Body composition and basal metabolic rate in pregnant women

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ABSTRACT: Pregnancy, a milieu of physiological and metabolic adaptation, is associated with enhanced basal metabolic rate by alteration in maternal tissue and metabolism to ensure foetal growth and development. A cross-sectional study of Indian Baniya females was conducted to assess the relationship between basal metabolic rate and body composition during pregnancy. The 20–40 year old female subjects were broadly categorized in two groups; pregnant (N=198) and non-pregnant (N=35). Anthropometric measurements of each subject included height and weight, with basal metabolic rate (BMR), fat mass (FM), fat-free mass (FFM) and total body water (TBW) assayed by bioelectric impedance body composition analyzer. The descriptive statistics revealed pregnancy associated weight gain, increased FFM, FM, TBW and BMR with marked changes during the second and third trimesters. Although multiple linear regression analysis showed substantial change in BMR due to both FM and FFM, fat-free mass contributed to a much lesser extent. Pregnancy, as an anabolic phase of the female reproductive cycle, is associated with metabolic flexibility which alters the relationship between body composition and BMR. These findings however require further validation in longitudinal design studies.

KEY WORDS: pregnant women, body composition, basal metabolic rate, Baniya

Introduction

Pregnancy is an integral phase of the female reproductive life requiring a continuum of physiological and metabolic adjustments. Protein and fat accretion in maternal, foetal and placental tissue demands supplementary energy intake for the maintenace of maternal homeostasis and sustenance of foetal growth, which otherwise may lead to a potential impasse. The energy requirements can be derived factorially from increments in basal metabolic rate (BMR). This is attributed to increased oxygen consumption from enhanced maternal circulation, respiration, renal function and increased tissue mass (Hytten 1980). The BMR change depends on gestational weight-gain (Prentice et al. 1996), pre-pregnancy nutritional status (Forsum et al. 1988), fat content (Forsum 2004; Lof et al.

2005) and foetal size (Butte 1999), and tremendous inter-individual variability in its magnitude is noted in females in the same population and apparently with similar dietary consumption (Goldberg et al. 1993).

Understanding physiological variability in body composition is of great concern, because although low BMR is an appropriate energy-sparing adaptation in undernourished pregnant females, it can also be a predisposing risk factor in development of adult obesity (Weyer et al. 1999; Ravussin et al. 1988; Lawrence et al. 1987). Extensive literature in the past decade has revealed the association of BMR with components of a bi-compartmental model of body composition: fat mass (FM) and fat-free mass (FFM). Although the relationship between BMR and metabolically active FFM is a cornerstone in the study of physiological aspects of body weight regulation and human energy requirements (Weinsier et al. 1992; Wang et al. 2000), the additional role played by FM as an independent factor influencing BMR has been a matter of contention (Nelson et al. 1992; Svendsen et al. 1993).

Therefore, this study assesses the relationships between BMR and FM and FFM in a homogeneous group of pregnant and non pregnant females to dispel discrepancies in the association between body composition and BMR in new mothers.

Materials and Methods

This cross-sectional study comprises 198 pregnant Indian Baniya females categorized in trimesters according to pregnancy period; trimester 1 (N=37), trimester 2 (N=55) and trimester 3 (N=106).

A plausible explanation for the highest number of females being in their 3rd trimester is that a maximum number of females begin seeking ante-natal care during this period. Controls consisted of 35 non-pregnant females, matched in age and socio-economic status to the subjects.

The term 'Baniya' is adopted from the Sanskrit word 'vanijya' denoting traders in the northern and western provinces. This community is believed to have originated 5,000 years ago when their ancestor, Maharaja Agrasen of Haryana, divided theVaishya community into eighteen clans. This community was the third in the fourfold division of the Hindu caste system, and although the Baniya are endogamous at community level, they are strictly exogamous at the clan level to regulate alliances.

The purpose of this study was explained to all volunteer subjects and written consent for participation and data collection was obtained from each subject. The study protocol was duly approved by the institutional ethical clearance committee. All anthropometric measurements were taken by trained anthropologists using the standard techniques of Weiner and Lourie (1981). Stature was measured with an anthropometer rod to the nearest 0.1 cm and weight was recorded to the nearest 0.5 kg. The body composition inclusive of basal metabolic rate (BMR), fat mass (FM), fat free mass (FFM) and total body water (TBW) was assayed using a 50kHz single frequency body-composition analyser (TBF-310H14 A). This utilizes a patented "foot to foot" tetrapolar bioelectric impedance technique where the subjects stand barefoot on a metal sole-plate which incorporates the electrodes. Bioelectrical imped-

ance analysis (BIA) is a relatively simple, quick and non-invasive technique providing acceptable estimates of body composition (Segal 1985, Lukaski and Bolonchuk 1987, Frankenfield 1999). It potentially estimates altered hydration during pregnancy (Levario-Carrillo et al. 2006; Lukaski et al. 2007).

Statistical analysis

Statistical analysis was performed by the Statistical Package of Social Sciences, 16.0 (SPSS, Inc., Chicago, IL). Basic data was presented as means and standard deviations and analysis of variance (ANOVA) with the Duncan post hoc test was used to reveal significant differences in the means of the variables. Homogeneity of variance was estimated using Levene's test, and Welch test values obtained from the robust F test for equality of means was recorded for variables with unequal variance. Bivariate Pearson correlation coefficients were used to determine the linear relationships between BMR and FFM, fat mass, total body water and weight. Multiple linear regression analysis assessed the independent effects of body composition parameters on BMR during pregnancy. Regression analysis with interaction terms (pregnancy x FFM; pregnancy x fat mass; pregnancy x TBW) was then performed to evaluate the effect of pregnancy on the relationship between BMR and body composition. The coefficient of determination (R^2) determined the explained variance in BMR. Collinearity diagnostics of tolerance and variance inflation factors explored multi-collinearity in the predictor variables. This model endorses the assumption of non multi-collinearity with individual VIF scores much lower than 10 (Bowerman and O'Connell 1990)

and tolerances not less than 0.2 (Menard 1995). A probability (p) value less than 0.05 was considered significant.

Results

The basic characteristic of the pregnant and non-pregnant females are summarized in Table 1. All variables except stature differed significantly between the groups at <0.001. The mean values of BMR, body weight, fat mass, fat-free mass and total body water were significantly higher also at $p < 0.001$ in pregnant females in their 3rd trimester compared to other pregnant and non-pregnant women. Thus, changes were significant in the progression from the 2nd to the 3rd trimester. The total gain in the above variables during pregnancy was 493.54 kcal/day, 10.20 kg, 4.32 kg, 3.66 kg and 3.46 kg respectively.

Table 2 depicts the Pearson's correlation coefficients for the subjects' body weight, FFM, FM and TBW with basal metabolic rate. The result for pregnant females revealed a significantly stronger relationship between BMR and weight (r=0.848, $p < 0.001$) followed by FM (r=0.802, $p < 0.001$), FFM (r=0.788, $p < 0.001$) and TBW (r=0.771, $p < 0.001$). In the non-pregnant females, the correlation of BMR with FFM (r=0.799, $p < 0.001$) precedes the association with weight (r=0.719, $p < 0.001$), FM (r=0.682, $p < 0.001$) and TBW (r=0.613, $p < 0.001$).

In stepwise multivariate regression analysis (Table 3), the BMR dependent variable, adjusted for age, parity and physical activity was modelled as a linear function of the independent FM, FFM and TBW variables. The coefficient of determination for pregnancy periods (R^2) established (1) 34% BMR varia-

Table 1. Descriptive characteristic of pregnant and non-pregnant females

Variables	Pregnancy period	N	Mean	SD	*F*-value	*p*-value
Stature (cm)	1st trimester	37	154.94	6.37	0.41	0.744
	2nd trimester	55	155.29	4.65		
	3rd trimester	106	155.92	5.71		
	non pregnant	35	156.04	5.83		
Weight (kg)	1st trimester	37	62.70	15.38	19.29	<0.001
	2nd trimester	55	63.73	11.91		
	3rd trimester	106	72.98	10.79		
	non pregnant	35	59.61	9.89		
BMR (kcal/day)	1st trimester	37	5858.58	553.34	18.92	<0.001
	2nd trimester	55	5976.07	480.77		
	3rd trimester	106	6352.12	454.86		
	non pregnant	35	5812.23	411.31		
Fat (%)	1st trimester	37	31.73	8.13	11.33	<0.001
	2nd trimester	55	30.85	8.55		
	3rd trimester	106	35.79	5.77		
	non pregnant	35	29.43	7.18		
Fat mass (kg)	1st trimester	37	22.28	8.94	11.97	<0.001
	2nd trimester	55	20.67	8.74		
	3rd trimester	106	26.60	7.71		
	non pregnant	35	18.54	7.41		
FFM (kg)	1st trimester	37	42.70	4.13	21.00	<0.001
	2nd trimester	55	43.19	3.68		
	3rd trimester	106	46.36	4.30		
	non pregnant	35	40.78	3.86		
Total body water (TBW)	1st trimester	37	30.43	3.83	22.73	<0.001
	2nd trimester	55	31.64	2.72		
	3rd trimester	106	33.89	3.12		
	non pregnant	35	29.67	2.83		

tion due to FFM in trimester 1, (2) the major variation in BMR due to the FFM was 92.5% and only 4.7% variation was caused by increased TBW in trimester 2 and (3) 85.5% and 12.0% variability in BMR in trimester 3 was explained by FM and FFM, respectively. The F statistic for the multiple regression analysis showed significant results for all the above models, and body composition components which did not pose any change in BMR were excluded from stepwise regression analysis. Non-standardized regression coefficients (B-value) revealed the inde-

pendent contribution of body composition parameters to BMR. Although the single-unit increase in FFM and FM elevated BMR by 53.50 and 30.09 units, respectively in pregnant females; only FM (B=44.35) contributed significantly to the change in BMR with 63.9% of variation noted in the non-pregnant women.

Linear regression was used with the interaction term-(pregnancy × FM), (pregnancy x FFM) and (Pregnancy × TBW) to examine the varied relationships of FFM, FM and TBW with BMR in both pregnant and non-pregnant groups

Table 2. Pearson correlation coefficient for relationship between BMR and body composition parameter in pregnant and non-pregnant females

Pregnancy period	Weight (kg)	Fat mass (%)	FFM (kg)	TBW (kg)
1st trimester	0.391*	0.289	0.390*	0.386*
2nd trimester	0.987**	0.962**	0.923**	0.924**
3rd trimester	0.985**	0.925**	0.822**	0.810**
Non-pregnant	0.719**	0.799**	0.682**	0.613**
Pregnant (All)	0.848**	0.788**	0.802**	0.771**

Table 3. Stepwise multiple regression analysis for prediction of BMR (kJ/d) from fat-free mass (FFM), fat mass (FM) and total body water (TBW) in non-pregnant and pregnant women

Pregnancy period	Variables	R^2	ß-value	CI (95%)		*p*-value
				Lower	Upper	
Non-pregnant	FM	0.639	44.35	32.54	56.15	<0.001
1st trimester	FFM	0.340	52.27	9.91	94.63	0.017
2nd trimester	FM	0.925	39.39	35.86	42.91	<0.001
	TBW	0.047	58.80	47.81	69.79	<0.001
3rd trimester	FM	0.855	41.59	40.21	42.97	<0.001
	FFM	0.120	42.82	40.36	45.27	<0.001
Pregnant	FM	0.643	30.09	24.21	35.97	<0.001
	FFM	0.108	53.50	42.02	64.98	<0.001

Table 4. Multiple regression analysis evaluating the effect of pregnancy on the relationship between BMR and body composition

Variable	ß-value	CI95%		*p*-value
		Lower	Upper	
Pregnancy × FM	20.63	14.31	26.96	<0.001
Pregnancy × FFM	0.52	–40.27	41.31	0.980
Pregnancy × TBW	–13.99	–69.71	41.71	0.621

(Table 4). The results showed pregnancy interacted positively with fat mass to induce BMR change, precisely as in the non-pregnant females.

Discussion

Pregnancy, a milieu of physiological and metabolic adaptation, is associated with enhanced BMR from alteration in maternal tissue and metabolism to ensure foetal growth and development. The variability in altered body composition imposes differential energy requirement in pregnant females in similar or diverse populations.

In this study, pregnancy was found to be associated with weight gain, increased fat free mass, fat mass and BMR, with remarkable changes observed in the second and third trimesters. This concurs with studies illustrating pregnancy-asso-

ciated change in body composition and BMR (Goldberg et al. 1993; Forsum et al. 1988; Lof et al. 2005). The accelerated BMR here is explained by increased oxygen consumption from enhanced maternal circulation, respiration, renal function and increased tissue mass (Hytten 1980).The large increase in BMR witnessed during progression from the 2nd to the 3rd trimester emanated from the combination of the following; (1) a greater FFM in the foetus which increased total energy expenditure (TEE) by 1264 kJ/d and (2) increased FFM plasma levels in the gestation period provided both the high-energy requirements of foetal and uterine tissue and the more moderate energy needed by skeletal muscle(Butte et al. 1999).

The pregnant and non-pregnant Baniya females recorded significant correlations of BMR with body weight, FM, FFM and total body water. A positive correlation of weight with cumulative BMR increase in expectant females accorded with Butte et al's 2004 observation that gestational weight gain is a principal determinant of incremental energy requirements during pregnancy. Regression analysis revealed the significant contribution of fat mass to BMR in the non-pregnant females who volunteered for this study. This does not agree with Lof et al's 2005 assessment that BMR in non-pregnant females is significantly associated with FFM but not with total body fat. The substantial change in BMR in the pregnant females was due to combined FM and FFM; although fat free mass contributed to a much lesser extent. Our findings are substantiated by Lof et al. (2005) who also reported a significant correlation of FFM and total body fat with BMR during pregnancy. However, other studies present

discordant results for either the FM or FFM as BMR predictor variable. Butte et al. (2004) asserted that changes in BMR during pregnancy were correlated with changes in FFM but not with fat mass, and, Bronstein et al. (1996) considered that fat mass was a significant predictor of BMR, while FFM was not. A possible justification for these findings lies in the increased metabolic activity of otherwise metabolically less active adipose tissue during pregnancy. The pre-pregnancy total body fat associated with maternal nutritional status and weight gain during pregnancy also results in BMR variability (Lof et al. 2005). Ellison (2001) demonstrated that energy flux has a closer association with reproductive functions than energy stores. Hormonal changes during pregnancy underpin this association and are most closely associated with growth rather than body composition per se. Biochemical studies have presented a plausible verdict, indicating increased lipid metabolism due to elevated plasma lipoprotein concentrations (Campbell-Brown and Hytten 1998). Furthermore, leptin and resistin adipocyte-derived hormones regulate energy metabolism via fat oxidation (Okerede et al. 2004).

The energy requirement during pregnancy attributable to increased basal metabolism remains controversial due to conflicting data on maternal fat deposition and putative reduction in the mother's physical activity. While Hytten and Leitch (1971) stated that the energy cost of pregnancy could be met by economy of action without increased food intake, Forsum (2004) and Butte et al. (2004) disagreed. Their assessment of total energy expenditure during pregnancy determined that the decreased energy spent on physical activity was insufficient to counteract the energy cost of pregnan-

cy, because of fat retention and the increased energy required to maintain metabolism (Forsum 2004; Butte et al. 2004). Because of limitations imposed in this study, we were unable to assess total energy expenditure in pregnant women., and the cross-sectional study design,precluded consideration of inter-individual variability in the magnitude of BMR change attributable to gestational weight gain, pre-pregnancy nutritional status and foetal size. Regardless of these shortcomings which can be rectified in future research, the significant relationship of FM and FFM with enhanced BMR determined herein substantially advances knowledge of nutritional requirements during pregnancy.

Conclusion

In conclusion, pregnancy is an anabolic phase of the female reproductive cycle associated with metabolic flexibility where the relationship between body composition and BMR alters. While the increased basal metabolic rate associated with accelerated fat mass and fat free mass synthesis confirms their contribution to enhanced BMR, validation of this aspect of the human life cycle can be effected by research utilizing longitudinal study design.

Author contribution

The study was conceptualized by SB and SK; SB contributed to the acquisition of data. Statistical analysis and interpretation of the data was executed by DV. The article was drafted by SB, SK and DV. The manuscript was revised critically and finally approved for publication by SB and SK. All authors read and approved the final manuscript.

Conflict of interest

Authors declare no competing interest.

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