Nutrition 60 (2019) 227–229

Contents lists available at ScienceDirect

Nutrition

journal homepage: www.nutritionjrnl.com

Brief report

Body composition measurement by air displacement plethysmography in pregnancy: Comparison of predicted versus measured thoracic gas volume

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ARTICLE INFO

Article History:
Received 1 March 2018
Received in revised form 9 August 2018
Accepted 1 September 2018

Keywords:
Air displacement plethysmography
Body composition
Fat mass
Obesity
Pregnancy
Thoracic gas volume

ABSTRACT

Objectives: Body composition measurements with air displacement plethysmography (ADP) define body volume, which must be corrected for thoracic gas volume (TGV). We hypothesized that physiologic changes owing to pregnancy could affect the accuracy of predicted TGV and introduce errors into body composition measurements.

Methods: We investigated the effect of measuring versus predicting TGV on the accuracy of body composition calculations measured with ADP in overweight and obese pregnant women. The fat and fat-free masses of 110 women were determined with ADP with predicted and measured TGV.

Results: Measured TGV decreased from early to late pregnancy ($P = 0.0002$). Compared with measured TGV, predicted TGV was 6.3% higher during early gestation and 12.6% higher during late gestation (both $P \leq 0.001$). The use of predicted instead of measured TGV in body composition calculations resulted in an overestimation of fat mass by 0.8% during the early stage, and 2.6% during the late stage of pregnancy (both $P \leq 0.001$).

Conclusions: Measuring TGV increases the accuracy of body composition measurement by ADP in overweight and obese women, particularly during the late stage of pregnancy.

Introduction

Excess body adiposity has been linked to pregnancy-associated maternal and offspring morbidity [1]. Body composition reflects nutritional status and provides more precise information about the adiposity of the body than the widely used body mass index (BMI) [2]. There is marked interindividual variation in fat mass (FM) and fat-free mass (FFM) gain, which emphasizes the importance of measuring body composition [3]. Air displacement plethysmography (ADP) is recognized as a valid method to measure adiposity in overweight and obese nonpregnant women [4], and has been proposed as the preferred method to assess maternal FM during pregnancy [3].

Body composition calculations from ADP measurements are based on defining body volume, which must be corrected for thoracic gas volume (TGV). Physiologic changes during pregnancy, such as the growth of the uterus, weight gain, and swelling, likely affect lung volume. Therefore, predicted TGV, which is based on the height and age of the subject, might not be applicable in the use of body composition calculations with ADP.

In a previous small study of women with a normal weight, the prediction of TGV compared with the actual measurement was suggested to result in an overestimation of body fat by 0.5% at 32 wk of pregnancy [5]. Also, body weight changes have been found to influence measured TGV in nonpregnant overweight women [6]. Nonetheless, predicted TGV has been used to define FM during pregnancy in recent studies [7,8]. Both pregnancy and a high BMI score might interfere with the estimation of TGV during pregnancy; therefore, we investigated the use of predicted versus

Sources of support: This work was supported by State funding for university-level health research, Academy of Finland (#258606), the Diabetes Research Foundation, and the University of Turku Graduate School (personal funding to Dr. Outi Pellonperä).

Conflicts of interest: None.

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https://doi.org/10.1016/j.nut.2018.09.035
0899-9007/

Table 1
Characteristics of the pregnant women

Characteristics	N = 110
Primipara	49 (44.5)
Age (years)	30.2 ± 4.8
Prepregnancy body mass index (kg m^{-2})	29.8 ± 4.1
Overweight	61 (55.5)
Obese	49 (44.5)
Gestational age first visit	13.5 ± 2.5
Gestational age second visit	35.3 ± 1.1

Overweight body mass index: 25 to 29.9 kg m^{-2}; obese body mass index ≥ 30.0 kg m^{-2}
Data are presented as numbers and percentages or mean ± standard deviation.

measured TGV in the calculation of FM measured by ADP in overweight and obese women during early and late gestation.

Methods

This prospective study examined 110 pregnant women in Southwest Finland. The data were collected from overweight and obese women who participated in a mother–infant dietary intervention trial (ClinicalTrials.gov Identifier: NCT01922791). Women at <17 gestational weeks and a BMI score of ≥25 kg/m^{-2} were recruited in the study. The study was conducted in accordance with the guidelines of the Declaration of Helsinki and approved by the ethics committee of the Hospital District of Southwest Finland. Written informed consent was obtained from all subjects.

We included the first 110 women who attended both study visits that were conducted during the early and late stages of pregnancy (mean: 13.5 and 35.1 gestational weeks, respectively; Table 1). The women were generally in good health, although 29 women reported having asthma or allergies, 5 reported mild mental disorders, 5 reported migraine, 4 reported hypothyroidism controlled by medication, and 2 reported psoriasis.

Body composition measurements

During the study visits, all 110 women had their body composition and weight measured. During the first visit, height was measured to the nearest 0.1 cm with a wall stadiometer. ADP and an electronic scale (Bod Pod, COSMED, Inc., Concord, CA) were used to measure body volume and weight in accordance with the manufacturer's instructions. FM and FFM were calculated from density using the formulas devised by van Raaij et al. [9], which consider the length of gestation and the presence of marked general swelling (n = 2 during early and n = 20 during late gestation, respectively) when necessary. TGV was measured whenever possible (n = 100 during early gestation and n = 106 during late gestation) and used in the calculations of FM and FFM. After overnight fasting and emptying of the bladder, the subjects entered the measurement chamber wearing a tight cap and underwear, and were advised not to exercise or shower on the morning of the measurements.

Statistical analysis

The normality of the data was checked visually from histograms. The data were summarized as frequencies and percentages for categorical variables and as means and standard deviations for normally distributed continuous variables. The 95% confidence intervals were calculated in cases where differences were reported. In the comparisons, the paired samples *t* test was used to calculate the difference in measured TGV between early and late gestation and calculate the differences between measured and predicted TGV in body composition results. A *P*-value of < 0.05 was considered significant. The analyses were conducted with IBM SPSS statistics, version 22.0 for Windows (IBM SPSS Inc., Chicago, IL).

Results

The clinical characteristics of the women are presented in Table 1. Measured TGV decreased from early to late gestation ($P = 0.0002$; Table 2). The use of predicted instead of measured TGV resulted in a statistically significant overestimation of 0.37 kg and 0.75 kg of FM during early and late gestation, respectively. Predicted TGV was 6.3% higher than measured TGV during early gestation. Subsequently, body volume, FM, and body fat percentage (BF%) calculated with the predicted TGV were 0.1%, 0.8%, and 1.1% higher, respectively ($P \leq 0.002$ for all comparisons) than the values obtained with the measured TGV. During late gestation, predicted TGV was 12.6% higher than measured TGV. Based on the predicted TGV, body volume was 0.2%, FM 2.6%, and BF% 2.0% higher ($P < 0.001$ for all comparisons) than with measured TGV.

Discussion

We demonstrated here that the use of predicted instead of measured TGV in body composition calculations results in an overestimation of FM and BF% by approximately 1% during early gestation and by 2% during late gestation in overweight and obese women.

In nonpregnant individuals, prediction of TGV does not affect body composition results significantly compared with measured TGV [10,11]. However, similar to the results of our study, the prediction of TGV during late gestation has been reported to lead to a slight overestimation of body fat by 0.5% at 32 gestational weeks in women of normal weight [5]. Our results reveal that a greater overestimation at a mean of 35 gestational weeks could be due to the obesity status of our subjects and, together with early gestation measurements, might also indicate that the overestimation increases somewhat as the pregnancy progresses. With advanced gestational age, the growing uterus can cause an additional elevation of the diaphragm and affect TGV. This possible error could be diminished by measuring instead of trying to predict TGV.

Body composition measurements using ADP are influenced by several factors (e.g., body hair, clothing, and fasting state) and gestational weeks during pregnancy. Alterations in these conditions might already introduce inaccuracies into the calculations. Because measurement of TGV is straightforward and feasible (i.e., we had a success rate of 96% during late gestation), the measurement of TGV is recommended to minimize these errors.

Table 2
Predicted and measured thoracic gas volume. Body volume, fat mass and body fat percentage calculated applying the predicted and measured thoracic gas volume on both study visits.

Variable of body composition measurement	Measured*		Predicted		Mean difference	95% CI	*P*-value†
	Mean	SD	Mean	SD			
Thoracic gas volume *in* early/late gestation (L)	3.08	0.69	3.27	0.24	0.19	0.08–0.31	0.001
Thoracic gas volume *in* early/late gestation (L)	2.91	0.59	3.28	0.24	0.37	0.28–0.46	< 0.0001
Body volume *in* early/late gestation (L)	84.3	14.5	84.4	14.5	0.07	0.03–0.12	0.002
Body volume *in* early/late gestation (L)	93.2	14.0	93.4	14.0	0.14	0.11–0.18	< 0.0001
Fat mass *in* early/late gestation (kg)	37.3	10.3	37.6	10.3	0.37	0.14–0.60	0.002
Fat mass *in* early/late gestation (kg)	38.5	9.95	39.5	10.5	0.75	0.56–0.95	< 0.0001
Fat percentage *in* early/late gestation	43.5	5.74	44.0	5.77	0.49	0.20–0.79	0.001
Fat percentage *in* early/late gestation	40.7	5.54	41.6	5.54	0.83	0.62–1.04	< 0.0001

CI, confidence interval; SD, standard deviation
*Data were available for 100 and 106 participants at the first and second study visits, respectively.
†Paired samples *t* test

The strength of this study was its prospective nature with a relatively large sample size compared with earlier studies that involved ADP measurements during pregnancy [3,5,7,8,12]. Because previous knowledge about this subject was scarce, new information applicable for use to measure gestational body composition was generated.

Conclusions

An accurate measurement of body composition is called for to better identify mothers at risk of obesity-related gestational complications. Predicting TGV in ADP measurements results in an overestimation of FM during late gestation. The assessment of TGV improves the accuracy of body composition measurements and is therefore recommended, particularly in overweight women during the later stages of pregnancy.

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