The Importance of Psychosocial Variables in Predicting Low Birth Weight

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Full Text: Headnote ABSTRACT: Objective: An analysis of a pre-existing data set of 606 inner city pregnant women collected by the Fetal Alcohol Research Center of Wayne State University School of Medicine in Detroit, Michigan, was conducted to determine if the inclusion of psychosocial variables would improve the prediction of low birth weight. Method: Along with the usual medical and demographic data typically collected by obstetricians interested in low birth weight, data collection had also included variables assessing maternal comfort, feelings of hopefulness, intimacy of relationship with the baby's father, and alcohol and drug use. The sample was divided into cases for developing the mathematical models and test cases for comparing two different mathematical approaches-discriminant function analysis (DFA) and a computer simulation modeling method derived from chaos theory (dynamic systems modeling or DSM). Unlike DFA, DSM required a priori specification of the relationships among the variables. Findings: Psychosocial variables were needed by both mathematical approaches to achieve the best predictions of which women would deliver low birth weight infants. Alcohol and drug use were also important. The DSM method correctly identified 74 of 78 women who did not deliver low birth weight infants compared to 69 of 78 for DFA. It correctly identified 16 of the 22 low birth weight (LBW) infants compared to 11 of 22 for DFA. Both models performed better than existing models in the literature which do not consider psychosocial measures or drug and alcohol consumption. DSM performed better than DFA. Its sensitivity was 80%; efficiency was 90%; and specificity, 92%. DSM's a prior specification of variables included both independent contributions of psychosocial factors to medical risk and modulating effects of psychosocial factors on medical risks. Conclusions: Psychosocial variables and alcohol and drug use measures permitted significant improvement in the ability to predict risk for low birth weight. Dynamic systems modeling was better than DFA and should be further explored and developed to create an explanatory theory for low birth weight which could be used to guide a clinical trial of psychosocial intervention its prevention. KEY WORDS: Low birth weight, psychosocial variables, discriminant function analysis (DFA), dynamic systems modeling (DSM).
INTRODUCTION Spontaneous preterm delivery and low birth weight may be the most important problems facing obstetrical care providers in the 1990's (Creasy &Merkatz, 1990). The incidence of premature delivery (before 37 weeks of gestation) was 10% in 1986 (Morrison, 1990), but contributes 60% of perinatal mortality and morbidity (The American College of Obstetricians and Gynecologists, 1989, McCormick, 1991). Neonatal intensive care may be the most expensive item in our health care budget (Morrison, 1990; Gjerdingen, 1992). Current methods of identifying the women who will deliver before term rely on obstetrical history, demographic factors or premonitory symptoms and are neither sensitive nor specific (Papiernik, 1969). Present attempts to predict premature labor and low birth weight are based mainly on medical and demographic parameters (Creasy &Herron, 1981; Main, Richardson, Gabbe, Strong, &Weller, 1991). These attempts suffer from a high rate of false positives. Systems that score the risk for preterm labor and low birth weight have not been sufficiently discriminating to identify patients for prevention programs (Committee to Study the Prevention of Low Birth Weight. Preventing Low Birth Weight, 1985). The addition of psychosocial variables could add to the predictive power of existing procedures (Omer, Elizer, Barnea, Friedlander, &Palti, 1986). The purpose of this endeavor was to explore the importance of psychosocial variables in predicting low birth weight. Two mathematical methods were to be compared to determine the potential usefulness of DSM for psychosocial/biomedical research and on predicting which women are at risk for low birth weight. METHODS Sample A database of 606 low income women who delivered single infants in five hospitals in Detroit and

Wayne County, Michigan, was provided by Dr. Robert Sokol of the Fetal Alcohol Research Center of Wayne State University School of Medicine. The women were interviewed by Dr. Sokol's group 2-6 days postpartum. Of the 606 subjects, 58% were black, the mean age was 23.3, mean parity was 1.2, the median income was $5-10,0000, and 82% were single. Data collection procedures are described elsewhere (Poland, Ager, Olson, &Soko, 1990; Giblin, Poland, Waller, &Ager, 1988; Poland, Ager, Olson, &Sokol, 1990; Giblin, Poland, &Ager, 1990; Poland, Ager, &Sokol, 1991) Variables used in this study included: Social Support. An Intimacy factor contained questions about the nature of the relationship with the baby's father, marital status, and when in gestation a second person was told about the pregnancy. A Comfort factor included tangible resources such as household items and income, help from family and friends, and housing-related problems. Medical Risk. A composite medical risk score was derived from summing the weighted individual risks as follows: weights of two points each for diabetes, hypertension and previous low birth weight infant, and a weight of one point for age <16 years or >35 years and for hematocrit <28%. Habits. Tobacco use was scored as none, light (< = one pack per day) and heavy (> one pack per day). Drinking was scored as total number of drinks over pregnancy and categorized as none, light (4 to 99 drinks) and heavy (> 100 drinks). Severity of drug use was determined by assigning weights based upon physical and addictive effects so that marijuana = 1; heroin, methadone and cocaine = 2. These weights were then multiplied by frequency of use over pregnancy to yield a total score. These scores were then categorized into none, light use (score <210) or heavy use (score >= 210). Prenatal Care. Amount of prenatal care was derived from a modified Kessner Index with scores = O to 3 as previously described [37-39]. This variable was dichotomized to no care and inadequate care = 1 and adequate care = 2. Source of care was based upon the content, i.e., the average number of routine procedures performed at each site, scored from 1 to 3. Other Variables. Amount of insurance was coded as none, present during part of pregnancy or over the entire pregnancy; feelings about pregnancy was coded as a five point scale from very unhappy to very happy; how hopeful the woman was about the future was a four point scale from not at all hopeful to very hopeful; and the month of gestation pregnancy was first suspected was calculated based upon the calendar month pregnancy was suspected, month of delivery and length of gestation. Birthweight was recorded in grams. Reliability Coding accuracy had been maintained by periodic comparisons of two raters' independent coding of a random subset (25%) of interviews and medical charts. Percent agreement on coding accuracy was greater than 95%. Reliabilities in the socio-demographic and medical procedures variables were all greater than 0.96. Specificity and sensitivity of heroin reported compared to lab testing in the same patients and was 0.75 and 0.95 respectively; cocaine was 0.86 and 0.57 respectively; and cannabis was 0.78 and 0.60 respectively. Statistical Analysis Univariate frequency distributions along with descriptive sample statistics were calculated. Items with missing values on 10% or more of subjects were eliminated from further analysis. Discriminant function analysis was developed on half the sample (randomly selected) and then tested on the other half of the sample. Discriminant Function Analysis Variables for entry into the discriminant function analysis (DFA) consisted of race, suspect (month the woman first suspected she was pregnant), risk (weighted medical risk not including substance abuse), hopeful (how hopeful the woman is about the future), drinking (total drinking during pregnancy), care (where the woman goes for most of her care, insurance (level of health insurance), first feel (how the woman first felt about being pregnant), drugs (total drug use during pregnancy), comfort (how much social support the woman felt that she had), parity, smoking (during pregnancy), intimacy (how intimate the woman feels with her husband/baby's father/primary support providers) and the Kessner variable. Dynamic Systems Modeling Bell and Bell (1980) have recommended dynamic systems computer modeling for its requirement that an operational statement of theory be stated a priori which can then be easily tested, confirmed or refuted. Meadows (1980) has recommended analyzing data sets with computer modeling because: 1) they make precise and rigorous statements of theory, 2) when theory is explicit, it can be examined by critics for inconsistencies, 3) computer models can contain much more information than mental models, 4) computer models proceed from assumptions to conclusions in a logical, error-free manner, unlike mental models, 5) computer models can be easily altered to represent different assumptions or alternate hypotheses. DSM was developed at the Massachusetts Institute of Technology in the 1950's, primarily by Jay Forrester (Forrester, 1961, 1969, 1975) who brought together ideas from control engineering, cybernetics, and organizational development theory to develop a guiding philosophy and set of representational techniques for simulating complex, nonlinear, multi-loop, feedback systems. In DSM the theory to explain the data must be stated mathematically prior to data entry and analysis. That theory emerges from the knowledge and experience of the investigators. Data are then entered into the model to determine if its predictions match observable reality. A successful model correctly predicts clinical data (Mehl, 1990). Development of the Model The Stella II modeling shell (High Performance Systems, 1991) was used for model development. In this study, a previously existing computer simulation model (Mehl, 1990) was modified and expanded to predict birthweight and gestational age. The procedure by which the model is developed is similar in intent to DFA, but involves the investigator more intensively as model builder. The process of actual model development on the 100 test cases was iterative. When the model did not predict a test case, the investigator studied that case (and others like it) to determine what was different about this case. Theory was then modified to explain the unpredicted case. If the case was now predictable, prior cases were re-run to be sure that predictability had not changed. Thus, no change was made that would alter prior predictability. This process was time-consuming and investigator intensive, but allowed theory refinement at the same time as model development. Of the remaining cases, 100 were randomly selected as a "test" data set for comparing the performance of DFA and DSM. The remaining unselected cases were available to DFA as a training data set upon which the formula to be applied to the test data set was developed. The same 15 variables were available to both methods for prediction of birthweight and gestational age. The adjusted phi-square method was used to compare DFA and DSM. RESULTS DSM Operation: The heart of the model was a differential equation which controls a variable called "Time to Start Labor," initialized so that labor starts at 40 weeks gestation in the usual case. When the current time within the simulation equals "Time to Start Labor," Gestational Age is fixed along with Birthweight (which is dependent upon Gestational Age). "Running" the simulation consists of starting 26 months prior to the estimated date of confinement to put the model into homeostasis prior to conception and activation of the pregnancy module. Since this validation study consisted of a data set from one point in time, we assumed that variables were constant throughout the simulation. A power of DSM not exploited in this study is its capacity to handle time-series data for each variable (vector data along the time axis; the meaning of dynamic). Variables decreasing gestational age at onset of labor included Negative feelings upon discovery of the pregnancy, low hope for the future, young age, high medical risk, lack of health insurance (an index of poverty), no prenatal care, and a composite variable called "discomforted concealment," scored when there was no prenatal care in the presence of adequate health insurance with very low levels of comfort about the pregnancy. Intimacy, good prenatal care, race, not being black, and high levels of comfort returned the time of delivery to full-term. When the "Conception" variable switches from "O" to "1", the pregnancy module is activated. "Time to Start Labor" has a value of the current time plus 40 weeks, and the factors listed in Table 1 begin to increase or decrease this 40 week value. Birthweight was incremented in each model iteration. Factors which decreased the rate of growth of the fetus included medical risk, lack of social support, low levels of comfort, substance abuse, "dysthymic teenager" (a composite variable present when a woman under age 20 with very low levels of both comfort and intimacy), black race, and "exploitive prenatal care" (many procedures in a low level setting). Fetal growth rate was restored by high levels of comfort. Increasing parity was associated with increasing birth weights. A non-linear function derived from existant research on fetal growth and development controlled fetal growth by weeks gestation. This function allowed average fetal growth by weeks of gestation and was the main driver of birthweight. There was a different in the maximum importance of Intimacy and of Comfort on Birthweight and on "Time to Start Labor." Psychosocial factors mitigated the effects drug and alcohol use.

Table 1
Correctly Identified Birth Weight by DSM (n = 100)

	DFA Outcome		*DSM Outcome*	
	LBW	*Not LBW*	*LBW*	*Not LBW*
LBW	13	11	16	6
Not LBW	7	69	4	74

Comparison	*DFA*	*DSM*
Efficiency (%)	82	90
Sensitivity (%)	65	80
Specificity (%)	86	92
PPV (%)	54	72
RR (%)	5.9	14.2
Adjusted Phi	0.54	0.74
Adjusted Phi-squared	29%	55%

Of the 78 women in the test sample who did not have low birth weight infants, DSM correctly identified 74 of them (Table 1). It missed 4 of these women, predicting them as belonging to the low birth weight group. DFA correctly identified 69 of these same women, misclassifying nine of them into the low birth weight group. The prematurity and low birth weight group of these inner Detroit women was 22%, a common rate for this and similar populations. Of the 22 women who had low birth weight infants, DSM correctly identified 16 and missed 6. DFA correctly identified 11 and missed 11. The adjusted phi-square method was used to compare the two procedures. DSM performed significantly better than DFA at the p = 0.01 level. DISCUSSION What is unusual about DSM and strange to some researchers is that theory is derived before computation, unlike statistical methods (DFA) in which theory results from computation. In DSM, computation confirms that the proposed theory predicts reality. It does not guarantee that the proposed theory is the only possible explanation, but merely renders it plausible. The theory of low birthweight generated by our DSM model states that medical risk is reduced by positive psychosocial factors (intimacy and comfort) and increased by negative psychosocial factors. The woman's feelings about the baby at the time she learns she is pregnant and her levels of hope and/or depression influence birthweight. Drugs and alcohol decrease birthweight. (Tobacco had the most powerful effect of the substances considered.) Good prenatal care increases birthweight, through an as yet unknown means. The theory developed from DSM suggests that the effect of medical risk is non-linear, reduced in those under age 18, in women who have had prior children, in women with positive psychosocial circumstances who do not smoke, and among women who are hopeful about the future and very much want the baby. The contribution of young age has been debated in the literature. This model performed best with young age acting in an extremely non-linear manner through an exponential function. A poor, anxious, 12-year-old who initially felt miserable about being pregnant and denied it until the sixth month would experience an eight-fold greater negative effect on "Time to Start Labor" than a similar 21-year-old. A similar 16-year-old would experience a three-fold effect. Several important age cut-offs were noted in the data, which merit further investigation. The behavior of several functions seem to have discrete changes around ages 18, 21 and 26. In this population, these were points of discontinuity for the effects of medical risk, substance use and psychosocial factors. In support of these findings, Omer (1986) has reviewed work by Herms and Gabelman finding that women who later developed premature labor were less well adapted socially and less attached to their families than women who delivered at term. Comparisons: Computer Models and Conventional Statistics The only comparison between dynamic systems modeling and conventional statistics which we found in the literature was a study by Mass and Senge (1980) of a model developed by Forrester (1980, 1969) to explain sharp rises and declines in orders booked at industrial plants. Forrester's simulaton model explained these cycles through a driving variable called "delivery delay recognized by market." Mass and Senge (1980) took calculated data from Forrester and subjected them to statistical testing. The data were exactly calculated by a computer and fit the curves precisely. Conventional statistics were successful in identifying the important variables. When a 5-10% error variation was introduced into the data, conventional statistics were no longer useful. Both DFA and DSM showed high levels of prediction, higher than other reports available in the literature. The reason for this can be hypothesized to be due to the inclusion of variables related to psychosocial status and lifestyle. Both techniques showed that increased quality and quantity of prenatal care can improve pregnancy outcome. Both techniques showed that substances (drugs, alcohol and tobacco) can be major pregnancy risks. DSM, while investigator intensive, can produce comparable results to conventional, sophisticated multivarate analytic techniques. It may outperform these techniques in modeling complex inter-relationships among variables and in allowing the use of complex systems theory to be applied to the prenatal period. The value of DSM is that it is used to predict risk for the individual patient by putting that patient' data into the model and calculating outcome, an impossibility for a statistical model. The implications of these finding are important. Research has clearly identified a role for psychosocial factors in premature labor and in low birth weight. The prospective trials to date of psychosocial interventions have been unsophisticated and have not proven helpful. Psychiatrists have a role in helping obstetricians to design psychosocial interventions which are much more behaviorally specific and capable of changing key variables within short periods of time. References

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