A Risk Score for Childhood Obesity in an Urban Latino Cohort

Jacob O. Robson, MD, MAS[1], Sofia G. Verstraete, MD, MAS[1], Stephen Shiboski, PhD[2], Melvin B. Heyman, MD, MPH[1], and Janet M. Wojcicki, PhD, MPH[1]

Objective To assess whether individual obesity risk factors, present during gestation, and the first 6 months of life, can be combined into a simple prognostic model that has the ability to accurately predict childhood obesity at age 5 years in a high-risk cohort.

Study design A total of 201 Latina women were recruited during pregnancy, and their infants followed longitudinally. Ten risk factors for childhood obesity were included in an initial logistic model; a second reduced model was created via stepwise deletion (confirmed with nonparametric conditional random forest classifier), after which 5 risk factors remained. From each model, an obesity risk equation was derived, and an obesity risk score was generated for each patient. Derived algorithms were assessed using discrimination, calibration, and via predictive statistics.

Results Of the 166 children followed through age 5 years, 56 (32%) met criteria for childhood obesity. Discrimination accuracy for both derivation models was excellent, and after optimism-corrected bootstrapping, both models showed meaningful clinical performance. Both models were adequately calibrated, showed strong sensitivity and negative predictive value at conservatively set obesity risk thresholds, and displayed excellent specificity among those classified as highest risk. Birth weight z-score and change in weight-for-age z-score between birth and 6 months were the risk factors with the strongest contribution to the obesity risk score.

Conclusions Obesity risk algorithms are reliable in their prediction of childhood obesity and have the potential to be integrated into the electronic medical record. These models could provide a filter for directing early prevention resources to children with high obesity risk but should be evaluated in a larger external dataset. *(J Pediatr 2016;172:29-34)*.

Despite the medical and financial severity of childhood obesity, it has proven difficult to treat. Longitudinal data show that once childhood obesity is present, it is likely to persist into adolescence and adulthood.[1] Pediatric health care practitioners (HCPs) have, thus, turned their focus to obesity prevention. Many recent studies have focused on single risk factors that are highly associated childhood obesity and are present during gestation or early infancy, such as maternal smoking and rapid early infant weight gain, as potential prevention targets.[2] However, as the development of childhood obesity is influenced by genetic, environmental, and socioeconomic factors, in a complex interaction, targeting single obesity risk factors for intervention may be ineffective.

Prognostic modeling, whereby influence weights from multiple risk factors are combined to estimate an individual's risk of a medical outcome,[3] may be useful. An accurate childhood obesity risk score, derived from the presence of known prenatal and early postnatal obesity risk factors, could provide a simple means of identifying infants at low risk of obesity and directing them to standard weight monitoring,[4] while reserving intensive obesity prevention resources for those at high risk. This would be particularly useful in medical centers serving the urban poor, where the prevalence of obesity is often high,[5] yet resources are low. The purpose of this study was to examine whether a prognostic model for childhood obesity could be derived from data gathered among an urban, Latino cohort, using only objective measures available from the medical record in a low resource setting.

Methods

Latina women living in the San Francisco area were recruited during their pregnancy for a prospective cohort study. The full recruitment protocol has been described previously.[6] Demographic and general health characteristics of maternal participants were collected and maternal body mass index (BMI) was

BMI	Body mass index
EMR	Electronic medical record
HCP	Health care practitioner
NPV	Negative predictive value
PPV	Positive predictive value
WFA	Weight-for-age

From the [1]Division of Pediatric Gastroenterology, Hepatology, and Nutrition, Department of Pediatrics, and [2]Department of Epidemiology and Biostatistics, University of California San Francisco, San Francisco, CA

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calculated from self-reported prepregnancy weight and height on the intake questionnaire. Mothers with preexisting diabetes, polycystic ovary syndrome, insulin dependent gestational diabetes, and those with health issues or beliefs that would prevent breastfeeding were excluded from the cohort. Infants were excluded at delivery if they had any special care needs or an Apgar score ≤7 at 5 minutes of life. A total of 201 mothers were enrolled in the study, 196 infants met criteria for participation, and 166 mother-child pairs (83% and 85%, respectively) remained in follow-up at 5 years.

At birth, 6 months, 1 year, and subsequent annual visits, anthropometric measures were obtained on child participants, using standard digital scales for weight and tape measurements for length. Weight and height were calculated based on sex-specific Centers for Disease Control growth references. A small percentage of the participants (<5% at each time point) could not attend study visits, so weight and height measures were extracted from the medical record. Data were obtained on the child's nutritional intake via maternal interviews.

The Committee on Human Research at University of California, San Francisco approved all study procedures. Written informed consent was obtained from all participants at study entry and follow-up visits. Data collection ran from 2006-2012, and statistical analysis was conducted from 2014-2015.

For our predictive modeling, we included only risk factors that were clearly defined, reliably measurable, and available in standard clinical settings. We only considered predictors that have been previously described as affecting infant or childhood weight status.[6,7] Whenever possible, we avoided dichotomization or categorization of linear predictors.[8] All continuous predictors were checked for nonlinearity. The primary outcome was childhood obesity at age 5 years, defined as BMI ≥95th percentile, using Centers for Disease Control growth references.[9]

In reviewing our longitudinal data, we identified 19 candidate predictors of childhood obesity, including 11 prenatal/maternal and 8 early postnatal risk factors (**Table I**; available at www.jpeds.com). We applied our guiding principles in creating the predictive model, removing several maternal variables, including maternal depression, employment status, and years in the US, because of concerns over infrequent inclusion in the standard medical record and/or time burden on the HCP to document. Maternal smoking was excluded because of low prevalence of smoking in the cohort (both during pregnancy and in the first year of follow-up, reported smoking prevalence was <3%). Gestational age was excluded because of colinearity with birth weight and little independent predictive value.

Statistical Analyses

The 10 remaining candidate predictors were placed into a logistic regression model, referred to as the "full model." An obesity risk score was generated for each participant, with the regression constant serving as the intercept and the beta-coefficient indicating the adjusted contribution of each predictor to the obesity risk (**Table II**; available at www.jpeds.com). The predicted risk of obesity was calculated using the formula $1/(1 + \hat{e}^{-\text{risk score}})$.[10] We also developed an alternate predictive regression model using two variable selection strategies: stepwise backward deletion using the 20% significance level as a criterion for variable retention, and based on variable importance rankings from a nonparametric conditional random forest classifier (**Figure 1**; available at www.jpeds.com).[11] Both approaches resulted in the same group of 5 predictors, which were used to fit a "reduced model." Risk scores were also created for each patient using this model. Regression diagnostics for each model included identification of observations with high leverage, assessment for pairwise interactions and nonlinearity.

Both the full model and the reduced model were evaluated for discrimination and calibration performance. Discrimination was assessed by creating a receiver operating characteristic curve, with concordance index (area under the receiver operating characteristic) ≥0.8 considered to be excellent accuracy and ≥0.75 clinically meaningful.[12] Model calibration was analyzed using the Hosmer-Lemeshow goodness of fit test, with $P < .05$ defined as failure of adequate agreement between estimated and observed values.[12] To test predictive accuracy, an arbitrary risk threshold (eg, obesity risk score >50th percentile) was established, and those above the threshold were labeled as positive on the prognostic test for childhood obesity. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) for the prognostic test at several different risk thresholds were calculated, as were likelihood ratios.

Because of the small sample size in this specific cohort, we elected not to split the dataset into derivation and validation sets. Rather, we used the entire sample to develop the prediction models and estimated internal measures of prediction performance using the bootstrap with 1000 samples.[13] Statistics were performed with Stata 13 (StataCorp LP, College Station, Texas) and R v 3.2.2 (Vienna, Austria).

Because 17% and 12% of individuals had missing observations for at least 1 predictor in the full and reduced models, respectively, we used chained multiple imputation to assess the sensitivity of our estimated scores to missing information.[14] In both cases, estimates from imputed data were quite similar to those obtained using observed data, so we present results from the latter only.

Results

Our cohort had relatively low prevalence of higher education, employment, and English proficiency, comparable with the underserved, recent immigrant populations typically seen at urban safety net hospitals (**Table III**). Maternal prepregnancy BMI was reflective of national obesity trends among Latina women,[15] with 33% of mothers in the overweight range and an additional 18% obese.