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Maternal obesity, lifestyle factors and associated pregnancy outcomes in Ibadan, Nigeria: a Nigerian cohort study

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Maternal obesity is a neglected but modifiable maternal health threat in Nigeria associated with adverse pregnancy outcomes. We investigated maternal obesity, lifestyle factors, and pregnancy outcomes in Ibadan, Nigeria. We used the Ibadan Pregnancy Studtudy (IbPCS) data. Maternal obesity (BMI ≥ 30.0 kg/m^2) was the primary outcome variable, and pregnancy outcomes were secondary. Information on lifestyle characteristics, i.e. diet and physical activity in pregnancy, were obtained using standardised instruments. We constructed bivariate, multivariate logistic and Poisson models at < 0.05 significance. The prevalence of maternal obesity was 19.3%: 95% CI (17.5 – 21.3). Maternal age, parity and income were associated (p < 0.05) with maternal obesity. Regular physical activity was associated with decreased odds of maternal obesity. Maternal obesity was directly related to experiencing any adverse pregnancy outcome by twofold [Adjusted Odds Ratio: 1.87, 95% CI (1.36 – 2.57). The relative risk (RR) of macrosomia: RR 1.83, 95% CI (1.08 – 3.08)], caesarean section: [RR: 1.41, 95% CI (1.09 – 1.81)], and birth asphyxia at 1 min [RR: 1.50, 95% CI (1.01 – 2.37)], GDM [RR 1.74 (95% CI): (1.15 – 2.62). Maternal obesity is prevalent in Ibadan and increases the risk of adverse perinatal events. Maternal services should emphasise physical activity and a healthy diet to reduce maternal obesity.

Obesity is the excessive storage of fat that could impair health and is an important maternal and public health challenge in the twenty-first century[1]. Worldwide, the prevalence of obesity nearly tripled in the last four decades, with about two billion overweight and 650 million obese adults[2] Globally, obesity among women of reproductive age increased concomitantly with the rise of obesity in the general population[3,4]. Maternal obesity or obesity in pregnancy has been defined as a prepregnancy body mass index (BMI) equal to or greater than 30 kg/m^2[3]. Maternal obesity threatens maternal and child health because of its associated short-term and long-term complications. The prevalence of maternal obesity in Africa ranges from 0.7% to 56.4%[4].

Diet and physical activity are vital modifiable factors of maternal obesity, especially in low and middle countries (LMIC) undergoing economic and nutritional transitions[5]. The nutritional transition refers to a change from traditional diets rich in grains, fruits, and vegetables to Westernised diets rich in processed foods high in sugar, salt and saturated fats. Also, there has been a remarkable drop in physical activity levels due to adopting sedentary lifestyles from an undue reliance on technology and automated devices, sedentary pastimes such as watching television and sedentary occupations requiring prolonged sitting hours[6,7]. The changes in dietary habits, physical activity, and sedentary behaviour have contributed to an increase in positive energy balance and obesity over time. Hence, nutritional factors and physical activity are potential exposures that could be improved by public health interventions to prevent and mitigate the challenge of maternal obesity and its consequences[8]. However, they have received little attention in sub-Saharan Africa, especially Nigeria[9].

Furthermore, maternal obesity adversely affects maternal and child health[10–12]. For instance, maternal obesity has become the leading risk factor for preventable maternal mortality in higher-income countries. with 50 per cent of maternal deaths occurring in obese compared to normal-weight women in the United Kingdom[13]. Similarly, higher neonatal mortality rates have been documented among obese mothers than mothers with average weight in sub-Saharan Africa[14]. The non-fatal outcomes of maternal obesity consist of gestational diabetes and hypertension in pregnancy, including pre-eclampsia, increased operative delivery, macrosomia, shoulder dystocia, increased hospital admissions, and health care costs[15–17]. Maternal obesity also has long-term

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implications on the mother's and her infant's health and well-being, especially by programming the child's future risk for chronic diseases[18].

Nigeria is still has among the highest numbers of maternal deaths worldwide, second to India[19,20]. Simultaneously, Nigeria has also experienced one of the highest rises in the prevalence of maternal obesity globally in the last decade[21]. In addition, certain socio-cultural factors or dietary practices, including food choices and myths such as "eating for two" during pregnancy and sedentary behaviours during pregnancy, have also contributed to the increased risk of maternal obesity and excessive gestational weight gain among Nigerian women[22,23]. Hence, maternal obesity is an emerging and neglected maternal health threat in Nigeria. This can worsen the maternal mortality burden and strain its fragile health system through increased pregnancy complications and surgical interventions, higher cost of treatment, need for sophisticated equipment, prolonged hospital stays and neonatal admissions[24]. Therefore, tackling maternal obesity and its consequences has become necessary because, if left unattended, it can reverse the ongoing gains in maternal and child mortality reduction in Nigeria. Modifiable lifestyle factors such as diet and physical activity are effective interventions that can mitigate the effect of maternal obesity, and this has been largely unaddressed in Nigeria and sub-Saharan Africa (sSA)[4]. This study is essential for assessing the size and burden of maternal obesity to prioritise it within Nigeria's maternal health care framework[17]. This study investigated the influence of sociodemographic and lifestyle factors (diet and physical activity) on maternal obesity and the associated pregnancy outcomes in Ibadan, Nigeria, using a prospective cohort study – the Ibadan Pregnancy Cohort Study (IbPCS).

Methods

Study design and participants

The Ibadan Pregnancy Cohort Study (IbPCS) methodology has been fully described elsewhere[25]. The IbPCS is a prospective cohort study investigating the associations between maternal obesity and lifestyle characteristics with gestational diabetes mellitus (GDM), gestational weight gain and pregnancy outcomes in Ibadan, Nigeria. The study was carried out from April 2018 to September 2019 among 1745 pregnant women and antenatal care attendees of four health facilities within the Ibadan metropolis: University College Hospital, Adeoyo Maternity Teaching Hospital, Jericho Specialist Hospital and Saint Mary Catholic Hospital, Oluyoro, Ibadan. These facilities are major comprehensive obstetric services providers and referral centres for obstetric emergencies within the Ibadan metropolis, Oyo State, South-West of Nigeria. Respondents were recruited early in pregnancy (gestational age ≤ 20 weeks) during their booking antenatal visits (mean gestation age (GA) at booking 16.7 ± 4.1 weeks and followed up throughout pregnancy until delivery. The eligibility criteria are as follows: within the early 20 weeks, maternal age ≥ 18 years or severe medical co-morbidity. Data were collected using pretested, interviewer-administered questionnaires and structured proforma at booking, third trimester, and delivery. An oral glucose tolerance test was conducted between 24 and 28 weeks of gestation to ascertain the diagnosis of GDM using the criteria of the International Association of Diabetic and Pregnancy Study Group (IADPSG). The research nurses abstracted the delivery information and pregnancy outcome data from medical records (case files, surgical reports, nursing records, discharge summaries, etc.). Lifestyle characteristics (Physical Activity and Dietary Patterns) were assessed using the pregnancy physical activity questionnaire (PPAQ) and a semi-quantitative food frequency questionnaire. Pregnancy outcomes assessed were the mode of delivery, macrosomia, low birth weight (LBW), prematurity, postdated pregnancy, birth asphyxia, postpartum haemorrhage (PPH) and perineal tear. In this current study, we examined the influence of sociodemographic and lifestyle factors, particularly diet and physical activity, on maternal obesity and the associated pregnancy outcomes in Ibadan, Nigeria. This study's primary outcome was maternal obesity, and pregnancy outcomes were secondary. The sociodemographic and lifestyle factors were explanatory variables. The flow chart of study participants from recruitment until delivery by obesity status and adverse events is displayed in Fig. 1.

Measures

Dietary pattern and physical activity

The Ibadan Pregnancy Cohort Study assessed the dietary habits of pregnant women during enrolment using a food frequency questionnaire. Dietary data were analysed using principal component analysis (PCA), and five dietary patterns were extracted and named "protein rich with non-alcoholic beverages diet", "fruits", "typical diet with alcoholic beverages", "legumes", and "refined grains" dietary patterns. The maternal dietary patterns and the associated factors of the Ibadan pregnancy cohort participants have been fully described and published[26].
Physical activity: The study participants' physical activity levels and sedentary behaviour were assessed using the Pregnancy Physical Activity Questionnaire (PPAQ) and analysed using the PPAQ guidelines[27]. We obtained total energy expenditure in metabolic equivalent hours per week. We categorised energy expenditure by intensity (vigorous, moderate, light, & sedentary) and type (household/care, occupation-related, transportation-related, and sports/exercise). Notably, the Ibadan pregnancy cohort participants' physical activity patterns and sedentary behaviours have been published[28]. Maternal Body mass index (BMI): BMI was classified according to the WHO cutoff points: underweight (< 18.5 kg/m2), normal weight (18.5–24.9 kg/m2), overweight (25.0–29.9 kg/m2), and obese (30 kg/m^2)[29]. We constructed the *Wealth Index* using household items such as radio and television, which were transformed into scores and tertiles using principal component analysis[20]. We assessed the participants' mode of transport and grouped them into (i.) passive transport (ownership of motorised transport) and active transport (e.g. walking)[30].

Pregnancy outcomes

(i.) Caesarean section refers to the infant's abdominal surgical delivery, whether elective or emergency; (ii.) *Spontaneous vaginal delivery*: the delivery of the child through the vagina; iii.*) Induction of labour* refers to

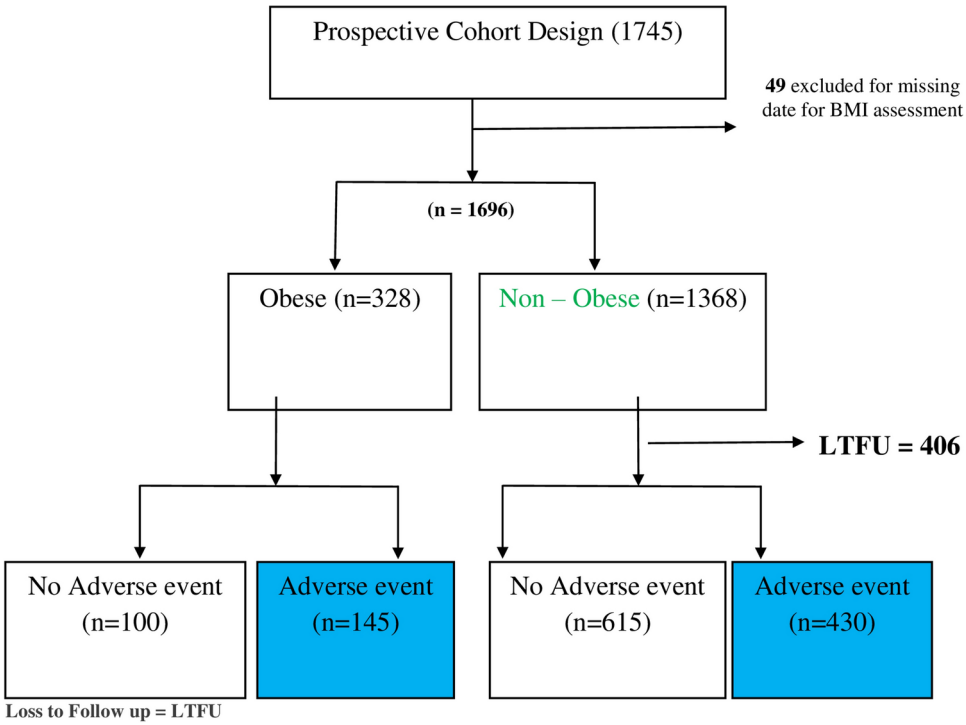

Fig. 1. Flow chart of study participants from recruitment until delivery by obesity status and adverse event.

infants born following the stimulation of the process of childbirth. (iv.) *Macrosomia* refers to infants with birthweight ≥ 4.0 kg while LBW babies are < 2.5 kg; (v.) *Gestational diabetes Mellitus*: GDM diagnosis was made based on the IADPSG criteria[31]. (vi.) Preterm birth occurred before 37 completed weeks of gestation, while postdated pregnancy refers to infants born after 42 completed weeks. vii.) *Birth Asphyxia* at 1 min and 5 min: defined as infants with APGAR score ≤ 7 at one minute and five minutes respectively; (viii.) *Postpartum Haemorrhage*: Blood loss ≥ 500 mls post-vaginal delivery and ≥ 1000mls post-caesarean section; ix.) *Any Adverse Event*: Women who had experienced at least one negative pregnancy outcome in the woman. These were ascertained from the health facility delivery records. *Explanatory variables:* The explanatory variables examined were maternal age (< 20, 20 -29, 30 -39, ≥ 40 years); gravidity (primigravida, gravida 2–4, gravida ≥ 5; parity (primipara, para 2–4, gravida ≥ 5; employment status (employed, unemployed); marital status (single, ever married); maternal education (≤ primary, secondary, tertiary); religion (Christianity, Islam); ethnicity (Yorubas, Non Yorubas); income per month in Naira (< 20,000, 20,000- 99,000; ≥ 100,000), mode of transportation (active, passive). The choice of these explanatory variables was from the scientific literature.

Statistical analysis

Statistical analysis was performed using STATA version 13. The summary statistics for categorical variables were reported as proportions, and continuous variables were reported as means and standard deviations. The chi-square test assessed the association between maternal body mass index and specific background characteristics of the pregnant women. Bivariate logistic regression was used to estimate the crude and adjusted odds ratios (OR) with the 95% confidence intervals of sociodemographic factors associated with maternal obesity. Variables statistically significant ($p < 0.05$) at the bivariate analysis (age, parity, monthly income, mode of transportation) were subjected to multivariate analysis. We excluded gravidity, ethnicity and wealth index because of multicollinearity and redundancy. Univariate logistic regression was used to test the association between certain lifestyle factors and maternal obesity, and we reported crude odds ratios and 95% confidence intervals. We fitted multivariate logistic regression models to test for the association between maternal obesity and any adverse perinatal event. We fitted two models. Model *A* showed the unadjusted estimates and the 95% CI. Model *B* was adjusted for age, education, employment status, religion, income and parity and showed adjusted estimates. We obtained the incidence rates of pregnancy outcomes by obesity status and assessed associations between maternal obesity and specific pregnancy outcomes using the Poisson regression analysis. Unadjusted and adjusted relative risks and 95% confidence intervals were reported. The covariates adjusted for socioeconomic characteristics.

Ethics declaration

The study was approved by the University of Ibadan/University College Hospital (UI/UCH) Institutional Review Board (UI/EC/15/0060) and Oyo State Ministry of Health Ethical Committee (AD/13/479/710). The study protocol and conduct adhered to the principles in the Declaration of Helsinki. We obtained verbal and written informed consent from respondents before recruitment into the study.

Results

Participants' characteristics by body mass index

The characteristics of pregnant women in the Ibadan Pregnancy Cohort Study by the body mass index are shown in Table 1. The baseline characteristics of the IbPCS were maternal age (29.8 ± 5.3 years), BMI (26.2 ± 7.1 kg/m2), primigravida (32.7%), married (94.5%), and tertiary level education (68.1%). Overall, the distribution of BMI was as follows: underweight 50 (3.0%), normal weight 846 (49.9%), overweight 473 (27.9%), obese 328 (19.3%). Maternal BMI varied significantly among the study participants by age ($p < 0.001$), gravidity ($p < 0.001$), marital status ($p < 0.001$), income ($p < 0.001$), and wealth tertiles ($p < 0.001$). Obesity increased with age, parity, income and wealth index ($p < 0.001$). In addition, the mode of transportation also significantly differed by maternal BMI ($p = 0.007$).

		Maternal BMI categories (kg/m^2)				
		Underweight < 18.5	Normal weight 18.5 – 24.9	Overweight 25 – 29.9	Obese ≥30.0	
	Total	50 (3.0)	846 (49.9)	473 (27.9)	328 (19.3)	p-value
Characteristics						
Age group						
< 20	32 (1.9)	4 (12.5)	23 (71.9)	4 (12.5)	1 (3.1)	**< 0.001**
20 – 29	808 (47.6)	24 (3.0)	484 (59.9)	179 (22.1)	121 (15.0)	
30 – 39	790 (46.6)	22 (2.8)	318 (40.3)	272 (34.4)	178 (22.5)	
≥ 40 years	66 (3.9)	0 (0.0)	20 (30.3)	18 (27.3)	28 (42.4)	
Gravidity						
Primigravida	553 (32.7)	28 (5.0)	341 (61.7)	126 (22.8)	58 (10.5)	**< 0.001**
2 – 4	952 (56.4)	18 (1.9)	442 (46.4)	286 (30.4)	203 (21.3)	
≥ 5	64 (3.8)	3 (1.6)	59 (32.1)	58 (31.5)	64 (34.8)	
Parity						
Nulliparous	745 (44.1)	32 (4.3)	434 (58.4)	174 (23.4)	104 (14.0)	**< 0.001**
1 – 3	853 (50.5)	17 (2.0)	377 (44.2)	267 (31.3)	192 (22.5)	
≥ 4	90 (5.3)	1 (1.1)	29 (32.2)	31 (34.4)	29 (32.2)	
Marital status						
Single	94 (5.5)	4 (4.2)	60 (63.8)	15 (16.0)	15 (16.0)	**0.017**
Ever married	1602 (94.5)	46 (2.9)	785 (49.0)	458 (28.6)	313 (19.5)	
Education						
≤ Primary	47 (2.8)	1 (2.1)	21 (44.7)	13 (27.7)	12 (25.5)	0.089
Secondary	492 (29.1)	18 (3.7)	266 (54.0)	113 (23.0)	95 (19.3)	
≥ Tertiary	1153 (68.1)	31(2.7)	544 (48.1)	346 (30.0)	221 (19.2)	
Occupation						
Employed	1512 (89.2)	44 (2.9)	743 (49.1)	427 (28.2)	298 (19.7)	0.396
Unemployed	184 (10.8)	6 (3.3)	102 (55.4)	46 (25.0)	30 (16.3)	
Religion						
Christianity	983 (58.3)	26 (2.6)	469 (47.7)	285 (23.4)	203 (20.7)	0.117
Islam	704 (41.7)	24 (23.4)	371 (52.7)	185 (26.3)	124 (17.6)	
Ethnicity						
Yorubas	1520 (89.2)	48 (3.2)	776 (51.1)	427 (28.2)	277 (19.7)	**0.002**
Non-Yorubas	173 (10.8)	2 (1.2)	68 (39.3)	54 (31.2)	49 (28.3)	
Income per month (Naira)						
< 20,000	564 (37.9)	21 (3.7)	319 (56.6)	139 (24.6)	85 (15.1)	**< 0.001**
20,000 – 99,999	821 (55.1)	19 (2.3)	376 (45.8)	259 (31.5)	167 (20.3)	
≥ 100,000	105 (7.0)	3 (2.9)	39 (37.1)	26 (24.8)	37 (35.2)	
Wealth tertiles						
Poor	570 (37.9)	24 (4.2)	323 (56.6)	127 (22.3)	96 (16.8)	**< 0.001**
Middle	562 (34.1)	12 (2.1)	295 (52.5)	149 (26.5)	106 (18.9)	
Richest	564 (34.2)	14 (2.5)	227 (40.3)	197 (34.9)	127 (22.3)	
Mode of transportation						
Active	860 (50.7)	22 (2.6)	485 (56.4)	214 (24.9)	133 (15.5)	0.007
Passive	836 (49.3)	28 (3.6)	360 (43.0)	259 (31.0)	195 (23.3)	

Table 1. Characteristics of Pregnant women by their body mass index.

Association between sociodemographic and maternal obesity

The association between sociodemographic factors and maternal obesity is shown in Table 2. In crude analysis, there was a direct relationship between maternal obesity and age, gravidity, parity, ethnicity, and income and wealth index. In the adjusted analysis, we found that women 35 years and above had increased odds for maternal obesity (adjusted odds ratio AOR): 1.53 95% CI (1.13 – 2.09) compared with women less than 35 years. Similarly, the odds for maternal obesity also increased with parity, i.e. women with para 1–3 AOR: 1.45 95% CI (1.08 – 1.94) and para ≥ 4 AOR: 2.24 95% CI (1.28 – 3.93). Maternal obesity was also associated with income, with those earning *20,000 – 99,999* – AOR: 1.37 95% CI (1.02 – 1.84) and ≥ *100,000* naira AOR: 2.63 95% CI (1.62 – 4.29) than those who earned < *20,000*. Women who engaged in passive transportation also had a positive association with maternal obesity (AOR): 1.59 95% CI (1.21 – 2.09) than women with active transport.

Association between dietary patterns and maternal obesity

The association between dietary patterns and maternal obesity are displayed in Table 3. None of the five dietary patterns had a statistically significant association with maternal obesity: protein-rich diet with a non-alcoholic

	Maternal obesity		Associated factors			
	Obese 328 (19.3%)	Non-obese 1368 (80.7%)	Crude OR (95% CI)	p-value	Adjusted OR (95% CI)	p-value
Characteristics						
Age group						
< 35	228 (16.9)	1,222 (83.1)	1.00		1.00	
≥ 35 years	100 (28.9)	246 (71.0)	2.15 (1.64 – 2.83)	< 0.001	1.53 (1.13 – 2.09)	0.007
Gravidity						
Primigravida	58 (10.5)	495 (89.5)	1.00			
2—4	203 (21.3)	749 (78.7)	2.31 (1.68 – 3.16)	< 0.001	-	
≥ 5	64 (34.8)	120 (65.2)	4.55 (3.03 – 6.84)	< 0.001	-	
Parity						
Nulliparous	104 (13.9)	641 (86.1)	1.00		1.00	
1—3	192 (22.5)	661 (77.5)	1.79 (1.37 – 2.33)	< 0.001	1.45 (1.08 – 1.94)	0.014
≥ 4	29 (32.2)	61 (67.8)	2.93 (1.80 – 4.78)	< 0.001	2.30 (1.28 – 3.93)	0.005
Marital status						
Single	15 (16.0)	79 (84.0)	1.00			
Ever Married	313 (19.5)	1289 (80.5)	1.27 (0.72 – 2.24)	0.396	-	
Education						
≤ Primary	12 (25.5)	35 (74.5)	1.00			
Secondary	95 (19.3)	397 (80.7)	0.69 (0.34 – 1.39)	0.309	-	
≥ Tertiary	221 (19.2)	932 (80.8)	0.69 (0.35 – 1.35)	0.281	-	
Occupation						
Employed	298 (19.7)	1215 (80.3)	1.00			
Unemployed	30 (16.3)	154 (83.7)	1.25 (0.83 – 1.89)	0.272	-	
Religion						
Christianity	203 (20.6)	780 (79.4)	1.00			
Islam	124 (17.6)	580 (82.4)	0.82 (0.64 – 1.05)	0.122	-	
Ethnicity						
Yorubas	277 (18.2)	1243 (81.8)	1.00			
Non-Yorubas	49 (28.3)	124 (71.7)	0.55 (0.39 – 0.79)	0.001	-	
Income per month (Naira)						
< 20,000	85 (15.1)	479 (84.9)	1.00		1.00	
20,000 – 99,999	167 (20.3)	654 (79.7)	1.43 (1.07 – 1.91)	0.013	1.37 (1.02 – 1.84)	0.036
≥ 100,000	37 (35.2)	68 (64.8)	3.06 (1.93 – 4.86)	< 0.001	3.06 (1.62 – 4.29)	0.001
Wealth tertiles						
Poor	96 (16.8)	474 (83.2)	1.00			
Middle	106 (18.9)	456 (81.4)	1.14 (0.84 – 1.55)	0.383	-	
Richest	126 (22.3)	438 (77.7)	1.42 (1.05 – 1.90)	0.020	-	
Mode of transportation						
Active	133(15.5)	727 (84.5)	1.00		1.00	
Passive	195 (23.3)	641 (76.7)	1.66 (1.30 – 2.12)	< 0.001	1.59 (1.21 – 2.09)	< 0.001

Table 2. Factors associated with maternal obesity with crude and adjusted Odds Ratios and 95% Confidence Intervals.

	Maternal obesity + n = 328	Maternal obesity - n = 1368	Odds ratio (95% CI)	p-value
Dietary patterns				
Protein-rich diet and non-alcoholic beverages				
Lower tertile	124 (22.0)	441 (78.0)	1.00	
Middle tertile	103 (18.1)	466 (81.9)	0.78 (0.59 – 1.05)	0.106
Upper tertile	101 (18.0)	461 (82.0)	0.78 (0.58 – 1.04)	0.096
P for trend	*0.662*			
Fruits				
Lower tertile	112 (20.0)	452 (80.0)		
Middle tertile	107 (19.0)	452 (80.0)	0.94 (0.70 – 1.27)	0.707
Upper tertile	109 (19.2)	459 (80.8)	0.96 (0.71 – 1.29)	0.777
P for trend	*0.392*			
Typical diet with alcohol				
Lower tertile	115 (20.2)	455 (79.8)	1.00	
Middle tertile	113 (20.2)	447 (79.8)	1.00 (0.74—1.34)	0.999
Upper tertile	100 (17.7)	466 (82.3)	0.97 (0.72—1.30)	0.281
P for trend	*0.285*			
Legumes				
Lower tertile	115 (19.4)	452 (80.6)	1.00	
Middle tertile	111 (19.7)	453 (80.3)	1.02 (0.76—1.36)	0.915
Upper tertile	108 (18.9)	463 (81.1)	0.97 (0.72—1.30)	0.826
P for trend	*0.825*			
Refined grains				
Lower tertile	99 (17.5)	466 (82.5)	1.00	
Middle tertile	113 (20.0)	453 (80.0)	1.17 (0.87—1.58)	0.293
Upper tertile	116 (20.5)	449 (79.5)	1.22 (0.90—1.64)	0.198
P for trend	*0.201*			

Table 3. Association between dietary patterns and maternal obesity in Ibadan, Nigeria.

beverage pattern ($p > 0.05$), fruits ($p > 0.05$), typical diet with alcohol ($p > 0.05$), legumes ($p > 0.05$), and refined grains ($p > 0.05$). The protein-rich diet with a non-alcoholic beverage had an inverse relationship with maternal obesity [OR (95% CI): 0.78 (0.58 – 1.04)]. High adherence to the refined grains diet pattern positively correlated with maternal obesity.

Association between physical activity and maternal obesity

The association between physical activity and maternal obesity are displayed in Table 4. The mean total activity in metabolic equivalent was not significantly different ($p = 0.717$) between obese (292.4 ± 130.1) and non-obese (289 ± 123.1) women. Overall, the high level of total activity was associated with an increased odds of maternal obesity. For instance, the middle tertile [OR (95% CI): 1.36 (1.01—1.17)], upper tertile [OR (95% CI): 1.07 (0.79—1.45)] compared with the lower tertile. Physical activity was disaggregated by intensity and type. We found that the influence of physical activity depended on the type of activity, with a high household caring activity significantly associated with increased odds of maternal obesity: middle tertile [OR (95% CI): 1.21 (0.90 – 1.64)], upper tertile [OR (95% CI): 1.38 (1.03—1.86)] compared with the lower tertile *(P for trend = 0.033)*. Conversely, a high occupation-related activity had a significant inverse association with maternal obesity: middle tertile [OR (95% CI): 0.88 (0.66 – 1.17)], upper tertile [OR (95% CI): 0.69 (0.51 – 0.93)] compared with the lower tertile *(P for trend = 0.017)*.

Association between maternal obesity and pregnancy outcomes

The association between maternal obesity and pregnancy outcomes are shown in Tables 5 & 6. Women with obesity had a twofold likelihood of experiencing at least one adverse perinatal event [AOR (95% CI): 1.92 (1.40 – 2.65)] after controlling for background variables. Specifically, Table 6 shows the association between maternal obesity and specific pregnancy outcomes (relative risk (RR) and the 95% confidence intervals). Caesarean section [RR 1.48 (95% CI): (1.17 – 1.88)], SVD [RR 0.78 (95% CI): (0.09 – 0.97), macrosomia [RR 1.81 (95% CI): (1.04 -3.16), GDM [RR 1.74 (95% CI): (1.15 – 2.62), birth asphyxia [RR 1.58 (95% CI): (1.03 -2.41] increased among obese women compared with non-obese women.

Discussion

Addressing maternal obesity and its consequences is necessary to forestall the reversal of the gains of maternal and child mortality reduction efforts in Nigeria. We investigated maternal obesity, lifestyle factors and associated pregnancy outcomes using the Ibadan Pregnancy Cohort Study**.** In this study, maternal obesity was assessed

	Maternal obesity +	Maternal obesity -	Odds ratio (95% CI)	p-value
	n = 328	n = 1368		
Total Activity (METs)	292.4 ± 130.1	289.0 ± 123.1		0.717
Total Activity				
Lower tertile	98 (17.4)	466 (82.6)	1.00	
Middle tertile	126 (22.2)	411 (77.8)	1.36 (1.01 – 1.82)	**0.041**
Upper tertile	104 (18.4)	466 (81.5)	1.07 (0.79 – 1.45)	0.651
P for trend	*0.662*			
Sedentary behaviour				
Lower tertile	120 (21.3)	443 (78.7)	1.00	
Middle tertile	95 (16.8)	470 (83.2)	0.75 (0.55 – 1.01)	0.055
Upper tertile	113 (19.9)	455 (80.1)	0.92 (0.69 – 1.22)	0.555
P for trend	*0.549*			
Light intensity activity				
Lower tertile	104 (18.4)	462 (81.6)	1.00	
Middle tertile	115 (20.5)	446 (79.5)	1.15 (0.85 – 1.54)	0.368
Upper tertile	109 (19.2)	460 (80.8)	1.05 (0.78 – 1.42)	0.736
P for trend	*0.740*			
Moderate intensity activity				
Lower tertile	111 (19.6)	456 (80.4)	1.00	
Middle tertile	117 (20.6)	451 (79.4)	1.07 (0.80 – 1.42)	0.667
Upper tertile	100 (17.8)	461 (82.2)	0.89 (0.66 – 1.20)	0.451
P for trend	*0.458*			
Vigorous intensity activity				
Lower tertile	208 (19.7)	849 (80.3)	1.00	
Middle tertile	49 (19.7)	200 (80.3)	1.00 (0.71 – 1.42)	1.000
Upper tertile	71 (18.2)	319 (81.8)	1.91 (0.67 – 1.22)	0.529
P for trend	*0.556*			
Household caring activity				
Lower tertile	95 (16.7)	95 (16.7)	1.00	
Middle tertile	111 (19.6)	111 (19.6)	1.21 (0.90 – 1.64)	0.213
Upper tertile	122 (21.8)	122 (21.8)	1.38 (1.03 – 1.86)	**0.033**
P for trend	***0.033****			
Occupation related activity				
Lower tertile	123 (21.9)	438 (78.1)	1.00	
Middle tertile	113 (19.8)	457 (81.2)	0.88 (0.66 – 1.17)	0.385
Upper tertile	92 (16.3)	473 (87.7)	0.69 (0.51 – 0.93)	**0.016**
P for trend	***0.017****			
Transportation-related activity				
Lower tertile	123 (19.4)	511 (81.6)	1.00	
Middle tertile	99 (19.3)	415 (81.7)	0.99 (0.74 – 1.33)	0.952
Upper tertile	106 (19.3)	422 (81.7)	1.00 (0.75 – 1.33)	0.980
P for trend	*0.948*			
Sport activity				
Lower tertile	120 (19.1)	507 (80.7)	1.00	
Middle tertile	99 (18.8)	429 (81.3)	0.98 (0.73—1.31)	0.867
Upper tertile	109 (20.2)	432 (79.9)	1.07 (0.80—1.42)	0.665
P for trend	*0.670*			

Table 4. Association between physical activity and maternal obesity in Ibadan, Nigeria.

using BMI at the first antenatal visit during early pregnancy (≤ 20 weeks gestation), which has also been used by other researchers[15,32,33]. The ideal prepregnancy weight is not often available in Africa as most pregnancies are unplanned, and there is low health literacy. Also, the closest proxy, the first-trimester weight, is not usually available in the hospital setting because Nigerian women often book late for ANC[34,35]. Therefore, the pragmatic measure has been the maternal weight or BMI at the first antenatal visit during early pregnancy. The prevalence of maternal obesity was 19.3%, exceeding those reported by earlier studies in Nigeria (7.4 – 10.1%)[36–40], but lower compared to recent studies in Nigerian cities where maternal obesity is reported in a third of the pregnant

Variables	Model A		Model B	
	Unadjusted odds ratio (95%CI)	p-value	Adjusted odds ratio[§] (95%CI)	p-value
Maternal Obesity	2.07 (1.56 – 2.70)	< 0.001	1.87 (1.36 – 2.57)	< 0.001

Table 5. Association between maternal obesity and having at least one adverse perinatal outcome. [§]*Adjusted for age, education, employment, religion, income and parity.*

	Pregnancy outcomes		Relative risk (95% CI)	p-value	Adjusted relative risk (95% CI)	p-value
	Yes	No				
Caesarean section (n = 1277)						
Not obese	229(28.9)	735 (71.1)	1		1	
Obese	117(48.2)	126 (51.8)	**1.67 (1.42–1.96)**	**< 0.001**	**1.48 (1.17 – 1.88)**	**0.001**
SVD (n = 1290)						
Not obese	678 (64.9)	367 (35.12)	1		1	
Obese	118 (48.2)	127 (51.8)	**0.74 (0.65–0.85)**	**< 0.001**	**0.78 (0.09–0.97)**	**0.025**
IOL (n = 1290)						
Not obese	43(4.1)	1,002(95.9)	1		1	
Obese	7(2.9)	238(97.1)	0.69 (0.32–1.52)	0.359	0.64 (0.25–1.66)	0.359
Macrosomia (n = 1163)						
Not obese	47(5.0)	893(95.0)	1		1	
Obese	22(9.9)	201(90.1)	**1.97 (1.19–3.27)**	**0.009**	**1.86 (1.04 -3.16)**	**0.036**
LBW (n = 1163)						
Not obese	83(8.8)	857(91.2)	1		1	
Obese	13(5.8)	210(94.2)	0.66 (0.37–1.16)	0.143	0.74 (0.40–1.40)	0.366
GDM (n = 693)						
Not obese	105 (18.4)	467 (81.6)	1		1	
Obese	39 32.2)	82 (67.8)	**1.75 (1.21–2.54)**	**0.003**	**1.74 (1.21–2.62)**	**0.008**
Preterm (n = 1200)						
Not obese	145(14.8)	833(85.2)	1		1	
Obese	32(14.4)	190(85.59)	0.97 (0.68 -1.38)	0.876	0.88 (0.57—1.36)	0.563
Postdate (n = 1238)						
Not obese	50 (5.1)	928 (94.9)	1		1	
Obese	8 (3.6)	214 (96.4)	0.70 (0.33 -1.49)	0.358	0.80 (0.37—1.36)	0.573
APGAR at 1 min (n = 838)						
Not obese	105(15.4)	579(84.7)	1		1	
Obese	33(21.4)	121(78.6)	**1.39 (0.98–1.98)**	0.066	**1.58 (1.03—2.41)**	**0.034**
APGAR at 5 min (n = 838)						
Not obese	33(4.8)	651(95.2)	1		1	
Obese	8(5.2)	146(94.8)	1.08 (0.51–2.28)	0.847	1.48 (0.66—2.28)	0.336
PPH (n = 1199)						
Not obese	141(13.5)	904(86.5)	1		1	
Obese	45(18.4)	200(81.6)	1.36 (1.00–1.85)	0.051	1.41 (0.98–2.01)	0.053
Perineal Tear (n = 1148)						
Not obese	212 (22.7)	722 (77.3)	1		1	
Obese	48 (22.4)	166 (77.6)	0.99 (0.74–1.30)	0.933	1.04 (0.73 – 1.49)	0.796

Table 6. Associations between maternal obesity and pregnancy outcomes in Ibadan, Nigeria.

population[41–43]. The rise in the prevalence of maternal obesity can be attributed to the ongoing epidemiologic and nutritional transitions in West Africa, including Nigeria[44]. Additionally, increased urbanisation, characterised by sedentary life, including sedentary occupations and increased availability of highly processed and energy-dense foods, reduces energy expenditure and improves energy balance[21]. Reporting prevalence has been an essential step in tackling the problem of maternal obesity[45–47] by estimating the problem and creating awareness[48], informing preventive strategies and interventions such as establishing a surveillance system for pregnant women and formulating treatment guidelines for obese pregnant in the United Kingdom[47].

The sociodemographic factors associated with maternal obesity in this study were age, parity, and income. Older age and higher parity had positive associations with maternal obesity. For example, women aged 35 years

and above had a twofold risk of maternal obesity compared to younger women below 35. The direct relationship between maternal age and maternal obesity is well reported, even among studies conducted in Nigeria[4,38,40,49]. Also, the association between parity and maternal obesity increased stepwise, indicating the influence of gestational weight gain and postpartum weight retention. Income also had a positive dose–response relationship with maternal obesity. The association between socioeconomic status (measured by education, occupation, and income) and obesity has been of keen research interest both in developed and developing countries. Sobal and Stunkard, in their classic work in 1989, reported on the relationship between socioeconomic status (SES) and obesity, finding a strong inverse association among women in high-income countries but a positive association in developing countries where obesity increases with wealth and availability of food[50]. While researchers have also corroborated the direct association between SES and obesity reported in LMIC[50–52], those from HIC have confirmed the inverse relationship[12,47]. Income ensures access to excess food and promotes physical inactivity created by a technology-dependent obesogenic environment. An obesogenic environment is the sum of influences in the surroundings or conditions of life, such as excessive dependence on cars and passive transportation, sedentary occupations and entertainment and the use of labour-saving devices that promote obesity. For example, we found in this current study that the majority had television sets (98.0%), smartphones (85.0%), cable television (75%), and washing machines (34.1%). Hence, high-income earners in Nigeria need behavioural change communication on healthy lifestyles. Higher income can also increase health literacy, access to medical screenings, more nutritious diet choices, and exercise.

A healthy lifestyle during pregnancy has received much less attention, particularly in developing countries. Lifestyle modification during pregnancy can reduce the complications associated with maternal obesity and excessive gestational weight gain, particularly among obese women. The pregnancy period provides a window of opportunity to inform, educate, and encourage women on lifestyle modification because pregnant women have increased contact with the health care system and are interested in the well-being of their unborn child. Unfortunately, Nigerian researchers and healthcare providers have given very little attention to lifestyle issues among pregnant women.

In this study, we examined the relationship between dietary and physical activity with maternal obesity among the study participants. Even though none of the five dietary patterns showed statistical significance, the findings still have clinical and public health relevance. Mainly, we found that the protein-rich diet with non-alcoholic beverages dietary pattern with high loading on animal proteins, red meat, fish, and eggs, which improves satiety and green vegetables, which are low in calories and high in micronutrients, reduced the odds of maternal obesity (OR = 0.78) hence preventing weight gain and obesity. On the contrary, the refined grain dietary pattern positively correlates with maternal obesity because they often lack dietary fibre, increase postprandial blood glucose, and increase the risk of obesity and glucose dysfunction from insulin resistance and chronic inflammation. Very few studies have examined the relationship between dietary patterns and maternal obesity. Flynn and her colleagues in the UK Pregnancies Better Eating and Activity Trial (UPBEAT) Consortium investigated dietary habits among a large cohort of obese pregnant women[53]**.** They described four dietary patterns: *Fruits and vegetables*, *African/Caribbean*, *Processed*, and *snacks*. However, these researchers could not elucidate the associations between dietary patterns and maternal obesity because all participants were obese women.

Physical activity is a modifier of weight gain and obesity. It has several benefits during pregnancy, such as increased energy expenditure, improved cardiovascular fitness, controlled blood sugar and blood pressure and improved mood[54]. Therefore, the WHO recommends that pregnant women have at least 150 min of moderate-intensity physical activity weekly[55]. However, this study found that high total activity (i.e. the mid-tertile total activity was associated with higher odds of maternal obesity compared with lower tertile total activity) and household caring activities were positively associated with maternal obesity *(P for trend = 0.033)*. The positive association between physical activity and obesity is surprising because energy expenditure should lead to weight loss rather than weight gain. However, the plausible explanation may be that the energy expenditure associated with physical activity is also related to the depletion of glycogen stores and stimulated appetite by releasing the ghrelin hormone, leading to post-exercise hunger and may cause overeating[56–58]. Therefore, if pregnant women overeat after exercise to replenish energy loss, there may be weight gain rather than the expected weight loss or maintenance. Health professionals must support pregnant women in physical activity, including advice on post-exercise hunger and nutrition to prevent excessive eating and weight gain. This finding calls for further research in our setting. Expectedly, increased occupational-related activity significantly reduced the odds of maternal obesity *(P for trend = 0.017)*. The workplace provides a platform for physical activity during and outside pregnancy. Occupation-related activities were the most common type of physical activity in this study population. We hypothesise that the difference in the food environment between the household and the workplace may also explain this finding because access to food and food intake may be higher in the house than at the workplace, which may explain the positive association of household caring activities with obesity.

Maternal obesity has been reported as a significant predictor of adverse pregnancy outcomes, including maternal and neonatal mortality in developed and developing countries[14,15,40,43,59–62]. The pregnancy outcomes significantly related to maternal obesity were macrosomia, caesarean section, GDM, and birth asphyxia at one minute. Maternal obesity increased the risk of macrosomia by almost twofold (RR = 1.86). In a systematic review and meta-analysis, Gaudet and her colleagues confirmed that maternal obesity contributes to macrosomia, the pooled OR 2.17[63]. Maternal obesity contributes to fetal overgrowth through insulin resistance and increased feotal metabolic fuels. Macrosomia is associated with difficult delivery caused by cephalo-pelvic disproportion, prolonged labour, and shoulder dystocia, hence the likelihood of operative interventions during delivery[59,64]. We found that maternal obesity was associated with a 50% higher risk of having a caesarean delivery, a finding corroborated by several researchers[60,62,65]. The mechanism for the increased incidence of caesarean delivery among obese women includes reduced uterine contractions, increased pregnancy complications, macrosomia

leading to cephalo-pelvic disproportion and concomitant pregnancy complications. Overall, maternal obesity was associated with a twofold risk of an adverse perinatal event. Finally, this study provides the evidence required to tackle the challenge of maternal obesity, which is an emerging maternal health threat in Nigeria. This can be achieved by creating awareness, community engagement, advocacy, and strategies to halt the progression and begin to reverse the burden of obesity, especially among women of reproductive age. Addressing maternal obesity will prevent poor pregnancy outcomes and the future risk of non-communicable diseases in Nigeria.

Strengths and limitation

The main strengths of our study are the relatively large sample size and the use of a prospective cohort study design that provided the opportunity to examine the multiple risk factors and outcomes associated with maternal obesity within the Nigerian context. Additionally, we investigated modifiable lifestyle factors, namely dietary patterns and physical activity (which other researchers had not examined in Nigeria), thereby providing evidence for encouraging and implementing lifestyle modification to control maternal obesity. Also, maternal weights and heights were objectively assessed, thereby limiting measurement errors and misclassification bias associated with self-reported variables. However, the study has limitations, such as the loss of follow-up bias commonly related to prospective studies. In this study, 406 out of 1745 pregnant women (23.3%) were lost to follow-up, primarily due to foetal losses. This was accounted for in the sample size calculation by assuming a 40% attrition rate. The lifestyle characteristics were only assessed at baseline, so we could not evaluate the changes in lifestyle during pregnancy could not be considered. The dietary patterns and physical activity assessment were self-reported; hence, recall bias may not be ruled out. Our study may not be generalisable to women in rural areas or those who obtained maternal care in primary health care settings. Hence, future studies should seek to ascertain changes in lifestyle during pregnancy and examine rural dwellers and those who obtain maternal care from the lower tier of the health system.

Importantly, maternal obesity was measured using maternal BMI at our study's first antenatal visit during early pregnancy (≤ 20 weeks) and not prepregnancy BMI. In sub-Saharan Africa, including Nigeria, pregnancies are often unplanned, and there is low health literacy; hence, the ideal prepregnancy weight is rarely available [4]. Also, the closest proxy, the first-trimester weight, is not usually available in hospital settings because Nigerian women often book late for ANC. Therefore, the pragmatic measure has been the weight /BMI at the first antenatal visit during early pregnancy[15,32,60]. Hence, this study set a ≤ 20-week gestation cutoff with a mean gestational age at booking of 16.4 ± 4.2 weeks. Consequently, we may have slightly overestimated maternal obesity because of minimal gestational weight gain during enrollment into the study. Additionally, residual confounding may have contributed to our findings, such as the influence of maternal appetite, which should be explored in future studies.

Conclusions

Maternal obesity is prevalent among pregnant women in Ibadan, Nigeria. Maternal obesity increases the risk of having adverse perinatal events, including macrosomia, caesarean section, GDM and birth asphyxia. Maternal services should emphasise physical activity and a healthy diet to reduce maternal obesity and its associated risks. The influence of some lifestyle factors on maternal obesity was equivocal. More studies are required on the effect of lifestyle factors, including post-exercise nutrition, food environment and maternal appetite. In addition, in this study, we examined the influence of lifestyle factors on maternal obesity. Future studies should examine the influence of lifestyle factors on adverse pregnancy outcomes.

Data availability

The datasets generated and analysed during the current study are not publicly available because they contain potentially identifying and confidential information. However, they are available from the UI/UCH Ethics Committee (uiuchec@gmail.com) upon reasonable request if it meet the criteria for accessing confidential data.

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Conceptualization: I.A.A. Methodology: I.A.A, E.A.B, A.O.O, Software I.A.A. Validation: I.A.A, E.A.B, A.O.O, Formal analysis I.A.A; Investigation I.A.A; Recourses I.A.A.; Investigation, I.A.A., Resources, I.A.A.; Data Curation I.A.A; Writing – Original Draft Preparation, I.A.A, Writing – Review & Editing, I.A.A, E.A.B, A.O.O, Visualization, I.A.A, Supervision; E.A.B, A.O.O.; Project Administration I.A.A; Funding Acquisition; I.A.A. All authors have read and agreed to the published version of the manuscript.

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Declarations

Competing interests

The authors declare no financial or non-financial competing interests.

Additional information

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