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Relationship between maternal body composition during pregnancy and infant's birth weight in Nairobi informal settlements, Kenya

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ABSTRACT

Background Maternal nutrition depletion during pregnancy compromises fetal programming, and is a cause of adverse birth outcomes. Maternal body composition measurement using direct body composition assessment methods such as the deuterium dilution technique provides better prediction of birth outcomes as compared with commonly used techniques like anthropometry. This study assessed body composition of pregnant mothers in urban informal settlements in Nairobi, Kenya, and established the relationship between maternal body composition and infant birth weight.

Methods Deuterium dilution technique was used to determine body composition, including total body water (TBW), fat-free mass (FFM) and fat mass (FM), among 129 pregnant women who were enrolled into the study in their first or second trimester. Descriptive statistics and regression analysis were applied using Stata V.13.

Results The mean TBW, FFM and FM were 33.3 L (±4.7), 45.7 kg (±6.5) and 17.01 kg (±7.4), respectively. Both TBW and FFM were significantly related to maternal age and gestation/pregnancy stage during body composition assessment while FM was significantly associated with gestation stage during body composition assessment. TBW and FFM were significantly lower in younger mothers (<20 years) compared with older mothers (≥20 years). The mean birth weight was 3.3 kg±0.42 kg. There was a positive association between infant birth weight and maternal TBW (p=0.031) and FFM (p=0.027), but not FM (p=0.88).

Conclusion Non-fat components of the body (TBW and FFM) have a positive association with birth weight. Therefore, interventions to improve optimal maternal feeding practices, to enhance optimal gains in FFM and TBW during pregnancy are recommended, especially among young mothers.

What this paper add

- Maternal TBW and FFM have a positive relationship with infant's birth weight while FM does not.
- TBW, FFM and FM were significantly lower among younger mothers (< 20 years), compared to older mothers (> 20 years), suggesting targeted interventions on improving maternal nutrition in these and similar settings especially among young mothers for improved child health and well-being.
- TBW, FFM and FM increase as pregnancy progresses.

INTRODUCTION

Birth weight is an important predictor of child health, nutrition status and survival.[1] Low birth weight (LBW) is associated with increased risk of neonatal death and child undernutrition[2] which has adverse health and developmental consequences from childhood through to adulthood.[3–5] Similarly, high birth weight is a major risk factor for childhood obesity, and consequent adulthood obesity, and other chronic diseases.[6 7] Maternal body composition during pregnancy is an indicator of maternal nutrition and an important predictor of birth outcomes, including birth weight.[8] Maternal body composition and nutrient stores during pregnancy influence the availability of nutrients for fetal growth and development,[8] with significant effects on fetal genetic development,[9] immune function[10] cardiovascular function, and birth weight.[11–13]

The two-compartment model of body composition assessment subdivides the human total body weight into fat mass (FM) and fat-free mass (FFM). FM refers to the total amount of fat in the body, while FFM refers to the part that is non-fat, including proteins, bone mass, non-bone mass and total body water (TBW).[14] TBW refers to the total water content of the body, including intracellular and extracellular body water. In normal adults, TBW is approximately 73% of the FFM.[14 15]

Direct body composition assessment methods such as the deuterium dilution technique are more objective in body composition assessment than traditional methods like anthropometric and skinfold measurements.[8 16 17] The deuterium dilution technique is a gold standard method of direct

Table 1 Participant's sociodemographic and economic characteristics

Characteristics		n=125 n (%)	Mean+SD
Informal settlement	Korogocho	73 (58.4)	
	Viwandani	52 (41.6)	
Maternal age in complete years	<20	26 (20.8)	23.8+5.2
	20–24	42 (33.6)	
	25–29	36 (28.8)	
	≥30	13 (10.4)	
	Don't know/can't remember	8 (6.4)	
Parity	0	47 (37.6)	
	1–2	60 (48)	
	3–4	13 (10.4)	
	5–7	5 (4)	
Marital status	Single	26 (20.8)	
	Married/in union	95 (76)	
	Others	4 (3.2)	
Ethnic group	Somali/Borana/Garre	7 (5.6)	
	Kikuyu and Embu	38 (30.4)	
	Kamba	18 (14.4)	
	Kisii	4 (3.2)	
	Luhya	26 (20.8)	
	Luo	23 (18.4)	
	Taita	2 (1.6)	
	Others	7 (5.6)	
Religion	Christian	111 (88.8)	
	Muslim	9 (7.2)	
	Traditional	1 (0.8)	
	Others	4 (3.2)	
Highest level of education	None/less than primary	21 (16.8)	
	Primary school	80 (64.0)	
	Secondary school	16 (12.8)	
	College/university	2 (1.6)	
	Missing	6 (4.8)	
Occupation	Unemployed	88 (70.4)	
	Employed (informal)	27 (21.6)	
	Employed (formal)	6 (4.8)	
	Missing	4 (3.2)	
Pregnancy stage at body composition assessment	First trimester	20 (16.0)	
	Second trimester	105 (84.0)	
Number of ANC visits (at the time of BC)			
	0	20 (16.0)	
	1–3	50 (40.0)	
	>3	55 (44.0)	
Number of illnesses experienced during pregnancy			
	0	38 (30.4)	
	1	39 (31.2)	
	2	31 (24.8)	
	3–5	17 (13.6)	

ANC, antenatal care; BC, body composition.

body composition assessment and is based on the assumption that the water content of FFM is relatively constant at approximately 73% in normal adults with an average increase of about 2% during pregnancy period.[14 16]

Urban informal settings, where about 70% of urban dwellers in low and middle-income countries live, are characterised by poor maternal and child health indicators, mainly due to high levels of poverty and poor access to health services.[18 19] In these settings, LBW contributes significantly to premature child deaths and child stunting for children less than 5 years.[20 21] However, there is paucity of evidence on maternal body composition during pregnancy and its relationship with birth weight in the same settings which would form a pertinent part of the overall evidence base towards policy framework and guidelines for more rational maternal child health public health planning, with a focus on the unprivileged population segments. This study aimed to establish the body composition of pregnant women using the stable isotope (deuterium) dilution technique and investigated the relationship between maternal body composition and birth weight among pregnant women in two urban informal settlements in Nairobi, Kenya.

METHODS

Study setting and participants

The study was conducted in the Korogocho and Viwandani slums in Nairobi, settings characterised by poor access to basic amenities including portable water, waste disposal, health and education services.[21–23] These settings also have poor housing, high levels of food insecurity and are exposed to high levels of unemployment, violence and teenage pregnancy.[24 25] In addition, Kenyan urban informal settlements have higher infant mortality rates (75 in 1000 live births) compared with other subpopulations,[26] and birth weight is a major cause of poor child health and deaths in the two settlements.[20 21]

A calculated sample of 129 women in their first and second trimesters were recruited to participate in this study, which was nested within a broader maternal infant and young child nutrition (MIYCN) study. The

Table 2 Linear regression analysis of maternal total body water (TBW) by maternal characteristics

Variable (Ref)	n=125 n (%)	Univariate regression analysis				Multiple linear regression analysis*			
		Coefficient	P value	CI (95%) Lower	CI (95%) Upper	Coefficient	P value	CI (95%) Lower	CI (95%) Upper
Site (Korogocho)	73 (58.4)								
Viwandani	52 (41.6)	1.30	0.126	−2.99	0.37	−0.91	0.376	−2.97	1.136
Maternal age (<20 years)	26 (20.8)								
20–24	42 (33.6)	2.14	0.063	−0.11	4.41	2.74	0.044†	0.07	5.40
25–29	36 (28.8)	3.17	0.008†	0.84	5.50	4.13	0.009†	1.04	7.23
≥30	13 (10.4)	3.20	0.041†	−0.39	6.62	5.10	0.010†	1.23	8.97
Marital status (Single)	26 (20.8)								
Married/living together	95 (76)	1.54	0.131	−0.46	3.55	−0.05	0.963	−2.51	2.39
Ethnicity (Somali)	7 (5.6)								
Kikuyu/Embu	38 (30.4)	−2.43	0.189	−6.06	1.20	−8.32	0.052	−16.70	0.06
Kamba	18 (14.4)	−3.09	0.123	−7.02	0.85	−8.95	0.141	−17.51	−0.39
Kisii	4 (3.2)	−1.22	0.661	−6.76	4.31	−5.27	0.272	−14.75	4.20
Luhya	26 (20.8)	0.18	0.926	−3.58	3.94	−4.83	0.248	−13.09	3.43
Luo	23 (18.4)	0.91	0.636	−2.90	4.72	−4.24	0.304	−12.39	3.91
Taita	2 (1.6)	−3.87	0.282	−10.95	3.21	−8.13	0.132	−18.78	2.51
Religion (Christian)	111 (88.8)								
Muslim	9 (7.2)	0.13	0.937	−3.02	3.27	−4.15	0.233	−11.03	2.72
Traditional	1 (0.8)	−6.32	0.173	−15.46	2.81	−5.39	0.275	−15.17	4.38
Parity (0)	47 (37.6)								
1–2	60 (48)	0.86	0.347	−0.94	2.66	−0.3	0.762	−2.75	2.02
3–4	13 (10.4)	1.82	0.212	−1.05	4.69	−1.35	0.462	−4.99	2.28
5–7	5 (4.0)	3.46	0.114	−0.84	7.76	0.12	0.965	−5.45	5.70
Occupation (None)	88 (70.4)								
Informal	27 (21.6)	0.99	0.330	−1.01	2.99	−1.72	0.179	−4.25	0.80
Formal	6 (4.8)	−0.91	0.642	−4.75	2.94	−0.39	0.861	−4.88	4.09
Education (None)	21 (16.8)								
Primary school	80 (64.0)	−0.92	0.422	−3.16	1.33	0.19	0.874	−2.27	2.67
Secondary school	16 (12.8)	−2.35	0.129	−5.39	0.69	1.41	0.462	−2.38	5.20
College/university	2 (1.6)	−1.31	0.704	−8.09	5.48	−2.11	0.584	−9.76	5.53

Continued

Table 2 Continued

Variable (Ref)	n=125 n (%)	Univariate regression analysis				Multiple linear regression analysis*			
		Coefficient	P value	CI (95%) Lower	Upper	Coefficient	P value	CI (95%) Lower	Upper
Trimester (First)	20 (16.0)								
Second	105 (84.0)	2.74	0.024†	0.47	4.96	3.569	0.010†	0.87	6.25
Number of ANC visits (None)	20 (16.0)								
1–3	50 (40.0)	−0.77	0.542	−3.24	1.71	−1.574	0.273	−4.41	1.26
>3	55 (44.0)	−1.78	0.152	−4.21	0.66	−2.287	0.095	−4.98	0.40
Pregnancy complications (0)	38 (30.4)								
1	39 (31.2)	0.10	0.924	−2.03	2.23	−0.222	0.850	−2.54	2.10
2	31 (24.8)	−0.64	0.575	−2.89	1.61	0.192	0.885	−2.44	2.82
3–5	17 (13.6)	−0.20	0.886	−2.89	2.50	−1.279	0.398	−4.27	1.71

*Adjusting for sociodemographic (age, marital status, ethnicity, religion, parity, study area), socioeconomic (education, occupation) and health related (ANC attendance, pregnancy complications and weight).
†Significant at p<0.05.
ANC, antenatal care.

MIYCN study involved the follow-up of a cohort of over 1000 women from pregnancy until 1 year after delivery to determine the feeding practices and nutrition status of mothers and children in this cohort in the two slums.[27] The MIYCN study was implemented from 2012 to 2014 within the Nairobi Urban Health and Demographic Surveillance System (NUHDSS), which is run by the African Population and Health Research Center. NUHDSS has been in operation since 2002 and involves surveillance of the population living in Korogocho and Viwandani, to monitor their health and demographic outcomes.[22] Systematic sampling was used to select the 129 pregnant women from the larger cohort of 1000 women recruited into the MIYCN study, whereby every eighth eligible mothers listed in the MIYCN study were recruited to participate in this study.

Study procedure

The pregnant women who were sampled to participate in the study were contacted by the researcher, informed about the study and invited to a central place within the study community, where the deuterium dosing, saliva sample collection, anthropometric measurements (weight and height) and a face-to-face interview on socioeconomic, demographic, health and health-seeking behaviour and pregnancy characteristics were conducted. Their gestation stage at the time of body composition was established through the date of their last menstrual period as recorded in the mother and child booklet (issued during antenatal care (ANC) visits), and recall for those who did not have the mother and child booklet. The deuterium dilution procedures were carried out by a professional specialist trained on this technique by the International Atomic Energy Agency (IAEA), while the interviews were conducted by trained research assistants.

Deuterium dosage and analysis for body composition of the pregnant mothers was done as described by the IAEA.[14] The mothers were then followed up after delivery to collect their infant's birth weight and sex, as recorded in the mother and child health booklet at delivery in the hospital.

Data analysis

Stata V.13 (StataCorp, College Station, TX) was used for statistical analysis. Descriptive summary statistics were calculated for socioeconomic and demographic characteristics, and body composition measurements. The relationship between maternal characteristics (sociodemographic, economic, health), maternal body composition (TBW, FFM, FM) and infant's birth weight was determined using linear regression analysis while controlling for potential confounders.

RESULTS

Four out of the 129 mothers recruited to participate in the study did not complete the deuterium dosage procedure and were therefore excluded in the analysis of maternal characteristics. Thus, a total sample of 125 mothers were

Table 3 Linear regression analysis of maternal fat free mass (FFM) by maternal characteristics

		Univariate regression analysis				Multiple linear regression*			
				CI (95%)				CI (95%)	
Variable (Ref)	n=125 n (%)	Coefficient	P value	Lower	Upper	Coefficient	P value	Lower	Upper
Site (Korogocho)	73 (58.4)								
Viwandani	52 (41.6)	−1.73	0.141	−4.06	0.60	−1.40	0.331	−4.25	1.44
Maternal age (<20)	26 (20.8)								
20–24	42 (33.6)	2.90	0.071	−0.25	6.05	4.24	0.031†	0.39	8.09
25–29	36 (28.8)	4.31	0.012†	1.06	7.56	6.18	0.007†	1.74	10.62
≥30	13 (10.4)	4.23	0.087	−0.63	9.08	7.70	0.008†	2.11	13.28
Marital status (Single)	26 (20.8)								
Married/living together	95 (76)	2.159	0.133	−0.60	4.92	−0.33	0.852	−3.76	3.10
Ethnic group (Somali)	7 (5.6)								
Kikuyu/Embu	38 (30.4)	−3.32	0.189	−8.30	1.66	−11.90	0.074	−23.47	−0.32
Kamba	18 (14.4)	−4.23	0.123	−9.62	1.17	−12.72	0.075	−24.53	−0.091
Kisii	4 (3.2)	−1.68	0.661	−9.27	5.91	−7.14	0.271	−20.15	5.88
Luhya	26 (20.8)	0.47	0.858	−4.7	5.65	−7.21	0.212	−18.65	4.23
Luo	23 (18.4)	1.25	0.636	−3.98	6.48	−6.13	0.285	−17.35	5.09
Taita	2 (1.6)	−5.30	0.282	−15.01	4.41	−11.46	0.122	−26.10	3.18
Religion (Christian)	111 (88.8)								
Muslim	9 (7.2)	0.13	0.951	−4.20	4.47	−6.09	0.213	−15.60	3.40
Traditional	1 (0.8)	−8.70	0.172	−21.25	3.85	−6.83	0.325	−20.33	6.68
Parity (0)	47 (37.6)								
1–2	60 (48)	1.25	0.324	−1.24	3.74	−0.65	0.701	−3.94	2.67
3–4	13 (10.4)	2.490	1.255	0.21	6.44	−2.02	0.432	−7.03	2.99
5–7	5 (4)	4.74	0.123	−1.17	10.64	0.07	0.971	−7.60	7.74
Occupation (None)									
Informal	27 (21.6)	1.55	0.271	−1.24	4.35	−2.84	0.132	−6.51	0.83
Formal	6 (4.8)	−1.24	0.642	−6.52	4.039	−0.66	0.831	−6.83	5.50
Education (None)	21 (16.8)								
Primary school	80 (64.0)	−1.20	0.443	−4.29	1.89	0.22	0.903	−3.18	3.62
Secondary school	16 (12.8)	−3.22	0.135	−7.40	0.96	2.05	0.441	−3.17	7.26
College/university	2 (1.6)	−1.79	0.713	−11.11	7.54	−3.33	0.532	−13.89	7.23

Continued

Table 3 Continued

Variable (Ref)	n=125 n (%)	Univariate regression analysis				Multiple linear regression*			
		Coefficient	P value	CI (95%) Lower	Upper	Coefficient	P value	CI (95%) Lower	Upper
Gestation stage (First trimester)	20 (16.0)								
Second trimester	105 (84.0)	3.67	0.021†	0.53	6.87	5.36	0.007†	1.49	9.23
Number of ANC visits (None)	20 (16.0)								
1–3	50 (40.0)	−0.95	0.581	−4.37	2.46	−2.36	0.242	−6.30	1.57
>3	55 (44.0)	−2.43	0.152	−5.78	0.92	−3.20	0.091	−6.91	0.50
Pregnancy complication (None)	38 (30.4)								
1	39 (31.2)	0.03	0.993	−2.92	2.98	−0.06	0.971	−3.31	3.19
2	31 (24.8)	−0.99	0.533	−4.11	2.13	0.54	0.771	−3.14	4.22
3–5	17 (13.6)	−0.38	0.842	−4.10	3.34	−1.68	0.422	−5.78	2.45

*Adjusting for sociodemographic (age, marital status, ethnicity, religion, parity, study area), socioeconomic (education, occupation) and health related (ANC attendance, pregnancy complications and weight).
†Significant at p<0.05.
ANC, antenatal care.

included in the analysis. In addition, details of infants born to 27 of the mothers could not be established for reasons that some mothers had moved out of the study area (18), lost their babies through miscarriage or stillbirth (5), their babies were not weighed at birth (2) and refusal to continue participating in the study (2).

Maternal characteristics

Participants' socioeconomic and demographic characteristics are as described in table 1. Overall, the mean age of the participants was 23.8 (±5.2) years, 21% were less than 20 years and a majority (62%) were aged between 20 and 29 years. Majority of the participants (84%) were in the second trimester of their pregnancy. Sixteen per cent had not attended any ANC. Slightly more than two-thirds (70%) of the women reported to have experienced at least one complication or illness during pregnancy.

Maternal body composition

Total body water

The participants' TBW ranged from 23.30 to 44.80 L, the mean TBW was 33.3 L (±4.7), which was 53.1% of the mean body weight. TBW had a significant association with maternal age and the gestational stage (trimester when the body composition assessment was done). TBW was significantly lower among younger mothers who were aged less than 20 years compared with older mothers (above 20 years). In addition, participants in the second trimester had a significantly higher TBW compared with those in the first trimester. There was no significant association between TBW and marital status, religion, parity, occupation, education, ANC visits and pregnancy illness/complications during pregnancy, at both univariate and multiple regression analyses (table 2).

Fat-free mass

FFM ranged from 31.90 to 61.39 kg, with a mean of 45.7 kg (±6.5). Age and gestation stage were found to have a significant relationship with FFM. Mothers younger than 20 years had significantly lower FFM compared with those aged 20 and above. In addition, FFM was significantly higher among mothers in the second trimester compared with those in the first trimester. There was no significant association between FFM and marital status, religion, parity, occupation, education, ANC visits and pregnancy illness/complications during pregnancy, at both univariate and multiple regression analyses (table 3).

FM and body fat percentage

The mean FM and body fat percentage in this study were 17.01 kg (±7.4) and 26.8% (±8.1), respectively. There was a significant relationship between FM and maternal age based on linear regression analysis. FM was significantly lower for mothers younger than 20 years compared with older mothers. There was no significant relationship between FM and residence, marital status, occupation, education, ANC visits and pregnancy complication, and gestation stage at body composition (table 4).

Table 4 Linear regression analysis of maternal fat mass (FM) by maternal characteristics

		Univariate analysis				Multiple linear regression analysis*			
				CI (95%)				CI (95%)	
Variable (Ref)	n=125 n (%)	Coefficient	P value	Lower	Upper	Coefficient	P value	Lower	Upper
Site (Korogocho)	73 (58.4)								
Viwandani	52 (41.6)	−0.37	0.784	−3.02	2.29	−2.66	0.101	−5.83	0.51
Maternal age (<20 years)	26 (20.8)								
20–24	42 (33.6)	3.67	0.03†	0.34	6.99	7.28	0.001†	2.97	11.57
25–29	36 (28.8)	2.95	0.091	−0.49	6.37	7.89	0.002†	2.94	12.85
≥30	13 (10.4)	7.49	0.02	2.89	12.10	13.29	0.000†	7.05	19.52
Marital status (Single)	26 (20.8)								
Married/living together	95 (76)	−1.69	0.291	−4.83	1.45	−2.06	0.292	−5.89	1.76
Ethnic group (Somali)	7 (5.6)								
Kikuyu/Embu	38 (30.4)	0.08	0.981	−5.78	5.93	−14.98	0.023	−27.9	−2.06
Kamba	18 (14.4)	−1.59	0.622	−7.93	4.76	−16.97	0.062	−30.15	−3.78
Kisii	4 (3.2)	1.47	0.752	−7.45	10.39	−8.94	0.231	−23.46	5.59
Luhya	26 (20.8)	−1.73	0.581	−7.82	4.36	−17.31	0.972	−30.13	−4.59
Luo	23 (18.4)	−2.08	0.512	−8.22	4.07	−15.96	0.321	−28.49	−3.43
Taita	2 (1.6)	8.53	0.144	−2.88	19.95	−9.61	0.251	−25.95	6.74
Religion (Christian)	111 (88.8)								
Muslim	9 (7.2)	−0.83	0.742	−5.76	4.11	−12.82	0.462	−23.42	−2.22
Traditional	1 (0.8)	−10.32	0.163	−24.61	3.98	−5.82	0.443	−20.89	9.25
Parity (None)	47 (37.6)								
1–2	60 (48)	−0.83	0.562	−3.68	2.06	−3.08	0.101	−6.76	0.61
3–4	13 (10.4)	−1.06	0.644	−5.57	3.46	−4.12	0.152	−9.72	1.48
5–7	5 (4)	−0.98	0.78	−7.74	5.78	−4.98	0.251	−13.54	3.57
Occupation (None)									
Informal	27 (21.6)	1.84	0.251	−1.32	4.99	−2.92	0.161	−7.02	1.17
Formal	6 (4.8)	5.08	0.094	−0.88	11.04	4.47	0.202	−2.41	11.36
Education (None)	21 (16.8)								
Primary school	80 (64.0)	0.55	0.759	−2.99	4.09	0.77	0.694	−3.03	4.56
Secondary school	16 (12.8)	1.92	0.428	−2.86	6.71	2.56	0.384	−3.23	8.39
College/university	2 (1.6)	3.32	0.539	−7.35	13.98	−4.31	0.472	−16.09	7.48
Gestation stage (First trimester)	20 (16.0)								
Second trimester	105 (84.0)	2.12	0.251	−1.54	5.77	1.76	0.423	−2.56	6.09
Number of ANC visits (None)	20 (16.0)								
1–3	50 (40.0)	−1.37	0.488	−5.24	2.51	−2.14	0.345	−6.52	2.25
>3	55 (44.0)	−1.50	0.436	−5.30	2.30	−2.81	0.184	−6.94	1.33
Pregnancy complications (0)	38 (30.4)								
1	39 (31.2)	0.5	0.764	−2.82	3.83	2.19	0.231	−1.44	5.82
2	31 (24.8)	1.18	0.508	−2.33	4.69	1.31	0.533	−2.79	5.42
3–5	17 (13.6)	−1.29	0.543	−5.47	2.90	−2.66	0.253	−7.26	1.93

*Adjusting for sociodemographic (age, marital status, ethnicity, religion, parity, study area), socioeconomic (education, occupation) and health related (ANC attendance, pregnancy complications and weight).
†Significant at p<0.05.
ANC, antenatal care.

Infant's birth weight

Infant's birth weight ranged from 2.2 to 4.2 kg, with a mean birth weight of 3.3 kg (±0.42). Birth weight was further categorised into LBW (<2.5 kg), normal birth weight (2.5–4.0 kg) and high birth weight (>4.0 kg).[28] Majority of the children (94%) had normal birth weight, 3% of the children had LBW and the rest (3%) had high birth weight. Linear regression analysis showed no significant association between birth weight and child's sex, maternal sociodemographic characteristics (age, marital status, ethnicity, religion, parity, study area), maternal socioeconomic characteristics (education) and pregnancy characteristics (ANC attendance, pregnancy complications) (table 5).

Relationship between maternal body composition and birth weight

Linear regression was applied to establish the relationship between maternal body composition (TBW, FFM, FM) and infant's birth weight. There was a significant relationship between birth weight and maternal TBW (p=0.031) and maternal FFM (p=0.027), but no significant relationship was found between birth weight and FM (0.88) at both univariate and multivariate analyses, respectively (table 6). In this multivariate analysis, variables that had a p value ≤0.2 in the regression of birth weight against maternal and child characteristics (table 5) were treated as potential confounders and hence included in the model; they include maternal age, ethnicity, gestation stage at body composition and ANC attendance.

Table 5 Linear regression analysis of infant's birth weight by maternal and child characteristics

Variable (Ref)	Coefficient	P value	CI (95%) Lower	CI (95%) Upper
Site (Korogocho)				
Viwandani	−0.04	0.650	−0.21	0.13
Child characteristics				
Child's sex (Female)				
Male	0.14	0.872	−1.56	0.18
Maternal characteristics				
Maternal age (<20 years)				
20–24	0.14	0.054	0.00	0.27
25–29	0.11	0.132	−0.03	0.24
≥30	0.11	0.221	−0.06	0.27
Marital status (Single)				
Married/living together	0.09	0.385	−0.11	0.28
Ethnic group (Somali)				
Kikuyu/Embu	0.20	0.326	−0.19	0.58
Kamba	0.20	0.370	−0.24	0.63
Kisii	0.49	0.115	−0.10	1.08
Luhya	0.16	0.457	−0.25	0.56
Luo	0.31	0.141	−0.10	0.71
Taita	−0.58	0.201	−1.47	0.31
Religion (Christian)				
Muslim	−0.14	0.371	−0.46	0.18
Parity (0)				
1–2	0.09	0.342	−0.09	0.27
3–4	0.05	0.756	−0.25	0.34
5+	0.30	0.173	−0.13	0.73
Occupation (None)				
Informal	0.00	0.982	−0.20	0.21
Formal	0.03	0.878	−0.35	0.41
Education (None)				
Primary school	0.04	0.740	−0.18	0.26
Secondary school	0.03	0.862	−0.29	0.34
College/university	−0.02	0.947	−0.63	0.59
Number of ANC visits (None)				
1–3	0.17	0.291	−0.15	0.49
>3	0.08	0.623	−0.23	0.39
Pregnancy complications				
1	−0.10	0.371	−0.32	0.12
2	−0.06	0.636	−0.28	0.17
3–5	0.09	0.487	−0.17	0.35

ANC, antenatal care.

DISCUSSION

The IAEA estimates that water makes up to approximately 70%–75% of an individual's body weight at birth, but decreases to about 40%–60% in adulthood.[14] TBW in this study accounted for 53% of the total weight, which was within the IAEA estimated ranges. In addition, the IAEA estimates that optimal TBW among women (non-pregnant) ranges from 26 to 33 L, the mean TBW in this study was 33.3, slightly higher than the IAEA estimates among non-pregnant women; this could be due to the pregnancy, since studies have shown an increase in TBW levels in the course of pregnancy.[28] Related findings have reported the mean TBW of pregnant women in the first and second trimesters to be between 38.68 and 40.61 L, respectively,[29 30] the slight variation could be as a result of the varying study contexts.

The Kenya National Guidelines for Healthy Diets and Physical Activity 2017 highlight that optimal body fat percentage for women ranges from 12% to 25%. The mean body fat percentage for women in this study was 26.8%, slightly higher than the optimal ranges as stated in the guidelines, which would be as a result of the pregnancy, because maternal fat accretion during pregnancy occurs as a natural process to cater for fetal growth and development.[31] The reported lower body composition (TBW, FFM and FM) among teenage mothers compared

Table 6 Linear regression of birth weight by maternal body composition (TBW, FFM and FM)

	Univariate analysis				Multiple linear regression analysis*			
			CI (95%)				CI (95%)	
Birth weight	Coefficient	P value	Lower	Upper	Coefficient	P value	Lower	Upper
TBW	0.02	0.005†	0.01	0.04	0.022217	0.031†	0.002	0.04
FFM	0.02	0.003†	0.01	0.03	0.016453	0.027†	0.001	0.03
FM	0.01	0.276	0.00	0.02	0.000978	0.884	−0.01	0.01

*Adjusting for maternal age, ethnicity, trimester when body composition was done and antenatal care (ANC) visits.
†Significant at p<0.05.
FFM, fat-free mass; FM, fat mass; TBW, total body water.

with older mothers concurs with similar studies in other countries, for instance, younger mothers in Mexico had slightly lower TBW, FFM and FM compared with older mothers in both second and third trimesters of their pregnancy.[32] It is documented that teenage pregnancy depletes both fat and lean body mass among teenage mothers[33] and also hinders their linear growth. Furthermore, the WHO reports that pregnant teenagers have not achieved full growth and development and continue to grow even during the pregnancy.[34] This could explain the lower body composition levels (TBW, FFM, FM) among the young mothers compared with their older and mature counterparts. It is worth noting that lower FM levels are associated with maternal malnutrition in Kenya.[35]

The findings of this study reveal that maternal TBW and FFM increase as pregnancy progresses, from first to second trimester which is comparative to insights from a study in Sweden[6] which established that women in the third trimester (32 weeks) have a higher TBW level compared with those in the second trimester (14 weeks' gestation) with similar trends in Mexico, where TBW and FFM increased as women progressed from second to third trimester.[16] Butte *et al* hypothesised that the increase in TBW in the course of pregnancy is among the reasons for weight gain during pregnancy[29] while Ghezzi *et al* indicate that total intracellular and extracellular water significantly increase as pregnancy advances and return to the pre-pregnancy values within 60 days after delivery.[36] Among the components that contribute to increased TBW during pregnancy are the increased blood volume and extracellular fluids to support fetal development, while the progressive growth of uterine tissue, mammary and soft tissues contributes to the increased FFM as pregnancy progresses.[37]

The positive association between TBW and birth weight herein reported is amenable to observations in the USA and Tanzania[38 39] corresponding to a developed and developing nation, respectively, that established a positive correlation between TBW and birth weight, respectively, using the deuterium dilution methodology. It is important to note that lower TBW has been associated with intrauterine growth retardation, one of the risk factors for LBW.[40] The positive relationship between FFM and birth weight further compares with studies among Jamaican women in their first trimester and among Caucasian pregnant women in their second and third trimesters.[40 41] In these two studies, FFM was found to have a positive relationship with birth weight and to be a strong predictor of birth weight, whereby higher maternal FFM was linked with higher birth weights. An FFM higher than 40.76 kg has been associated with about a threefold risk for high birthweight babies (>4 kg) among Chinese women,[42] and hence increased risks of obesity in childhood and adulthood, and associated chronic diseases.[7]

Although there was no association between FM and birth weight in this study, a Swedish study found positive correlation between birth weight and FM of women in the third trimester using anthropometric assessments.[12] The current study, however, focused on women in the first and second trimesters. In addition, stores of certain types of fats such as the polyunsaturated fatty acids have been shown to promote optimal fetal and infant development and breast milk production post partum.[12 43]

This study focused on women in the first and second trimesters, and hence there may be body composition changes in the third trimester that were not captured in the study, which we acknowledge as a limitation. In addition, ANC attendance and complications experienced during pregnancy were based on the mothers' self-report and hence potential for recall bias. Use of the deuterium dilution technique assessment, a gold standard method of body composition assessment, is a key strength of the study, as this technique is considered as a more objective method of nutrition assessment compared with other methods such as anthropometry[8] which have been previously used to establish maternal nutrition status in the study area.

CONCLUSION

Maternal body composition TBW, FFM and FM among pregnant women in the study setting increase as pregnancy progresses among the pregnant women examined, but each of the components (TBW, FFM and FM) was significantly lower among teenage mothers (<20 years) compared with older mothers. Low maternal fat mas in Kenya has been associated with poor maternal nutrition, which has been shown to increase the risks of adverse birth outcomes including LBW, preterm births and child deaths. The positive association between TBW and FFM

and birth weight may be an indication of the important role played by TBW which includes the intracellular and extracellular body fluids and FFM which includes proteins and body tissue, in the fetal growth and development, and hence their influence on the infant's general birth weight. The low TBW, FFM and FM among teenage mothers compared with older mothers are therefore of concern, especially TBW and FFM measurements which had a positive association with infant's birth weight. Interventions focusing on improving maternal nutrition and gains in FFM and TBW during pregnancy in these and similar settings especially among young mothers would be a worthwhile quest for improved child health and well-being. This could be done through integrating nutrition counselling and support within the youth-friendly programmes that are specifically designed and targeted for youths and adolescents. This is even more important owing to the relatively high prevalence of teenage pregnancies among the urban poor and in the study area.

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