HHS Public Access

Author manuscript

Obesity (Silver Spring). Author manuscript; available in PMC 2020 July 01.

Published in final edited form as:

Obesity (Silver Spring). 2019 July ; 27(7): 1161–1167. doi:10.1002/oby.22502.

Do women know their pre-pregnancy weight?

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Conflict of Interest Statement: D.M.T. reports the patent SYSTEM AND METHOD FOR PREDICTING FETAL AND MATERNAL HEALTH RISKS™ which were filed within the U.S. and internationally. The U.S. Application was filed on 3/30/15 and assigned Serial No. 61/973,565 and the International Application was filed on 3/30/15 and assigned No. PCT/US2015/023257.

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Abstract

Objective: Pre-pregnancy weight may not always be known to women. We develop a model to estimate pre-pregnancy weight from measured pregnancy weight.

Methods: We developed and validated the model using participants from two studies [Project Viva, N=301, model development; and Fit for Delivery (FFD), model validation, N= 401]. We used data from the third study (PROGRESS), which included women from Mexico City, to demonstrate the utility of the newly developed model to objectively quantify pre-pregnancy weight.

Results: The model developed from the Project Viva study validated well with low bias: ($R^2=0.95$, $y=1.02x - 0.69$, bias=0.68 kg, 95% confidence intervals, [-4.86, 6.21]). Predictions in women from FFD demonstrated good agreement: ($R^2=0.96$, $y=0.96x+4.35$, bias =1.60 kg, confidence intervals: [-4.40,7.54], error range = -11.25 kg to 14.73 kg). High deviations from model predictions were observed in the PROGRESS study ($R^2=0.81$, $y=0.89x + 9.61$, bias =2.83 kg, [-7.70, 12.31], error range = -39.17 kg to 25.73 kg). The model was programmed into software: <http://pbrc.edu/research-and-faculty/calculators/prepregnancy/>

Conclusions: The developed model provides an alternative to determine pre-pregnancy weight in populations receiving routine health care that may not have accurate knowledge of pre-pregnancy weight. The software can identify misreporting and classification into incorrect gestational weight gain categories.

Keywords

Pre-pregnancy weight; gestational weight gain; mathematical model; low-income women

INTRODUCTION

Both high body mass index (BMI) and excess gestational weight gain are strong predictors of adverse pregnancy outcomes, including gestational diabetes mellitus (1), labor and delivery complications (2), fetal growth, and postpartum weight retention (3). To inform appropriate weight gain during pregnancy, the Institute of Medicine (IOM) in 2009 applied the wealth of existing available pregnancy outcome data to derive pre-pregnancy BMI specific gestational weight gain guidelines (4). Applying the correct IOM recommended gestational weight gain category and also accurately measuring gestational weight gain requires knowledge of pre-pregnancy weight.

Accurate pre-pregnancy weight is dependent on the patient's knowledge, requiring access to a scale or routine health care measurements. With the preponderance of prenatal health disparities in under-represented minority groups (5), it is not surprising that a recent study

attempting to implement a lifestyle intervention to promote healthy weight gain in pregnancy found that more than half of the low income participants did not have access to a scale (6). In these cases, the use of self-reported pre-pregnancy weight to calculate gestational weight gain and to establish the effectiveness of an intervention is prone to error.

Misreporting pre-pregnancy weight might allow some patients to be wrongfully categorized into a lower BMI category and therefore be recommended a larger amount of gestational weight gain in pregnancy (7). Misreported pre-pregnancy weight can also result in an incorrectly recorded magnitude of gestational weight gain in health care records now used for large scale national health surveillance efforts (8). A mathematical model that predicts pre-pregnancy weight from an initial pregnancy clinical visit could provide an objective estimate that can fill in gaps when true pre-pregnancy weight is unknown.

Here, we use two databases that collected clinically measured pre-pregnancy weight and a pregnancy weight to develop (9) and independently validate (10) a mathematical model predicting pre-pregnancy weight from a first prenatal clinic visit. We then demonstrate how the model can be used to evaluate self-reported pre-pregnancy weight when a measured weight is not available. Finally, we developed a software program that can be freely accessed to calculate pre-pregnancy weight, allowing for a comparison to a self-reported weight, and to flag potential inaccurate reporting. The software outputs an alert based on comparison to model predictions if self-reported weight is deemed misreported.

METHODS

Three studies were included for analysis. The Project Viva (11) and the Fit for Delivery (FFD) (10) studies included measured pre-pregnancy weight, age, race, height, parity, measured weight at the first prenatal visit and gestational age at first prenatal visit. The Project Viva study was used to develop a model that predicts pre-pregnancy weight from the first trimester measurements. The FFD study was used to test the model on independent data not used for model development. To demonstrate model utility for identifying misreported pre-pregnancy weight, we used the FFD study, which also included self-reported pre-pregnancy weight and a third study, the Programming Research in Obesity, Growth, Environment and Social Stressors (PROGRESS) (12, 13). The PROGRESS study consisted of women from Mexico City and included self-reported pre-pregnancy weight and all first trimester variables required for model input.

Participants

The Institutional Review Board for all participating institutions approved study procedures. Specifically, the Project Viva study was approved by the Human Subjects Committees of Harvard Pilgrim Health Care, Brigham and Women's Hospital, and Beth Israel Deaconess Medical Center. The FFD study was approved by the Institutional Review Boards at Miriam Hospital (Providence, RI), California Polytechnic State University (San Luis Obispo, CA), and Women, Infants', and Children's Hospital of Rhode Island (Providence RI). The PROGRESS study was approved by IRB Committees at National Institute of Public Health (INSP), Icahn School of Medicine at Mount Sinai (ISMMS), Harvard School of Public Health (HSHPS) and the Brigham and Women's Hospital.

All participants provided informed consent for participation in the respective parent studies. We summarize details of the three studies in Table 1 and briefly describe them below.

Project Viva—The Project Viva study recruited women who were receiving prenatal care at a multispecialty group practice in eastern Massachusetts (11). Study eligibility included a singleton pregnancy <22 weeks gestation at the initial clinical visit (median 9 weeks at recruitment), ability to answer questions in English, and plans to stay in the area after delivery. At recruitment, mothers self-reported their height and pre-pregnancy weight as well as age, race/ethnicity, parity, and date of last menstrual period (LMP). Gestational age was calculated by subtracting the date of the self-reported last menstrual period from the date of clinical visit. Of the 2128 enrolled women who delivered a live singleton infant, 301 had a measured weight recorded in their electronic medical record within 3 months prior to LMP. The reference dataset (N=301) from Project Viva data to develop the model predicting pre-pregnancy weight from the first trimester pregnancy visit.

In order to test for differences in pre-pregnancy BMI in the reference dataset versus the original study data, a Welch's t-test was performed in the statistical programming language **R** (R Core Team, www.R-project.org, 2017) on the self-reported pre-pregnancy BMI between the two groups.

The Fit for Delivery Study—The FFD study recruited 401 participants to examine whether a behavioral intervention during pregnancy could decrease the proportion of women who exceeded the 1990 Institute of Medicine (IOM) recommendations for gestational weight gains and increase the proportion of women who returned to pre-pregnancy weights by 6 month postpartum (10). At enrollment, each participant had a gestational age between 10 and 16 weeks, a self-reported BMI between 19.8 and 40 kg/m², and a singleton pregnancy. Gestational age was self-reported. Of the 401 patients enrolled 51 had a measured pre-pregnancy weight within 6 months of conception. The weights of the 51 participants were recorded in patient charts and were extracted for the purpose of testing the model developed using the Project Viva data. The first weight measured during gestation by study staff occurred during the first trimester except for one participant measured at the 16th week.

The FFD database was used to also compare the developed model against self-reported pre-pregnancy weight. The entire FFD database (N = 401), which included self-reported pre-pregnancy weights, was used for this second purpose.

Finally, because some women do not have their first clinical visit in the first trimester, but rather the second, we used the FFD database to determine how the model compares to self-reported pre-pregnancy weight when the first measured pregnancy weight was obtained in the second trimester. Of the 401 women in FFD, 196 patients had their first clinical pregnancy weight measured during the second trimester (91 – 113 days). This reference sample was used for the third purpose to apply how the well the model predicts self-reported pre-pregnancy weight in participants with routine health care using an input from a pregnancy weight obtained in the second trimester.

In order to test whether there were differences in the self-reported pre-pregnancy BMI between the two reference datasets and the original study data, a Welch's t-test was performed in the statistical programming language **R** (**R** Core Team, www.R-project.org, 2017).

The Programming Research in Obesity, Growth, Environment and Social Stressors (PROGRESS) study—The PROGRESS study recruited pregnant women in Mexico City receiving prenatal care during 2007–2011 through the Mexican Social Security System (Instituto Mexicano del Seguro Social) (IMSS) (12, 13). Women were eligible if they were less than 20 weeks gestation with a singleton pregnancy, at least 18 years old, and planned to reside in Mexico City for the next 3 years. Gestational age was calculated by subtracting the date of the self-reported last menstrual period from the date of clinical visit. Exclusion criteria included medical history of heart or kidney disease, consuming alcohol on a daily basis, or consumed steroid or anti-epilepsy drugs. A total of 1,054 women were enrolled. Women self-reported their pre-pregnancy weight during recruitment (mean weeks gestation: 18.3 ± 0.9) and a measured weight was collected at the first study visit during their 2nd trimester of pregnancy (112–158 days). Self-reported pre-pregnancy weight from PROGRESS participants were compared to model predictions.

Model Development—We developed a multi-linear regression model predicting pre-pregnancy weight using the Project Viva dataset. We considered maternal age, height, weight and gestational age at first clinical weight measurement during pregnancy, parity, and race/ethnicity as predictors. All linear, interaction, and squared terms were tested for significance. A reduced model with significant covariates was then developed as the finalized model. Model development was performed in the statistical package JMP (JMP Pro 10, Cary, NC 2010).

Confidence intervals were obtained from a bootstrap resampling analysis of 1000 replicates was performed using the statistical programming language **R** (**R** Core Team, www.R-project.org, 2017). The boot package in the R package was used to perform the resampling. After input of the number of replications, the dataset, and the model formulation, the software package computes confidence intervals for the model regression weights.

Model Validation—After input of the model explanatory variables from the FFD study; gestational day of first clinical visit, maternal weight at first clinical visit, maternal age, maternal height, and parity, the model was independently validated on measured pre-pregnancy weights. A Bland-Altman analysis was conducted in Microsoft Excel (Seattle, WA 2011) to test for agreement between model predictions and measured pre-pregnancy weights (14).

Comparing Self-reported Pre-pregnancy Weight in Different Populations—A Bland-Altman analysis was conducted between reported pre-pregnancy weights and model predicted using Microsoft Excel (Seattle, WA 2011) to test for variation in model predictions and self-reported pre-pregnancy weights in the FFD study versus the PROGRESS study (14). Since the PROGRESS study enrolled women in the second trimester, we also compared model predicted pre-pregnancy weight to self-reported pre-pregnancy weight in

FFD subjects with their first visit occurring in the second trimester. In both the FFD and PROGRESS datasets, all covariates required for model simulation were available.

Quantifying Tolerance to Flag Misreport—The average of the absolute difference between actual and predicted pre-pregnancy weight (mean absolute error) and standard deviation of mean absolute error was calculated from the model validation experiment. The tolerance was set as the sum of the mean absolute error and the standard deviation. In order to evaluate the validity of self-reported pre-pregnancy weight, the absolute difference between self-reported pre-pregnancy weight and model predicted pre-pregnancy weight was calculated. If this value was larger than the tolerance, then the participant was identified as likely misreporting.

Model Application to Identify Misclassification of Gestational Weight Gain Category—The Institute of Medicine recommended gestational weight gain (4) differs by pre-pregnancy BMI classifications; underweight ($<18.8 \text{ kg/m}^2$), normal weight (18.8 kg/m^2 – 25 kg/m^2), overweight (25 – 30 kg/m^2) and obesity ($\geq 30 \text{ kg/m}^2$), with higher amounts of allowable weight gain for lower BMI classifications. Therefore, applying the model to identify patients whose misreported pre-pregnancy weight placed them in an incorrect gestational weight gain category is important. The pre-pregnancy weight estimation calculator described in the next section flags individuals whose BMI classification derived from self-reported pre-pregnancy weight differs from the model derived classification. Using the calculator, we recorded the percentage of participants in the FFD study ($N=401$) and the PROGRESS study ($N=1054$) who were placed in a different gestational weight gain category by self-report versus model predicted.

Pre-Pregnancy Weight Calculators—A multi-subject program housing the model was developed using the Visual Basic Application within Microsoft® Excel. The software was designed for an intended end user conducting pregnancy research. The program was designed to output model predicted pre-pregnancy weight but also to provide basic information to the investigator on deviations between self-reported and model predicted weight and several alternative estimates for pre-pregnancy weight (for example the average of self-reported and model predicted pre-pregnancy weight). Any pre-pregnancy weight that exceeds the tolerance window around model predictions are highlighted for the user. Likewise, any discrepancies in BMI classification (underweight, normal weight, overweight, and obese) from self-reported pre-pregnancy weight compared to model predicted pre-pregnancy weight were also highlighted.

A second single subject calculator was developed using the RShiny platform (<https://shiny.rstudio.com/>). The intended end user of the single subject software is a clinician or individual. The output of the single-subject calculator was estimated pre-pregnancy weight, pre-pregnancy BMI, and pre-pregnancy BMI classification.

RESULTS

Participant Characteristics

Table 1 contains participant demographic information for the three datasets applied in this study. Table 1 also contains which variables were used for each specific application of the study. The participant summary statistics are reported for the largest sample size reference datasets used in this study. The difference in mean self-reported BMI between the original Project Viva study (N=2128) and the reference database used to develop the model (N=301) were not statistically significant ($t = 1.00$, $p = 0.32$). The difference between mean self-reported BMI between the original FFD study (N=401) and the reference dataset used for model validation (N=51) was statistically different; (mean BMI of the original study, 26.06 ± 5.52 , mean BMI of the reference dataset, 22.52 ± 3.74 , $t = 5.7493$, $p < 0.001$). The mean self-reported BMI between the original FFD study and the reference study of second trimester weights (N=196) were not statistically significant ($t = -0.34$, $p = 0.73$).

Pre-Pregnancy Estimation Model

Using Project Viva data, after testing all covariates and nonlinearities, only first trimester measured weight, gestational age, maternal height, and maternal age at conception were independently and significantly associated with pre-pregnancy weight. A reduced model that depended on these variables was developed as the final model:

$$\begin{aligned} \text{Pre-Pregnancy Weight} = & 6.10 + 0.99 \times \text{First Trimester Measured Weight (kg)} \\ & - 0.01 \times \text{Gestational Age (days) at First Weight Measurement} - 0.02 \times \text{Height (cm)} \\ & - 0.04 \times \text{Maternal Age (years)} - 0.09 \times \text{Parity} \end{aligned}$$

The adjusted R^2 was 0.98, $p < 0.001$.

The bootstrap resampling analysis resulted in 95% confidence intervals that contained the model coefficients and bootstrapped regression coefficients that were at the level of significance as the model.

Independent Model Validation

There was strong correlation between actual and predicted pre-pregnancy weight (Figure 1) in the FFD study ($R^2=0.95$, $y=1.02x - 0.69$). The bias (actual – predicted) was low (0.68 kg, 95% confidence 4.86, 6.21). The absolute mean error between actual and model predicted pre-pregnancy weight in the FFD study was 2.04 kg and the standard deviation was 2.08 kg. We defined the tolerance for misreport as the sum of the mean absolute error and standard deviation, calculated as approximately 4.0 kg.

Self-reported Pre-pregnancy Weight Compared to Model Predicted Weight

There was high correlation (Figure 2 A) between model predictions and self-reported pre-pregnancy weight in the FFD study ($R^2=0.96$). The slope of the line of regression was close to one with nearly zero y-intercept ($y=0.96x+4.35$). The bias between model predictions and self-reported pre-pregnancy weight was low (bias = 1.60 kg) with 95% confidence interval

given by $[-4.40, 7.54]$ (Figure 2 C). The range in the difference (model predictions – self-reported pre-pregnancy weight) was -11.25 kg to 14.73 kg. However, there was a lower correlation ($R^2=0.81$, $y=0.89x + 9.61$) and higher variation in the PROGRESS cohort (Figure 2 B), with a higher bias of 2.83 kg and larger confidence intervals $[-7.70, 12.31]$ (Figure 2 D). The range in the difference was -39.17 kg to 25.73 kg. On the other hand, comparison of model predicted pre-pregnancy weight to self-reported pre-pregnancy weight obtained from the FFD subjects enrolled in the second trimester did not include such a high variation (Figure 1 Supplemental Materials). The range in the difference for the FFD second trimester subjects was -10.80 kg to 12.98 kg.

Misclassification of Gestational Weight Gain Category

A summary of the breakdown for women placed into model estimated pre-pregnancy BMI categories that differed from their self-reported pre-pregnancy BMI categories appears in Table 3.

Fifteen percent of the FFD subjects were placed into model estimated pre-pregnancy BMI categories that differed from their self-reported pre-pregnancy BMI categories. Of these misclassifications, 89% of the women were placed in a higher BMI category than their self-reported BMI category (for example the model classified the individual as being overweight while their self-report classified them as normal weight) which would have resulted in higher allowable gestational weight gain according to the IOM guidelines (4).

Twenty-eight percent of the women in the PROGRESS study were estimated by the model in a different BMI category than defined by their self-reported pre-pregnancy weight. Of these misclassifications, 85% were predicted at a higher BMI category than their self-reported BMI.

Pre-Pregnancy Weight Calculators

Both, the multi-subject Excel based calculator and the single subject RShiny app are available at <http://pbrc.edu/research-and-faculty/calculators/prepregnancy/>

The multi-subject calculator requires users to input the total number of participants, self-reported pre-pregnancy weight, maternal height, gestational age in days at first clinical visit/study visit, measured maternal weight at first clinical visit/study visit, parity, and maternal age in years. The program outputs the user input of self-reported pre-pregnancy BMI (kg/m^2); model predicted pre-pregnancy BMI (kg/m^2); model predicted pre-pregnancy weight (kg); the difference between self-reported and model predicted pre-pregnancy weight; BMI classification from self-reported weight; BMI classification from the average of self-reported and model predicted, pre-pregnancy weight; BMI derived from the average of self-reported and model predicted pre-pregnancy weight; and BMI Classification derived from the average of self-report and model predicted pre-pregnancy weight. If the mean absolute difference between self-reported and model predicted pre-pregnancy weight exceeds the tolerance, the spreadsheet cell containing the difference is highlighted yellow. If the BMI classifications determined by self-reported pre-pregnancy weight and the average of self-reported and model predicted pre-pregnancy weight differ, the cell containing the average is highlighted green.

The single-subject calculator requires user inputs of explanatory variables. The calculator outputs predicted pre-pregnancy weight, pre-pregnancy BMI and pre-pregnancy BMI classification.

DISCUSSION

Excess or inadequate gestational weight gain are associated with adverse pregnancy outcomes (4). Thus, accurately estimating gestational weight gain is important. Since this estimation requires an accurate pre-pregnancy weight, knowledge of pre-pregnancy weight is also important. Pre-pregnancy weight is usually estimated using self-report (4) and the analysis presented here indicates that in women who are known to receive routine health care self-reported pre-pregnancy weight has some error, but is remarkably accurate—within 2.0 ± 2.1 kg. This finding is consistent with other studies (15). On the other hand, we demonstrate that there were much higher ranges of misreport among a sample of women in Mexico who may be less likely to know their pre-pregnancy weight—39.17 kg to 25.73 kg. For these cases, we developed two user-friendly web accessible software programs that predict pre-pregnancy from the first clinical visit during pregnancy.

The web accessible programs can now be used by clinical investigators and health care providers to estimate and compare pre-pregnancy weight with self-reported weight (<http://pbrc.edu/calculators/prepregnancy>) to assign a pre-pregnancy BMI classification and establish a healthy target for gestational weight gain. A summary of the need, benefits and clinical utility of the calculator appears in Table 4. Models such as this one can be easily embedded into an electronic medical data capture and calculated automatically from patient information already entered and with the input of patient weight and gestational age at the first prenatal appointment.

Our study has several limitations. First, we are unable to compare misclassification to any other study, because this is the first study that we are aware of that actually computes BMI misclassification categories. With the calculator, this can now be incorporated into future studies that are interested in estimating misclassification rates. Second, the range of the measured weights in the FFD study was small. This and the overall range of all datasets could limit our ability to test the validity of the model in women with overweight or obesity and in women of different race/ethnicities. Third, the Project Viva and FFD weights, although measured, were not measured using the same scale at the same time of the day. However, the model and validation include weight measurement error, which we assume to be random and consistent with clinical practice. Fourth, the first study visit by women in the PROGRESS study was much later in pregnancy than the data the model was developed and validated on. While this later first visit date may have resulted in the higher variance, the same variance was not observed in the FFD participants who were enrolled and weighed for first time early in the second trimester. Fifth, gestational age in all studies contained some type of self-report. For example, the Project Viva and PROGRESS studies relied on self-report of the date of the subject's last menstrual period. The FFD study relied on participant self-reported gestational age. Therefore, some variance in the model can arise from self-reported gestational age. Finally, the PROGRESS study did not directly ascertain whether participants had access to scales. Thus, while it is likely that women who deviated more than

10 kg from the model predictions did not have true knowledge of their pre-pregnancy weight, the PROGRESS study design did not include this information.

Despite these limitations, our study provides the first objective method to determine pre-pregnancy weight. As more data becomes available from controlled clinical studies in which a measured weight prior to conception is obtained, this model and extended applications can be improved upon. Nevertheless, an estimated weight derived from this population-based model, especially in women with overweight and obesity, will provide an objective measure which can be compared to self-report. Improper classification of preconception BMI can lead to inaccurate and potentially unhealthy clinical recommendations for total gestational weight gain and confound research analyzing the effects of total gestational weight gain on health outcomes

CONCLUSION

Knowledge of pre-pregnancy weight is critical to standardize gestational weight gain estimates and assign women to appropriate IOM gestational weight gain classifications. Reliance on self-reported pre-pregnancy weight may result in misclassification of pregravid BMI and overestimation of recommended gestational weight gain. Using a validated model, we have developed the first tool to objectively back-calculate pre-pregnancy weight from first clinical visit during gestation. This tool will aid clinicians and health care providers to properly classify pregnant women who may not know their body weights into the correct pre-pregnancy BMI category and therefore to counsel patients on the appropriate amount of gestational weight gain. Additionally, clinical investigators now have a method to standardize pre-pregnancy weight and hence gestational weight gain estimates.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Funding Statement: S.P. was supported by NIH DK071667

Abbreviations:

BMI body mass index

REFERENCES

1. Harper LM, Tita A, Biggio JR. The institute of medicine guidelines for gestational weight gain after a diagnosis of gestational diabetes and pregnancy outcomes. *Am J Perinatol* 2015;32(3):239–46. doi: 10.1055/s-0034-1383846. PubMed PMID: 24971568; PMCID: PMC4277741. [PubMed: 24971568]
2. Kwon HY, Kwon JY, Park YW, Kim YH. The risk of emergency cesarean section after failure of vaginal delivery according to prepregnancy body mass index or gestational weight gain by the 2009 Institute of Medicine guidelines. *Obstet Gynecol Sci* 2016;59(3):169–77. doi: 10.5468/ogs.2016.59.3.169. PubMed PMID: 27200306; PMCID: PMC4871932. [PubMed: 27200306]

3. Joseph NP, Hunkali KB, Wilson B, Morgan E, Cross M, Freund KM. Pre-pregnancy body mass index among pregnant adolescents: gestational weight gain and long-term post partum weight retention. *J Pediatr Adolesc Gynecol* 2008;21(4):195–200. doi: 10.1016/j.jpag.2007.08.006. PubMed PMID: 18656073. [PubMed: 18656073]
4. Rasmussen KM, Yaktine AL, Institute of Medicine (U.S.). Committee to Reexamine IOM Pregnancy Weight Guidelines Weight gain during pregnancy : reexamining the guidelines. Washington, DC: National Academies Press; 2009 xiv, 854 p. p.
5. Devoe JE, Baez A, Angier H, Krois L, Edlund C, Carney PA. Insurance + access not equal to health care: typology of barriers to health care access for low-income families. *Ann Fam Med* 2007;5(6): 511–8. doi: 10.1370/afm.748. PubMed PMID: 18025488; PMCID: PMC2094032. [PubMed: 18025488]
6. Olson CM, Strawderman MS, Graham ML. Association between consistent weight gain tracking and gestational weight gain: Secondary analysis of a randomized trial. *Obesity (Silver Spring)*. 2017;25(7):1217–27. doi: 10.1002/oby.21873. PubMed PMID: 28573669; PMCID: PMC5504884. [PubMed: 28573669]
7. Gilmore LA, Redman LM. Weight gain in pregnancy and application of the 2009 IOM guidelines: toward a uniform approach. *Obesity (Silver Spring)*. 2015;23(3):507–11. doi: 10.1002/oby.20951. PubMed PMID: 25521748; PMCID: 4340812. [PubMed: 25521748]
8. Deputy NP, Sharma AJ, Kim SY, Hinkle SN. Prevalence and characteristics associated with gestational weight gain adequacy. *Obstet Gynecol* 2015;125(4):773–81. doi: 10.1097/AOG.0000000000000739. PubMed PMID: 25751216; PMCID: PMC4425284. [PubMed: 25751216]
9. Oken E, Baccarelli AA, Gold DR, Kleinman KP, Litonjua AA, De Meo D, Rich-Edwards JW, Rifas-Shiman SL, Sagiv S, Taveras EM, Weiss ST, Belfort MB, Burris HH, Camargo CA Jr., Huh SY, Mantzoros C, Parker MG, Gillman MW. Cohort Profile: Project Viva. *Int J Epidemiol* 2014. doi: dyu008 [pii] 10.1093/ije/dyu008. PubMed PMID: 24639442.
10. Phelan S, Phipps MG, Abrams B, Darroch F, Schaffner A, Wing RR. Randomized trial of a behavioral intervention to prevent excessive gestational weight gain: the Fit for Delivery Study. *Am J Clin Nutr* 2011;93(4):772–9. doi: 10.3945/ajcn.110.005306. PubMed PMID: 21310836; PMCID: 3057546. [PubMed: 21310836]
11. Oken E, Baccarelli AA, Gold DR, Kleinman KP, Litonjua AA, De Meo D, Rich-Edwards JW, Rifas-Shiman SL, Sagiv S, Taveras EM, Weiss ST, Belfort MB, Burris HH, Camargo CA Jr., Huh SY, Mantzoros C, Parker MG, Gillman MW. Cohort profile: project viva. *Int J Epidemiol* 2015;44(1):37–48. doi: 10.1093/ije/dyu008. PubMed PMID: 24639442; PMCID: PMC4339753. [PubMed: 24639442]
12. Burris HH, Braun JM, Byun HM, Tarantini L, Mercado A, Wright RJ, Schnaas L, Baccarelli AA, Wright RO, Tellez-Rojo MM. Association between birth weight and DNA methylation of IGF2, glucocorticoid receptor and repetitive elements LINE-1 and Alu. *Epigenomics*. 2013;5(3):271–81. doi: 10.2217/epi.13.24. PubMed PMID: 23750643; PMCID: Pmc3787720. [PubMed: 23750643]
13. Braun JM, Wright RJ, Just AC, Power MC, Tamayo YOM, Schnaas L, Hu H, Wright RO, Tellez-Rojo MM. Relationships between lead biomarkers and diurnal salivary cortisol indices in pregnant women from Mexico City: a cross-sectional study. *Environmental health : a global access science source*. 2014;13(1):50. doi: 10.1186/1476-069x-13-50. PubMed PMID: 24916609; PMCID: 4068833. [PubMed: 24916609]
14. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet*. 1986;1(8476):307–10. PubMed PMID: 2868172. [PubMed: 2868172]
15. Mandujano A, Huston-Presley L, Waters TP, Catalano PM. Women's reported weight: is there a discrepancy? *J Matern Fetal Neonatal Med* 2012;25(8):1395–8. doi: 10.3109/14767058.2011.636099. PubMed PMID: 22067020. [PubMed: 22067020]

What is already known about this subject?

- Self-reported pre-pregnancy weights in women who receive routine health care agree well with measured pre-pregnancy weights.
- There is evidence of under-reporting of pre-pregnancy weights in women with higher BMI.
- Low-income women may not have access to a scale or receive routine health care.

What does this study add?

- This study provides a model to estimate pre-pregnancy weight from the first pregnancy clinical visit.
- This study provides software so clinicians and investigators can easily estimate pre-pregnancy weight by inputting information gathered at the first pregnancy visit.
- This study identifies women who may be classified into an incorrect gestational weight category due to misreported pre-pregnancy weight.

Figure 1. Bland Altman plots evaluating pre-pregnancy weight measured by a clinic scale versus model predictions.

Panel A is the correlation between actual and predicted pre-pregnancy weight in the FFD measured weights and Panel B is the Bland Altman plot.

Figure 2. Bland-Altman plots model predicted versus self-reported pre-pregnancy weights. There is good agreement between model predictions and self-reported weights in the FFD study conducted in the US in women who received routine health care (Panel A correlation plot and C Bland Altman plot). There is much more variation and deviation from model predictions in women from Mexico (Panel B correlation plot and D Bland Altman plot).

Table 1.

Summary of baseline characteristics of participant data used to develop, validate, and test the pre-pregnancy weight models is reported. The pre-pregnancy BMI was computed from self-reported pre-pregnancy weight. A description of how each study and reference database was used is included. Summary data is reported as mean $\pm$ SD.

Study	BMI (kg/m ²)	Height (cm)	Gestational day	Age (y)	Applied Variables	Application
Project Viva N=301(9)	24.0 $\pm$ 5.4	165.3 $\pm$ 7.0	53.1 $\pm$ 20.6	31.6 $\pm$ 5.8	1. Measured pre-pregnancy weights. 2. Demographic variables. 3. First trimester measured weight.	Model development.
FFD N=401 (10)	26.4 $\pm$ 5.7	162.5 $\pm$ 6.6	94.8 $\pm$ 12.6	28.7 $\pm$ 5.2	1. Measured pre-pregnancy weights (N=51). 2. Self-reported pre-pregnancy weights (N=401) 3. Second trimester measured weights (N=196)	1. Measured pre-pregnancy weights were used to test model. 2. Self-reported pre-pregnancy weight were used to compare to model predictions. 3. Second trimester weight was used as the model input for the first clinical visit weight. Resulting model predictions were compared to self-reported pre-pregnancy weight.
PROGRESS N=1054 (12, 13)	26.1 $\pm$ 5.5	155.1 $\pm$ 5.5	131.1 $\pm$ 6.5	27.7 $\pm$ 5.5	1. Self-reported pre-pregnancy weights. 2. First/second trimester measured weights.	Self-reported pre-pregnancy weight were used to compare to model predictions.

Table 2.

Model coefficients derived from the Project Viva study. Reported are the model coefficients, the standard error and p value for each model coefficient.

Model Term	Coefficient	Std Error	Prob> t
Intercept	6.10	3.03	0.05*
Weight at First Visit	0.99	0.01	<.0001*
Gestational Age (days)	−0.01	0.01	0.04*
Height (cm)	−0.02	0.02	0.23
Maternal Age (years)	−0.04	0.02	0.05
Parity	−0.09	0.14	0.52

Table 3:

The percent of participants from the FFD study and the PROGRESS study that were classified by the mathematical model into a different gestational weight gain category. The majority of the misclassifications involved participants who self-reported a lower pre-pregnancy weight from the model predictions. The majority of misclassifications that occurred in both the FFD and PROGRESS studies were women who self-reported pre-pregnancy weights into a normal weight category, but were classified by the model into an overweight category.

Study	% Misclassified Total	% Misclassifications into a lower BMI group	% Model Classified Overweight, Self-reported Normal Weight	% Model Classified with Obesity, Self-reported Overweight
FFD	15%	89%	67%	24%
PROGRESS	28%	85%	64%	24%

Table 4:

A summary of the needs, benefits, and clinical utility of the pre-pregnancy weight calculator.

<p>Weight is required to compute patient BMI</p> <p>In pregnancy, pre-pregnancy weight is used to define healthy weight gain projections</p> <p>Some women may not have access to a scale.</p> <p>Patient self-reported weight is sometimes under-estimated.</p> <p>Underestimating pre-pregnancy weight can lead to less conservative BMI classification prescribing more liberal weight gain in pregnancy.</p> <p>The pre-pregnancy weight calculator predicts pre-pregnancy weight, confirms the validity of patient self-report and shows if pre-pregnancy BMI is misclassified.</p>
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