



Original Article

Validation of Thomas Formula in Estimation of Pre-Pregnancy Weight in Bogor City, Indonesia

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ARTICLE INFO

Article History:

Received: 2024-10-23

Published: 2025-03-29

Keywords:

Body mass index;
Estimated weight; Pre-pregnancy weight; Self-reported weight; Thomas formula

ABSTRACT

Accurate pre-pregnancy weight is crucial for optimal pregnancy outcomes. However, self-reported pre-pregnancy weight often differs from estimated values owing to various factors. This study aimed to compare pre-pregnancy weight with the self-reported method and estimated using the Thomas formula in pregnant women in Bogor, Indonesia. This cross-sectional study was conducted among 160 pregnant women in Bogor. Pre-pregnancy weight was assessed using both self-reported and the Thomas formula estimation. Differences between the two methods were analyzed using the Wilcoxon Signed-Rank Test. Our study revealed a significant median difference between self-reported and estimated pre-pregnancy weight, with 56.5 kg and 58.4 kg, respectively (p -value<0.001). Women tended to underestimate their pre-pregnancy weight by -1.7 kg (SD=3.8). There was a difference in the proportion of body mass index (BMI) categories based on self-reported and estimated pre-pregnancy weights. However, the classification of BMI before pregnancy was generally consistent between the two methods. The Thomas formula proved to be more sensitive in predicting the incidence of overweight than underweight in Bogor City. A limitation of this study is that it did not directly validate the measured pre-pregnancy weight, which led to the result that self-reported pre-pregnancy weight may underestimate the actual weight. Although Thomas's formula provides a precise estimate, it is important to consider the limitations of the self-report and estimation methods. Therefore, healthcare providers should be aware of these differences, use a combination of approaches to assess pre-pregnancy weight, and provide appropriate nutritional counseling



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INTRODUCTION

Gestational weight gain is a critical indicator in monitoring the health of the mother and fetus. Gestational weight gain, as recommended by the Institute of Medicine (IOM), can reduce the risk of complications during pregnancy and postpartum.¹ The pre-pregnancy weight is significant, as the pre-pregnancy body mass index (BMI) can affect the pregnancy outcome. Pre-pregnancy underweight increases the risk of premature birth and low birth weight (LBW).^{2,3} Moreover, pre-pregnancy overweight more than doubles the risk of preeclampsia and gestational diabetes.⁴ In

addition, overweight during pregnancy are more likely to have a cesarean section in delivery, and their babies are more likely to have congenital heart or neural tube defects at birth.⁵

Planning a pregnant woman's nutritional intake requires pre-pregnancy weight.¹ However, data on pre-pregnancy weight is often inaccurate, which causes memory limitations, weight fluctuations, and lack of record keeping. Inaccurate data can affect inappropriate nutritional intake planning and gestational weight gain recommendations.^{6,7} Self-reported pre-pregnancy weight can be used as baseline data for determining gestational weight gain recommendations.⁸ However, pregnant women often have difficulty remembering the pre-pregnancy weight, especially if some time has passed. This can be caused by various factors that affect health and nutritional intake during pregnancy. Perception of weight can be affected by the physiological changes that occur during pregnancy, including increased blood and fluid volume. In addition, pregnancy symptoms such as nausea and vomiting, as well as emotional stress, can disrupt eating patterns and make it difficult for mothers to remember their initial weight. Overall health and perception of a person's weight can be affected by malnutrition. Some people's genetic predisposition to weight changes can contribute to difficulty remembering their pre-pregnancy weight.⁹ The gold standard time for pre-pregnancy weight measurement is 1-3 months before conception.^{6,10} Due to the limited data on weight measurement at that time, there needed to be a method to determine more accurate pre-pregnancy weight based on data from mothers who had been declared pregnant.

A previous study found a significant difference of 1,089 kg on average between maternal self-reported weight and weight measured at the start of pregnancy. However, this difference did not significantly impact pre-pregnancy BMI classification for most pregnant women.¹¹ A study showed that pregnant women with poor nutritional status, namely pre-pregnancy weight below 45 kg, height below 150 cm, BMI below 18.5 kg/m², and middle-upper arm circumference (MUAC) below 23.5 cm, tend to experience less weight gain during pregnancy compared to normal pre-pregnancy nutritional status.¹² Therefore, it is vital to know the pre-pregnancy BMI to get good attention and monitoring on gestational weight gain.

The Thomas Formula, a method used to estimate ideal pre-pregnancy weight, has been developed based on data from America and Mexico.⁶ However, its accuracy in populations with unique characteristics, such as pregnant women in Bogor City, needs further validation. This study aims to compare the pre-pregnancy weight between the self-reported method and Thomas formula estimation among first-trimester pregnant women in Bogor City. The results of this study are expected to provide a more accurate tools to assess pre-pregnancy weight so can provide more optimal recommendation for nutritional management during pregnancy.

METHODS

This study used a *cross-sectional* design with research variables, namely maternal pre-pregnancy weight using the self-reported method, weight at the first Antenatal Care (ANC), and estimated pre-pregnancy weight using the Thomas formula. The formula was pre-pregnancy weight = $6.10 + [0.99 \times \text{weight in the first trimester (kg)}] - [0.01 \times \text{Gestational age (days) at the beginning of the measurement}] - [0.02 \times \text{height (cm)}] - [0.04 \times \text{Maternal age (years)}] - [0.09 \times \text{parity}]$ ⁶. To ensure data accuracy, all data were collected in the first trimester, before 13-14 weeks of gestation. This time was chosen because it was considered the most appropriate period to obtain accurate information. Data on weight at first ANC, gestational age, and height were obtained from documentation of direct measurements during the first ANC visit. Age and parity data were obtained through interviews with pregnant women. By collecting data in the early stages of pregnancy, we minimized the possibility of recall bias because pregnant women tend to remember their pre-pregnancy weight more easily over a short period of time.

The study was conducted in ten Community Health Centers (CHC) in Bogor City in August-September 2024. Community Health Centers were selected with inclusion criteria, namely having the highest number of LBW cases in 2023, or CHC with the highest first ANC visits (K1), and/or there are stunting specific areas in the CHC working area. The CHCs of Cipaku, Kedung Badak, North Bogor, Pasir Mulya, Tegal Gundil, Warung Jambu, Mekarwangi, and South Bogor were

selected for having the highest LBW cases. Sindangbarang and East Bogor were selected for having the highest ANC K1 visits. And in the Kedung Badak and Pasir Mulya areas there are three villages of stunting specific areas.

The sample size was 160 pregnant women obtained by accidental sampling at their first ANC (<14 weeks) at the CHC who were willing to be respondents. The inclusion criteria for pregnant women were first ANC of <14 weeks, weight and height data at the first ANC, and singleton pregnancy. Data were obtained using the interview method and documentation from the Maternal and Child Health Book (MCB). This research has passed the review of the health ethical research commission of the Faculty of Medicine, University of Sultan Ageng Tirtayasa number 76 /UN43.20/KEPK/2024.

The data were analyzed using the median difference test and depicted in a plot graph, as stated by Bland & Altman.¹³ The difference test uses the non-parametric *Wilcoxon Signed-Rank test* with a p-value <0.05 and 95% Confidence Intervals (CI). Sensitivity and specificity analysis used the Receiver Operating Characteristic (ROC) curve and Area Under Curve (AUC). The ROC and AUC curves assessed the ability of the Thomas formula estimation to identify pregnant women who are underweight and overweight. The AUC value is between 0 and 1 because the x and y axes have values ranging from 0 to 1. If the AUC value is close to 1, the diagnostic test's overall performance is improving, and a test with an AUC value = 1 means that the performance is very accurate.

RESULTS

Subject characteristics based on Table 1 shows that the average age of pregnant women was 28.6 years, the average marriage age was 5.9 years, the average gestational age at first ANC was 7.1 weeks, the average parity was 1.2 times, the average pre-pregnancy weight with the self-reported method was 58.4 kg, the average of pre-pregnancy weight with the Thomas formula estimation was 60.1 kg, the average weight at first ANC was 59.5 kg, the average maternal height was 155.6 cm, the average pre-pregnancy BMI based on the self-reported method was 24.2 kg/m², and the average BMI based on the Thomas formula estimation was 24.9 kg/m².

Table 1. Characteristics of pregnant women (n=160)

Characteristics	Mean	SD	Median	Min-max
Mother's age (years)	28.6	5.3	28.0	16.0-48.0
Age of marriage (years)	5.9	5.1	5.0	0-21.0
Gestational age at first ANC (weeks)	7.1	2.2	7.0	3.0-13.0
Parity	1.2	0.9	1.0	0-4.0
Pre-pregnancy weight (kg)*	58.4	12.1	56.5	36.0-90.0
Pre-pregnancy weight (kg)**	60.1	12.3	58.4	39.1-105.6
Weight at first ANC (kg)	59.5	12.5	58.0	38.0-105.0
Mother's height (cm)	155.6	5.9	155.0	141.0-168.0
BMI before pregnancy* (kg/m ²)	24.2	4.8	23.4	15.0-38.0
BMI before pregnancy** (kg/m ²)	24.9	4.9	24.4	16.3-43.9

*Self-reported method

**Thomas formula estimation

The Kolmogorov-Smirnov data normality test shown that the pre-pregnancy weight data based on the self-reported method and Thomas formula estimation are not normally distributed with consecutive sig values of 0.002 and 0.000, respectively. So, the hypothesis testing method used is the non-parametric median difference test *Wilcoxon Signed-Rank Test*.

Table 2 reveals a wide range of variation in the self-reported pre-pregnancy weight, spanning from 36 to 90 kg, with an average of 58.4 kg. This substantial variation underscores the potential for inaccuracies in pregnant mothers' self-reported pre-pregnancy weight. In contrast, the estimated weight by the Thomas formula shows a similar, albeit slightly wider, range of variation, from 39.1 to 105.6 kg, with an average of 60.2 kg. The median comparison test further confirmed a significant difference between the median weight of the self-reported method and the Thomas

formula ($p < 0.05$).

Table 2. Comparison of pre-pregnancy weight

	Self-reported	Thomas Formula
Mean (SD)	58.4 (12.1)	60.2 (12.3)
Median	56.5	58.4
Min-max	36.0-90.0	39.1 – 105.6
Pvalue	<0.001	
Range of differences (kg)	-15.9 – 14.6	
Mean SD difference (kg)	-1.7 (3.8)	
Median difference (kg)	-1.5	
Limit of agreement (kg)	-9.1 – 5.7	

The range of differences showed that the difference between the weight of the self-reported method and estimated by the Thomas formula ranged from -15.9 kg to 14.6 kg. This means some mothers remember the weight much lower or higher than the Thomas formula estimation. The mean of differences is -1.7 kg, which means that pregnant women tend to remember the pre-pregnancy weight lower than the Thomas formula estimation. The Limit of Agreement at 95% CI shows between -9.9 kg to 5.7 kg, which means that in 95% of cases, the difference between the weight of the self-reported method and the Thomas formula estimation will be in this range. These results are also depicted in Figure 1. Moreover, the pre-pregnancy BMI category was compared based on self-reports and estimations by the Thomas formula weight. The results are shown in Table 3 as follows.

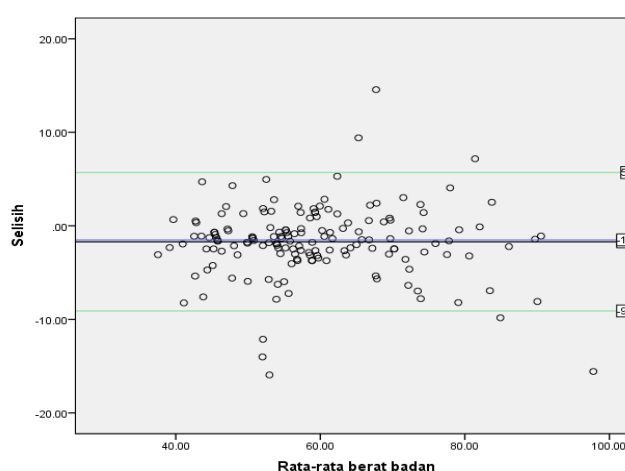


Figure 1. Bland-Altman plot comparing pre-pregnancy weight based on weight-adjusted self-reported method with Thomas formula

Table 3. Comparison of pre-pregnancy BMI using self-reported method and Thomas formula estimation

IMT	BMI Thomas formula			Total
	Underweight n (%)	Normal n (%)	Overweight n (%)	
BMI self-reported method				
Underweight	11 (61.1)	7 (38.9)	0	18
Normal	1 (1.2)	65 (81.3)	14 (17.5)	80
Overweight	0	3 (4.8)	59 (95.2)	62
Total	12 (7.5)	75 (46.8)	73 (45.7)	160

Table 3 shows that BMI can be categorized differently when using weight based on the self-reported method and the Thomas formula estimation. As many as 61.1% of pregnant women are

categorized as underweight based on two methods, while the rest are categorized as normal according to BMI based on Thomas formula estimation. More than half of the mothers who remember their weight as normal are also categorized as normal based on the Thomas formula (81.3%). Likewise, in the overweight category, 95.2% are categorized as overweight. Based on the Pearson Chi-Square test, it was obtained that the p-value was <0.001 , meaning that there was a difference in the proportion of the BMI category based on the self-reported method and BMI based on the Thomas formula estimation.

The sensitivity and specificity analysis of the measurements, crucial in detecting underweight and overweight, are presented in the form of a curve known as the Receiver Operating Characteristic (ROC) curve and the Area Under Curve (AUC). These curves, as shown in Figure 2 and Figure 3, play a vital role in our understanding and detection of underweight and overweight in pregnant women.

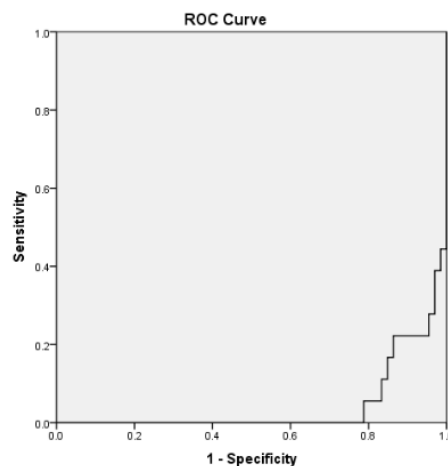


Figure 2. ROC curve of pre-pregnancy BMI using the Thomas formula in detecting underweight in pregnant women

Figure 2 shows that the AUC value of BMI with the Thomas formula estimation has a meager value of 4.4% or 0.044, meaning that this model is less accurate in detecting underweight. In this study, the results obtained that the BMI underweight threshold, according to the Ministry of Health¹⁴, namely 18.5, has a sensitivity value of 38.9% and a specificity of 98.5%

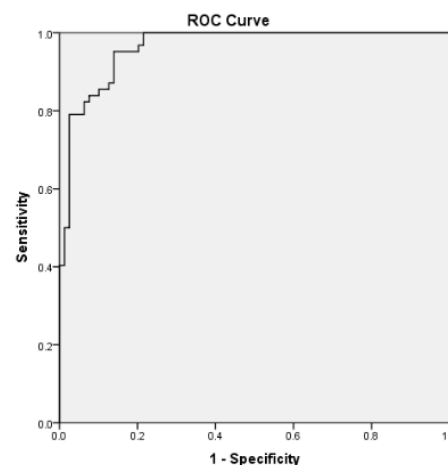


Figure 3. ROC curve of pre-pregnancy BMI using the Thomas formula in detecting overweight in pregnant women

Figure 3 shows that the AUC value of BMI with the Thomas formula estimation has a good value of 96.3% or 0.963, meaning that this model is accurate in detecting overweight pregnant women. In this study, the results obtained that the threshold for overweight BMI, according to the Ministry of Health¹⁴, namely 25.0, has a sensitivity value of 95.2% and a specificity of 16.5%.

DISCUSSION

Pre-pregnancy weight is essential for assessing maternal health and managing pregnancy outcomes. However, direct measurements of pre-pregnancy weight are often unavailable, necessitating the use of an approximate measure. One study concluded that a 0.88 kg reduction from the initial gestational weight provides a close estimate of the actual pre-pregnancy weight.¹⁰ In addition, the weight measured in the first trimester showed good agreement with the self-reported pre-pregnancy weight, with differences generally within ± 2 kg. This can be a viable alternative when pre-pregnancy weight is unavailable.¹⁵

However, pre-pregnancy weight by self-reported method tends to be less accurate because it is often lighter than the actual pre-pregnancy weight. This method should be used cautiously when calculating first-trimester weight gain. Some recommendations state that early pregnancy weight can provide a more accurate estimate of pre-pregnancy weight compared to self-reported weight, although misclassification can still occur.^{10,16–18}

The Thomas formula, developed by Thomas et.al⁶, is a promising tool for estimating pre-pregnancy weight. This model, validated using data from three different studies in the United States and Mexico, has created publicly accessible software. This software is expected to be a reliable alternative for determining pre-pregnancy weight, particularly for populations lacking accurate information. Its ability to identify misreporting and inappropriate classification in the category of weight gain during pregnancy is another advantage, instilling confidence in its use.⁶

This study collected data on pre-pregnancy weight using the self-reported method, so validation with other methods is needed to determine the weight closest to the actual weight. The study results showed that pregnant women in Bogor City tend to reduce their pre-pregnancy weight using the self-reported method. This is indicated by the significant difference between the median weight based on the self-reported method and the Thomas formula estimation. The median weight based on the self-reported method is much lower than the Thomas formula estimation. The range of weight differences between the two methods was quite large, namely -15.9 kg to 14.6 kg, with an average of -1.7 kg and a median of -1.5 kg. These results align with those of Masiero et al.¹¹, who showed a significant difference in pre-pregnancy weight with the self-reported and estimation methods. In addition, the literature review also shows that the difference in weight based on the self-reported method and measurement results ranges from 0.29 to 2.94 kg but is not limited to weight measurements 1-3 months before pregnancy, which is referred to as the gold standard period.¹⁹ So, this significant difference in body weight was thought to be related to the tendency to underestimate weight, especially when it is associated with health problems.¹⁰ However, various factors in Thomas' formula can also be influential, such as older gestational age at the first ANC, causing the mother to have already experienced significant weight gain, and causing the estimated pre-pregnancy weight to be greater.

This condition has significant consequences for health professionals working in healthcare services. Health professionals should be more aware of the possibility of underestimating and underreporting pre-pregnancy weight. If there is no information about the mother's pre-pregnancy weight, health professionals can determine the pre-pregnancy weight by estimating the Thomas formula with an earlier first ANC.

The results of the comparative analysis of pre-pregnancy BMI showed that most individuals categorized as underweight based on their self-reported method were also categorized the same based on the Thomas formula estimation. However, there were several cases where mothers considered underweight based on the self-reported method were categorized as normal based on the Thomas formula estimation. While in the normal category, most individuals categorized as normal according to the self-reported method were also categorized as normal based on the Thomas formula estimation. However, 17.5% of individuals considered their nutritional status normal but were categorized as overweight based on the Thomas formula estimation.

Generally, the self-reported pre-pregnancy weight method is accurate, especially for the normal and overweight categories.^{10,11} However, there is a tendency for pregnant women to underestimate their weight, especially in the overweight category. Although other assumptions can occur where the mother has experienced significant weight gain in early pregnancy, the

difference in weight based on the self-reported method and the Thomas formula estimation is quite different. Estimation with the Thomas formula can provide a relatively good estimate of the pre-pregnancy BMI category. This method can help identify individuals who may underestimate their weight and need further medical attention, especially to determine the recommended gestational weight gain. The difference in BMI between the two measurement methods can be caused by various factors, such as psychological factors (e.g, the desire to look thinner), physiological factors (e.g, changes in metabolism during pregnancy), socio-cultural factors (e.g, lack of awareness of the importance pre pregnancy normal nutritional status).¹⁰ So there still needs to be regular weight monitoring, especially for women of childbearing age who are still reproductively active.

Based on the sensitivity and specificity analysis, it shows that the Thomas formula estimation was more sensitive in detecting pregnant women with overweight nutritional status before pregnancy. The Thomas formula model is very unsuitable for detecting underweight pregnant women. In contrast, this model is better at detecting overweight pregnant women than detecting underweight. However, the low specificity level indicates that there are still many pregnant women who are not overweight who are misclassified as overweight. This may be due to several factors, such as: the quality and quantity of data used to train the model may be inadequate, individual physiological variations, environmental factors, or measurement errors.²⁰⁻²²

The limitation of this study is that it does not validate pre-pregnancy weight data from direct measurements. In addition, the long gestational age range of ten weeks may affect the results of pre-pregnancy weight estimation using the Thomas formula. Therefore, several factors need to be considered to obtain more accurate estimation results for the detection of nutritional status in pregnant women. First, a thorough evaluation of the model needs to be performed, starting from the selection of features and algorithms used to the parameters applied. New models can also be developed based on Indonesia's population. Second, the quality of the data used to train the model should be improved by collecting more representative and accurate data, such as earlier gestational age, equalized gestational age for validation, or compared with pre-pregnancy weight based on direct measurement. Other factors that may affect nutritional status, such as gestational age, previous pregnancy history, and baseline health conditions, should also be considered. The accuracy of the model in detecting the nutritional status of pregnant women has significant clinical implications, so that it can provide recommendations for weight gain in pregnant women based on pre-pregnancy BMI.

CONCLUSION

Based on the study's results, it can be concluded that pre-pregnancy weight based on the self-reported method and the Thomas formula estimation was significantly different, with a range of differences in the 95% CI of -9.9 kg to 5.7 kg. This difference in weight also causes differences in the pre-pregnancy BMI category, but most were in the same category in both methods of determining pre-pregnancy weight. The Thomas formula model is more sensitive to detecting cases of overweight pregnant women in Bogor City. These findings highlight the importance of validating the developed formulas to ensure the accuracy of anthropometric data when direct measurement cannot be performed. It also provides empirical evidence that the self-report method reports lower weight than the Thomas formula, but has the same pre-pregnancy BMI category. Therefore, the pre-pregnancy BMI can be determined using the Thomas formula if pre-pregnancy weight data are not obtained. Thus, health workers can provide recommendations for normal pregnancy weight gain according to the pre-pregnancy BMI.

Author's Contribution Statement: Mukhlidah H.S: Conceptualization, Methodology, Formal analysis, Visualization, Writing – original draft, Writing – review & editing. Hardinsyah: Conceptualization, Methodology, Writing – review & editing, Supervision. Katrin Roosita: Visualization, Writing –review & editing, Supervision. Budi, IS: Writing – review & editing, Supervision.

Conflicts of Interest: All authors have no conflicts of interest to disclose.

Source of Funding: This study was financially supported by the Ministry of Education, Culture, Research and Technology (Kemdikbudristek) under Grant No. 22129/IT3.D10/PT.01.03/P/B/2024. The Kemdikbudristek had no influence over the study design, data interpretation, or publication decision.

Acknowledgement: Special thanks to the Directorate General of Higher Education, Research and Technology, Ministry of Education, Culture, Research and Technology, for funding this research under the Doctoral Dissertation Research scheme (PPS-PDD) with contract number 22129/IT3.D10/PT.01.03/P/B/2024.

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