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ORIGINAL PAPER

Potential of clinical anthropometry in the assessment of health risks and complications of overweight and obesity in pregnant women: assessment of body composition using Matiegka equations

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Abstract

Aim: Complications associated with obesity may negatively affect the physiological growth and development of the fetus and the health of the child. The aim of the research was to determine the effect of pregnancy and the postpartum period on the body composition of first-time pregnant women using standardized anthropometric methods with the use of the Matiegka method for fractionation of body composition. *Design:* A longitudinal cohort study. *Methods:* The study was conducted in gynecological outpatient clinics on a population of 40 nulligravidas aged 18–40 years. The women were assessed in three stages corresponding to the trimesters of pregnancy and Stage IV, the postpartum period of six weeks. The parameters obtained were used to determine body composition according to the Matiegka method. The women were divided into two groups according to BMI, normal weight and overweight and obesity. *Results:* Significant changes in body composition were found during the measurements in Stages I–IV, with a decrease in skeletal muscle mass and an increase in fat component. There were significant changes in body composition between the categories of women with BMI normal weight and BMI overweight and obese in the ratio of skeletal muscle to body fat. *Conclusion:* The results indicate that monitoring body composition in pregnant women is important not only for preventing maternal obesity, but also for preventing fetal macrosomia and possible maternal and neonatal morbidity and mortality associated with childbirth and the postpartum period.

Keywords: anthropometry, body composition, first-time mother, postpartum period, pregnancy, trimester.

Introduction

Entering pregnancy overweight or obese is associated with an increased risk of gestational diabetes and hypertension, as well as a higher likelihood of delivering by cesarean section (Dodd et al., 2011; Thrift & Callaway, 2014). All women experience insulin resistance in their tissues during pregnancy (Baci et al., 2013). If a woman is in the normal weight category, her body is able to compensate and she does not develop gestational diabetes and its associated complications, such as fetal macrosomia, with possible shoulder dystocia at birth, injury to the baby at birth, or cesarean delivery. Obesity in pregnancy also poses a risk to the health of the child in adulthood (Catalano et al., 1991; HAPO Study Cooperative Research Group, 2008).

Internationally, the diagnosis of obesity is based on the Body Mass Index (BMI), with a BMI > 30 kg/m^2 indicating obesity (Han et al., 2006). Given the many limitations in the use of BMI, the assessment of maternal adiposity needs to be reviewed (Prentice & Jebb, 2001).

Understanding the process of controlling gestational weight gain in overweight and obese women is a contribution to the knowledge about changes in the body composition of pregnant women, which is related to the development of fat mass and fat-free mass in women, and also fetal unit weight gain (Balani et al., 2014; Eriksson et al., 2011; Kopp-Hoolihan et al., 1999). For this reason, much attention is currently being paid to body composition and its changes during pregnancy in groups of women in the relevant BMI categories (Lof & Forsum, 2004; Paxton et al., 1998).

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In particular, attention is being paid to how the distribution of adipose tissue changes during pregnancy in relation to the influence of female metabolism and its impact on fetal growth and development in each trimester of pregnancy (Heymsfield et al., 2005; Most et al., 2018).

In pregnant women, the focus is primarily on examining body composition using a two-component model, that is, dividing body mass into two components: fat mass (FM) and fat-free mass (FFM), the latter of which includes the mass of all other body tissues without body fat, including total body water, bone, protein and non-bone mineral mass (Heymsfield et al., 2005; Most et al., 2018).

The technical possibilities of new imaging methods used to determine the body composition of women during pregnancy are presented in expert studies including (Most et al., 2018; Widen & Gallagher, 2014): bioimpedance analysis, hydrodensitometry, dual X-ray absorptiometry, magnetic resonance imaging, air displacement, and ultrasound.

It is currently impossible to use the technically demanding methods mentioned above in practice due to the high price of the instruments, high operating costs, the demand for professional services, the impossibility of transport, and the use of these methods in the field.

Most et al. (2018) and Widen and Gallagher (2014) note that the methods cited for assessing the body composition of women during pregnancy are problematic, as they cannot completely distinguish the total ratio of fat and fat-free mass from the maternal-fetal unit. It is also necessary to take into account that the use of some methods such as dual X-ray absorptiometry, is inappropriate in terms of the health of the pregnant woman and the fetus due to X-ray radiation (even if the X-ray exposure is low) (Marshall et al., 2016). Similarly, the use of bioimpedance analysis in pregnant women is inappropriate due to physiological changes during pregnancy, such as increased blood volume, venous stasis, and leg swelling (Hájek et al., 2014; Roztočil et al., 2017).

A suitable method for monitoring pregnant women is the anthropometric method of body weight fractionation according to the Matiegka equations (Bláha et al., 1986; Bláha et al., 2007). This method belongs to the four-component model of body composition (McArdle et al., 2010).

Aim

The main objective of the longitudinal anthropological research was to determine the effect of pregnancy and the postpartum period on the body composition of first-time pregnant women using standardized anthropometric methods with the use of the Matiegka equations method of body composition fractionation.

Methods

Design

A longitudinal cohort study.

Sample

The study population consisted of 40 pregnant women aged 18.12 to 40.99 years (M = 31.73 years). The longitudinal study was conducted in three gynecological outpatient clinics in Kroměříž, Olomouc and Přerov and in the Center for Mother and Child in Zlín.

Only women with singleton pregnancies were included in the research. They were enrolled in the study based on the following criteria: being a nulligravida, that is, a woman who had not been exposed to previous pregnancy changes, and having no chronic disease, cardiovascular disease, endocrine disease, etc. Women were enrolled in the study on a voluntary basis after signing a written informed consent form.

Pregnant women were measured repeatedly at four stages corresponding to trimesters of pregnancy and postpartum: Stage I: Week 12 (Week 11 – Week 13); Stage II: Week 27 (Week 26 – Week 28); Stage III: Week 37 (Week 36 – Week 38) and Stage IV: 6–8 weeks after delivery. The week of pregnancy was determined by an early obstetric ultrasound.

Based on the determination of chronological age (Kopecký et al., 2019) women were categorized into two age groups: up to 29.99 years, and 30.00 years and older according to the World Health Organization classification (Table 1).

Table 1 Age categories according to the WHO (Kopecký et al., 2019)

Age (years)	N	M	Me	Min	Max	SD
The total population of women	40	31.73	31.68	18.12	40.99	5.18
Up to 29.99	12	25.69	26.09	18.12	29.84	3.72
Over 30.00	28	34.32	33.47	30.33	40.99	3.17

N – number of subjects; M – arithmetic mean; Me – median; Min – minimum value; Max – maximum value; SD – standard deviation

Data collection

Body parameters were measured using standardized anthropometric methods (Bláha et al., 1986; Marfell-Jones et al., 2006). The measurements were performed by one person, a midwife, who was trained by an anthropometric expert. During the research, pregnant women were measured in their underwear, without shoes. The measurements took place in the morning.

Body height, width and circumference parameters were measured to the nearest 0.1 cm, body weight to the nearest 0.1 kg, and skinfolds were measured at 6 sites to the nearest 0.5 mm. Width and circumference parameters of the upper and lower limbs and skinfolds were measured on the right side of the body.

The anthropometric parameters were measured using the following anthropometric instruments: anthropometer A-226, cephalometer K-221, pelvimeter P-216, modified callipers type BEST II K-501, calliper M-222, tape measure, and digital personal scale ETA 3775 (Kopecký et al., 2014).

For pregnant women, the BMI was calculated from their current body height and weight (Hackley et al., 2007) at each stage of measurement by dividing weight in kilograms by height squared (kg/m^2). Based on the calculated BMI, pregnant women were classified into the appropriate World Health Organization (WHO) BMI category (Hainer et al., 2021).

To analyze the body composition of pregnant women in Stages I, II, III and IV, body weight fractionation was performed according to the Matiegka equations (Bláha et al., 1986; Bláha et al., 2007). According to the Matiegka equations, the proportions of skeletal weight, skeletal muscle, fat, and the rest of the body in absolute value (kg) and percentage value (%) were determined by measuring the following parameters:

Skeletal weight – O:

$O = o^2 \times L \times k_1$

$o = (o_1 + o_2 + o_3 + o_4) / 4$

where o_1 ... biepicondylar breadth of the humerus (cm), o_2 ... breadth of the wrist (cm), o_3 ... biepicondylar breadth of the femur (cm), o_4 ... breadth of the ankle (cm), L ... body height (cm), k_1 ... 1.2.

Mass of the skin and subcutaneous adipose tissue weight – D:

$D = d \times S \times k_2$

$d = ½ \times (d_1 + d_2 + d_3 + d_4 + d_5 + d_6) / 6$

where d ... resulting sum of skinfolds in centimeters, d_1 ... skinfold at biceps muscle (cm), d_2 ... skinfold at the volar forearm (cm), d_3 ... skinfold at the thigh (cm), d_4 ... skinfold at the calf II (cm), d_5 ... skinfold at the chest II (cm), d_6 ... skinfold at the abdomen (cm)

S ... body surface area by Du Bois: $S = 71.84 \times W^{0.425} \times L^{0.725}$

S ... body surface area (cm^2), W ... body weight (kg), L ... body height (cm), k_2 ... 0.13.

Skeletal muscle weight – M:

$M = r^2 \times L \times k_3$

$r = (r_1 + r_2 + r_3 + r_4) / 4$

where r_1 ... radius of the upper arm circumference when relaxed (cm), r_2 ... radius of forearm circumference (cm), r_3 ... radius of the median circumference of the thigh (cm), r_4 ... radius of the maximum circumference of the calf (cm), L ... body height (cm), k_3 ... 6.5.

Circumferences were corrected by deducting the thickness of the skin and subcutaneous tissue. Formula for computing the radius (r_x) of circumference (Cr_x) corrected for fat:

$r_x = (Cr_x – 3.1416 \times skinfold_x) / 2 \times 3.1416$

Cr_1 – circumference of the relaxed arm (cm), Cr_2 – maximum circumference of the forearm (cm), Cr_3 – median circumference of the thigh (cm), Cr_4 – maximum circumference of the calf (cm),

$Skinfold_1$ – d_1 ... skinfold at biceps muscle (cm), $Skinfold_2$ – d_2 ... skinfold at the volar forearm (cm), $Skinfold_3$ – d_3 ... skinfold at the thigh (cm), $Skinfold_4$ – d_4 ... skinfold at the calf II (cm).

Residual mass – R:

$R = W – (O + D + M)$

Where W ... actual weight of body mass, O... portion of the weight of skeletal mass, D... portion of the weight of skin plus subcutaneous adipose tissue, M ... portion of the weight of muscle mass.

Body mass fractions in percentages (%):

O (%) = (skeletal weight in kg / body weight in kg) × 100

D (%) = (skin plus subcutaneous adipose tissue in kg / body weight in kg) ×100

M (%) = (skeletal muscle weight in kg / body weight in kg) ×100

R (%) = (residual mass in kg / body weight in kg) × 100.

The sum of the four components equaled the body weight.

Determination of the fetal unit

Determination of the fetal unit Hájek et al. (2014), Procházka et al. (2011), Roztočil et al. (2017), Thompson et al. (2007), and Zwinger (2004) provided data on fetal weight, amount of amniotic fluid, and placental weight at different weeks of gestation, that is, the factors involved in gestational weight gain during pregnancy.

The authors state that at 27 weeks gestation the fetal weight is 1150 g, amniotic fluid 600 g and placenta 350 g. At 37 weeks gestation, they report a fetal weight of 3000 g, amniotic fluid 800 g and placenta 500 g. These data and the longitudinal ultrasound measurements at 27 and 37 weeks of gestation were then used to calculate and subsequently determine the fetal unit, i.e. the sum of fetal, amniotic fluid and placental weights. For the 27th week (2nd trimester), the fetal unit weight was determined to be 2,100 g, and at the 37th week (3rd trimester) of gestation, the fetal unit weight corresponds to 4,300 g. The 2nd and 3rd trimester weeks were determined from anthropometric measurements for research purposes.

We do not report the weight fractions of the embryo-fetal unit in the 1st trimester because they are irrelevant to the overall weight of the pregnant woman.

Data analysis

Statistical characteristics were calculated from the measured somatic parameters in the study population: arithmetic mean (M), median (Me), standard deviation (SD), range of variation (R), minimum (Min) and maximum (Max) values, inter-stage increments (diff) and differences between the mean values of the studied parameters (d) in pregnant women in the BMI normal and BMI overweight and obesity categories at the respective stages of the study.

Data normality was verified using the Shapiro–Wilk test. According to the results of data validation and their graphical representation using a frequency histogram of the respective parameters, the following statistical tests were used to evaluate the relationships between the variables: the one-sample t-test, Mann–Whitney U-test, Wilcoxon paired signed-rank test, and non-parametric one-way ANOVA for dependent measures, Friedman test. Tests were performed at significance levels of $^{*}p < 0.05$, $^{**}p < 0.01$, and $^{***}p < 0.001$.

For the numerical processing of the obtained data, mathematical statistics methods (Hendl, 2004) were applied using Microsoft Excel 2016 and TIBCO Statistica software package, version 13.3.

Results

Body height did not change during the longitudinal measurements between Stage I and IV, oscillating around a mean value of 165.30 cm (165.18–165.33 cm). The results of the Friedman test (one-way ANOVA for dependent measures) show that at each stage of the measurement of weight, weight reduced and BMI reduced by the fetal unit in the 2nd trimester (2.1 kg) and 3rd trimester (4.3 kg), the differences were highly significant (p = 0.000). In the last Stage IV, that is, after the postpartum period (between 6 and 8 weeks after delivery), the weight of the women was no longer reduced. The body weight was 7.78 kg higher and the BMI was 2.93 kg/m^2 higher compared to the baseline 1st trimester measurements (Table 2).

This reduction in body weight was also reflected in gestational weight gain. In the case of the actual weight, the mean gestational gain was 10.22 kg, while in the case of the weight reduced by the fetal unit, the mean gestational gain was 5.91 kg.

Table 2 Changes in somatic parameters between Stages I–IV

Stage	**Weight (kg)**			**Weight reduced (kg)**				**BMI kg/m²**		
	M	SD	diff	M	SD	diff	d	M	SD	diff
I	63.09	12.81	-	-	-	-	-	23.09	4.51	-
II	68.48	13.55	5.39**	66.39	13.56	3.30**	2.09**	24.28	4.64	1.19**
III	73.31	13.65	4.83**	69.00	13.66	2.61**	4.31**	25.31	4.89	1.03**
IV	70.87	12.93	2.44**	-	-	-	-	26.02	4.60	0.71**

*M – arithmetic mean; SD – standard deviation; diff – difference in the mean values for measurements between Stages I and IV and their statistical significance; d – difference in the mean values between weight and weight reduced at a particular stage (Wilcoxon paired signed-rank test); **p < 0.01 – level of significance*

Women were categorized as being of normal weight, overweight and obese according to the baseline measurements, that is, at Stage I (1st trimester), and according to the BMI calculation (Table 3). There was still no weight gain. Often the weight was the same as at the beginning of the pregnancy.

The approach to body composition analysis was similar to that used in other studies assessing changes in body composition in pregnant women by BMI category (Dodd et al., 2015; Most et al., 2018; Soltani & Fraser, 2000; Straughen et al., 2013). One possible way was to compare the BMI normal weight and BMI overweight and obesity categories. For this purpose, women were grouped as follows: Group 1 comprising women categorized as normal weight by BMI (n = 29) and Group 2 comprising overweight (n = 8) and obese (n = 3) women, that is, 11 women in total. Hereafter, the groups will be referred to in the text as Group 1 BMI normal weight (n = 29) and Group 2 BMI overweight and obesity (n = 11). The classification of women into BMI categories shows that 27.5% were overweight or obese (Table 3).

Table 3 Classification of pregnant women into WHO BMI categories (Hainer et al., 2021)

Age (years)	**Group 1 normal weight**		**Group 2 overweight**		**Group 2 obesity**		**Total**	
	N	%	N	%	N	%	N	%
18.00–29.99	9	75.00	2	16.67	1	8.33	12	30.00
30.00–40.00	20	71.43	6	21.43	2	7.14	28	70.00
Total	29	72.50	8	20.00	3	7.50	40	100.00

N – number of subjects; % – percentage of subjects; WHO – World Health Organization, BMI – Body Mass Index

There were no statistically significant differences (Mann–Whitney U-test) in body height between Stage I and Stage IV for women in both study groups, that is, BMI normal weight and BMI overweight and obesity.

The results showed that in terms of morphological structure of the studied women, divided into BMI normal weight and BMI overweight and obesity categories, the variables of weight (kg) and individual body weight components in absolute (kg) and relative (%) units showed highly significant statistical differences (Table 4).

Between Stages I and IV, developmental stability was observed in the skeletal component, which did not show significant changes (one-way ANOVA for dependent measures, Friedman test) in either group of women. However, when comparing the BMI normal weight and BMI overweight and obesity groups, a significant difference was found in favor of women in the BMI normal weight category for the relative skeletal fraction score (Table 4, Figure 2).

Notably, women in the BMI normal weight category had a 12.2% (3.17 kg) decrease in skeletal muscle mass between Stages I and III, while for women in the BMI overweight and obesity category, the decrease was 14.6% (4.83 kg). At the same time, there was a greater increase in skeletal muscle mass during the postpartum period in the BMI normal weight group (7%, 15.6 kg) compared to the BMI overweight and obesity category (1.6%, 0.14 kg) (Table 4). Furthermore, there was an increase in the fat component between Stage I and III measurements of 8.99 kg (111.8%) in women in the BMI normal weight category and 10.54 kg (53%) in women in the BMI overweight and obesity group. Subsequently, during the postpartum period, women in the BMI normal weight category showed a gradual decrease in the fat fraction, while women in the BMI overweight and obesity category showed a rather marked increase in the fat fraction (Table 4, Figure 1).

The absolute and relative values of the calculated residual mass component showed a statistically significant difference between the group of women in the BMI normal weight category and the BMI overweight and obesity group (Table 4, Figure 2).

There was also a noticeable difference in trend between Stages III and IV (Figure 1). Women in the BMI normal weight category showed a continuous decrease in the percentage of the fat fraction and a gradual increase in skeletal muscle. In those in the BMI overweight and obesity category, the trend was the opposite, with an increase in the fat fraction and a decrease in the percentage of skeletal muscle. There was also an apparent "crossover" of the muscle (decrease) and fat (increase) components between Stages II and III in the BMI overweight and obesity category. This trend was not observed for women in the BMI normal weight category.

Table 4 Changes in body weight (kg) and body composition according to the Matiegka equations (kg, %) in pregnant women in BMI categories during Stages I to IV

Stage	BMI normal weight				BMI overweight and obesity					
	M	Me	SD	diff	M	Me	SD	diff	d	p
Weight (kg)										
I	56.71	56.00	6.10	-	79.91	77.50	10.34	-	22.90	0.000***
II	59.88	61.00	6.54	3.17**	83.54	83.00	12.32	3.63**	23.66	0.000***
III	62.75	65.00	7.68	2.87**	85.47	87.00	12.28	1.93**	22.72	0.000***
IV	65.03	64.00	8.13	2.28**	86.27	85.00	10.34	0.80$^{ns.}$	21.24	0.000***
Skeletal weight (kg)										
I	8.16	7.95	1.12	-	9.60	9.07	1.65	-	1.44	0.003**
II	8.32	8.13	1.06	0.16$^{ns.}$	9.40	9.13	1.05	-0.20$^{ns.}$	0.78	0.007**
III	8.33	8.00	1.15	0.01$^{ns.}$	9.74	9.04	1.40	0.34$^{ns.}$	1.41	0.002**
IV	8.91	8.40	1.47	0.58$^{ns.}$	9.64	9.22	1.12	-0.10$^{ns.}$	0.73	0.142$^{ns.}$
Skeletal weight (%)										
I	14.38	14.58	1.19	-	12.06	11.70	1.78	-	4.32	0.000***
II	13.92	14.06	1.14	-0.46$^{ns.}$	11.33	11.14	1.11	-0.73$^{ns.}$	2.59	0.000***
III	13.32	13.27	1.26	-0.60$^{ns.}$	11.44	11.25	1.15	0.11$^{ns.}$	2.03	0.000***
IV	13.72	13.57	1.56	0.40$^{ns.}$	11.29	11.25	1.66	-0.15$^{ns.}$	2.43	0.000***
Skeletal muscle weight (kg)										
I	25.88	26.78	4.60	-	33.26	34.33	5.00	-	7.38	0.000***
II	24.67	24.70	4.77	-1.21**	29.70	29.15	4.53	-3.56**	5.03	0.005**
III	22.71	22.18	4.23	-1.96**	28.43	27.69	3.64	-1.27**	5.72	0.000***
IV	24.30	23.88	5.72	1.59**	28.57	28.32	3.00	0.14$^{ns.}$	4.24	0.024*
Skeletal muscle weight (%)										
I	45.50	46.78	5.60	-	41.65	42.15	3.81	-	3.85	0.043*
II	41.08	40.38	5.89	-4.42**	35.62	35.34	3.13	-6.03**	5.46	0.006**
III	36.32	36.84	5.92	-4.76**	33.48	32.39	3.65	-2.14**	2.84	0.048**
IV	37.28	37.40	6.60	0.96**	33.30	32.14	3.25	-0.18$^{ns.}$	3.98	0.012**
Fat mass (kg)										
I	8.04	8.35	3.43	-	19.88	17.97	6.43	-	11.83	0.000***
II	12.07	12.37	4.54	4.03**	27.39	25.51	7.11	7.51**	15.32	0.000***
III	17.03	16.40	6.35	4.96**	30.42	27.78	7.98	3.03**	13.39	0.000***
IV	16.21	15.54	6.63	-0.82$^{ns.}$	30.99	28.88	8.09	0.57$^{ns.}$	14.78	0.000***
Fat mass (%)										
I	14.21	14.18	5.88	-	24.67	24.49	6.27	-	10.66	0.000***
II	20.15	19.88	7.34	5.94**	32.51	31.59	4.51	7.84**	12.36	0.000***
III	26.79	26.24	8.23	6.64**	35.21	36.53	5.08	2.70**	8.42	0.003**
IV	24.87	24.37	9.43	-1.92$^{ns.}$	35.53	34.70	5.77	0.32$^{ns.}$	10.66	0.001***
Residual mass (kg)										
I	14.64	14.84	1.42	-	17.17	17.21	1.73	-	2.53	0.000***
II	14.82	15.05	1.47	0.18$^{ns.}$	17.05	16.89	1.65	-0.12$^{ns.}$	2.23	0.000***
III	14.68	14.75	1.40	-0.14$^{ns.}$	16.89	16.39	1.84	-0.16$^{ns.}$	2.21	0.000***
IV	15.62	15.39	2.23	0.94**	17.07	16.39	1.61	0.18$^{ns.}$	1.45	0.049**
Residual mass (%)										
I	25.91	25.76	1.88	-	21.61	21.22	1.88	-	4.30	0.000***
II	24.85	24.32	2.01	-1.06**	20.54	20.63	1.18	-1.07**	4.31	0.000***
III	23.58	23.52	2.36	-1.27**	19.87	20.07	1.28	-0.67**	3.71	0.000***
IV	24.14	24.27	2.82	0.56**	19.89	20.05	1.59	0.02$^{ns.}$	4.25	0.000***

*BMI – Body Mass Index; M – arithmetic mean; Me – median; SD – standard deviation; diff – difference in the mean values for measurements between Stages I and IV and their statistical significance; d – difference in the mean values between BMI normal weight and BMI overweight and obesity at a particular stage; p – level of significance; **p < 0.01; ***p < 0.001; ns. – nonsignificant*

The observed trend of "crossover" of increase in the fat fraction and decrease in the muscle fraction in the BMI overweight and obesity category is risky in terms of physical condition and health. Women should be duly informed that they need to pay increased attention to diet and maintain appropriate levels of physical activity during the postpartum period. During the postpartum period (between Stages III and IV), there was a halt in the increase in the fat component of normal weight women due to the greater muscle component, which is metabolically involved in the burning of body fat. For the BMI overweight and obesity group, this trend was not evident (Figure 1).

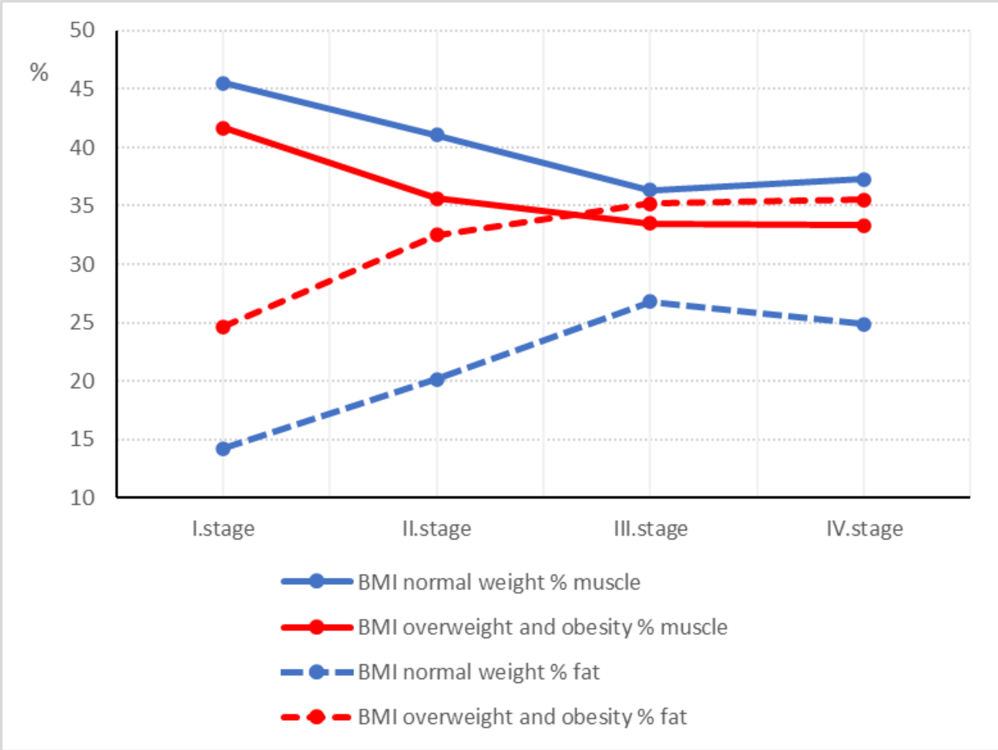

Figure 1 Changes in the percentage of the fat and muscle components according to the Matiegka equations in pregnant women in the BMI normal weight and BMI overweight and obesity categories between Stages I and IV

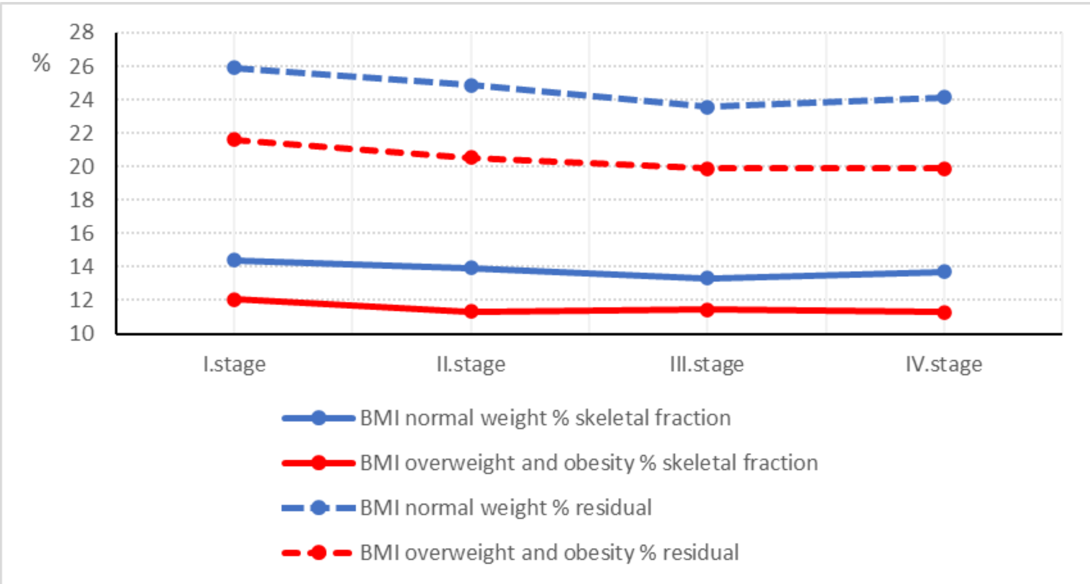

Figure 2 Changes in the percentage of the skeletal fraction and calculated residual mass according to the Matiegka equations in pregnant women in the BMI normal weight and BMI overweight and obesity categories between Stages I and IV

Discussion

Baseline somatic characteristics of the study population of first-time pregnant women (n = 40) were compared with reference parameters of contemporary women (Kopecký et al., 2016). The comparison showed that the body height and weight of the study population did not differ from the normal population of women in the Czech Republic (Table 5).

Table 5 Comparison of body height and weight of women with reference data in the Czech Republic

Parameter	**Study population (N = 40)**		**Women 2015 (N = 2606)**			
	M	SD	M	SD	d	p
Age (years)	31.73	5.18	34.26	16.00	2.53	0.318$^{ns.}$
Body height (cm)	165.30	6.78	165.99	6.37	0.69	0.497$^{ns.}$
Body weight (kg)	63.10	12.81	65.67	11.62	2.57	0.166$^{ns.}$

N – number of subjects; M – arithmetic mean; SD – standard deviation; d – difference in the mean values between the study population and reference data in the Czech Republic; p – level of significance (one-sample t-test); ns. – nonsignificant

In terms of comparing the results of our longitudinal research, we could not find any studies in databases that applied a similar approach by using body weight fractionation with the Matiegka equations. The method and results showed that it is possible to estimate body composition in pregnant women, that is, to quantitatively separate the growth of the embryo and fetus, amniotic fluid, and placenta from the weight of the pregnant woman when assessing changes in her body composition. The study conducted sought to address a key research question that has been discussed in many research papers on how to determine body composition in women during pregnancy (Balani et al., 2014; Eriksson et al., 2011; Heymsfield et al., 2005; Lof & Forsum, 2004; Most et al., 2018; Widen & Gallagher, 2014).

Our results provide a practical way to address this major deficiency in clinical practice for assessing body composition in pregnant women. The sum of all components was calculated and this weight, which we defined as the fetal unit weight, was subtracted from the weight of the pregnant woman in Stages II and III of the measurement. The Matiegka method used also showed that it is possible to analyze the amount of skeletal muscle and fat components, thus objectively assessing energy intake and expenditure and providing better estimates of energy requirements for fetal growth, as well as specifically aiding in the control of gestational weight gain (Heslehurst et al., 2008; Hronek et al., 2011).

In agreement with other authors (Dodd et al., 2015; Larciprete et al., 2003; Widen & Gallagher, 2014), we confirmed an increase in fat mass and a decrease in fat-free body mass during pregnancy. However, our research suggests that the changes in fat-free body mass, or its decrease, are mainly at the level of skeletal muscle, that is. the active component of fat-free body mass. The results also indicate that skeletal muscle decline was more pronounced in the BMI overweight and obesity category compared to the normal weight category of women. It is evident that during the postpartum period, women in the BMI normal weight category show a stagnation in the increase in the fat component and more of an increase in skeletal muscle, whereas women in the BMI overweight and obesity category continued to show an increase in the fat fraction and a decrease in skeletal muscle. Taken together, our results are consistent with findings in the literature that there is a significant increase in skinfolds during pregnancy, and the results could subsequently be used to calculate estimates of body composition (fat fraction and fat-free body mass) using appropriate regression equations with respect to BMI, race, and possibly a specific period in pregnancy (Kannieappan et al., 2013; López et al., 2011; Widen & Gallagher, 2014).

Limitation of the study

Standardized anthropometry is an appropriate way of assessing the somatic characteristics and body composition of women during pregnancy. It is a non-invasive and affordable method. However, it places great demands on the accuracy of measurements, adherence to the measurement methodology, and timing of measurements in pregnant women. A limiting factor may be the willingness of pregnant women to participate in longitudinal research, as evidenced by our experience. Initially, a total of 49 women were included in the study. Due to missed appointments with the gynecologist and thus missed measurement dates (Stage II), three women were excluded from the research. During Stage III, three more women were excluded due to premature birth, two women moved during the measurement, and one woman withdrew without giving a reason. It is also important to arrange for a gynecological clinic where the research can take place.

Conclusion

The Matiegka method allows to determine not only the amount of body fat (fat mass), the fat component, but also the fat-free mass, which in this case includes the skeletal and muscle components and the mass of the residual component (internal organs and fluids). The results have shown that anthropometric measurement is suitable for monitoring the somatic characteristics as well as the body composition of women not only during pregnancy, but also during the preconception and postpartum periods. Body composition analysis may point not only to obesity, but also to “false negative obesity” in women with relatively high amounts of adipose tissue at normal BMI values. This may also help to modify dietary and physical activity recommendations during pregnancy because of its varying effects on metabolic and cardiovascular health, and adverse maternal and fetal outcomes. At the same time, however, it must be emphasized that standardized anthropometry methods place great demands on the person performing the actual measurement, as well as on their training and practice.

The present study provides the following insights into the care of overweight and obese women for midwifery practice: regularly monitor the BMI of women prior to planned conception; expand body composition monitoring in the overweight and obesity category by using skinfold anthropometry and by determining the proportion of fat-free and fat components; provide information on the risks associated with obesity in pregnancy in terms of the health of the woman and the proper development of the fetus; monitor weight gain; draw attention to appropriate food choices; and motivate the woman to engage in regular physical activity during her pregnancy, which must be adapted to her current state of health in collaboration with her doctor.

Ethical aspects and conflict of interest

The research was approved by the Ethics Committee of the Faculty of Health Sciences of Palacký University in Olomouc, Czech Republic on 25 January 2016 a 24 January 2017 in accordance with the Helsinki Declaration (UPOL-7821/1040-2016, UPOL-7812/1040-2017)

The authors of the article agree to participate in the manuscript.

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Author contributions

Conception and design (MK, RH), data collection (MK, RH, MLD), data analysis and interpretation (MK, RH, LM, KJ, MLD), manuscript draft (MK, RH, LM), critical revision of the manuscript (MK, RH, LM, KJ, MLD), final approval of the manuscript (MK).

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