of mothers who gained adequate weight, an average decrease of 246 g. Moreover, the birth weight of newborns whose mothers were underweight, had a previous history of abortion (termination of pregnancy before the 28th week of gestation) or miscarriages, and had gestational hypertension, were significantly lower than those whose mothers were without this history. Program officers and policy-makers may need to design appriopriate interventions on preventing LBW. Pregnancy related weight management should be actively promoted through intensive counselling during routine antenatal care consultations. The practical applicability of the IOM guidelines and the effect of GWG (according to IOM recommendations) on pregnancy outcomes need further investigation in Ethiopian context.

Ethics approval

Ethics approval for the study was obtained from the Haramaya University Institutional Health Research Ethics Review Committee [IHRERC/200/2018], Addis Ababa Health Bureau Institutional Review Board [A/A/HB/2576/227] and the University of Technology Sydney, Human Research Ethics Committee [UTS HREC18-2610].

Patient and Public Involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research

Consent for publication

Informed consent was obtained from all participants for publication.

Availability of data and materials

The datasets used for the analysis are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

FA has conceived the study, performed data collection and analyses, and drafted the manuscript. AC. YD, MF, and AH have critically revised the design of the study, participated in the analyses, interpretation of the findings and draft of the manuscript. All authors read this manuscript and finally approved for submission.

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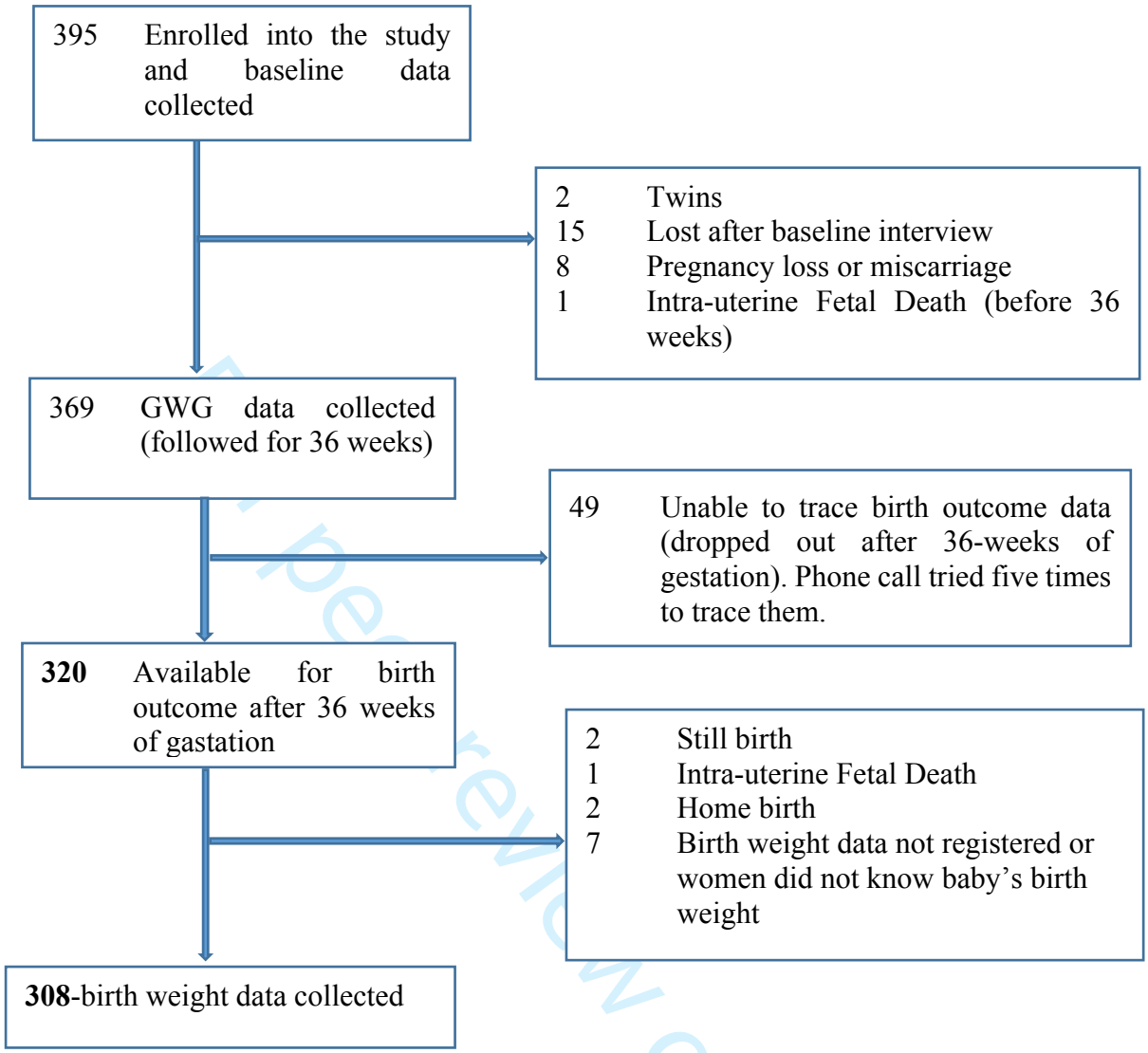

Figure 1: Flowchart showing data collection process from January to September 2019, Addis Ababa, Ethiopia

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Page 1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Pages 2 and 3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Pages 3 to 5
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 5
Methods			
Study design	4	Present key elements of study design early in the paper	Page 5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Pages 5 and 6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	Pages 5 and 6
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Pages 6 and 7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Page 6
Bias	9	Describe any efforts to address potential sources of bias	Pages 6 and 7
Study size	10	Explain how the study size was arrived at	Page 5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Pages 7 and 8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Pages 7 and 8
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	Figure 1
		(*d*) If applicable, explain how loss to follow-up was addressed	Figure 1
		(*e*) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Figure 1
		(b) Give reasons for non-participation at each stage	Figure 1
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Page 8, Tables 1 and 2
		(b) Indicate number of participants with missing data for each variable of interest	Tables 1 to 4
		(c) Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	Report numbers of outcome events or summary measures over time	NA
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Page 12 and 13, Table 4
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 14
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Pages 14 to 16
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 3
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 18

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Influence of Gestational Weight Gain on the Baby's Birth Weight in Addis Ababa, Central Ethiopia: A Follow-up Study

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Abstract

Background: Gestational weight gain (GWG) is an important indicator of fetal wellbeing during pregnancy. Inadequate or excessive GWG could have undesirable effects on birth weight. However, information regarding the influence of GWG on birth weight is lacking from the Ethiopian setting.

Objective: The aim of this study was to determine the influence of GWG and other maternal related factors on birth-weight in Addis Ababa, Ethiopia.

Design and methods: A cohort of pregnant women who received the first antenatal care before or at 16 weeks of gestation in health centres in Addis Ababa were followed from 10 January to 25 September, 2019. Data were collected using a structured questionnaire and medical record reviews. We conducted multivariable linear regression analysis to determine the independent effect of gestational weight on birth weight.

Results: Of the 395 women enrolled in the study, the outcome of pregnancy was available for 329 (83.3%) of the participants. The mean birth weight was 3130 (standard deviation, 509)gm. The proportion of low-birth weight (<2500gm) was 7.5% (95%CI: 4.8% to 11.0%). Babies born to underweight women were 151gm (95%CI: 6 to 309gm, p=0.049) lighter than babies born to normal weight women. Similarly, babies whose mothers gained inadequate weight were 248gm (95%CI: 113 to 384gm, p<0.001) lighter compared to those who gained adequate weight. Moreover, babies whose mothers had a previous history of abortion or miscarriages or developed gestational hypertension in the current pregnancy were 147gm (95% CI: 3 to 291gm, p=0.045) and 311gm (95%CI: 63 to 553gm, p=0.012) lighter, respectively, compared to those whose mothers had not.

Conclusions: Pre-pregnancy weight, GWG, having had previous history of abortion or miscarriages, and developing gestational hypertension during a current pregnancy was

independently associated with birth weight. Pregnancy related weight management should be actively promoted through intensive counselling during routine antenatal care contacts.

Key words: Pre-pregnancy weight; Gestational weight gain; Birth weight; Pregnancy outcomes

Strengths and limitations of this study

- ✓ We prospectively followed the weight of women in order to assess GWG and its influence on birth weight.
- ✓ The United State Inistitue of Medicine GWG recommendations are the recommendations of high-income countries, may not be suitable in low-income settings such as Ethiopia.
- ✓ We measured pre-pregnancy BMI before or at 16 weeks of gestation, at which time there may already have been an increase or decrease of gestational weight.
- ✓ This study was conducted in the capital city of Ethiopia in the public health facilities; the situation in other parts of the country and private health facilities may be different.

Introduction

Gestational weight gain (GWG) is attributable to pregnancy related changes that women experience such as the increase in size of the uterus and the developing fetus, placenta, amniotic fluid, an increase in breast size, extracellular fluid and blood volume. The American Institute of Medicine (IOM) has published recommendations for GWG of 12.5 to 18 kg for underweight women; 11.5 to 16 kg for normal weight women, 7 to 11 kg for overweight women and 5 to 9 kg for obese women.[1]

Gestational weight gain is a powerful indicator of maternal [2] and fetal [1] nutrition during pregnancy. Adequate GWG supports the growth and development of the fetus.[3] Both extremes, excessive or inadequate GWG, could result in undesirable pregnancy outcomes.[4-7] Excessive GWG is associated with pre-eclampsia,[8-10] caesarean birth,[8 10 11] macrosomia, large for gestation age and high birth weight.[7] On the other hand, inadequate weight gain is associated with intrauterine growth restriction,[12] low for gestational age, pre-term birth,[13-15] and low birth weight.[6 7]

Birth weight is one of the most important health indices in the growth, development and future survival of a newborn baby.[16] Birth weight is high if it is >4000 gm [17] or low if it is <2500 gm.[18] Low birth weight (LBW) is a proxy measure of intrauterine malnutrition. Intrauterine malnutrition has life-long consequences for the fetus.[19] Identifying the influence of GWG on birth weight at the local level is importance to provide an appropriate nutrition intervention during the pregnancy to reduce the risk of intrauterine malnutrition, and to improve GWG and birth soutcomes. This could help to break the vicious intergenerational cycle of malnutrition. [20]

Factors influencing birth weight have been reported as including but not limited to, maternal characteristics such as maternal age,[21] pre-pregnancy body mass index (BMI)[22], nutritional status, smoking,[23 24] and physical activity.[25-27] Factors related to the amount of growth and weight gain during pregnancy, and overall health of the mother and the fetus [28 29] also affect the amount of birth weight. In high income settings, the majority of pregnant women gain excessive geastational weight and their babies are at a high risk of being macrosomic.[8 10 11] However, the majority of pregnant women in low-income settings including Ethiopia gain

inadequate gestational weight.[30-32] Hence, the effect of GWG on birth weight is expected to be different in these settings. While there are a number of studies on factors affecting birth weight in Ethiopia, the influence of GWG on birth weight is not well understood in this setting. This study aimed to determine the influence of GWG and other maternal related factors on birth weight in Addis Ababa, a central Ethiopian population.

Methods

Study setting and period

This study was conducted in Addis Ababa, which is the capital and largest city in Ethiopia. Partcipants were selected from nine health centres. Details of the study setting and numbers of women recrituded from each facility were reported in the previously published paper.[31] A cohort of pregnant women were followed from prior to or at their 16th week of gestation until they gave birth to assess their GWG and the baby's birth weight from 10 January to 25 September, 2019.

Sample size determination

We calculated the sample size using Open Epi Version 2.3 using double proportion formula. The assumptions for the sample size calculation were alpha value 0.05; power 80%; exposed to non-exposed ratio 1:2 (proportion of adequate GWG = 28% (exposure); and proportion of inadequate GWG = 69% (non-exposure))[30]; proportion of LBW among women who gained adequate gestational weight =1.7%; proportion of LBW among women who gained inadequate gestational weight =17.5%, [21] loss to follow-up =20%. The required sample was 189 (exposed =63, and control =126). However, since this study was part of another large study, we recruited

a sample size of 395 and the details of the sample size calculation assumptions were described in the study published elsewhere. [31]

Participants

Pregnant women who came to health centres before or at 16 weeks gestation for antenatal care were invited to participate and those who agreed were recruited. We limited eligibility to women with a singleton pregnancy and no co-morbidities such as diabetes and hypertension.

Measurements

We used structured questionnaires with trained interviewers and face-to-face semi-structured interviews during the baseline data collection. The questionnaires collected information on socio-demographic characteristics, previous history of abortion (termination of pregrnancy before the 28th week of gestation), low birth weight and stillbirth, pregnancy intention (planned/unplanned), gravidity, food insecurity and dietary diversity, physical activity, intimate partner violence, and depression related symptoms. Data collectors measured baseline weight and height of the women, and mid-upper arm circumference. Women's medical records were also reviewed both during baseline data collection and after birth to collect data such as gestational age (ultrasound result), blood pressure, level of haemoglobin, random blood sugar result, weight at the 36th weeks of gestation, mode of birth, episiotomy, birth weight, and sex of the baby. These data were reviewed by the primary author. Women were followed from prior to or at their 16th week of gestation until they gave birth to assess their GWG and the baby's birth weight. Sixteen women (5.2%) gave birth in a rural location and we were unable to access the birth records. For these women, the birth weight information was ascertained through a phone call to the mother.

The primary outcome variable in this study was birth weight. However, other pregnancy outcome variables such as the occurrence of gestational hypertension, modes of birth, episiotomy, and birth outcomes (live birth, miscarriage, stillbirth or intra-uterine fetal death) were also considered as outcome variables.

We assessed the household food insecurity using the Household Food Insecurity Access Scale (HFIAS) [33] and the dietary diversity of the women using the minimum dietary diversity-women (MDD-W) tool.[34] Women's physical activity level was measured using the International Physical Activity Questionnaire (IPAQ-long form).[35] Perinatal depression symptoms were measured using the Edinburgh postnatal depression scale (EPDS),[36] and intimate partner violence was measured using a questionnaire used by the World Health Organization (WHO) multi-country study on women's health and domestic violence. [37]

Statistical analysis

We double entered into Census and Survey processing System (CSPro version 7.1). We exported data to STATA (version14, Stata Corp, 2015) for cleaning and analysis. Missing data were handled by performing pairwise deletion in the analysis. A particular variable was excluded when it had a missing value, but the case can still be used when analysing other variables with non-missing values. Hence, the analyses were performed on subsets of the data depending on where values are missing without completely omitting a case with some missing variables from the analyses. Descriptive statistics including frequencies, means, and standard deviations were computed to describe the data. We calculated GWG by subtracting women's baseline weight from their weight at the 36th weeks of gestation. The adequacy of GWG (inadequate, adequate or excessive) was determined using the IOM criteria. Birth weight was

analysed as a categorical and continuous variable. Birth weight was classified as <2.5 kg (low birth weight), 2.5 kg to 3.9 kg (normal birth weight), ≥4.0 kg (macrosomia). The relation-ship between birth weight as a categorical variable (i.e., LBW, normal birth weight or macrosomia) and other variables were reported descriptively using percentages. Since the number of LBW and macrosomic babies were small, we were unable to perform a regression analysis using birth weight as a categorical variable. Therefore, the influence of GWG and other variables on birth weight was assessed using a linear regression model. Variables with P-value <0.25 in the bivariable analysis were included in the multivariable analyses. However, some variables like food insecurity was considered important and forced in to the multivariable model irrespective of the p-value. The assumptions for linear regression were checked. Scatter plots showed that observations were linear. Multi collinearity was checked using the variance inflation factor (VIF). The mean VIF value was 1.44. The VIF value for each predictor variable was < 3, which showed that there was no multi-collinearity among variables.

We performed multivariable linear regression analysis to determine the independent effect of gestational weight gain on birth weight, adjusting for other potential factors (educational status, average household monthly income, and previous history of abortion (termination of pregrnancy before the 28th week of gestation), consuming meat or chicken in the last 24 hours, food insecurity, pre-pregnancy weight, maternal haemoglobin level, occurrence of gestational hypertension, and sex of the baby).

Results

Of the 395 women enrolled in the study, the outcome of the pregnancy was available for 329 (83.3%) of the participants. Eight of the 329 pregnancies ended in miscarriage (fetal loss before

28 weeks); four ended in stillbirths (fetal loss at or after 28 weeks); and the remaining were live births (Figure 1).

The mean age of the women was 25.3 (standard deviation, 3.9) years. Other socio-demographic and socio-ecomonic variables of the participants were reported elsewhere.[31] As shown in Table 1, half of the participants 199 (50.4%) were multigravida, of which 40.7% had previous history of abortion or miscarriage; 4.5% had previous history of stillbirth; and 3.3% had previous history of LBW. Twenty-one (5.8%) developed gestational hypertension during their current pregnancy, while one woman developed gestational diabetes. Eighty two percent (82%) gave birth via spontaneous vaginal birth (SVD), with 47.5% assissited with episiotomy. The majority of infants had normal birth weight (89.6%) and 7.5% had low birth weight. Twelve babies (3.9%) were born pre-term (Table 1).

As shown in Table 2, 85.6% of women who gained inadequate gestational weight gave birth vaginally, while 74.4% of women who gained adequate gestational weight gave birth vaginally; 9.3% of women who gained inadequate gestational weight gave birth to LBW babies, while 4.5% of women who gained adequate gestational weight gave birth to LBW babies. Four percent (4.0%) of the women who gained inadequate gestational weight developed gestational hypertension while 11% and 6% of women who gained adequate and excess gestational weight, respectively, developed gestational hypertension (Table 2).

Table 1: Pregnancy and pregnancy outcome related data of the study participants, Addis Ababa, Ethiopia, 2019

Variable	Frequency	Percentage
Gravidity (395)		
Primi gravida	196	49.6
Gravida 2	115	29.1
Gravida 3	54	13.7
gravida 4 and above	30	7.6
Inter–pregnancy interval (192)		
Less than 23 months	53	27.6
Greater or equal to 23 months	139	72.4
Previous history of abortion or miscarriages (199)		
Yes	81	40.7
No	118	59.3
Previous history of stillbirth (198)		
Yes	9	4.5
No	189	95.5
Mode of birth (314)		
Spontaneous vaginal birth	257	81.8
Caesarean section	57	18.2
Episiotomy (255)		
Yes	121	47.5
No	134	52.5
Sex of the baby		
Male	146	46.6
Female	167	53.4
Gestational hypertension		
Yes	21	5.8
No	338	94.2
Birth Weight		
Low birth weight	23	7.5
Normal birth weight	276	89.6
Macrosomia	9	2.9
Pre-term birth (births before 37 weeks)		
Yes	12	3.9
No	296	96.1

Table

Table 2: Association between gestational weight gain and pregnancy outcomes, Addis Ababa, Ethiopia, 2019

Variables	Gestational weight gain			P-value for χ^2 test
	Inadequate GWG n (%)	Adequate GWG n (%)	Excess GWG n (%)	
Gestational hypertension (357)				
Yes	9 (3.8)	11 (11.0)	1 (5.9)	0.035
No	231(96.2)	89 (89.0)	16 (94.1)	
Total	240 (100)	100 (100)	17 (100)	
Mode of birth (313)				
Spontaneous vaginal delivery	179 (85.6)	67 (74.4)	11 (78.6)	0.064
Caesarean section	30 (14.4)	23 (25.5)	3 (21.4)	
Total	209 (100)	90 (100)	14 (100)	
Episiotomy (255)				
Yes	84 (47.5)	32 (47.8)	5 (45.5)	
No	93 (52.5)	35 (52.2)	6 (55.5)	0.990
Total	177 (100)	67 (100)	11 (100)	
Birth weight (307)				
LBW	19 (9.3)	4 (4.5)	0 (0.0)	
Normal birth weight	183 (89.7)	78 (87.6)	14 (100)	0.008
Macrosomia	2 (1.0)	7 (7.9)	0 (0.0)	
Total	204(100)	89(100)	14(100)	
Sex of the baby (312)				
Male	98 (46.9)	40 (44.9)	8 (57.1)	0.696
Female	111 (53.1)	49 (55.1)	6 (42.9)	
Total	209 (100)	87(100)	14(100)	
Pre-term baby (270)				
Yes	9 (5.1)	3 (3.9)	0 (0)	0.651
No	169 (94.9)	74 (96.1)	14 (100)	
Total	178 (100)	77(100)	14 (100)	

The mean birth weight was 3.13 kg with standard deviation (SD) of 0.51 kg. It was 3.04 kg (SD = 0.49 kg) among women who gained inadequate gestational weight; 3.30 kg (SD = 0.52 kg) kg among women who gained adequate gestational weight; and 3.25 kg (SD =0.53 kg) among women who gained excessive gestational weight; 3.02 kg (SD =0.46 kg) among underweight women; and 3.14 kg (SD=0.53 kg) among normal weight women. The proportion of LBW was 10.3% (95% CI: 4.0 % to 21.2%) among underweight women while it was 6.7% (95% CI: 3.6% to 11.2%) among normal weight women. Similarly, 27.8% women who developed gestational hypertension gave birth to LBW babies while only 5.7% women who

did not develop gestational hypertension gave birth to LBW babies; 12.7% women with low MUAC (<23cm) gave to LBW babies compared to women with high MUAC (6.5%) (Table 3).

Table 3: Birth weight in relation to different factors in women of Addis Ababa, Ethiopia, 2019

Variable	LBW, n (%)	Normal birth weight, n (%)	Macrosomia, N (%)	Mean birth weight (standard deviation) (kg)
Women's age category (n=308)				
< 20 years	1 (7.1)	13 (92.9)	0 (0.0)	2.96 (0.50)
20 to 29 years	18 (7.3)	220 (89.4)	8 (3.3)	3.13 (0.51)
≥30 years	4 (8.3)	43 (89.6)	1 (2.1)	3.14 (0.53)
Marital status (n=308)				
Married	22 (7.4)	267 (89.9)	8 (2.7)	3.13 (0.51)
Single	1 (9.1)	9 (81.8)	1 (9.1)	3.15 (0.46)
Educational status (n=308)				
No formal education	2 (8.0)	23 (92.0)	0 (0.0)	3.17 (0.49)
Primary	12 (9.7)	111(89.5)	1 (0.8)	3.01(0.48)
Secondary	8 (9.0)	75 (84.3)	6 (6.7)	3.15 (0.58)
Tertiary	1 (1.4)	67 (95.7)	2 (2.9)	3.23 (0.45)
Occupational Status (n=308)				
House duty	14 (9.2)	133 (87.5)	5 (3.3)	3.07 (0.54)
Employee	4 (4.0)	95 (94.0)	2 (2.0)	3.19 (0.44)
Merchant	2 (6.1)	29 (87.8)	2 (6.1)	3.26(0.55)
Others*	3 (13.4)	19 (86.4)	0(0.0)	3.00(0.47)
Average monthly income (n=284)				
< 5000 ETB**	16 (8.3)	173 (90.1)	3 (1.6)	3.10 (0.51)
5000 to 10,000 ETB	5 (8.1)	54 (87.1)	3 (4.8)	3.10 (0.49)
≥ 10,000 ETB	1 (3.3)	28 (93.4)	1 (3.3)	3.28 (0.46)
Pregnancy intention (n=304)				
Intended	22 (8.0)	246 (89.5)	7 (2.5)	3.12 (0.51)
Unintended	1 (3.4)	26 (89.7)	2 (6.9)	3.22 (0.48)
Gravidity (n=308)				
Primigravida	9 (6.2)	132 (91.0)	4 (2.8)	3.11 (0.50)
Multigravida	14 (8.6)	144 (88.3)	5 (3.1)	3.14 (0.52)
Time gap between pregnancy (n=252)				
< 23 months	4 (9.8)	37 (90.2)	0 (0.0)	3.09 (0.51)
≥ 23 months	10 (8.6)	101 (87.1)	5 (4.3)	3.16 (0.53)
Dietary Diversity (n=308)				
Low dietary diversity	1 (1.9)	50 (96.2)	1 (1.9)	3.09 (0.49)
High dietary diversity	22 (8.6)	226 (88.3)	8 (3.1)	3.13 (0.52)
Physical Activity (n=308)				
Low	13 (9.0)	127 (88.2)	4 (2.8)	3.10 (0.50)
Moderate	7 (5.5)	115 (90.6)	5 (3.9)	3.15 (0.52)
High	3 (8.1)	34 (91.9)	0 (0.0)	3.15 (0.53)
MUAC*** (n=301)				
Low MUAC	7 (12.7)	46 (83.6)	2 (3.7)	3.02 (0.53)
High MUAC	16 (6.5)	223 (90.6)	7 (2.9)	3.15 (0.50)
Pre-pregnancy weight (n=307)				
Underweight	6 (10.3)	52 (89.7)	0 (0.0)	3.02 (0.46)
Normal weight	13 (6.7)	173 (89.2)	8 (4.1)	3.14 (0.53)
Overweight or obese	4 (7.1)	51 (91.1)	1 (1.8)	3.14 (0.50)
Gestational hypertension (n=298)				
Yes	5 (27.8)	12 (66.7)	1 (5.5)	2.93 (0.69)
No	16 (5.7)	257 (91.8)	7 (2.5)	3.14 (0.49)
Intimate partners violence (n=308)				
Yes	2 (3.5)	53 (93.0)	2 (3.5)	3.13 (0.50)
No	21(8.4)	223 (88.8)	7 (2.8)	3.12 (0.51)

Food insecurity (n=304)				
Food secure	19 (7.1)	239 (89.9)	8 (3.0)	3.12 (0.50)
Food insecure	4 (10.5)	33 (86.8)	1 (2.6)	3.12 (0.58)
Consuming meat or chicken in the last 24 hours (n=307)				
Yes	5 (5.7)	80 (92.0)	2 (2.3)	3.20 (0.50)
No	18 (8.2)	195 (88.6)	7 (3.2)	3.09 (0.51)
Perinatal depression (n=308)				
Yes	3 (9.1)	29 (87.9)	1 (3.0)	3.14 (0.51)
No	20 (7.3)	247 (89.8)	8 (2.9)	3.05 (0.49)

*students, daily labourer, farmer; **Ethiopian Birr; *** MUAC = Mid Upper Arm Circumference

Predictors of infants' birth weight

Of the variables included in the multivariable analysis, previous history of abortions or miscarriages, occurrence of gestational hypertension, pre-pregnancy weight and GWG were significantly associated with infants' birth weight at p-value <0.05.

The ß–coefficient showed that infants born to underweight women were 150 gm (95% CI: 6 to 309 gm, p=0.049) lighter than infants born to normal weight women. Similarly, infants whose mothers had inadequate weight gain were 248 gm (95% CI: 113 to 384 gm, p<0.001) lighter compared to those who gained adequate weight. In the same vein, infants whose mothers had previous history of abortion or miscarriages and developed gestational hypertension during current pregnancy were 147 gm (95% CI: 3 to 291 gm, p=0.045) and 311 gm (95% CI: 63 to 553 gm, p = 0.012) respectively lighter compared to those whose mothers had not (Table 4).

Maternal age, educational status, monthly income, haemoglobin level, pregnancy intention, gravidity, dietary diversity, food insecurity, physical activity, intimate partners' violence, and perinatal depression were not significantly associated with birth weight.

Table 4: Bivariable and multivariable linear regression analysis for predictors of birth weight (in gram) in Addis Ababa, Ethiopia 2019

Variable	Bivariate regression			Multivariable regression		
	Crude-ß	95%CI	P-value	Adjusted ß	95%CI	P-value
Women's age			0.446			
< 20 years	-176.0	-451.7 to 99.7	0.210	---	---	---
20 to 29 years	Ref					
≥30 years	6.0	-151.9 to 164.7	0.936	---	---	---
Educational status			0.065			
No formal education	- -57.6	-289.6 to 174.5	0.626	-83.3	- 332.1 to 168.8	0.515
Primary	-194.8	-343.7 to -45.9	0.010	-152.2	- 315.9 to 11.5	0.068
Secondary	-84.1	-243.2 to 74.9	0.299	-59.4	-228.9 to 110.9	0.493
Tertiary	Ref			Ref		
Occupational Status			0.258			
House duty	-116.57	-244.5 to 11.4	0.274	---	---	---
Employee	Ref					
Merchant	67.9	-131.9 to 267.8	0.504	---	---	---
Others*	-185.1	-419.6 to 49.5	0.122	---	---	---
Average monthly income			0.190			
< 5000 ETB*	-177.9	-372.5 to 16.6	0.073	- 112.9	-323.9 to 99.0	0.293
5000 to 10000 ETB	-175.9	-396.4 o 44.4	0.117	-161.9	-389.1 to 64.8	0.161
≥10000 ETB	Ref			Ref		
Pregnancy intention			0.294			
Intended	Ref					
Unintended	104.8	-91.4 to 301.1	0.294	---	---	---
Previous history of abortion or miscarriages			0.119			
Yes	-109.7	-247.8 to 28.5	0.119	- 147.2	-291.3 to -3.2	0.045
No	Ref			Ref		
Gravidity	15.9	-36.6 to 68.4	0.552			
Dietary Diversity			0.600			
Low	Ref					
High	-40.7	-193.4 to 112.0	0.600	---	---	---
Physical Activity			0.641			
Low	-51.7	-236.9 to 133.4	0.583	---	---	---
Moderate	4.1	-183.6 to 191.8	0.966	---	---	---
High	Ref					
Consuming meat or chicken in the last 24 hours			0.085			
Yes	111.4	-15.4 to 238.2	0.085	130.6	5.5 to 266.7	0.060
No	Ref			Ref		
Pre-pregnancy weight			0.173			
Underweight	-114.9	-264.7 to 34.8	0.132	-150.9	-308.6 to -5.8	0.049
Normal weight	Ref			Ref		
Overweight or obese	57.2	-94.5 to 209.0	0.458	1.4	- 168.6 to 169.6	0.987
Gestational hypertension			0.076			
Yes	-216.7	-455.9 to 22.5	0.076	-310.7	-552.8 to -62.7	0.012
No	Ref			Ref		
GWG**			<0.001			
Inadequate	-252.9	-377.4 to -128.4	<0.001	-248.2	-383.6 to -112.8	<0.001
Adequate	Ref			Ref		
Excessive	47.8	-329.5 to 233.9	0.739	-58.5	-360.4 to 243.5	0.703
Sex of the baby			0.198			
Male	Ref			Ref		
Female	-75.0	-189.0 to 39.0	0.198	-111.6	-290.0 to 5.8	0.062
Maternal haemoglobin	-41.0	-81.2 to -0.9	0.045	-31.0	-72.4 to 10.3	0.141
Intimate partners violence			0.906			

Yes	8.8	-138.6 to 156.2	0.906	---	---	---
No	Ref					
Food insecurity			0.924			
Food secure	Ref			Ref		
Food insecure	-8.4	-183.5 to 166.6	0.924	52.8	-124.2 to 229.9	0.557
Perinatal depression			0.355			
Yes	-86.9	-271.8 to 97.8	0.355	---	---	---
No	Ref					

*ETB=Ethiopian Birr; **GWG=Gestational Weight Gain

Discussion

A cohort of pregnant women who started their ANC follow-up prior to or at 16 weeks of gestation were followed until they gave birth to assess the influence of GWG and other factors on birth weight. The overall mean birth weight was 3130 gm (SD, 509 gm). The proportion of LBW was 7.5% (95% CI: 4.8 % to 11.0%). It was 9.3% (95% CI: 5.7% to 14.2%) of women who gained inadequate gestational weight gave birth to LBW babies while 4.5% (95% CI: 1.2 % to 11.1%) of women who gained adequate gestational weight gave birth to LBW babies. In addition, women's pre-pregnancy weight, GWG, having had previous history of abortion, occurrence gestational hypertension were the significant predictors of birth weight.

The proportion babies born with low birth weight (7.5% (95% CI: 4.8 % to 11.0%)) was comparable with the findings from the nationwide study using the 2016 Ethiopia Demographic Health Survey data, which was 13.2% (95% CI:10.7% to 15.7 %),[38] but lower than a finding from a meta-analysis conducted in 2018 in Ethiopia (pooled LBW data from 1995 to 2017), which was 17.3% (95% CI: 14.1% to 20.4 %).[39] Studies conducted in different parts of the country reported that factors such as maternal educational,[38] employment status, income and maternal age [39] are significantly associated with baby's birth weight. However, these factors were not associated with birth weight in our study. This may be due to the small sample size in our study because a relativily large number of women (64 women) were lost from the study before their birth outcomes were assessed. In addition, we were unable to access the birth

records for sixteen women (5.2%) since they gave birth in a rural . Birth weight information was ascertained through a phone call to the mother.

In our study, infants born to underweight women were 151 gm lighter than infants born to normal weight women. The proportion of LBW was higher (10%) among underweight women compared to that of normal weight women (6.7%). Our study confirmed most prior reports that women's pre-pregnancy weight is associated with birth weight. [7 21 22 40] Maternal undernutrition, which is characterised by low pre-pregnancy weight and inadequate gestational weight gain, can negatively influence fetal growth that could lead to lower birth weight.

Gestational weight gain was found to have a significant influence on birth weight. However, this finding needs to take an account of a number of issues. Firstly, the IOM GWG recommendations are the recommendations for high-income countries. These recommendations may not be suitable in low-income settings such as Ethiopia. Secondly, we measured pre-pregnancy weight before or at 16 weeks of gestation, at which time women may already experienced an increase or decrease of gestational weight. Finally, women's last weight was measured at 36 weeks of gestation; hence there may be some weight gain after 36 weeks of gestation. Having those issue in mind, our study indentified that babies whose mothers gained inadequate gestational weight were significantly lighter than infants of mothers who gained adequate weight. Moreover, 9.3% of women who gained inadequate gestational weight gave birth to LBW babies compared to babies of women who gained adequate gestational weight (4.5%). Other studies in similar settings also reported that LBW was more common among women who gained inadequate gestational weight than among women who gained adequate weight.[21 41] While there is a strong need for extra nutritional intake during pregnancy, more than a quarter of pregnant women (27.3%) in Addis Ababa restrict their food intake to

avoid weight gain.[42] This is mostly due to perceived severity of birth complications as a result of large for gestational age babies will make the birth more difficult and lead to a caesarean birth.[43 44] Decreased nutrient intake due to poor dietary practices together with socio-economic and environmental factors could affect fetal growth, which also leads to lower birth weight.[45] Poor nutritional status among pregnant women may be associated with reduced placental size, which may lead to a reduction of nutrient transfer to the fetus from the placenta. Furthermore, low nutritional status of mothers might reduce serum concentrations of hormones such as estrogen and leptin, which could result in impairement of the fetal growth.[39] Nutritional counselling during pregnancy may improve women's feeding behaviour and hence, their nutritional status which may help mothers to decrease the risk of giving birth to LBW babies.[46 47]

We found that the birth weight of newborns whose mothers had previous history of abortions or miscarriages were significantly lower than those whose mothers had no history of abortions or miscarriages, an average decrease of 147 gm. This could be due to forty percent (40%) of multigravida women had previous history of abortions or miscarriages; 22% of these women experienced abortions or miscarriages at least two times. This may indicate that reproductive health and family planning use by women and their partners is low. A study conducted by the DKT Ethiopia (a non-profit organisation that promotes family planning), in 2018, on 880 women who recived post-abortion care showed that 83.4% of aborted pregnancies were unplanned; and 91.6% of the women intentionally aborted their pregnancy.[48] This would suggest that the Ethiopian government needs to improve access to information and knowledge of reproductive choices and access to family planning services for both men and women.

Consistent with other studies, [49-52] our study showed gestational hypertension was significantly associated with lower infant birth weights. Infants born to mothers with gestational hypertension were 311 gm lighter than infants born to mothers without gestational hypertension. Similarly, 27.8% of women with gestational hypertension gave birth to LBW babies while 5.7% of women without gestational hypertension gave birth to LBW babies. Although the relationship between gestational hypertension and an optimal intrauterine environment requires further exploration, some studies indicated that gestational hypertension is related to placental blood flow,[53 54] which affects fetal development including birth weight.

In our study, nearly a half of the women (47.5%) who had a spontaneous vaginal birth had an episiotomy. The prevalence of episiotomy in Ethiopia was much higher than the recommended level by the WHO, which is 10%.[55] Another study from southern Ethiopia reported that the prevalence of episotomy was 68%.[56] According to the 2016 Ethiopian emergency obstetric and newborn care assessment report, 9% of primary postpartum hemorrhage and 8% of maternal sepsis are attributed to episiotomy.[57] The reasons for this high prevalence of episotomy in Ethiopian setting may be due to the liberal use of episiotomy among care providers or other maternal related factors such as high prevalence of female genital mutilation. This may need further investigation.

Factors such as dietary diversity, food insecurity, physical activity, perinatal depression, and intimate partimars violence were not associated with birth weight in our study. This could be due to a number of reasons. Firstly, these factors were captured before or at 16 weeks of gestations. The occurrence of these factors at different stage of pregnancy would have different effects on GWG and birth weight. Future studies may need to measure the magnituted of dietary diversity, food insecurity, physical activity, perinatal depression, and intimate partner violence

during different trimesters of pregnancy and their effects on GWG and birth weight. Secondly, our sample size was relatively small because a significant number of women were lost during the follow-up before their birth outcome was captured. Finally, the effect of these factors may need to be checked in different settings such as rural areas where a signinificant number of women suffer from house hold food insecurity.

Strengths and limitations of this study

The strength of this study was women were prospectively followed to their GWG and birth weight. This study has some limitations. Firstly, a relativily large number of women (64) lost from the study before their birth outcome was assessed. In addition, we were unable to access the birth records for sixteen women (5.2%) since they gave birth in a rural location and birth weight information was ascertained through a phone call to the mother. Secondly, the IOM GWG recommendations are the recommendations of high-income countries. These recommendations may not be suitable in low-income settings such as Ethiopia. Thirdly, we measured pre-pregnancy weight before or at 16 weeks of gestation, at which time there may already have been an increase or decrease of gestational weight. In addition, women's last weight was measured at 36 weeks of gestation; hence there may be some weight gain after 36 weeks of gestation. Finally, this study was conducted in the capital city of Ethiopia in the public health facilities; the situation in other parts of the country and private health facilities may be different.

Conclusion

We found that GWG was significantly associated with infants' birth weight. Infants whose mothers gained inadequate gestational weight were significantly lighter than the infants of mothers who gained adequate weight, an average decrease of 246 g. Moreover, the birth weight of newborns whose mothers were underweight, had a previous history of abortion (termination of pregnancy before the 28th week of gestation) or miscarriages, and had gestational hypertension, were significantly lower than those whose mothers were without this history. Program officers and policy-makers may need to design appriopriate interventions on preventing LBW. Pregnancy related weight management should be actively promoted through intensive counselling during routine antenatal care consultations. The practical applicability of the IOM guidelines and the effect of GWG (according to IOM recommendations) on pregnancy outcomes need further investigation in the Ethiopian context.

Ethics approval

Ethics approval for the study was obtained from the Haramaya University Institutional Health Research Ethics Review Committee [IHRERC/200/2018], Addis Ababa Health Bureau Institutional Review Board [A/A/HB/2576/227] and the University of Technology Sydney, Human Research Ethics Committee [UTS HREC18-2610].

Patient and Public Involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research

Consent for publication

Informed consent was obtained from all participants for publication.

Availability of data and materials

The datasets used for the analysis are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

FA has conceived the study, performed data collection and analyses, and drafted the manuscript. AC. YD, MF, and AH have critically revised the design of the study, participated in the analyses, interpretation of the findings and draft of the manuscript. All authors read this manuscript and finally approved for submission.

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Figure legend

Figure 1: Flowchart showing data collection process from January to September 2019, Addis Ababa, Ethiopia

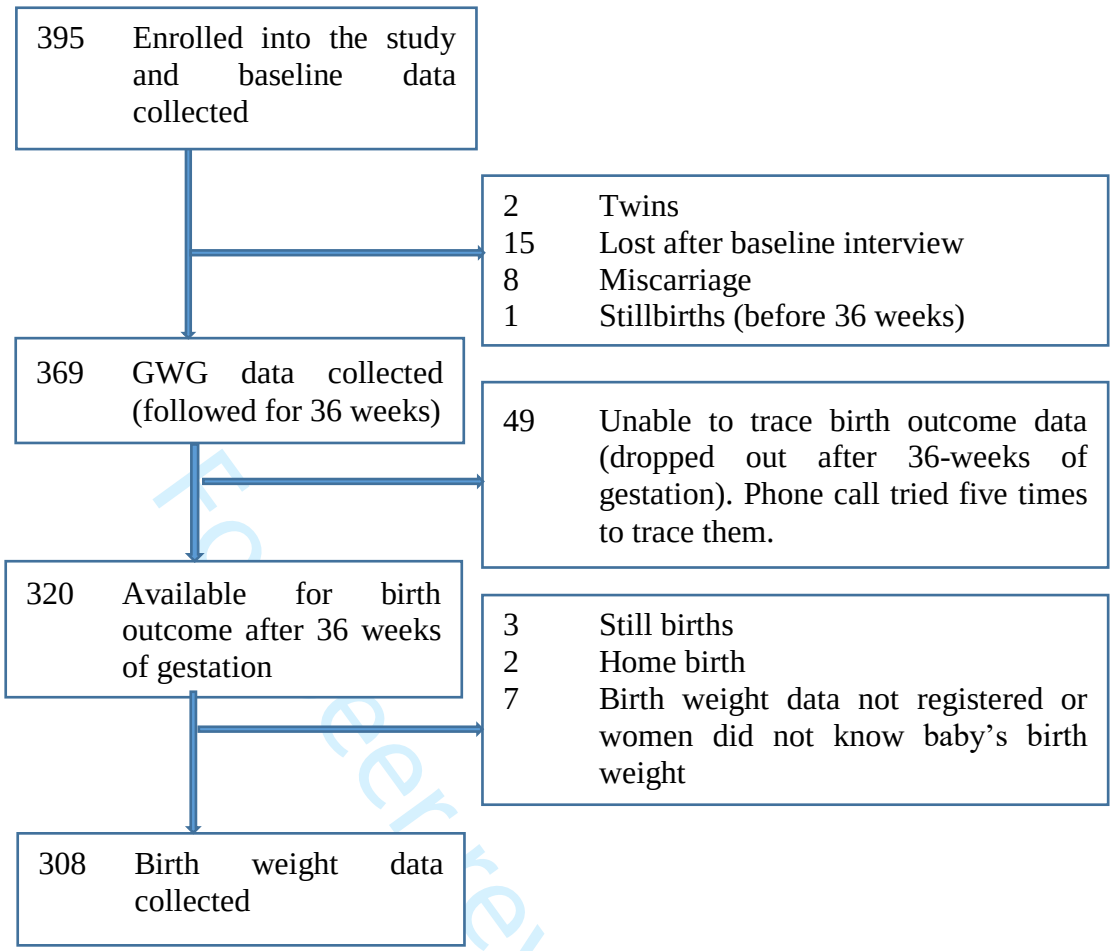

Figure 1: Flowchart showing data collection process from January to September 2019, Addis Ababa, Ethiopia

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Page 1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Pages 2 and 3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Pages 3 to 5
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 5
Methods			
Study design	4	Present key elements of study design early in the paper	Page 5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Pages 5 and 6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	Pages 5 and 6
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Pages 6 and 7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Page 6
Bias	9	Describe any efforts to address potential sources of bias	Pages 6 and 7
Study size	10	Explain how the study size was arrived at	Page 5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Pages 7 and 8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Pages 7 and 8
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	Figure 1
		(*d*) If applicable, explain how loss to follow-up was addressed	Figure 1
		(*e*) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Figure 1
		(b) Give reasons for non-participation at each stage	Figure 1
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Page 8, Tables 1 and 2
		(b) Indicate number of participants with missing data for each variable of interest	Tables 1 to 4
		(c) Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	Report numbers of outcome events or summary measures over time	NA
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Page 12 and 13, Table 4
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 14
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Pages 14 to 16
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 3
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 18

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Influence of Gestational Weight Gain on the Baby's Birth Weight in Addis Ababa, Central Ethiopia: A Follow-up Study

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Influence of Gestational Weight Gain on Baby's Birth Weight in Addis Ababa, Central Ethiopia: A Follow-up Study

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Abstract

Background: Gestational weight gain (GWG) is an important indicator of fetal wellbeing during pregnancy. Inadequate or excessive GWG could have undesirable effects on birth weight. However, information regarding the influence of GWG on birth weight is lacking from the Ethiopian setting.

Objective: This study aimed to determine the influence of GWG and other maternal-related factors on birth weight in Addis Ababa, Ethiopia.

Design and methods: A cohort of pregnant women who received the first antenatal care before or at 16 weeks of gestation in health centres in Addis Ababa were followed from January 10 to September 25, 2019. Data were collected using a structured questionnaire and medical record reviews. We conducted a multivariable linear regression analysis to determine the independent effect of gestational weight on birth weight.

Results: Of the 395 women enrolled in the study, the participants' pregnancy outcome was available for 329 (83.3%). The mean birth weight was 3130 (standard deviation, 509) gm. The proportion of low-birth-weight (<2500 gm) was 7.5% (95% CI: 4.8% to 11.0%). Babies born to underweight women were 151 gm (95% CI: 6 to 309 gm, p=0.049) lighter than babies born to normal-weight women. Similarly, babies whose mothers gained inadequate weight were 248 gm (95% CI: 113 to 384 gm, p<0.001) lighter than those who gained adequate weight. Moreover, babies whose mothers had a previous history of abortion or miscarriages or developed gestational hypertension in the current pregnancy were 147 gm (95% CI: 3 to 291 gm, p=0.045) and 311gm (95% CI: 63 to 553 gm, p=0.012) lighter, respectively, compared to those whose mothers had not.

Conclusions: Pre-pregnancy weight, GWG, having had a previous history of abortion or miscarriages, and developing gestational hypertension during a current pregnancy were

independently associated with birth weight. Pregnancy-related weight management should be actively promoted through intensive counseling during routine antenatal care contacts.

Keywords: Pre-pregnancy weight; Gestational weight gain; Birth weight; Pregnancy outcomes

Strengths and limitations of this study

- ✓ We prospectively followed the women's weight to assess GWG and its influence on birth weight.
- ✓ The United States Institute of Medicine GWG recommendations are recommendations of high-income countries that may not be suitable in low-income settings such as Ethiopia.
- ✓ We measured pre-pregnancy BMI before or at 16 weeks of gestation, at which time there may already have been an increase or decrease of gestational weight.
- ✓ This study was conducted in the capital city of Ethiopia in the public health facilities; the situation in other parts of the country and private health facilities may be different.

Introduction

Gestational weight gain (GWG) is attributable to pregnancy-related changes that women experience, such as the increase in the size of the uterus and the developing fetus, placenta, amniotic fluid, an increase in breast size, extracellular fluid, and blood volume. The American Institute of Medicine (IOM) has published recommendations for GWG of 12.5 to 18 kg for underweight women, 11.5 to 16 kilograms (kg) for normal-weight women, 7 to 11 kg for overweight women, and 5 to 9 kg for obese women. [1]

Gestational weight gain is a powerful indicator of maternal [2] and fetal [1] nutrition during pregnancy. Adequate GWG supports the growth and development of the fetus. [3] Both extremes, excessive or inadequate GWG, could result in undesirable pregnancy outcomes. [4-7] Excessive GWG is associated with pre-eclampsia, [8-10] cesarean birth, [8 10 11] macrosomia, large for gestation age, and high birth weight. [7] On the other hand, inadequate weight gain is associated with intrauterine growth restriction, [12] low for gestational age, preterm birth, [13-15] and low birth weight. [6 7]

Birth weight is one of the most important health indices in a newborn baby's growth, development, and future survival. [16] Birth weight is high if it is >4000 gm [17] or low if it is <2500 gm. [18] Low birth weight (LBW) is a proxy indicator for intrauterine malnutrition. Intrauterine malnutrition has life-long consequences for the fetus. [19] Identifying the influence of GWG on birth weight at the local level is important to provide an appropriate nutrition intervention during the pregnancy to reduce the risk of intrauterine malnutrition and improve GWG and birth outcomes. This could help to break the vicious intergenerational cycle of malnutrition. [20]

Factors influencing birth weight have been reported as including but not limited to maternal characteristics such as maternal age, [21] pre-pregnancy body mass index (BMI), [22] nutritional status, smoking, [23 24] and physical activity. [25-27] Factors related to the amount of growth and weight gain during pregnancy and the overall health of the mother and the fetus [28 29] also affect the amount of birth weight. In high-income settings, most pregnant women gain excessive gestational weight, and their babies are at a high risk of microsomia. [8 10 11] However, most pregnant women in low-income settings, including Ethiopia, gain inadequate gestational weight. [30-32] Hence, the effect of GWG on birth weight is expected to be different in these

settings. While there are several studies on factors affecting birth weight in Ethiopia, the influence of GWG on birth weight is not well understood in this setting. This study aimed to determine the influence of GWG and other maternal-related factors on birth weight in Addis Ababa, a central Ethiopian population.

Methods

Study setting and period

This study was conducted in Addis Ababa, Ethiopia's capital and largest city. Participants were selected from nine health centres. The previously published paper reported details of the study setting and numbers of women recruited from each facility. [31] A cohort of pregnant women were followed from before or at their 16th week of gestation until they gave birth to assess their GWG and the baby's birth weight from January 10 to September 25, 2019.

Sample size determination

Using the double proportion formula, we calculated the sample size using Open Epi Version 2.3. The assumptions for the sample size calculation were alpha value 0.05; power 80%; exposed to non-exposed ratio 1:2 (proportion of adequate GWG = 28% (exposure); and proportion of inadequate GWG = 69% (non-exposure))[30]; proportion of LBW among women who gained adequate gestational weight =1.7%; proportion of LBW among women who gained inadequate gestational weight =17.5%, [21] loss to follow-up =20%. The required sample was 189 (exposed =63, and control =126). However, since this study was part of another large study, we recruited a sample size of 395. The details of the sample size calculation assumptions were described in the study published elsewhere. [31]

Participants

Pregnant women who came to health centres before or at 16 weeks gestation for antenatal care were invited to participate, and those who agreed were recruited. We limited eligibility to women with a singleton pregnancy and no co-morbidities such as diabetes and hypertension.

Measurements

We used structured questionnaires with trained interviewers and face-to-face semi-structured interviews during the baseline data collection. The questionnaires collected information on socio-demographic characteristics, previous history of abortion (termination of pregnancy before the 28th week of gestation), low birth weight and stillbirth, pregnancy intention (planned/unplanned), gravidity, food insecurity, dietary diversity, physical activity, intimate partner violence, and depression-related symptoms. Data collectors measured baseline weight and height of the women and mid-upper arm circumference. Women's medical records were also reviewed both during baseline data collection and after birth to collect data such as gestational age (ultrasound result), blood pressure, level of hemoglobin, random blood sugar result, weight at the 36th weeks of gestation, mode of birth, episiotomy, birth weight, and sex of the baby. The primary author reviewed these data. Women were followed from before or at their 16th week of gestation until they gave birth to assess their GWG and the baby's birth weight. Sixteen women (5.2%) gave birth in a rural location, and we could not access the birth records. The birth weight information was ascertained for these women through a phone call to the mother.

The primary outcome variable in this study was birth weight. However, other pregnancy outcome variables such as the occurrence of gestational hypertension, modes of birth,

episiotomy, and birth outcomes (live birth, miscarriage, or stillbirth) were also considered as outcome variables.

We assessed the household food insecurity using the Household Food Insecurity Access Scale (HFIAS) [33] and the women's dietary diversity using the minimum dietary diversity-women (MDD-W) tool. [34] Women's physical activity level was measured using the International Physical Activity Questionnaire (IPAQ-long form). [35] Perinatal depression symptoms were measured using the Edinburgh postnatal depression scale (EPDS),[36] and intimate partner violence were measured using a questionnaire used by the World Health Organization (WHO) multi-country study on women's health and domestic violence. [37]

Statistical analysis

We double entered the data into Census and Survey Processing System (CSPro version 7.1). We exported data to STATA (version14, Stata Corp, 2015) for cleaning and analysis. Missing data were handled by performing pairwise deletion in the study. A particular variable was excluded when it had a missing value, but the case can still be used when analysing other variables with non-missing values. Hence, the analyses were performed on subsets of the data depending on where values are missing without completely omitting a case with missing some variables from the analyses.

Descriptive statistics, including frequencies, means, and standard deviations, were computed to describe the data. We calculated GWG by subtracting women's baseline weight from their weight at the 36th week of gestation. The adequacy of GWG (inadequate, adequate, or excessive) was determined using the IOM criteria. Birth weight was analysed as a categorical and continuous variable. Birth weight was classified as <2.5 kg (low birth weight), 2.5 kg to

3.9 kg (normal birth weight), ≥4.0 kg (macrosomia). The relationship between birth weight as a categorical variable (i.e., LBW, normal birth weight, or macrosomia) and other variables was reported descriptively using percentage. Since the number of LBW and macrosomic babies were small, we could not perform a regression analysis using birth weight as a categorical variable. Therefore, using a linear regression model, we assessed the influence of GWG and other variables on birth weight. Variables with P-value <0.25 in the bivariable analysis were included in the multivariable analyses. However, some variable like food insecurity was considered important and forced into the multivariable model irrespective of the p-value. The assumptions for linear regression were checked. Scatter plots showed that observations were linear. Multicollinearity was checked using the variance inflation factor (VIF). The mean VIF value was 1.44. The VIF value for each predictor variable was < 3, which showed no multicollinearity among variables.

We performed multivariable linear regression analysis to determine the independent effect of gestational weight gain on birth weight, adjusting for other potential factors (educational status, average household monthly income, and previous history of abortion (termination of pregnancy before the 28th week of gestation), consuming meat or chicken in the last 24 hours, food insecurity, pre-pregnancy weight, maternal hemoglobin level, occurrence of gestational hypertension, and sex of the baby).

Results

Of the 395 women enrolled in the study, the participants' pregnancy outcome was available for 329 (83.3%). Eight of the 329 pregnancies ended in miscarriage (fetal loss before 28 weeks), three ended in stillbirths (fetal loss at or after 28 weeks), and the remaining were live births (Figure 1).

The mean age of the women was 25.3 (standard deviation, 3.9) years. Other socio-demographic and socio-economic variables of the participants were reported elsewhere.[31] As shown in Table 1, half of the participants, 199 (50.4%), were multigravida, of which 40.7% had a previous history of abortion or miscarriage; 4.5% had a prior history of stillbirth, and 3.3% had a previous history of LBW. Twenty-one (5.8%) developed gestational hypertension during pregnancy, while one woman developed gestational diabetes. Eighty-two percent (82%) gave birth via spontaneous vaginal birth (SVD), with 47.5% assisted with episiotomy. Most infants had normal birth weight (89.6%), and 7.5% had low birth weight. Twelve babies (3.9%) were born pre-term (Table 1).

As shown in Table 2, 85.6% of women who gained inadequate gestational weight gave birth vaginally; 74.4% of women who gained adequate gestational weight gave birth vaginally; 9.3% of women who gained inadequate gestational weight gave birth to LBW babies; while 4.5% of women who gained adequate gestational weight gave birth to LBW babies. Four percent (4.0%) of the women who gained inadequate gestational weight developed gestational hypertension, while 11% and 6% of women who gained adequate and excess gestational weight, respectively, developed gestational hypertension (Table 2). The details for the participants' GWG status, including trimester-specific GWG, were reported elsewhere. [31]

Table 1: Pregnancy and pregnancy outcome-related data of the study participants, Addis Ababa, Ethiopia, 2019

Variable	Frequency	Percentage
Gravidity (395)		
Primi gravida	196	49.6
Gravida 2	115	29.1
Gravida 3	54	13.7
gravida 4 and above	30	7.6
Inter–pregnancy interval (192)		
Less than 23 months	53	27.6
Greater or equal to 23 months	139	72.4
Previous history of abortion or miscarriages (199)		
Yes	81	40.7
No	118	59.3
Previous history of stillbirth (198)		
Yes	9	4.5
No	189	95.5
Mode of birth (314)		
Spontaneous vaginal birth	257	81.8
Caesarean section	57	18.2
Episiotomy (255)		
Yes	121	47.5
No	134	52.5
Sex of the baby		
Male	146	46.6
Female	167	53.4
Gestational hypertension		
Yes	21	5.8
No	338	94.2
Birth Weight		
Low birth weight	23	7.5
Normal birth weight	276	89.6
Macrosomia	9	2.9
Pre-term birth (births before 37 weeks)		
Yes	12	3.9
No	296	96.1

Table 2: Association between gestational weight gain and pregnancy outcomes, Addis Ababa, Ethiopia, 2019

Variables	Gestational weight gain			P-value for χ^2 test
	Inadequate GWG n (%)	Adequate GWG n (%)	Excess GWG n (%)	
Gestational hypertension (357)				
Yes	9 (3.8)	11 (11.0)	1 (5.9)	0.035
No	231(96.2)	89 (89.0)	16 (94.1)	
Total	240 (100)	100 (100)	17 (100)	
Mode of birth (313)				
Spontaneous vaginal delivery	179 (85.6)	67 (74.4)	11 (78.6)	0.064
Caesarean section	30 (14.4)	23 (25.5)	3 (21.4)	
Total	209 (100)	90 (100)	14 (100)	
Episiotomy (255)				
Yes	84 (47.5)	32 (47.8)	5 (45.5)	
No	93 (52.5)	35 (52.2)	6 (55.5)	0.990
Total	177 (100)	67 (100)	11 (100)	
Birth weight (307)				
LBW	19 (9.3)	4 (4.5)	0 (0.0)	
Normal birth weight	183 (89.7)	78 (87.6)	14 (100)	0.008
Macrosomia	2 (1.0)	7 (7.9)	0 (0.0)	
Total	204(100)	89(100)	14(100)	
Sex of the baby (312)				
Male	98 (46.9)	40 (44.9)	8 (57.1)	0.696
Female	111 (53.1)	49 (55.1)	6 (42.9)	
Total	209 (100)	87(100)	14(100)	
Pre-term baby (270)				
Yes	9 (5.1)	3 (3.9)	0 (0)	0.651
No	169 (94.9)	74 (96.1)	14 (100)	
Total	178 (100)	77(100)	14 (100)	

The mean birth weight was 3.13 kg with a standard deviation (SD) of 0.51 kg. It was 3.04 kg (SD = 0.49 kg) among women who gained inadequate gestational weight; 3.30 kg (SD = 0.52 kg) kg among women who gained adequate gestational weight; and 3.25 kg (SD =0.53 kg) among women who gained excessive gestational weight; 3.02 kg (SD =0.46 kg) among underweight women; and 3.14 kg (SD=0.53 kg) among normal-weight women. The proportion of LBW was 10.3% (95% CI: 4.0 % to 21.2%) among underweight women while it was 6.7% (95% CI: 3.6% to 11.2%) among normal-weight women. Similarly, 27.8% of women who developed gestational hypertension gave birth to LBW babies while only 5.7% of women who

did not develop gestational hypertension gave birth to LBW babies; 12.7% of women with low MUAC (<23cm) gave to LBW babies compared to women with high MUAC (6.5%) (Table 3).

Table 3: Birth weight in relation to different factors in women of Addis Ababa, Ethiopia, 2019

Variable	LBW, n (%)	Normal birth weight, n (%)	Macrosomia, N (%)	Mean birth weight (standard deviation) (kg)
Women's age category (n=308)				
< 20 years	1 (7.1)	13 (92.9)	0 (0.0)	2.96 (0.50)
20 to 29 years	18 (7.3)	220 (89.4)	8 (3.3)	3.13 (0.51)
≥30 years	4 (8.3)	43 (89.6)	1 (2.1)	3.14 (0.53)
Marital status (n=308)				
Married	22 (7.4)	267 (89.9)	8 (2.7)	3.13 (0.51)
Single	1 (9.1)	9 (81.8)	1 (9.1)	3.15 (0.46)
Educational status (n=308)				
No formal education	2 (8.0)	23 (92.0)	0 (0.0)	3.17 (0.49)
Primary	12 (9.7)	111(89.5)	1 (0.8)	3.01(0.48)
Secondary	8 (9.0)	75 (84.3)	6 (6.7)	3.15 (0.58)
Tertiary	1 (1.4)	67 (95.7)	2 (2.9)	3.23 (0.45)
Occupational Status (n=308)				
House duty	14 (9.2)	133 (87.5)	5 (3.3)	3.07 (0.54)
Employee	4 (4.0)	95 (94.0)	2 (2.0)	3.19 (0.44)
Merchant	2 (6.1)	29 (87.8)	2 (6.1)	3.26(0.55)
Others*	3 (13.4)	19 (86.4)	0(0.0)	3.00(0.47)
Average monthly income (n=284)				
< 5000 ETB**	16 (8.3)	173 (90.1)	3 (1.6)	3.10 (0.51)
5000 to 10,000 ETB	5 (8.1)	54 (87.1)	3 (4.8)	3.10 (0.49)
≥ 10,000 ETB	1 (3.3)	28 (93.4)	1 (3.3)	3.28 (0.46)
Pregnancy intention (n=304)				
Intended	22 (8.0)	246 (89.5)	7 (2.5)	3.12 (0.51)
Unintended	1 (3.4)	26 (89.7)	2 (6.9)	3.22 (0.48)
Gravidity (n=308)				
Primigravida	9 (6.2)	132 (91.0)	4 (2.8)	3.11 (0.50)
Multigravida	14 (8.6)	144 (88.3)	5 (3.1)	3.14 (0.52)
Time gap between pregnancy (n=252)				
< 23 months	4 (9.8)	37 (90.2)	0 (0.0)	3.09 (0.51)
≥ 23 months	10 (8.6)	101 (87.1)	5 (4.3)	3.16 (0.53)
Dietary Diversity (n=308)				
Low dietary diversity	1 (1.9)	50 (96.2)	1 (1.9)	3.09 (0.49)
High dietary diversity	22 (8.6)	226 (88.3)	8 (3.1)	3.13 (0.52)
Physical Activity (n=308)				
Low	13 (9.0)	127 (88.2)	4 (2.8)	3.10 (0.50)
Moderate	7 (5.5)	115 (90.6)	5 (3.9)	3.15 (0.52)
High	3 (8.1)	34 (91.9)	0 (0.0)	3.15 (0.53)
MUAC*** (n=301)				
Low MUAC	7 (12.7)	46 (83.6)	2 (3.7)	3.02 (0.53)
High MUAC	16 (6.5)	223 (90.6)	7 (2.9)	3.15 (0.50)
Pre-pregnancy weight (n=307)				
Underweight	6 (10.3)	52 (89.7)	0 (0.0)	3.02 (0.46)
Normal weight	13 (6.7)	173 (89.2)	8 (4.1)	3.14 (0.53)
Overweight or obese	4 (7.1)	51 (91.1)	1 (1.8)	3.14 (0.50)
Gestational hypertension (n=298)				
Yes	5 (27.8)	12 (66.7)	1 (5.5)	2.93 (0.69)
No	16 (5.7)	257 (91.8)	7 (2.5)	3.14 (0.49)
Intimate partners violence (n=308)				
Yes	2 (3.5)	53 (93.0)	2 (3.5)	3.13 (0.50)
No	21(8.4)	223 (88.8)	7 (2.8)	3.12 (0.51)

Food insecurity (n=304)				
Food secure	19 (7.1)	239 (89.9)	8 (3.0)	3.12 (0.50)
Food insecure	4 (10.5)	33 (86.8)	1 (2.6)	3.12 (0.58)
Consuming meat or chicken in the last 24 hours (n=307)				
Yes	5 (5.7)	80 (92.0)	2 (2.3)	3.20 (0.50)
No	18 (8.2)	195 (88.6)	7 (3.2)	3.09 (0.51)
Perinatal depression (n=308)				
Yes	3 (9.1)	29 (87.9)	1 (3.0)	3.14 (0.51)
No	20 (7.3)	247 (89.8)	8 (2.9)	3.05 (0.49)

*students, daily labourer, farmer; **Ethiopian Birr; *** MUAC = Mid Upper Arm Circumference

Predictors of infants' birth weight

Of the variables included the multivariable model, previous history of abortions or miscarriages, occurrence of gestational hypertension, pre-pregnancy weight, and GWG were significantly associated with infants' birth weight at p-value <0.05.

The ß–coefficient showed that infants born to underweight women were 150 gm (95% CI: 6 to 309 gm, p=0.049) lighter than infants born to normal-weight women. Similarly, infants whose mothers had inadequate weight gain were 248 gm (95% CI: 113 to 384 gm, p<0.001) lighter than those who gained adequate weight. In the same vein, infants whose mothers had a previous history of abortion or miscarriages and developed gestational hypertension during current pregnancy were 147 gm (95% CI: 3 to 291 gm, p=0.045) and 311 gm (95% CI: 63 to 553 gm, p = 0.012), respectively, lighter compared to those whose mothers had not (Table 4).

Maternal age, educational status, monthly income, hemoglobin level, pregnancy intention, gravidity, dietary diversity, food insecurity, physical activity, intimate partners' violence, and perinatal depression were not significantly associated with birth weight.

Table 4: Bivariable and multivariable linear regression analysis for predictors of birth weight (in gram) in Addis Ababa, Ethiopia 2019

Variable	Bivariate regression			Multivariable regression		
	Crude-ß	95%CI	P-value	Adjusted ß	95%CI	P-value
Women's age			0.446			
< 20 years	-176.0	-451.7 to 99.7	0.210	---	---	---
20 to 29 years	Ref					
≥30 years	6.0	-151.9 to 164.7	0.936	---	---	---
Educational status			0.065			
No formal education	- -57.6	-289.6 to 174.5	0.626	-83.3	- 332.1 to 168.8	0.515
Primary	-194.8	-343.7 to -45.9	0.010	-152.2	- 315.9 to 11.5	0.068
Secondary	-84.1	-243.2 to 74.9	0.299	-59.4	-228.9 to 110.9	0.493
Tertiary	Ref			Ref		
Occupational Status			0.258			
House duty	-116.57	-244.5 to 11.4	0.274	---	---	---
Employee	Ref					
Merchant	67.9	-131.9 to 267.8	0.504	---	---	---
Others*	-185.1	-419.6 to 49.5	0.122	---	---	---
Average monthly income			0.190			
< 5000 ETB*	-177.9	-372.5 to 16.6	0.073	- 112.9	-323.9 to 99.0	0.293
5000 to 10000 ETB	-175.9	-396.4 o 44.4	0.117	-161.9	-389.1 to 64.8	0.161
≥10000 ETB	Ref			Ref		
Pregnancy intention			0.294			
Intended	Ref					
Unintended	104.8	-91.4 to 301.1	0.294	---	---	---
Previous history of abortion or miscarriages			0.119			
Yes	-109.7	-247.8 to 28.5	0.119	- 147.2	-291.3 to -3.2	0.045
No	Ref			Ref		
Gravidity	15.9	-36.6 to 68.4	0.552			
Dietary Diversity			0.600			
Low	Ref					
High	-40.7	-193.4 to 112.0	0.600	---	---	---
Physical Activity			0.641			
Low	-51.7	-236.9 to 133.4	0.583	---	---	---
Moderate	4.1	-183.6 to 191.8	0.966	---	---	---
High	Ref					
Consuming meat or chicken in the last 24 hours			0.085			
Yes	111.4	-15.4 to 238.2	0.085	130.6	5.5 to 266.7	0.060
No	Ref			Ref		
Pre-pregnancy weight			0.173			
Underweight	-114.9	-264.7 to 34.8	0.132	-150.9	-308.6 to -5.8	0.049
Normal weight	Ref			Ref		
Overweight or obese	57.2	-94.5 to 209.0	0.458	1.4	- 168.6 to 169.6	0.987
Gestational hypertension			0.076			
Yes	-216.7	-455.9 to 22.5	0.076	-310.7	-552.8 to -62.7	0.012
No	Ref			Ref		
GWG**			<0.001			
Inadequate	-252.9	-377.4 to -128.4	<0.001	-248.2	-383.6 to -112.8	<0.001
Adequate	Ref			Ref		
Excessive	47.8	-329.5 to 233.9	0.739	-58.5	-360.4 to 243.5	0.703
Sex of the baby			0.198			
Male	Ref			Ref		
Female	-75.0	-189.0 to 39.0	0.198	-111.6	-290.0 to 5.8	0.062
Maternal haemoglobin	-41.0	-81.2 to -0.9	0.045	-31.0	-72.4 to 10.3	0.141
Intimate partners violence			0.906			

Yes	8.8	-138.6 to 156.2	0.906	---	---	---
No	Ref					
Food insecurity			0.924			
Food secure	Ref			Ref		
Food insecure	-8.4	-183.5 to 166.6	0.924	52.8	-124.2 to 229.9	0.557
Perinatal depression			0.355			
Yes	-86.9	-271.8 to 97.8	0.355	---	---	---
No	Ref					

*ETB=Ethiopian Birr; **GWG=Gestational Weight Gain

Discussion

A cohort of pregnant women who started their ANC follow-up before or at 16 weeks of gestation was followed until they gave birth to assess the influence of GWG and other factors on birth weight. The overall mean birth weight was 3130 gm (SD, 509 gm). The proportion of LBW was 7.5% (95% CI: 4.8 % to 11.0%); 9.3% (95% CI: 5.7% to 14.2%) of women who gained inadequate gestational weight gave birth to LBW babies; while 4.5% (95% CI: 1.2 % to 11.1%) of women who gained adequate gestational weight gave birth to LBW babies. In addition, women's pre-pregnancy weight, GWG, having had a previous history of abortion, the occurrence of gestational hypertension were the significant predictors of birth weight.

The proportion of babies born with low birth weight (7.5% (95% CI: 4.8 % to 11.0%)) was comparable with the findings from the nationwide study using the 2016 Ethiopia Demographic Health Survey data, which was 13.2% (95% CI:10.7% to 15.7 %),[38] but lower than a finding from a meta-analysis conducted in 2018 in Ethiopia (pooled LBW data from 1995 to 2017), which was 17.3% (95% CI: 14.1% to 20.4 %).[39] Studies conducted in different parts of the country reported that maternal education,[38] employment status, income, and maternal age [39] are significantly associated with a baby's birth weight. However, these factors were not associated with birth weight in our study. This may be due to the sample size in our study being small because relatively a large number of women (64 women) lost from the study before their birth outcome was assessed. In addition, we were unable to access the birth records for sixteen

women (5.2%) since they gave birth in a rural location, and birth weight information was ascertained through a phone call to the mother.

In our study, infants born to underweight women were 151 gm lighter than infants born to normal-weight women. The proportion of LBW was higher (10%) among underweight women than that of normal-weight women (6.7%). Our findings were consistent with most prior reports that women's pre-pregnancy weight is associated with birth weight. [7 21 22 40] Maternal undernutrition, characterised by the low pre-pregnancy weight and inadequate gestational weight gain, can negatively influence fetal growth, leading to lower birth weight.

Gestational weight gain was found to have a significant influence on birth weight. However, this finding needs to take account of a number of issues. Firstly, the IOM GWG recommendations are the recommendations of high-income countries. These recommendations may not be suitable in low-income settings such as Ethiopia. Secondly, we measured pre-pregnancy weight before or at 16 weeks of gestation, at which time there may already have been an increase or a decrease of gestational weight. Finally, women's last weight was measured at 36 weeks of gestation; hence there may be some weight gain after 36 weeks. Having those issues in mind, our study identified that babies whose mothers gained inadequate gestational weight were significantly lighter than infants of mothers who gained adequate weight. Moreover, 9.3% of women who gained inadequate gestational weight gave birth to LBW babies compared to women who gained adequate gestational weight (4.5%). Other studies in similar settings also reported that LBW was more common among women who gained inadequate gestational weight than among women who gained adequate weight. [21 41] While there is a strong need for extra nutritional intake during pregnancy, more than a quarter of pregnant women (27.3%) in Addis Ababa restrict their food intake to avoid weight gain.[42]

This is primarily due to the perceived severity of birth complications due to large for gestational age babies making the birth more difficult and leading to cesarean birth.[43 44] Decreased nutrient intake due to poor dietary practices together with socio-economic and environmental factors could affect fetal growth, which also leads to lower birth weight.[45] Poor nutritional status among pregnant women may be associated with reduced placental size, which may lead to a reduction of nutrient transfer to the fetus from the placenta. Furthermore, the low nutritional status of mothers might reduce serum concentrations of hormones such as estrogen and leptin, which could result in impairment of fetal growth.[39] Nutritional counseling during pregnancy may improve women's feeding behaviour and hence, their nutritional status, which may help mothers to decrease the risk of delivering LBW babies.[46 47]

We found that the birth weight of newborns whose mothers had a previous history of abortions or miscarriages was significantly lower than those whose mothers had no history of abortions or miscarriages, an average decrease of 147 gm. This could be due to forty percent (40%) of multigravida women having had a previous history of abortions or miscarriages; 22% of these women experienced abortions or miscarriages at least two times. This would indicate that women and their partners' reproductive health and family planning use is low. A study conducted by the DKT Ethiopia (a non-profit organisation that promotes family planning), in 2018, on 880 women who received post-abortion care showed that 83.4% of aborted pregnancies were unplanned, and 91.6% of the women intentionally aborted their pregnancy.[48] This would suggest that the Ethiopian government needs to improve access to information and knowledge of reproductive choices and access to family planning services for both men and women.

Consistent with other studies, [49-52] our study showed gestational hypertension was significantly associated with lower infant birth weights. Infants born to mothers with gestational hypertension were 311 gm lighter than infants born to mothers without gestational hypertension. Similarly, 27.8% of women with gestational hypertension gave birth to LBW babies, while 5.7% of women without gestational hypertension gave birth to LBW babies. Although the relationship between gestational hypertension and an optimal intrauterine environment requires further exploration, some studies indicated that gestational hypertension is related to placental blood flow,[53 54] which affects fetal development, including birth weight.

In our study, nearly half of the women (47.5%) who gave birth through spontaneous vaginal birth had an episiotomy. The prevalence of episiotomy in Ethiopia was much higher than the recommended level by the WHO, which is 10%.[55] Another study from southern Ethiopia reported that the prevalence of episiotomy was 68%.[56] According to the 2016 Ethiopian emergency obstetric and newborn care assessment report, 9% of primary postpartum hemorrhage and 8% of maternal sepsis are attributed to episiotomy.[57] The reasons for this high prevalence of episiotomy in the Ethiopian setting may be due to the liberal use of episiotomy among care providers or other maternal-related factors such as the high prevalence of female genital mutilation. This may need further investigation.

Factors such as dietary diversity, food insecurity, physical activity, perinatal depression, and intimate partners violence were not associated with birth weight in our study. This could be due to a number of reasons. Firstly, these factors were captured before or at 16 weeks of gestations. The occurrence of these factors at a different stage of pregnancy would have different effects on GWG and birth weight. Future studies may need to measure the magnitude of dietary diversity, food insecurity, physical activity, perinatal depression, and intimate partner

violence at different trimesters of pregnancy and their effects on GWG and birth weight. Secondly, our sample size was relatively small because a significant number of women were lost during the follow-up before their birth outcome was captured. Finally, the effect of these factors may need to be checked in different settings, such as rural areas where a significant number of women suffer from household food insecurity.

Strengths and limitations of this study

The strength of this study was that women were prospectively followed to their GWG and birth weight. This study has some limitations. Firstly, a relatively large number of women (64) lost from the study before their birth outcome was assessed. In addition, we were unable to access the birth records for sixteen women (5.2%) since they gave birth in a rural location, and birth weight information was ascertained through a phone call to the mother. Secondly, the IOM GWG recommendations are the recommendations of high-income countries. These recommendations may not be suitable in low-income settings such as Ethiopia. Thirdly, we measured pre-pregnancy weight before or at 16 weeks of gestation, at which time there may already have been an increase or decrease of gestational weight. In addition, women's last weight was measured at 36 weeks of gestation; hence there may be some weight gain after 36 weeks of gestation. Finally, this study was conducted in the capital city of Ethiopia in the public health facilities; the situation in other parts of the country and private health facilities may be different.

Conclusion

We found that GWG was significantly associated with infants' birth weight. Infants whose mothers gained inadequate gestational weight were significantly lighter than the infants of mothers who gained adequate weight, an average decrease of 248 gm. Moreover, the birth weight of newborns whose mothers were underweight had a previous history of abortion (termination of pregnancy before the 28th week of gestation) or miscarriages, and had gestational hypertension, was significantly lower than those whose mothers were without this history. Program officers and policy-makers may need to design appropriate interventions to prevent LBW. Pregnancy-related weight management should be actively promoted through intensive counseling during routine antenatal care consultations. The practical applicability of the IOM guidelines and the effect of GWG (according to IOM recommendations) on pregnancy outcomes need further investigation in the Ethiopian context.

Ethics approval

Ethics approval for the study was obtained from the Haramaya University Institutional Health Research Ethics Review Committee [IHRERC/200/2018], Addis Ababa Health Bureau Institutional Review Board [A/A/HB/2576/227] and the University of Technology Sydney, Human Research Ethics Committee [UTS HREC18-2610].

Patient and Public Involvement

Patients or the public were not involved in our research's design, conduct, reporting, or dissemination plans.

Consent for publication

Informed consent was obtained from all participants for publication.

Availability of data and materials

The datasets used for the analysis are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

FA has conceived the study, performed data collection and analyses, and drafted the manuscript. AC. YD, MF, and AH have critically revised the design of the study, participated in the analyses, interpretation of the findings, and the draft the manuscript. All authors read this manuscript and finally approved it for submission.

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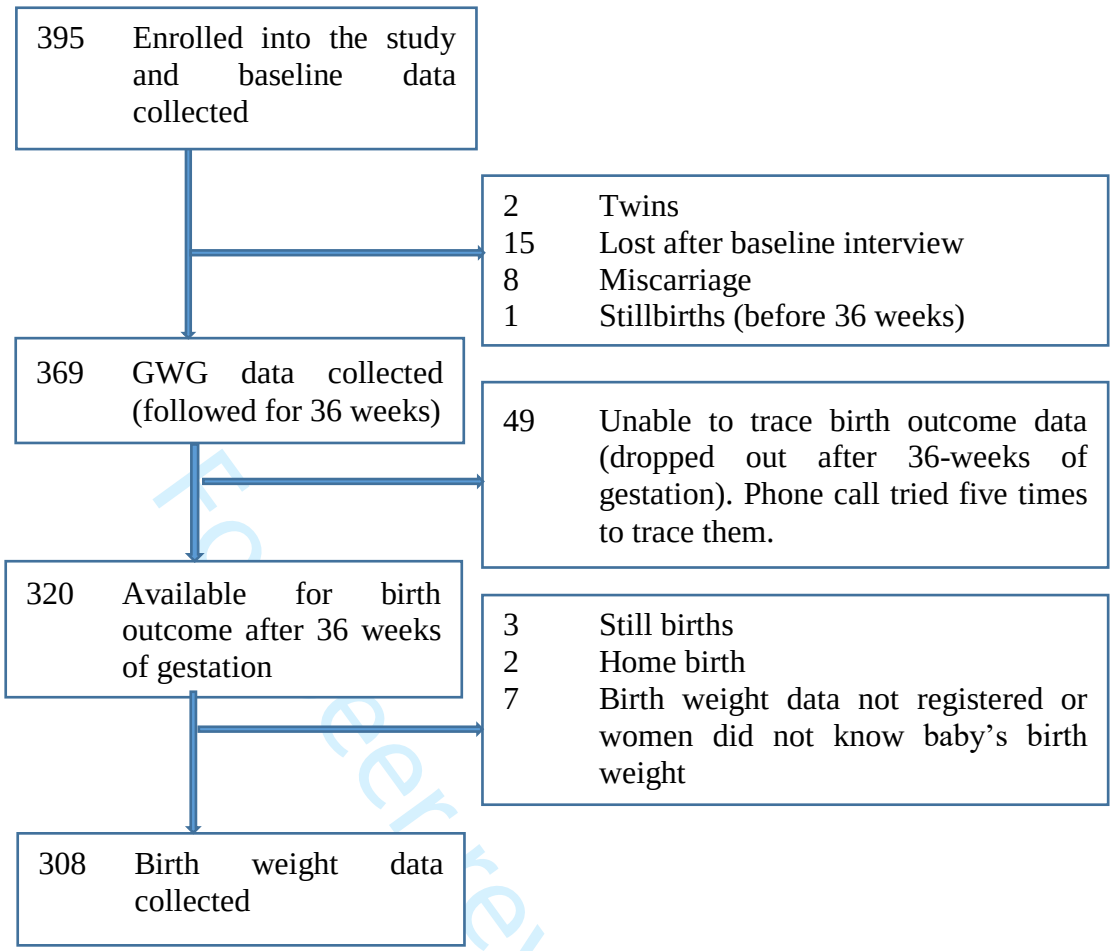

Figure 1: Flowchart showing data collection process from January to September 2019, Addis Ababa, Ethiopia

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Page 1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Pages 2 and 3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Pages 3 to 5
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 5
Methods			
Study design	4	Present key elements of study design early in the paper	Page 5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Pages 5 and 6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	Pages 5 and 6
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Pages 6 and 7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Page 6
Bias	9	Describe any efforts to address potential sources of bias	Pages 6 and 7
Study size	10	Explain how the study size was arrived at	Page 5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Pages 7 and 8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Pages 7 and 8
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	Figure 1
		(*d*) If applicable, explain how loss to follow-up was addressed	Figure 1
		(*e*) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Figure 1
		(b) Give reasons for non-participation at each stage	Figure 1
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Page 8, Tables 1 and 2
		(b) Indicate number of participants with missing data for each variable of interest	Tables 1 to 4
		(c) Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	Report numbers of outcome events or summary measures over time	NA
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Page 12 and 13, Table 4
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 14
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Pages 14 to 16
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 3
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 18

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Influence of Gestational Weight Gain on Baby's Birth Weight in Addis Ababa, Central Ethiopia: A Follow-up Study

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Abstract

Background: Gestational weight gain (GWG) is an important indicator of fetal wellbeing during pregnancy. Inadequate or excessive GWG could have undesirable effects on birth weight. However, information regarding the influence of GWG on birth weight is lacking from the Ethiopian setting.

Objective: This study aimed to determine the influence of GWG and other maternal-related factors on birth weight in Addis Ababa, Ethiopia.

Design and methods: A cohort of pregnant women who received the first antenatal care before or at 16 weeks of gestation in health centres in Addis Ababa were followed from January 10 to September 25, 2019. Data were collected using a structured questionnaire and medical record reviews. We conducted a multivariable linear regression analysis to determine the independent effect of gestational weight on birth weight.

Results: Of the 395 women enrolled in the study, the participants' pregnancy outcome was available for 329 (83.3%). The mean birth weight was 3130 (standard deviation, 509) gm. The proportion of low-birth-weight (<2500 gm) was 7.5% (95% CI: 4.8% to 11.0%). Babies born to underweight women were 151 gm (95% CI: 6 to 309 gm, p=0.049) lighter than babies born to normal-weight women. Similarly, babies whose mothers gained inadequate weight were 248 gm (95% CI: 113 to 384 gm, p<0.001) lighter than those who gained adequate weight. Moreover, babies whose mothers had a previous history of abortion or miscarriages or developed gestational hypertension in the current pregnancy were 147 gm (95% CI: 3 to 291 gm, p=0.045) and 311gm (95% CI: 63 to 553 gm, p=0.012) lighter, respectively, compared to those whose mothers had not.

Conclusions: Pre-pregnancy weight, GWG, having had a previous history of abortion or miscarriages, and developing gestational hypertension during a current pregnancy were

independently associated with birth weight. Pregnancy-related weight management should be actively promoted through intensive counseling during routine antenatal care contacts.

Keywords: Pre-pregnancy weight; Gestational weight gain; Birth weight; Pregnancy outcomes

Strengths and limitations of this study

- ✓ We prospectively followed the women's weight to assess GWG and its influence on birth weight.
- ✓ The United States Institute of Medicine GWG recommendations are recommendations of high-income countries that may not be suitable in low-income settings such as Ethiopia.
- ✓ We measured pre-pregnancy BMI before or at 16 weeks of gestation, at which time there may already have been an increase or decrease of gestational weight.
- ✓ This study was conducted in the capital city of Ethiopia in the public health facilities; the situation in other parts of the country and private health facilities may be different.

Introduction

Gestational weight gain (GWG) is attributable to pregnancy-related changes that women experience, such as the increase in the size of the uterus and the developing fetus, placenta, amniotic fluid, an increase in breast size, extracellular fluid, and blood volume. The American Institute of Medicine (IOM) has published recommendations for GWG of 12.5 to 18 kg for underweight women, 11.5 to 16 kilograms (kg) for normal-weight women, 7 to 11 kg for overweight women, and 5 to 9 kg for obese women. [1]

Gestational weight gain is a powerful indicator of maternal [2] and fetal [1] nutrition during pregnancy. Adequate GWG supports the growth and development of the fetus. [3] Both extremes, excessive or inadequate GWG, could result in undesirable pregnancy outcomes. [4-7] Excessive GWG is associated with pre-eclampsia, [8-10] cesarean birth, [8 10 11] macrosomia, large for gestation age, and high birth weight. [7] On the other hand, inadequate weight gain is associated with intrauterine growth restriction, [12] low for gestational age, preterm birth, [13-15] and low birth weight. [6 7]

Birth weight is one of the most important health indices in a newborn baby's growth, development, and future survival. [16] Birth weight is high if it is >4000 gm [17] or low if it is <2500 gm. [18] Low birth weight (LBW) is a proxy indicator for intrauterine malnutrition. Intrauterine malnutrition has life-long consequences for the fetus. [19] Identifying the influence of GWG on birth weight at the local level is important to provide an appropriate nutrition intervention during the pregnancy to reduce the risk of intrauterine malnutrition and improve GWG and birth outcomes. This could help to break the vicious intergenerational cycle of malnutrition. [20]

Factors influencing birth weight have been reported as including but not limited to maternal characteristics such as maternal age, [21] pre-pregnancy body mass index (BMI), [22] nutritional status, smoking, [23 24] and physical activity. [25-27] Factors related to the amount of growth and weight gain during pregnancy and the overall health of the mother and the fetus [28 29] also affect the amount of birth weight. In high-income settings, most pregnant women gain excessive gestational weight, and their babies are at a high risk of microsomia. [8 10 11] However, most pregnant women in low-income settings, including Ethiopia, gain inadequate gestational weight. [30-32] Hence, the effect of GWG on birth weight is expected to be different in these

settings. While there are several studies on factors affecting birth weight in Ethiopia, the influence of GWG on birth weight is not well understood in this setting. This study aimed to determine the influence of GWG and other maternal-related factors on birth weight in Addis Ababa, a central Ethiopian population.

Methods

Study setting and period

This study was conducted in Addis Ababa, Ethiopia's capital and largest city. Participants were selected from nine health centres. The previously published paper reported details of the study setting and numbers of women recruited from each facility. [31] A cohort of pregnant women were followed from before or at their 16th week of gestation until they gave birth to assess their GWG and the baby's birth weight from January 10 to September 25, 2019.

Sample size determination

Using the double proportion formula, we calculated the sample size using Open Epi Version 2.3. The assumptions for the sample size calculation were alpha value 0.05; power 80%; exposed to non-exposed ratio 1:2 (proportion of adequate GWG = 28% (exposure); and proportion of inadequate GWG = 69% (non-exposure))[30]; proportion of LBW among women who gained adequate gestational weight =1.7%; proportion of LBW among women who gained inadequate gestational weight =17.5%, [21] loss to follow-up =20%. The required sample was 189 (exposed =63, and control =126). However, since this study was part of another large study, we recruited a sample size of 395. The details of the sample size calculation assumptions were described in the study published elsewhere. [31]

Participants

Pregnant women who came to health centres before or at 16 weeks gestation for antenatal care were invited to participate, and those who agreed were recruited. We limited eligibility to women with a singleton pregnancy and no co-morbidities such as diabetes and hypertension.

Measurements

We used structured questionnaires with trained interviewers and face-to-face semi-structured interviews during the baseline data collection. The questionnaires collected information on socio-demographic characteristics, previous history of abortion (termination of pregnancy before the 28th week of gestation), low birth weight and stillbirth, pregnancy intention (planned/unplanned), gravidity, food insecurity, dietary diversity, physical activity, intimate partner violence, and depression-related symptoms. Data collectors measured baseline weight and height of the women and mid-upper arm circumference. Women's medical records were also reviewed both during baseline data collection and after birth to collect data such as gestational age (ultrasound result), blood pressure, level of hemoglobin, random blood sugar result, weight at the 36th weeks of gestation, mode of birth, episiotomy, birth weight, and sex of the baby. The primary author reviewed these data. Women were followed from before or at their 16th week of gestation until they gave birth to assess their GWG and the baby's birth weight. Sixteen women (5.2%) gave birth in a rural location, and we could not access the birth records. The birth weight information was ascertained for these women through a phone call to the mother.

The primary outcome variable in this study was birth weight. However, other pregnancy outcome variables such as the occurrence of gestational hypertension, modes of birth,

episiotomy, and birth outcomes (live birth, miscarriage, or stillbirth) were also considered as outcome variables.

We assessed the household food insecurity using the Household Food Insecurity Access Scale (HFIAS) [33] and the women's dietary diversity using the minimum dietary diversity-women (MDD-W) tool. [34] Women's physical activity level was measured using the International Physical Activity Questionnaire (IPAQ-long form). [35] Perinatal depression symptoms were measured using the Edinburgh postnatal depression scale (EPDS),[36] and intimate partner violence were measured using a questionnaire used by the World Health Organization (WHO) multi-country study on women's health and domestic violence. [37]

Statistical analysis

We double entered the data into Census and Survey Processing System (CSPro version 7.1). We exported data to STATA (version14, Stata Corp, 2015) for cleaning and analysis. Missing data were handled by performing pairwise deletion in the study. A particular variable was excluded when it had a missing value, but the case can still be used when analysing other variables with non-missing values. Hence, the analyses were performed on subsets of the data depending on where values are missing without completely omitting a case with missing some variables from the analyses.

Descriptive statistics, including frequencies, means, and standard deviations, were computed to describe the data. We calculated GWG by subtracting women's baseline weight from their weight at the 36th week of gestation. The adequacy of GWG (inadequate, adequate, or excessive) was determined using the IOM criteria. Birth weight was analysed as a categorical and continuous variable. Birth weight was classified as <2.5 kg (low birth weight), 2.5 kg to

3.9 kg (normal birth weight), ≥4.0 kg (macrosomia). The relationship between birth weight as a categorical variable (i.e., LBW, normal birth weight, or macrosomia) and other variables was reported descriptively using percentage. Since the number of LBW and macrosomic babies were small, we could not perform a regression analysis using birth weight as a categorical variable. Therefore, we assessed the influence of GWG and other variables on birth weight using a linear regression model. Variables with P-value <0.25 in the bivariable analysis were included in the multivariable analyses. However, some variable like food insecurity was considered important and forced into the multivariable model irrespective of the p-value. The assumptions for linear regression were checked. Scatter plots showed that observations were linear. Multicollinearity was checked using the variance inflation factor (VIF). The mean VIF value was 1.44. The VIF value for each predictor variable was < 3, which showed no multicollinearity among variables.

We performed multivariable linear regression analysis to determine the independent effect of gestational weight gain on birth weight, adjusting for other potential factors (educational status, average household monthly income, and previous history of abortion (termination of pregnancy before the 28th week of gestation), consuming meat or chicken in the last 24 hours, food insecurity, pre-pregnancy weight, maternal hemoglobin level, occurrence of gestational hypertension, and sex of the baby).

Results

Of the 395 women enrolled in the study, the participants' pregnancy outcome was available for 329 (83.3%). Eight of the 329 pregnancies ended in miscarriage (fetal loss before 28 weeks), three ended in stillbirths (fetal loss at or after 28 weeks), and the remaining were live births (Figure 1).

The mean age of the women was 25.3 (standard deviation, 3.9) years. Other socio-demographic and socio-economic variables of the participants were reported elsewhere.[31] As shown in Table 1, half of the participants, 199 (50.4%), were multigravida, of which 40.7% had a previous history of abortion or miscarriage; 4.5% had a prior history of stillbirth, and 3.3% had a prior history of LBW. Twenty-one (5.8%) developed gestational hypertension during pregnancy, while one woman developed gestational diabetes. Eighty-two percent (82%) gave birth via spontaneous vaginal birth (SVD), with 47.5% assisted with episiotomy. Most infants had normal birth weight (89.6%), and 7.5% had low birth weight. Twelve babies (3.9%) were born pre-term (Table 1).

As shown in Table 2, 85.6% of women who gained inadequate gestational weight gave birth vaginally; 74.4% of women who gained adequate gestational weight gave birth vaginally; 9.3% of women who gained inadequate gestational weight gave birth to LBW babies; while 4.5% of women who gained adequate gestational weight gave birth to LBW babies. Four percent (4.0%) of the women who gained inadequate gestational weight developed gestational hypertension, while 11% and 6% of women who gained adequate and excess gestational weight, respectively, developed gestational hypertension (Table 2). The details for the participants' GWG status, including trimester-specific GWG, were reported elsewhere. [31]

Table 1: Pregnancy and pregnancy outcome-related data of the study participants, Addis Ababa, Ethiopia, 2019

Variable	Frequency	Percentage
Gravidity (395)		
Primi gravida	196	49.6
Gravida 2	115	29.1
Gravida 3	54	13.7
gravida 4 and above	30	7.6
Inter–pregnancy interval (192)		
Less than 23 months	53	27.6
Greater or equal to 23 months	139	72.4
Previous history of abortion or miscarriages (199)		
Yes	81	40.7
No	118	59.3
Previous history of stillbirth (198)		
Yes	9	4.5
No	189	95.5
Mode of birth (314)		
Spontaneous vaginal birth	257	81.8
Caesarean section	57	18.2
Episiotomy (255)		
Yes	121	47.5
No	134	52.5
Sex of the baby		
Male	146	46.6
Female	167	53.4
Gestational hypertension		
Yes	21	5.8
No	338	94.2
Birth Weight		
Low birth weight	23	7.5
Normal birth weight	276	89.6
Macrosomia	9	2.9
Pre-term birth (births before 37 weeks)		
Yes	12	3.9
No	296	96.1

Table 2: Association between gestational weight gain and pregnancy outcomes, Addis Ababa, Ethiopia, 2019

Variables	Gestational weight gain			P-value for χ^2 test
	Inadequate GWG n (%)	Adequate GWG n (%)	Excess GWG n (%)	
Gestational hypertension (357)				
Yes	9 (3.8)	11 (11.0)	1 (5.9)	0.035
No	231(96.2)	89 (89.0)	16 (94.1)	
Total	240 (100)	100 (100)	17 (100)	
Mode of birth (313)				
Spontaneous vaginal delivery	179 (85.6)	67 (74.4)	11 (78.6)	0.064
Caesarean section	30 (14.4)	23 (25.5)	3 (21.4)	
Total	209 (100)	90 (100)	14 (100)	
Episiotomy (255)				
Yes	84 (47.5)	32 (47.8)	5 (45.5)	
No	93 (52.5)	35 (52.2)	6 (55.5)	0.990
Total	177 (100)	67 (100)	11 (100)	
Birth weight (307)				
LBW	19 (9.3)	4 (4.5)	0 (0.0)	
Normal birth weight	183 (89.7)	78 (87.6)	14 (100)	0.008
Macrosomia	2 (1.0)	7 (7.9)	0 (0.0)	
Total	204(100)	89(100)	14(100)	
Sex of the baby (312)				
Male	98 (46.9)	40 (44.9)	8 (57.1)	0.696
Female	111 (53.1)	49 (55.1)	6 (42.9)	
Total	209 (100)	87(100)	14(100)	
Pre-term baby (270)				
Yes	9 (5.1)	3 (3.9)	0 (0)	0.651
No	169 (94.9)	74 (96.1)	14 (100)	
Total	178 (100)	77(100)	14 (100)	

The mean birth weight was 3.13 kg with a standard deviation (SD) of 0.51 kg. It was 3.04 kg (SD = 0.49 kg) among women who gained inadequate gestational weight; 3.30 kg (SD = 0.52 kg) kg among women who gained adequate gestational weight; and 3.25 kg (SD =0.53 kg) among women who gained excessive gestational weight; 3.02 kg (SD =0.46 kg) among underweight women; and 3.14 kg (SD=0.53 kg) among normal-weight women. The proportion of LBW was 10.3% (95% CI: 4.0 % to 21.2%) among underweight women while it was 6.7% (95% CI: 3.6% to 11.2%) among normal-weight women. Similarly, 27.8% of women who developed gestational hypertension gave birth to LBW babies while only 5.7% of women who

did not develop gestational hypertension gave birth to LBW babies; 12.7% of women with low MUAC (<23cm) gave to LBW babies compared to women with high MUAC (6.5%) (Table 3).

Table 3: Birth weight in relation to different factors in women of Addis Ababa, Ethiopia, 2019

Variable	LBW, n (%)	Normal birth weight, n (%)	Macrosomia, N (%)	Mean birth weight (standard deviation) (kg)
Women's age category (n=308)				
< 20 years	1 (7.1)	13 (92.9)	0 (0.0)	2.96 (0.50)
20 to 29 years	18 (7.3)	220 (89.4)	8 (3.3)	3.13 (0.51)
≥30 years	4 (8.3)	43 (89.6)	1 (2.1)	3.14 (0.53)
Marital status (n=308)				
Married	22 (7.4)	267 (89.9)	8 (2.7)	3.13 (0.51)
Single	1 (9.1)	9 (81.8)	1 (9.1)	3.15 (0.46)
Educational status (n=308)				
No formal education	2 (8.0)	23 (92.0)	0 (0.0)	3.17 (0.49)
Primary	12 (9.7)	111(89.5)	1 (0.8)	3.01(0.48)
Secondary	8 (9.0)	75 (84.3)	6 (6.7)	3.15 (0.58)
Tertiary	1 (1.4)	67 (95.7)	2 (2.9)	3.23 (0.45)
Occupational Status (n=308)				
House duty	14 (9.2)	133 (87.5)	5 (3.3)	3.07 (0.54)
Employee	4 (4.0)	95 (94.0)	2 (2.0)	3.19 (0.44)
Merchant	2 (6.1)	29 (87.8)	2 (6.1)	3.26(0.55)
Others*	3 (13.4)	19 (86.4)	0(0.0)	3.00(0.47)
Average monthly income (n=284)				
< 5000 ETB**	16 (8.3)	173 (90.1)	3 (1.6)	3.10 (0.51)
5000 to 10,000 ETB	5 (8.1)	54 (87.1)	3 (4.8)	3.10 (0.49)
≥ 10,000 ETB	1 (3.3)	28 (93.4)	1 (3.3)	3.28 (0.46)
Pregnancy intention (n=304)				
Intended	22 (8.0)	246 (89.5)	7 (2.5)	3.12 (0.51)
Unintended	1 (3.4)	26 (89.7)	2 (6.9)	3.22 (0.48)
Gravidity (n=308)				
Primigravida	9 (6.2)	132 (91.0)	4 (2.8)	3.11 (0.50)
Multigravida	14 (8.6)	144 (88.3)	5 (3.1)	3.14 (0.52)
Time gap between pregnancy (n=252)				
< 23 months	4 (9.8)	37 (90.2)	0 (0.0)	3.09 (0.51)
≥ 23 months	10 (8.6)	101 (87.1)	5 (4.3)	3.16 (0.53)
Dietary Diversity (n=308)				
Low dietary diversity	1 (1.9)	50 (96.2)	1 (1.9)	3.09 (0.49)
High dietary diversity	22 (8.6)	226 (88.3)	8 (3.1)	3.13 (0.52)
Physical Activity (n=308)				
Low	13 (9.0)	127 (88.2)	4 (2.8)	3.10 (0.50)
Moderate	7 (5.5)	115 (90.6)	5 (3.9)	3.15 (0.52)
High	3 (8.1)	34 (91.9)	0 (0.0)	3.15 (0.53)
MUAC*** (n=301)				
Low MUAC	7 (12.7)	46 (83.6)	2 (3.7)	3.02 (0.53)
High MUAC	16 (6.5)	223 (90.6)	7 (2.9)	3.15 (0.50)
Pre-pregnancy weight (n=307)				
Underweight	6 (10.3)	52 (89.7)	0 (0.0)	3.02 (0.46)
Normal weight	13 (6.7)	173 (89.2)	8 (4.1)	3.14 (0.53)
Overweight or obese	4 (7.1)	51 (91.1)	1 (1.8)	3.14 (0.50)
Gestational hypertension (n=298)				
Yes	5 (27.8)	12 (66.7)	1 (5.5)	2.93 (0.69)
No	16 (5.7)	257 (91.8)	7 (2.5)	3.14 (0.49)
Intimate partners violence (n=308)				
Yes	2 (3.5)	53 (93.0)	2 (3.5)	3.13 (0.50)
No	21(8.4)	223 (88.8)	7 (2.8)	3.12 (0.51)

Food insecurity (n=304)				
Food secure	19 (7.1)	239 (89.9)	8 (3.0)	3.12 (0.50)
Food insecure	4 (10.5)	33 (86.8)	1 (2.6)	3.12 (0.58)
Consuming meat or chicken in the last 24 hours (n=307)				
Yes	5 (5.7)	80 (92.0)	2 (2.3)	3.20 (0.50)
No	18 (8.2)	195 (88.6)	7 (3.2)	3.09 (0.51)
Perinatal depression (n=308)				
Yes	3 (9.1)	29 (87.9)	1 (3.0)	3.14 (0.51)
No	20 (7.3)	247 (89.8)	8 (2.9)	3.05 (0.49)

*students, daily labourer, farmer; **Ethiopian Birr; *** MUAC = Mid Upper Arm Circumference

Predictors of infants' birth weight

Of the variables included the multivariable model, previous history of abortions or miscarriages, occurrence of gestational hypertension, pre-pregnancy weight, and GWG were significantly associated with infants' birth weight at p-value <0.05.

The ß–coefficient showed that infants born to underweight women were 150 gm (95% CI: 6 to 309 gm, p=0.049) lighter than infants born to normal-weight women. Similarly, infants whose mothers had inadequate weight gain were 248 gm (95% CI: 113 to 384 gm, p<0.001) lighter than those who gained adequate weight. In the same vein, infants whose mothers had a previous history of abortion or miscarriages and developed gestational hypertension during current pregnancy were 147 gm (95% CI: 3 to 291 gm, p=0.045) and 311 gm (95% CI: 63 to 553 gm, p = 0.012), respectively, lighter compared to those whose mothers had not (Table 4).

Maternal age, educational status, monthly income, hemoglobin level, pregnancy intention, gravidity, dietary diversity, food insecurity, physical activity, intimate partners' violence, and perinatal depression were not significantly associated with birth weight.

Table 4: Bivariable and multivariable linear regression analysis for predictors of birth weight (in gram) in Addis Ababa, Ethiopia 2019

Variable	Bivariate regression			Multivariable regression		
	Crude-ß	95%CI	P-value	Adjusted ß	95%CI	P-value
Women's age			0.446			
< 20 years	-176.0	-451.7 to 99.7	0.210	---	---	---
20 to 29 years	Ref					
≥30 years	6.0	-151.9 to 164.7	0.936	---	---	---
Educational status			0.065			
No formal education	- -57.6	-289.6 to 174.5	0.626	-83.3	- 332.1 to 168.8	0.515
Primary	-194.8	-343.7 to -45.9	0.010	-152.2	- 315.9 to 11.5	0.068
Secondary	-84.1	-243.2 to 74.9	0.299	-59.4	-228.9 to 110.9	0.493
Tertiary	Ref			Ref		
Occupational Status			0.258			
House duty	-116.57	-244.5 to 11.4	0.274	---	---	---
Employee	Ref					
Merchant	67.9	-131.9 to 267.8	0.504	---	---	---
Others*	-185.1	-419.6 to 49.5	0.122	---	---	---
Average monthly income			0.190			
< 5000 ETB*	-177.9	-372.5 to 16.6	0.073	- 112.9	-323.9 to 99.0	0.293
5000 to 10000 ETB	-175.9	-396.4 o 44.4	0.117	-161.9	-389.1 to 64.8	0.161
≥10000 ETB	Ref			Ref		
Pregnancy intention			0.294			
Intended	Ref					
Unintended	104.8	-91.4 to 301.1	0.294	---	---	---
Previous history of abortion or miscarriages			0.119			
Yes	-109.7	-247.8 to 28.5	0.119	- 147.2	-291.3 to -3.2	0.045
No	Ref			Ref		
Gravidity	15.9	-36.6 to 68.4	0.552			
Dietary Diversity			0.600			
Low	Ref					
High	-40.7	-193.4 to 112.0	0.600	---	---	---
Physical Activity			0.641			
Low	-51.7	-236.9 to 133.4	0.583	---	---	---
Moderate	4.1	-183.6 to 191.8	0.966	---	---	---
High	Ref					
Consuming meat or chicken in the last 24 hours			0.085			
Yes	111.4	-15.4 to 238.2	0.085	130.6	5.5 to 266.7	0.060
No	Ref			Ref		
Pre-pregnancy weight			0.173			
Underweight	-114.9	-264.7 to 34.8	0.132	-150.9	-308.6 to -5.8	0.049
Normal weight	Ref			Ref		
Overweight or obese	57.2	-94.5 to 209.0	0.458	1.4	- 168.6 to 169.6	0.987
Gestational hypertension			0.076			
Yes	-216.7	-455.9 to 22.5	0.076	-310.7	-552.8 to -62.7	0.012
No	Ref			Ref		
GWG**			<0.001			
Inadequate	-252.9	-377.4 to -128.4	<0.001	-248.2	-383.6 to -112.8	<0.001
Adequate	Ref			Ref		
Excessive	47.8	-329.5 to 233.9	0.739	-58.5	-360.4 to 243.5	0.703
Sex of the baby			0.198			
Male	Ref			Ref		
Female	-75.0	-189.0 to 39.0	0.198	-111.6	-290.0 to 5.8	0.062
Maternal haemoglobin	-41.0	-81.2 to -0.9	0.045	-31.0	-72.4 to 10.3	0.141
Intimate partners violence			0.906			

Yes	8.8	-138.6 to 156.2	0.906	---	---	---
No	Ref					
Food insecurity			0.924			
Food secure	Ref			Ref		
Food insecure	-8.4	-183.5 to 166.6	0.924	52.8	-124.2 to 229.9	0.557
Perinatal depression			0.355			
Yes	-86.9	-271.8 to 97.8	0.355	---	---	---
No	Ref					

*ETB=Ethiopian Birr; **GWG=Gestational Weight Gain

Discussion

A cohort of pregnant women who started their ANC follow-up before or at 16 weeks of gestation was followed until they gave birth to assess the influence of GWG and other factors on birth weight. The overall mean birth weight was 3130 gm (SD, 509 gm). The proportion of LBW was 7.5% (95% CI: 4.8 % to 11.0%); 9.3% (95% CI: 5.7% to 14.2%) of women who gained inadequate gestational weight gave birth to LBW babies; while 4.5% (95% CI: 1.2 % to 11.1%) of women who gained adequate gestational weight gave birth to LBW babies. In addition, women's pre-pregnancy weight, GWG, having had a previous history of abortion, the occurrence of gestational hypertension were the significant predictors of birth weight.

The proportion of babies born with low birth weight (7.5% (95% CI: 4.8 % to 11.0%)) was comparable with the findings from the nationwide study using the 2016 Ethiopia Demographic Health Survey data, which was 13.2% (95% CI:10.7% to 15.7 %),[38] but lower than a finding from a meta-analysis conducted in 2018 in Ethiopia (pooled LBW data from 1995 to 2017), which was 17.3% (95% CI: 14.1% to 20.4 %).[39] Studies conducted in different parts of the country reported that maternal education,[38] employment status, income, and maternal age [39] are significantly associated with a baby's birth weight. However, these factors were not associated with birth weight in our study. This may be due to the sample size in our study being small because relatively a large number of women (64 women) lost from the study before their birth outcome was assessed. In addition, we were unable to access the birth records for sixteen

women (5.2%) since they gave birth in a rural location, and birth weight information was ascertained through a phone call to the mother.

In our study, infants born to underweight women were 151 gm lighter than infants born to normal-weight women. The proportion of LBW was higher (10%) among underweight women than that of normal-weight women (6.7%). Our findings were consistent with most prior reports that women's pre-pregnancy weight is associated with birth weight. [7 21 22 40] Maternal undernutrition, characterised by the low pre-pregnancy weight and inadequate gestational weight gain, can negatively influence fetal growth, leading to lower birth weight.

Gestational weight gain was found to have a significant influence on birth weight. However, this finding needs to take account of a number of issues. Firstly, the IOM GWG recommendations are the recommendations of high-income countries. These recommendations may not be suitable in low-income settings such as Ethiopia. Secondly, we measured pre-pregnancy weight before or at 16 weeks of gestation, at which time there may already have been an increase or a decrease of gestational weight. Finally, women's last weight was measured at 36 weeks of gestation; hence there may be some weight gain after 36 weeks. Having those issues in mind, our study identified that babies whose mothers gained inadequate gestational weight were significantly lighter than infants of mothers who gained adequate weight. Moreover, 9.3% of women who gained inadequate gestational weight gave birth to LBW babies compared to women who gained adequate gestational weight (4.5%). Other studies in similar settings also reported that LBW was more common among women who gained inadequate gestational weight than among women who gained adequate weight. [21 41] While there is a strong need for extra nutritional intake during pregnancy, more than a quarter of pregnant women (27.3%) in Addis Ababa restrict their food intake to avoid weight gain.[42]

This is primarily due to the perceived severity of birth complications due to large for gestational age babies making the birth more difficult and leading to cesarean birth.[43 44] Decreased nutrient intake due to poor dietary practices together with socio-economic and environmental factors could affect fetal growth, which also leads to lower birth weight.[45] Poor nutritional status among pregnant women may be associated with reduced placental size, which may lead to a reduction of nutrient transfer to the fetus from the placenta. Furthermore, the low nutritional status of mothers might reduce serum concentrations of hormones such as estrogen and leptin, which could result in impairment of fetal growth.[39] Nutritional counseling during pregnancy may improve women's feeding behaviour and hence, their nutritional status, which may help mothers to decrease the risk of delivering LBW babies.[46 47]

We found that the birth weight of newborns whose mothers had a previous history of abortions or miscarriages was significantly lower than those whose mothers had no history of abortions or miscarriages, an average decrease of 147 gm. This could be due to forty percent (40%) of multigravida women having had a previous history of abortions or miscarriages; 22% of these women experienced abortions or miscarriages at least two times. This would indicate that women and their partners' reproductive health and family planning use is low. A study conducted by the DKT Ethiopia (a non-profit organisation that promotes family planning), in 2018, on 880 women who received post-abortion care showed that 83.4% of aborted pregnancies were unplanned, and 91.6% of the women intentionally aborted their pregnancy.[48] This would suggest that the Ethiopian government needs to improve access to information and knowledge of reproductive choices and access to family planning services for both men and women.

Consistent with other studies, [49-52] our study showed gestational hypertension was significantly associated with lower infant birth weights. Infants born to mothers with gestational hypertension were 311 gm lighter than infants born to mothers without gestational hypertension. Similarly, 27.8% of women with gestational hypertension gave birth to LBW babies, while 5.7% of women without gestational hypertension gave birth to LBW babies. Although the relationship between gestational hypertension and an optimal intrauterine environment requires further exploration, some studies indicated that gestational hypertension is related to placental blood flow,[53 54] which affects fetal development, including birth weight.

Factors such as dietary diversity, food insecurity, physical activity, perinatal depression, and intimate partners violence were not associated with birth weight in our study. This could be due to a number of reasons. Firstly, these factors were captured before or at 16 weeks of gestations. The occurrence of these factors at a different stage of pregnancy would have different effects on GWG and birth weight. Future studies may need to measure the magnitude of dietary diversity, food insecurity, physical activity, perinatal depression, and intimate partner violence at different trimesters of pregnancy and their effects on GWG and birth weight. Secondly, our sample size was relatively small because a significant number of women were lost during the follow-up before their birth outcome was captured. Finally, the effect of these factors may need to be checked in different settings, such as rural areas where a significant number of women suffer from household food insecurity.

Strengths and limitations of this study

The strength of this study was that women were prospectively followed to their GWG and birth weight. This study has some limitations. Firstly, a relatively large number of women (64) lost

from the study before their birth outcome was assessed. In addition, we were unable to access the birth records for sixteen women (5.2%) since they gave birth in a rural location, and birth weight information was ascertained through a phone call to the mother. Secondly, the IOM GWG recommendations are the recommendations of high-income countries. These recommendations may not be suitable in low-income settings such as Ethiopia. Thirdly, we measured pre-pregnancy weight before or at 16 weeks of gestation, at which time there may already have been an increase or decrease of gestational weight. In addition, women's last weight was measured at 36 weeks of gestation; hence there may be some weight gain after 36 weeks of gestation. Finally, this study was conducted in the capital city of Ethiopia in the public health facilities; the situation in other parts of the country and private health facilities may be different.

Conclusion

We found that GWG was significantly associated with infants' birth weight. Infants whose mothers gained inadequate gestational weight were significantly lighter than the infants of mothers who gained adequate weight, an average decrease of 248 gm. Moreover, the birth weight of newborns whose mothers were underweight had a previous history of abortion (termination of pregnancy before the 28th week of gestation) or miscarriages, and had gestational hypertension, was significantly lower than those whose mothers were without this history. Program officers and policy-makers may need to design appropriate interventions to prevent LBW. Pregnancy-related weight management should be actively promoted through intensive counseling during routine antenatal care consultations. The practical applicability of the IOM guidelines and the effect of GWG (according to IOM recommendations) on pregnancy outcomes need further investigation in the Ethiopian context.

Ethics approval

Ethics approval for the study was obtained from the Haramaya University Institutional Health Research Ethics Review Committee [IHRERC/200/2018], Addis Ababa Health Bureau Institutional Review Board [A/A/HB/2576/227] and the University of Technology Sydney, Human Research Ethics Committee [UTS HREC18-2610].

Patient and Public Involvement

Patients or the public were not involved in our research's design, conduct, reporting, or dissemination plans.

Consent for publication

Informed consent was obtained from all participants for publication.

Availability of data and materials

The datasets used for the analysis are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

FA has conceived the study, performed data collection and analyses, and drafted the manuscript. AC. YD, MF, and AH have critically revised the design of the study, participated in the analyses, interpretation of the findings, and the draft the manuscript. All authors read this manuscript and finally approved it for submission.

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Figure legend

Figure 1: Flowchart showing data collection process from January to September 2019, Addis Ababa, Ethiopia

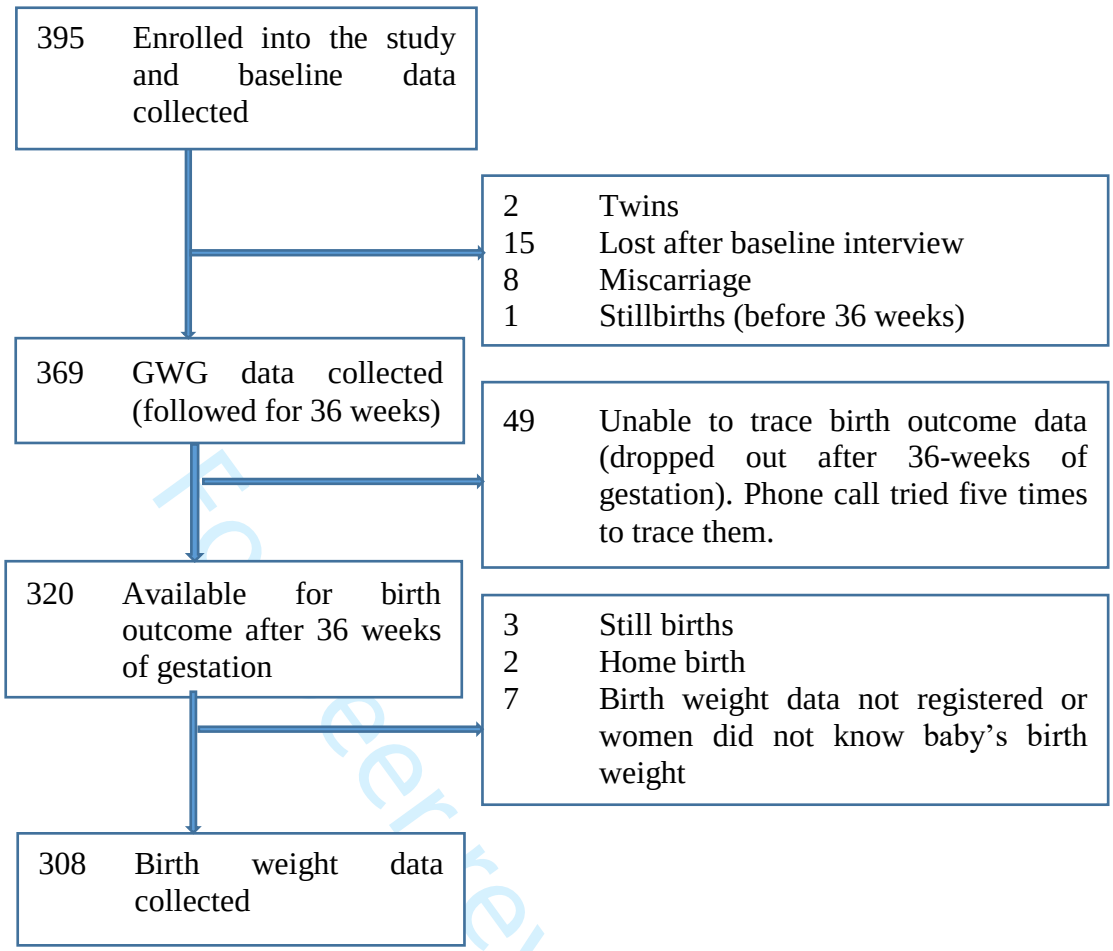

Figure 1: Flowchart showing data collection process from January to September 2019, Addis Ababa, Ethiopia

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Page 1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Pages 2 and 3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Pages 3 to 5
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 5
Methods			
Study design	4	Present key elements of study design early in the paper	Page 5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Pages 5 and 6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	Pages 5 and 6
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Pages 6 and 7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Page 6
Bias	9	Describe any efforts to address potential sources of bias	Pages 6 and 7
Study size	10	Explain how the study size was arrived at	Page 5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Pages 7 and 8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Pages 7 and 8
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	Figure 1
		(*d*) If applicable, explain how loss to follow-up was addressed	Figure 1
		(*e*) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Figure 1
		(b) Give reasons for non-participation at each stage	Figure 1
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Page 8, Tables 1 and 2
		(b) Indicate number of participants with missing data for each variable of interest	Tables 1 to 4
		(c) Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	Report numbers of outcome events or summary measures over time	NA
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Page 12 and 13, Table 4
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 14
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Pages 14 to 16
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 3
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 18

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.