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

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**Highlights**

- Predicted thoracic gas volume (TGV) was higher than measured TGV in pregnant women
- TGV decreases from early to late gestation in overweight/obese women
- Predicting TGV results in an overestimation of fat mass by 0.8% in early gestation
- In late gestation overestimation of fat mass due to TGV prediction was 2.6%
- Measuring TGV increases accuracy of body composition measurement by ADP


## ABSTRACT

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

*Methods:* We investigated the effect of measuring vs. predicting TGV on the accuracy of body composition calculations measured with ADP in overweight and obese pregnant women. Fat mass (FM) and fat free mass (FFM) 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 to measured TGV, predicted TGV was 6.3% higher in early gestation and 12.6% higher in late gestation (both $p\leq0.001$). The use of predicted instead of measured TGV in body composition calculations resulted in an overestimation of FM by 0.8% in early and by 2.6% in late pregnancy (both $p\leq0.001$).

*Conclusion:* Measuring TGV increases the accuracy of body composition measurement by ADP in overweight and obese women, particularly in late 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 BMI[2]. There is marked inter-individual variation in FM and FFM gain, emphasizing the importance of measuring body composition[3]. Air displacement plethysmography (ADP) is recognized as a valid method to measure adiposity in overweight and obese non-pregnant women[4], and it has also been proposed to be the preferred method for assessing maternal fat mass (FM) during pregnancy[3]. Body composition calculations from ADP measurements are based on defining body volume, which must be corrected for the thoracic gas volume (TGV). It is likely that physiological changes during pregnancy, such as growth of the uterus, weight gain and swelling, affect lung volume. Therefore, predicted TGV, which is based on height and age of the subject, might not be applicable in the use of body composition calculations with ADP. It has been suggested in a previous small study in normal-weight women that the prediction of TGV compared to its actual measurement results in an overestimation of body fat by 0.5% at 32 weeks of pregnancy[5]. It has also been found in non-pregnant overweight women that body weight changes influence measured TGV[6]. Nonetheless, predicted TGV has been used in defining FM during pregnancy in recent studies[7,8]. As both pregnancy and high BMI might interfere with the estimation of TGV during pregnancy, we investigated the use of predicted versus measured TGV in the calculation of FM measured by ADP in overweight and obese women in early and late gestation.

## MATERIALS AND METHODS

This prospective study examined 110 pregnant women living in Southwest Finland. The data were collected from overweight and obese women participating in a mother-infant dietary intervention trial (ClinicalTrials.gov Identifier: NCT01922791). Women at less than 17 gestational weeks and BMI $\geq$25kg $m^{-2}$ were recruited in the study. This study was conducted according to 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 conducted in early and late pregnancy (mean 13.5 and 35.1 gestational weeks, table 1). The women were generally in good health, although 29 reported having asthma or allergies, 5 mild mental disorders, 5 migraine, 4 hypothyroidism controlled by medication and 2 psoriasis.

**Body composition measurements**

On study visits, all 110 women had their body composition and weight measured. In the first visit, height was measured to the nearest 0.1cm with a wall stadiometer. ADP and an electronic scale (the Bod Pod system, COSMED, Inc., Concord, CA, USA) were used to measure body volume and weight according to the manufacturer's instructions. FM and fat free mass (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 in early and n=20 in late gestation, respectively), when necessary. TGV was measured whenever possible (n=100 in early and n=106 in late gestation) and used in the calculations of FM and FFM. After overnight fasting and emptying the bladder, the subjects entered the measurement chamber wearing a tight cap and underwear. They were advised not to exercise or to shower on the morning of 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. Ninety-five percent confidence intervals were calculated in cases where differences were reported. In the comparisons, paired samples t-test was used to calculate the difference in measured TGV between early and late gestation and to calculate

differences between measured and predicted TGV in body composition results. A p-value <0.05 was considered significant. Analyses were conducted with IBM SPSS statistics version 22.0 for Windows (IBM SPSS Inc. USA, Chicago, IL, USA).

**RESULTS**

The clinical characteristics of the women are presented in table 1.

Table 1. Characteristics of the pregnant women.

| Characteristics | N=110 |
|---|---|
| Primipara | 49 (44.5) |
| Age (years) | 30.2±4.8 |
| Pre-pregnancy BMI (kg $m^{-2}$) | 29.8±4.1 |
| Overweight | 61 (55.5) |
| Obese | 49 (44.5) |
| Gestational age 1st visit | 13.5±2.5 |
| Gestational age 2nd visit | 35.3±1.1 |

Overweight BMI 25-29.9 kg $m^{-2}$, Obese BMI ≥ 30.0 kg $m^{-2}$

Data are presented as numbers and percentages (in brackets) or mean ± SD

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 0.37kg and 0.75kg of FM in early and late gestation, respectively. Predicted TGV was 6.3% higher than measured TGV in 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≤0.002 for all comparisons) than the values obtained with the measured TGV. In late gestation, predicted TGV was 12.6% higher than the measured TGV. Based on the predicted TGV, the body volume was 0.2%, FM 2.6% and the BF% 2.0% higher (p<0.001 for all comparisons) than with measured TGV.

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.

| | Measured[a] | | Predicted | | Mean | | |
|---|---|---|---|---|---|---|---|
| | Mean | s.d. | Mean | s.d. | difference | 95% CI | P-value[b] |
| Thoracic gas volume in early gestation (l) | 3.08 | 0.69 | 3.27 | 0.24 | 0.19 | 0.08; 0.31 | 0.001 |
| Thoracic gas volume in late gestation(l) | 2.91 | 0.59 | 3.28 | 0.24 | 0.37 | 0.28; 0.46 | <0.0001 |
| Body volume in early gestation (l) | 84.3 | 14.5 | 84.4 | 14.5 | 0.07 | 0.03; 0.12 | 0.002 |
| Body volume in late gestation (l) | 93.2 | 14.0 | 93.4 | 14.0 | 0.14 | 0.11; 0.18 | <0.0001 |
| Fat mass in early gestation (kg) | 37.3 | 10.3 | 37.6 | 10.3 | 0.37 | 0.14; 0.60 | 0.002 |
| Fat mass in late gestation (kg) | 38.5 | 9.95 | 39.5 | 10.5 | 0.75 | 0.56; 0.95 | <0.0001 |
| Fat percentage in early gestation | 43.5 | 5.74 | 44.0 | 5.77 | 0.49 | 0.20; 0.79 | 0.001 |
| Fat percentage in late gestation | 40.7 | 5.54 | 41.6 | 5.54 | 0.83 | 0.62; 1.04 | <0.0001 |

CI = confidence interval

[a] data were available for 100 and 106 participants in the 1st and 2nd study visits, respectively

[b]Paired Samples T-test

**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 around one percent in early gestation and by two percent in late gestation in overweight and obese women.

In non-pregnant individuals, prediction of TGV does not affect body composition results significantly as compared to measured TGV[10,11]. However, in agreement with our study, it has previously been reported[5] that in late gestation, the prediction of TGV leads to a slight overestimation of body fat by 0.5% at 32 gestational weeks in normal weight women[5]. Our results revealing a greater overestimation at mean 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 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 TGV instead of trying to predict it. Body composition measurements using ADP are influenced by several factors (e.g. body hair, clothing, fasting state), and additionally by gestational weeks during pregnancy. Alterations in these conditions might already introduce inaccuracies into the calculations. Since measurement of TGV is straightforward and feasible, i.e. we had a success rate of 96% in late gestation, the measurement of TGV is recommended to minimize these errors.

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

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

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