

## Investigating Risk Factors Affecting Teenage Pregnancy Rates in the United States

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### ABSTRACT

*Teenage pregnancy is an issue in the United States and signifies a growing public health concern. Health efforts and research on potential risk factors for teenage pregnancy is essential to the public health sector. In this study, risk factors affecting the teenage pregnancy rate are being investigated using artificial intelligence methods, Artificial Neural Network (ANN) and Support Vector Machine (SVM) to assist with teenage pregnancy education and prevention. Data was collected on a national level from the U.S. Census Bureau, the Center for Disease Control and Prevention (CDC), and the U.S. Departments of Labor and Commerce from 1972 to 2008. The important risk factors found in the ANN and SVM models were consistent with the literature findings, and are major contributors to the teenage pregnancy rate. It is evident that ANN and SVM models have successfully demonstrated their model validity and applicability. Therefore, preventative measures should focus on per capita income, unemployment rate, alcohol consumption, poverty rate, and cigarette consumption to reduce the risk and incidence of teenage pregnancy in the United States.*

### INTRODUCTION

Teenage pregnancy has not only become a public health issue, but also a media focal point. After a thorough review of the literature, it was determined that current research regarding teenage pregnancy is limited. The rate of teenage births in the United States has fallen since the late 1950s from 96 births per 1,000 women aged 15-19 to 49 births per 1,000 in 2006. Teenage pregnancy and births among girls in their adolescent years has declined and may be explained to a change in trends of marriage. Marriage in teen years is now not as common as it was in the 1950s. In the 1950s, 13% of teens had children without being married, but in 2000 that rate was 79%. In the 1990s, the typical age of first marriage in the United States was 25 for women and 27 for men. "Shotgun marriages" were also common, but few pregnant teens marry before the baby is born. Teenage pregnancy is still a major issue whether a teenager is married or not, but the change in trends of pregnancy may be explained by change in trends of other factors such as marriage.

In the 1970s and early 1980s, the U.S. teen pregnancy rates increased. They remained steady through the 1980s, even as sexual activity among teens increased, due to the use of contraceptives among teenagers. In 1999, the Alan Guttmacher Institute did an analysis of teenage pregnancy and found that approximately one-quarter of the decline in teenage pregnancy in the United States between 1988 and 1995 was due to increased abstinence. Also, overall contraceptive use increased—but only slightly, from 78% in 1988 to 80% in 1995. Teenagers in 1995 were choosing more-effective methods. A significant proportion of girls have switched to some long-acting hormonal methods that were introduced to the U.S. market in the early 1990s. By 1995, more than one in eight teen contraceptive users (13%) was using a long-acting method,

and primarily because of this shift, sexually active teens became increasingly successful at avoiding pregnancy (The Guttmacher Report, 2002). The rates declined 19% from 117 pregnancies per 1,000 women aged 15-19 in 1990 to 93 per 1,000 in 1997—the lowest rate in 20 years. The recent decline is particularly encouraging, because—as with the teen birthrate decline—all population groups followed a similar pattern, regardless of young women's age, marital status, race or ethnicity (National Center for Health Statistics, 2001). However, in 2008, the National Institutes of Health reported that teen pregnancies in the United States increased for the first time since 1991. In 2005, teen pregnancy rates edged upward from 21 births per 1,000 teenage girls to 22 per 1,000 in 2006. Researchers reported uncertainty of the cause of the rate increase (National Institutes of Health, 2008).

Teenagers in the United States continue to experience substantially higher pregnancy rates and birthrates than do teens in other Western industrialized countries (Gold, Kawachi, Kennedy, Lynch, & Connell, 2001). The adolescent pregnancy rate in the United States, for example, is nearly twice that of Canada and Great Britain and approximately four times that of France and Sweden. Moreover, teen birthrates have declined less steeply in the United States than in other developed countries over the last three decades. While we are far from having a complete understanding of why teens have children, available research has identified four conditions associated with teenage childbearing. Teens most likely to have children are those: (1) from economically disadvantaged families and communities; (2) not doing well in school and having low aspirations for their own educational achievement; (3) from dysfunctional families; and (4) with substance abuse and behavioral problems (Keplinger, Lundbreg & Plotnick, 1998).

In the United States, some of a teenagers' risk for pregnancy includes factors such as poverty, parents with low levels of education, low performance in school, and single-parent families. The Tennessee Department of Health listed the following as factors contributing to teenage pregnancy: lack of family and community support, lack of involvement in school and recreational activities or after school programs, lack of feeling connected to school, family, and community, use of alcohol and other drugs, lack of health education, and limited knowledge about sex and sexuality (Department of Health, 2011). Teenage mothers are more likely to drop out of high school, be and remain single parents, and are less likely to attend college than those who become pregnant at an older age (Guttmacher Institute, 2004). In turn, there are repercussions from the teenage mother that heavily impact the life of the child, including: lower scores in math and reading into adolescence, repeat of a school grade, high school dropout, giving birth as a teenager, and being unemployed or underemployed as a young adult. Overall, being a teen mother perpetuates the cycle of teen motherhood (Guttmacher Institute, 2006). Teen pregnancy affects education in such a way that only a third of teenage mothers earn their high school diploma. And only 1.5% acquires a college degree by age 30. Adolescent childbearing is usually inconsistent with mainstream societal demands for making the transition into adulthood, gaining education and work experience, and financial stability (Guttmacher Institute, 2004). This paper addresses the risk factors, population, per capita income, poverty rate, education and unemployment, and cigarette and alcohol consumption as key components of teen pregnancy rate.

### **Population**

Based on the most recent data, teenage birthrates were highest in the states of Mississippi, Texas, Arizona, Arkansas and New Mexico; and states with the lowest birthrates were in New Hampshire, Vermont, Massachusetts, North Dakota and Maine. States with the largest number of teens also had the greatest number of teen pregnancies (O'Hare, 1999). Current trends in teenage pregnancies varied in different parts

of the U.S. in relation to prevailing socioeconomic conditions (Smith et al, 2007). Teens who live in urban or rural areas are more likely to give birth between 15-19 years old (Smith et al, 2007).

### **Per capita income**

Further literature exploration indicated that young people growing up in disadvantaged economic, familial and social circumstances are more likely than those who did not to engage in risky behavior and have a child during their adolescent years. However, at all socioeconomic levels, American teenagers are less likely than their peers in the other study countries to use contraceptives and more likely to have a child.

Among teens aged 15–17, income inequality and per capita income were independently associated with birth rate; the mean birth rate was 54 per 1,000 in counties with low income and high income inequality, and 19 per 1,000 in counties with high income and low inequality. Among older teens (aged 18–19) only per capita income was significantly associated with birth rate. Although teen childbearing is the result of individual behaviors, these findings suggest that community-level factors such as income and income inequality may contribute significantly to differences in teen birth rates (Gold, Kawachi, Kennedy, Lynch & Connell, 2001).

In comparison to previous research which concluded that early childbearing leads to lower levels of investment in education and labor market experience, which in turn leads to depressed socioeconomic status, other research concluded that teen mothers are now more likely than in the past to complete high school or obtain a GED, but they are still less likely than women who delay childbearing to go on to college (Keplinger, Lundbreg & Plotnick, 1998).

### **Poverty Rate**

Teen mothers are more likely to be homeless at a younger age and homeless more often when compared to homeless adult mothers. In 2002, teen mothers were 75% more likely to have reported being homeless more than once and they were over three times more likely to have first become homeless before the age of 18. Many homeless teen mothers grew up in unstable environments were removed from parental care, or witnessed domestic violence as a child; and one in four were actually abused as children themselves. The relationship between teen pregnancy and poverty in the US is strong and well documented (Guttmacher Institute, 2002).

Nearly 60% of teens who become mothers are living in poverty following the birth of their infant (Hofferth, 2001). This research supports the conclusion that family income has selective but, in some instances, quite substantial effects on child and adolescent well-being. Family income appears to be more strongly related to the child's ability and achievement than to their emotional outcomes. Children who live in extreme poverty or those have lived below the poverty line for multiple years appear, all other things being equal, to suffer the worst outcomes. The timing of poverty also seems to be important for certain child outcomes.

### **Education and Unemployment**

The instability of the economy affects adults as well as teenagers and children. Teenage pregnancy cast as a social problem was believed to be the result of lower levels of education, welfare dependency, and low-paying jobs, as well as greater health troubles for these teens and their babies. An environment that creates doubt in one's economic sphere may also create doubt in other areas (Winters & Winters, 2012).

Conduct problems in school can deflect obtaining an education. Educational level has been determined to be a risk factor in teenage pregnancy. The relationship between conduct problems at younger ages and teenage pregnancy by age 18 was analyzed and a statistically significant association found between early conduct problems and later risk of teenage pregnancy. The results suggest that the higher rate of teenage pregnancy among girls with early conduct problems reflected their tendencies have a risky taking behavior in their adolescence years (Woodard & Fergusson, 2000).

Manlove (1998) found that factors relevant to teens' school experiences—including characteristics of their school and classroom, their family background, and individual engagement—were associated with the risk of school-age pregnancy leading to a live birth. A set of proportional hazards models indicated that for all racial and ethnic groups, high levels of school engagement were associated with postponing pregnancy.

### **Cigarette and Alcohol Consumption**

A study done by Cavazos-Rehg et al. (2011), determined that alcohol users, no clear pattern of age or intensity of use, were at increased risk of sexual intercourse with and without a history of teenage pregnancy. Experimental cigarette use increased the risk of having sexual intercourse but did not reach significance for pregnancy. However, daily cigarette smokers had an increased risk for sexual intercourse with and without a history of pregnancy. The study also found, earlier age at substance use initiation and higher intensity of use may be associated with increased risk for teenage pregnancy. Zimmer-Gembeck & Helfand (2008) stated, "Adolescents who are potentially at greater risk for teenage pregnancy are those who use substances; yet, the bulk of current pregnancy prevention strategies do little to target or educate youth on the sexual health risks associated with substance use despite growing evidence demonstrating the efficacy of these strategies."

### **SIGNIFICANCE OF THE STUDY**

The teenage pregnancy rate is an undeniably powerful indicator of the overall well being in a population. This is a concern to public health practitioners because majority of adolescents are among unmarried and unemployed young women. The investigation of teenage pregnancy provides an opportunity for developing preventive strategies to improve population health. To our best knowledge, this study may be the first to use the Artificial Neural Network (ANN) and Support Vector Machine (SVM) to rank the important risk factors contributing teenage pregnancy in the U.S. If the most important predictors of teenage pregnancy in the U.S. can be identified, targeted interventions can be developed and the efficacy of pre-existing programs may be improved. Policy makers could further use this information to determine which social programs (i.e. smoking cessation campaigns, unemployment programs, and teen pregnancy prevention programs) should receive more government support. Also, ranking the most important risk factors at the national level could help identify national trend and regions affected by the same risk factors.

### **OVERVIEW OF ANN AND SVM MODELS**

ANN is an information processing paradigm inspired by the function of the human brain (Freeman & Skapura, 1991; Hinton, 1992; Zutada, 1992). The network consists of many processing units (neurons or nodes) that are linked together and embedded in the input, hidden, and output layers. These links multiply the neurons of the input and hidden layers by an individual weighing factor, which is a value analogous to the connection strength at a synapse (Dreiseitl & Ohno-Machado, 2002; Freeman & Skapura, 1991). The synaptic process of the ANN stores the knowledge needed to solve specific problems.

The ANN model is constructed with activation functions that establish nonlinear relationships between input layer neurons and hidden layer neurons, and nonlinear relationship between hidden layer neurons and output layer neurons. These activation functions allow for the identification, ranking, and interpretation of associations between teenage pregnancy and related risk factors.

The SVM classifier is operated on the principle of structural risk minimization (Vapnik, 1995). It was designed to minimize true risk of misclassifying examples during the model training. The SVM classifier has its advantage in the practical application for small sample and generalization because of structural risk minimization (Vapnik, 1995; Zeng, Xu, Gu, Liu, & Xu, 2008). It can be applied to the prediction of continuous outcome variables (Cristianini & Shawe-Taylor, 2000).

SVM allows researchers to construct nonlinear classifier as the solution to a quadratic problem in order to yield a minimum of error function. It seeks an optimal hyperplane to separate data from different categories through the computational short-cut of kernel functions (Cortes & Vapnik, 1995; Cristianini & Shawe-Taylor, 2000). The basic role of the kernel function is to calculate inner product values through a transformation in high-dimensional feature space, and ultimately maximize the margin of separation to yield high accuracy of data prediction.

In this study, ANN and SVM models used logistic and linear functions to determine the most important risk factors for teenage pregnancy.

### STUDY DESIGN AND DATA SOURCES

This retrospective study was designed to analyze teenage pregnancy rate in the 1972-2008 national natality dataset of the United States (See Figure 1), compiled by Centers for Disease Control and Prevention Wonder. The data, at the county level, was pre-coded according to uniform specifications, and passed through vigorous statistical quality checks (Centers for Disease Control and Prevention, 2011). As shown in Table 1, additional data in this study was taken from the U.S. Census Bureau the Office of Management and Budget, National Institute of Alcohol Abuse and Alcoholism, and the CDC on the national level for the following factors: U.S. per capita income, U.S. poverty rate, U.S. unemployment rate, U.S. cigarette consumption, U.S. alcohol consumption, and the percentage of the U.S. population who had less than 9 years of education.

Figure 1.

U.S. Teen Pregnancy Rates, Years 1972-2008

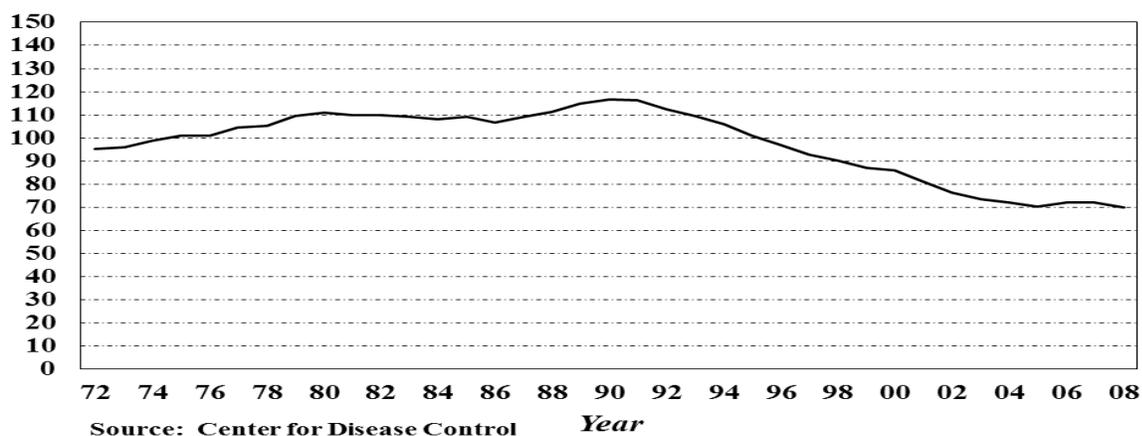


Table 1.  
Independent Variables for Teenage Pregnancy Rate

Variable Names	Variable Description	Measurement Scale	Source
PCpIncom	Income per person in a population. Often used to measure a country's standard of living.	It is calculated by taking a measure of all sources of income in the aggregate (such as GDP or GNP) and dividing it by the total population.	United States Census Bureau
Unemploy	U.S. Unemployment Rate: was a measure of the prevalence of unemployment (the amount of people that are without jobs, but are actively seeking within the last few weeks)	Measured by dividing the number of unemployed individuals by all individuals currently in the labor force	United States Census Bureau
PovRate	U.S. Poverty Rate: was a measure of the percentage of people in poverty per calendar year by the Current Population Survey. If the family income before taxes and without capital gain/noncash benefits is less than threshold, the entire family is in poverty	Measured annual poverty rates are based on the summation of reported annual income reported a few times a year divided by the sum of poverty thresholds at month intervals, resultant of changes in family composition.	Office of Management and Budget's Statistical Policy Directive 14.
Less9ED	Percent of U.S. Population Less than 9 Years of Education: this measure of educational attainment referred to the highest level of education that an individual has completed	American Community Survey	United States Census Bureau
Alcohol	U.S. Alcohol Consumption per 1,000 gallons: The liters of pure alcohol per capita by state were computed as the sum of alcohol production and imports, divided by the adult population (aged 15 years and older).	Calculated from official statistics on production, sales, import and export, taking into account stocks whenever possible.	National Institute of Alcohol Abuse and Alcoholism
Cigarette	Approximate average number of cigarettes smoked per adult per year	Adult per capita cigarette consumption was estimated by dividing total consumption by the number of persons aged $\geq 18$ years in the United States each year using data from the U.S. Census Bureau.	CDC

## **STUDY METHOD**

In order to identify risk factors that affect the teenage pregnancy rate in the U.S., ANN and SVM models were used for the data analysis. Six fundamental steps for the model construction are involved.

Step 1: The outcome variable and its six risk factors were collected in a fixed format flat file. The outcome variable was the teenage pregnancy rate for the United States in years 1972-2008. The risk factors included per capita income, unemployment rate, poverty rate, percentage of population who had less than 9 years of education, alcohol consumption, and cigarette consumption.

Step 2: A trial and error process was performed by applying all activation and kernel functions for the ANN and SVM, respectively. The ANN architecture consisted of four models from two activation functions (identity and sigmoid) between input and hidden layers and the same activation functions between hidden and output layers. The SVM topology contained four kernel functions as follows: linear, radial basis function (RBF), polynomial, and sigmoid.

Step 3: All possible ANN and SVM candidate models were trained and tested to achieve minimal prediction error by means of the cross-validation. The input data set was divided into three mutually exclusive subsets where two subsets were available for training; and one subset was used for testing purpose. The average results from three repeated processes were used to represent the prediction results for training and test data sets.

Step 4: The results of the ANN and SVM models were evaluated and compared with each other to determine if they were suitable for the teenage pregnancy study. The benchmark comparison was performed by comparing the normalized importance, the rank order of risk factors, and prediction accuracy.

Step 5: The most commonly used criterion, prediction error, was implemented to compare the prediction accuracy. Small prediction error is an indication of high accuracy in prediction. The prediction error is measured by the mean absolute percentage error (MAPE) or the average of all ratios of the absolute prediction errors to the actual values. A measure of the model fit, R-squared value, is known as the coefficient of determination. This is the proportion of variation in teenage pregnancy that is explained by risk factors in the model. A higher R-squared value leads to better model fitting.

Step 6: The most important risk factors for the ANN and SVM models were identified based on the normalized importance. The normalized importance provides a hierarchal viewpoint of the ranking of the risk factors.

## **EMPIRICAL RESULTS**

Using the teenage pregnancy rates for fifty states, all risk factors as displayed in Table 1 were included in the ANN and SVM models as the full variable models. Normalized importance along with rank order gave an indication of their important contribution to the outcome variable. The consistent results of the most important risk factors were clearly shown across both models. The risk factors that showed the largest influence on teenage pregnancy rate were (1) U.S per capita income; (2) Percent of the U.S. population with less than 9 years of education, (3) U.S cigarette consumption; and (4) U.S. poverty rate.

The risk factors associated with teenage pregnancy rates are consistent with the literature findings. It is important to reiterate that many of the risk factors form a major force to have impact on teenage pregnancy. In order to reduce the teenage pregnancy rate, intervention programs must be implemented to specifically target populations based on these research findings.

The prediction accuracy of the ANN and SVM models is based on the validation set or the average of model errors from the cross-validation. The ANN and SVM models demonstrated good fittings and highly accurate predictions with moderate high R squared values (0.951 and 0.972), and low values of MAPE (2.87% and 1.67%).

Table 2.  
Variables in the Equations for the ANN and SVM Models

Variables in Equation	ANN Model: Sigmoid <sup>a</sup> /Linear (Scaled Conjugate <sup>b</sup> )		SVM Model: RBF <sup>c</sup>	
	Normalized Importance	Rank Order	Normalized Importance	Rank Order
PCpIncom	100.000	1	100.000	1
Less9ED	96.068	2	44.298	2
Cigarette	28.460	3	42.112	3
PovRate	10.331	4	21.600	5
Alcohol	1.479	5	40.547	4
Unemploy	1.444	6	11.886	6

<sup>a</sup> Sigmoid is an S-shaped logistic regression equation written as  $o = 1 / (1 + e^{-s})$ , where o is the outcome variable,  $s = \sum_{i=0}^d w_i x_i$ , Xs are risk factors, and Ws are connection weights either from input layer to hidden layer.

<sup>b</sup> The idea of conjugate (orthogonal and well separated) is to allow each search direction be independent on all the other directions, which leads researchers straight to the solution.

<sup>c</sup> In the SVM RBF algorithm, the weight vector w is a normal to the hyperplane that separates two classes of examples, where C = 196.218, Gamma = 2.086, and P = 0.827.

## CONCLUSIONS

By constructing reasonable and workable ANN and SVM models, this study has accomplished its goal in assessing risk factors affecting U.S. teenage pregnancy rate. Therefore, it is reasonable to conclude that these models have demonstrated their model validity and applicability. The significant risk factors affecting teenage pregnancy rate were per capita income, percent of the population who had less than 9 years of education, cigarette consumption, poverty, and alcohol consumption. At least 95% of the variance in teenage pregnancy rate can be explained by the important risk factors identified in the ANN and SVM models.

Literature supports that the economy of a community is a major predictor of teenage pregnancy rate. Low per capita incomes, high cigarette consumption, and high poverty rates provide an environment for high teenage pregnancy rate. Research focusing on the development of interventions should emphasize how factors such as per capita income and poverty rate are associated with successive risk factors such as access to healthcare, quality education, and job opportunities. Risk factors, such as, cigarette and alcohol consumption are behavioral, controllable, and preventable, but continue to increase the rate of teenage pregnancy. Teenage cigarette and alcohol consumption are major societal concerns not only because underage smoking and drinking are illegal, but also because they are risk factors for teenage pregnancy, infant mortality, cancer, obesity, diabetes, strokes, cardiovascular disease, lung disease, and drug abuse, just to name a few. Focusing interventions on changing these behaviors can vastly affect the rate of teenage pregnancy. The identification and consistency in outlining the important risk factors for teenage pregnancy serves as a major contribution to maternal and infant health research. The classification of these risk factors on an ordinal scale facilitates future quantitative, as well as qualitative, research with a more direct approach.

ANN and SVM models complement each other well as they ascertain a nonlinear relationship between teenage pregnancy and related risk factors based on the partition datasets for training and testing rather than large samples for statistical inferences. There are several strengths and limitations to consider when using the ANN and SVM modeling approaches. Both can be developed by newcomers to artificial intelligence within a relatively short time frame, conditional on the availability of an appropriate data set and sophisticated software. Secondly, ANN and SVM models can implicitly detect complex nonlinear relationship between adverse birth outcome variable and risk factors. Thirdly, ANN and SVM models have the ability to detect all possible interactions between risk factors and can be developed using multiple different training algorithms. Fourthly, these models do not require any statistical assumption because they are data driven rather model driven. However, there are limitations of the ANN and SVM models; these models require greater computational resources. This study was unable to examine the relationship between race, age, family status, and other variables because they were not available in the dataset. ANN model is prone to overfitting and may be more difficult to use in the field of Public Health. Although ANN may overfit, it can be used to verify the results and evaluate the findings.

Although many women have shown that it is possible to have a successful life and be a teen mother, the likelihood of their child becoming pregnant as a teen continues to be a concern. The high national average for the teenage pregnancy rate signifies a growing public health concern; and research on potential risk factors for teenage pregnancy is essential to the public health sector. Cigarette consumption is a preventable risk factor, but per capita income and poverty are not. Although underlying factors do weigh heavily on the likelihood of teenage pregnancy, certain health behaviors can be managed through self-efficacy, awareness, edification, and lifestyle changes. State and local public health departments may identify target populations for teenage pregnancy prevention programs based on socioeconomic status, age, and ethnicity/race. Focusing prevention programs on ways to help avoid engaging in risky sexual activity will assist in reducing teenage pregnancy. Identifying important risk factors for teenage pregnancy rate enable the development of new initiatives geared toward reducing this rate among women who are at risk in target populations. Classifying the significance of risk factors also promotes the expansion of government funded public health initiatives such as teenage pregnancy prevention projects. Past research has shown that interventions have been effective in reducing the prevalence of public health problems. However, it is the

contribution of current research that aids in the continuous improvement of services to eliminate these public health issues.

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