

How Accurately Can We Predict Repeat Teen Pregnancy Based on Social Ecological Factors?

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Many factors at the individual, relationship, family, and community or environmental levels could predict repeat teen pregnancies or births, but research on certain factors is limited. In addition, few studies have examined whether these factors can accurately predict whether teen mothers will have a repeat pregnancy. This study examined theoretically selected predictors of repeat teen pregnancy among 945 pregnant and parenting teens (M age = 17), most of whom were Hispanic/Latina (86%). Logistic regression with 47 predictors measured at baseline was used to predict repeat pregnancy. Predictors were selected based on backward selection that aimed for a balance between model performance and model complexity. A random forest model was also used to determine how accurately repeat pregnancy could be predicted based on all predictors. Significant predictors of repeat pregnancy were the teen mother having a parent with a serious drinking or drug problem when she was a child, being older, not living with a mother figure, not intending to abstain from sex or use a long-acting reversible contraceptive, and having lower resiliency skills. However, predictors explained limited variance in repeat pregnancy, and their accuracy in predicting repeat pregnancy was low. More research is needed to identify accurate predictors of repeat pregnancy because this could inform program providers or developers about areas that warrant more focus in programming for teen parents, and it could help identify teen mothers at higher risk of a repeat pregnancy so they could be the focus of specific programming.

Keywords: predictive analytics, machine learning, repeat pregnancy, teen mothers, adolescent mothers

Parenthood presents many challenges for teens. They can find it difficult to complete high school and enroll in college and may face economic insecurity, parental stress, and mental health issues (Hodgkinson et al., 2014; Hoffman & Maynard, 2008; Partington et al., 2009). These challenges can be heightened for youth who have more than one teen birth (Manlove et al., 2004; Partington et al., 2009). Although repeat teen births have declined in recent years in the United States, they remain a concern: In 2018, 18.3% of births to mothers age 19 or younger were repeat births (Martin et al., 2019). Moreover, repeat birth rates for Hispanic/Latina teen

mothers were about 4 percentage points higher than rates for White, non-Hispanic/Latina teen mothers (Martin et al., 2019).

Research to understand predictors of repeat teen pregnancies is important because repeat pregnancies often result in repeat teen births (Finer & Henshaw, 2006). Multiple factors at the individual, relationship, family, and community or environmental level may predict repeat teen pregnancies, but research is limited in some areas. For example, a meta-analysis identified factors that predicted repeat teen pregnancy, including lack of contraceptive use, dropping out of school, living with a partner, and depression (Maravilla et al., 2017). However, many potentially important factors, such as intimate partner violence (IPV), have only been examined in a few studies (Raneri & Wiemann, 2007). Moreover, many studies focus on a small number of predictors, and not on the broader range of potential influences on repeat pregnancy (Maravilla et al., 2017). Finally, although research has identified some significant predictors of repeat teen pregnancy, few studies have examined how accurately they can predict whether mothers have a repeat pregnancy.

This study addressed these gaps by examining multiple potential predictors of repeat teen pregnancy among a sample of primarily Hispanic/Latina mothers. Studies have found Hispanic/Latina mothers to be more likely to have a repeat pregnancy than other racial/ethnic groups (Patel et al., 1997; Pfitzner et al., 2003), so it is particularly important to understand predictors of teen pregnancy for these mothers (Bouris et al., 2012). Although Hispanic/Latino mothers in the United States are diverse in terms of their

This article was published Online First June 27, 2022.

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This work was conducted under a contract (HHSP233201450026A) with the Office of Population Affairs (formerly the Office of Adolescent Health), within the Department of Health and Human Services. We thank the Office of Population Affairs for its support and input. The views expressed do not necessarily reflect the official policies of the Department of Health and Human Services, nor does mention of trade names, commercial practices, or organizations imply endorsement by the U.S. government. This study's design was preregistered (ClinicalTrials.gov Identifier NCT04181034); however, the analyses addressed in this article are exploratory and were not registered. The data are not publicly available.

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country of origin, access to resources, and history and experiences (Beaglehole, 2003; Pew Hispanic Center, 2009), “there appear to be some shared traditional values and experiences in the U.S. Latino population that affect teenage pregnancy, such as the value of motherhood and the influence of family and family communication” (Aparicio et al., 2016, p. 2). These values may mean that some predictors of repeat pregnancy are unique among this group. Because most prior research has not specifically examined social ecological predictors of repeat pregnancy among Hispanic/Latina youth, this study can provide new insights. This study also builds on prior work by examining how accurately repeat pregnancy can be predicted using a random forest machine learning technique that is comprehensive in capturing complex and nonlinear associations between the predictors and repeat pregnancy.

Understanding the predictors of repeat pregnancy could inform program providers or developers about areas that warrant more focus in programming for teen parents or help program providers identify mothers at higher risk of experiencing a repeat teen pregnancy so they could be the focus of for specific programming. In addition, this research could guide policymakers to direct programs that support pregnant and parenting teens to specifically address the factors that most strongly predict repeat pregnancy.

Social Ecological Theory

The social ecological model is a useful framework for examining repeat pregnancy because factors at different levels of teens’ social ecological environment can affect whether they experience a repeat pregnancy. The social ecological model outlines the different levels and types of influences on human behavior (Bronfenbrenner, 1977). Individual characteristics (such as background demographics or personality traits) influence outcomes, as do interpersonal factors (such as relationships with parents, peers, or romantic partners) and environmental factors (existing policies or neighborhood characteristics). Raneri and Wiemann (2007) used the social ecological model to examine the predictors of repeat pregnancy among teenage mothers. The authors found significant predictors at the individual, dyad (namely romantic partner relationships), and peer/community levels but not at the family or social system levels. Maravilla et al. (2017) used the social ecological model to examine the effects of 47 factors in a meta-analysis and found significant predictors at the individual, interpersonal, community, and family planning levels.

This study used a social ecological approach to examine possible predictors of teen pregnancy at four levels: individual, relationship (partner), family, and community or environmental (see Figure 1). Next, we summarize findings from existing literature across the four levels of predictors and describe how this study extends prior research about predictors at each level.

Individual Predictors

A teen’s own characteristics, attitudes, knowledge, intentions, and behavior can predict whether they have a repeat teen pregnancy. Contraceptive use, especially use of long-acting reversible contraceptives (LARCs), has been consistently related to lower levels of repeat pregnancy (Baldwin & Edelman, 2013; Damle et al., 2015; Isquick et al., 2017; Maravilla et al., 2017; Raneri & Wiemann, 2007; Tocce et al., 2012). Other individual variables

that have been related to repeat pregnancy include demographic characteristics like age and race/ethnicity, school performance, dropping out of high school, depressive symptoms, and delinquent or aggressive behavior (Barnet et al., 2008; Crittenden et al., 2009; Maravilla et al., 2017). Some other individual characteristics may be important predictors, but there has been only limited research on them. For instance, adverse childhood experiences (ACEs) may be important because youth who experience ACEs have high rates of risky sexual behavior and mental health issues during adolescence and adulthood (Felitti et al., 1998; Flaherty et al., 2013; Hughes et al., 2017).

Relationship Predictors

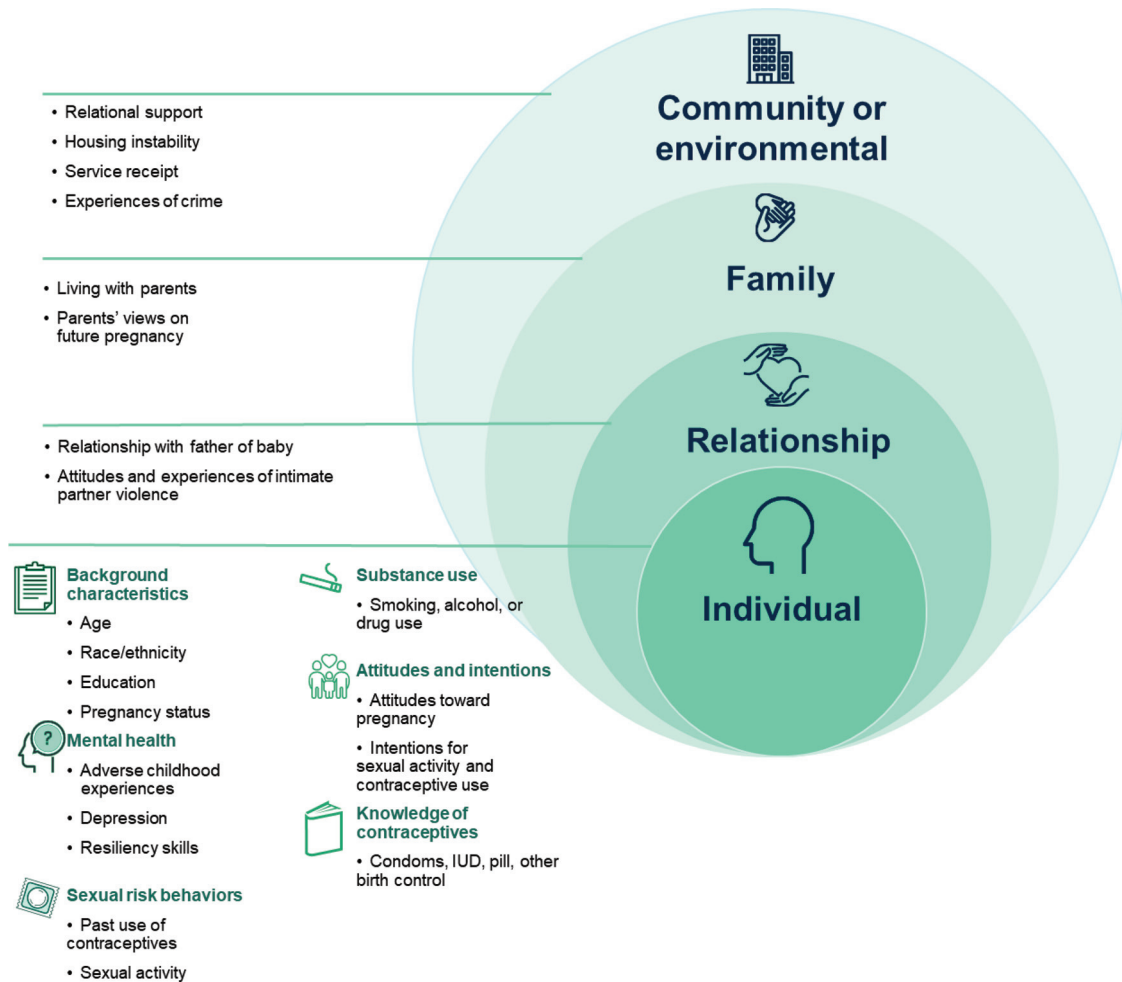
Teen mothers’ romantic relationships with the father of their child or a new partner can influence their likelihood of having a repeat pregnancy. Studies have found that characteristics of romantic relationships, as well as characteristics of the partner, can be important. Specifically, characteristics that have been related to repeat pregnancy are living with a partner, having more partner support in a relationship, and a gap of 3 or more years between the age of the teen mother and her partner (Maravilla et al., 2017; Raneri & Wiemann, 2007). Qualitative research with Hispanic/Latinx youth suggests that cultural ideas of machismo can result in men being dominant in relationships and make it harder for women to avoid pregnancy (Aparicio et al., 2016). Again, there has been limited research on some potentially important relationship factors such as IPV. Youth experiencing IPV may not have the ability to refuse sexual activity or require their partner to use contraceptives. Research has found that having been hit by a boyfriend or husband within 3 months of delivering a first child predicted a repeat pregnancy within 24 months (Raneri & Wiemann, 2007), but IPV has not been assessed often in analyses that include a wide range of other possible predictors.

Family Predictors

Factors related to teen mothers’ families, including teen mothers’ relationships with their own parents and their parents’ socioeconomic background, may also predict repeat pregnancy. However, a meta-analysis only found a few family predictors that were examined in more than one study, and none of those family predictors were significantly associated with repeat pregnancy (Maravilla et al., 2017). Single studies have found that having strong ties to parents (Reese & Halpern, 2017) and higher perceived parental monitoring (Crosby et al., 2002) were associated with reduced risk of repeat pregnancy among teen mothers, but these findings have not been consistently supported in other studies (Raneri & Wiemann, 2007). Other family factors, such as parents’ views on repeat pregnancies, have not been studied extensively in the literature yet, even though these may be important predictors of sexual activity (Dittus & Jaccard, 2000), particularly for Hispanic/Latinx teens (Bouris et al., 2012). For example, findings from a nationally representative survey of teens found that the majority of Hispanic/Latinx youths (55%) identified their parents as the greatest influence on their sexual decision-making, a proportion significantly greater than that reported by their White (42%) and African American (50%) peers (Albert, 2010).

Figure 1

Theoretical Model of Possible Predictors of Repeat Teen Pregnancy at the Individual, Relationship, Family, and Community or Environmental Levels, Using the Social Ecological Framework



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Community or Environmental Predictors

Teens' broader environment—such as their neighborhood or the policies or programs shaping their lives—can influence their sexual behavior outcomes. Overall, there has been limited research on the community or environmental predictors of repeat pregnancy, but some protective and risk factors have been identified. Religious involvement has been found to be a protective factor that is associated with lower rates of repeat pregnancy (Maravilla et al., 2017; Reese & Halpern, 2017). Conversely, having a high proportion of peers or friends who are teen parents was associated with increased rates of repeat pregnancy (Raneri & Wiemann, 2007). Some community factors, like having witnessed or been a victim of a crime, have not been studied in relation to repeat pregnancy, even though higher community arrest rates and increased neighborhood violence have been associated with increased rates of teen pregnancy or birth (Decker et al., 2018). In qualitative

research, young women also described how they see neighborhood violence as linked with sexual risk behaviors (Choby et al., 2012).

Approach and Significance for Field

This research addressed the following questions:

1. What individual, relationship, family, and community or environmental factors predict repeat teen pregnancy?
2. How accurately can we predict repeat teen pregnancy?

We examined multiple predictors at the individual, relationship, family, and community or environmental levels because factors at different levels of teens' social ecological environment may influence repeat pregnancy. We examined a broad range of predictors using logistic regression with backward

selection to identify key predictors of repeat teen pregnancy. Identifying key predictors could inform program providers about areas that warrant more focus in programming for teen parents. For example, finding that depression predicts repeat teen pregnancy would suggest that interventions could focus more on helping teen parents manage depression or on providing more mental health services.

We also assessed how well we can predict repeat teen pregnancy. Although a number of studies have identified significant predictors of repeat pregnancy, few of these examined how well the models predict repeat pregnancy. To determine how accurately we can predict repeat pregnancy, we (a) used a random forest machine learning technique that is comprehensive in capturing complex and nonlinear associations between the predictors and repeat pregnancy and (b) assessed the accuracy of the predictions. Accurately identifying the mothers at highest risk of repeat pregnancy could help program providers target services to the mothers who stand to gain the most.

We addressed both of these questions using a sample of primarily Hispanic/Latina pregnant and parenting teens. Hispanic/Latina mothers have some of the highest rates of teen births (Martin et al., 2019), which makes understanding the predictors of repeat pregnancy among this group particularly relevant for policy and practice.

Method

Data and Procedures

The analysis used existing data from the federal evaluation of California's Adolescent Family Life Program (AFLP) with Positive Youth Development (PYD), an enhanced case management program to support young parents operated by the state of California's Department of Public Health, Maternal, Child, and Adolescent Health division (Pressfield et al., 2020). Institutional review board approval for the study "Impacts of the Positive Youth Development Program for Expectant and Parenting Teens in California" was granted by the State of California Health and Human Services Agency Committee for the Protection of Human Subjects. This study's design was preregistered (ClinicalTrials.gov Identifier NCT04181034); however, the analyses addressed in this article are exploratory and were not registered. The data are not publicly available.

The AFLP-PYD study was a randomized controlled trial in which young mothers or sites enrolling young mothers were randomly assigned to receive either the AFLP-PYD program in the treatment group or standard AFLP in the control group. AFLP and AFLP-PYD did not have specific income requirements but primarily served low-income, high-need families (for more information on the evaluation design and results, see Zief et al., 2020). Both AFLP and AFLP-PYD provided case management services to teen mothers, although the AFLP-PYD program was more structured and had prescribed activities infused with principles of positive youth development. AFLP was intended to last 24 months, whereas AFLP-PYD was intended to last 12 months. The sample for the AFLP-PYD evaluation was recruited from 15 operating sites across California between December 2014 and January 2017. To be eligible for the evaluation, female youth between the

ages of 14 and 18 who were interested in participating had to be pregnant or parenting—with no limits on the age of the child for parenting participants—and speak English or Spanish. They also could not have received other similar services within the past 6 months or be enrolled in the Nurse Family Partnership home visiting program.

As part of the evaluation, participants completed three surveys: a baseline survey at the time of enrollment, a follow-up 12 months after enrollment, and another follow-up 24 months after enrollment. The baseline survey was administered as a computer-assisted telephone interview that could be completed on a study-provided cellular phone during the first visit with their case manager. If participants could not complete the survey during the first visit, they could complete it by phone after their first visit or mail in a hard-copy version within a month of enrollment. Ninety-eight percent of those who enrolled completed the baseline survey. The follow-up surveys were administered as either a web survey or computer-assisted telephone interview survey to ensure a high response rate. Participants had about 6 months to complete each follow-up survey. The 12-month response rates were similar for the AFLP-PYD and AFLP groups (88% and 87%, respectively). The 24-month follow-up response rate was 82% for both the AFLP-PYD and AFLP groups.

Sample

The overall sample size for the study was 1,330 pregnant or parenting teens, with 698 in the treatment group (which received the AFLP-PYD program) and 632 in the control group (which received the AFLP program). We included mothers from both groups to retain a larger sample because the AFLP-PYD treatment did not impact repeat pregnancy at either time point (Zief et al., 2020). The analytic sample includes mothers who had a baseline survey ($N = 1,300$) and had 12- or 24-month follow-up survey data on whether mothers experienced a repeat pregnancy ($N = 1,172$). The analysis included mothers who were younger than 21 at the 24-month follow-up because we were interested in repeat teen pregnancies ($N = 1,156$). A subset of mothers was excluded from the analysis because, due to wording of the question about repeat pregnancy on the 12-month follow-up survey instrument, it was unclear whether the repeat pregnancy occurred before or after program enrollment ($N = 9$). This left 1,145 mothers in the potential analytic sample. Of these mothers, 945 were included in the predictive models because they had all analytic variables.

Eighty-six percent of the participants in the analytic sample identified as Hispanic/Latina, and the rest identified as non-Hispanic Black, White, or another racial group. The mothers ranged in age from 14 to 18 at study enrollment, with an average age of 17. At the time of the baseline survey, 46% of the participants were pregnant with their first child, 3% were both currently pregnant and already parenting a child, and 51% were parenting but not currently pregnant. Nine in 10 pregnant participants (89%) were in their second or third trimester when they entered the program. Among participants who were already parenting, 94% had one child. Among those parenting, their youngest child ranged in age from newborn to 4 years, with an average age of 8 months.

Outcome Variable

The primary outcome in this analysis was having a repeat pregnancy within 24 months of study entry for mothers younger than age 21. Repeat pregnancies could have been reported at either the 12- or 24-month follow-up. On the 12-month follow-up survey, respondents were asked if they had been pregnant again, even if no baby was born, since the birth of the child they were either (a) pregnant with or (b) had most recently given birth to at the time of enrollment. On the 24-month follow-up survey, respondents were asked if they had been pregnant, even if no baby was born, since either (a) the last follow-up survey or (b) in the past 12 months, depending on whether they completed the 12-month follow-up survey or not. Because the amount of time that had elapsed from the previous birth could vary depending on whether the teen was pregnant or parenting at baseline, repeat pregnancies could have occurred from about 16 to 72 months after a mother's prior birth by the time of the 24-month follow-up. Because repeat pregnancies occurring within 24 months of an index birth put mothers and children at greatest risk of poor outcomes (Conde-Agudelo et al., 2006; Nerlander et al., 2015), sensitivity analyses examined rapid repeat pregnancies that occurred within 24 months of the prior birth.

Predictor Variables

We included a wide range of factors that could potentially predict repeat pregnancy from the baseline survey. We used predictors reported at baseline instead of using those reported at the first follow-up because some mothers had already had a repeat pregnancy at the time of the first follow-up, so predictors measured at the first follow-up may not have preceded the repeat pregnancy. Although using baseline predictors means the outcome is temporally distant, such predictors could be measured at the start of an intervention to help program staff understand which teens might be at the greatest risk of a repeat pregnancy.

Individual Predictors

To reflect the wide variety of possible predictors at the individual level, we examined different types of individual factors as potential predictors: background characteristics, mental health, sexual risk behaviors, substance use, attitudes and intentions, and knowledge of contraceptives (see Figure 1). Next, we describe the specific variables examined within these categories of predictors.

Background Characteristics. Background characteristics included study treatment group; age at baseline, a continuous variable in years; ethnicity, categorized as a binary indicator for Hispanic/Latina (any race); and a binary indicator of whether mothers were pregnant at baseline. Measures of educational attainment included a binary indicator for being enrolled in school if the mother reported being currently enrolled in any type of school, a GED program, or a post-high-school vocational program; a binary indicator for whether the mother reported having either a high school diploma or GED; and grades in school, an 8-point variable based on mothers' reports of their grades on their last report card, with responses ranging from mostly As to mostly lower than Ds, with a higher value indicating higher grades. Based on a response to a question about the highest level of education that the young mothers thought they would complete, we

created a binary indicator for expecting to complete college if they said they expected to complete a 2-year or community college degree, a 4-year college degree, or a master's degree, doctorate, or other advanced degree. We included binary indicators for whether mothers reported they ever repeated a grade or were ever suspended or expelled from school.

Mental Health. Resiliency skills (Cronbach's $\alpha = .62$) were measured using a scale developed by California's Department of Public Health, Maternal, Child, and Adolescent Health division. Scores were based on the average of seven 4-point Likert scale items (1 = *strongly disagree*; 4 = *strongly agree*) asking if the mothers are focusing on preventing negative things from happening in their life; if they set goals and think about what they need to do to reach them; if, when faced with a problem, they can usually find a solution; if they think going to college is important for getting a good job; if they are focused on achieving good and positive things in their life; if they have a plan for achieving their education and career goals; and if they do not usually plan too far ahead because things do not go as planned (reverse coded), with higher values indicating more resiliency skills. Whether mothers had experienced adverse childhood experiences from birth to age 13 was measured using eight binary indicators based on responses to an eight-variable series adapted from the 2011 National Survey of Children's Health (Centers for Disease Control & Prevention [CDC], 2012). Mothers were asked if someone in their family went hungry because they could not afford food; if a parent or guardian they lived with got divorced or separated, got in trouble with the law or went to jail, had a serious drinking or drug problem, or was mentally ill or suicidal; if they saw or heard their parents/guardians hit each other; if they had been in foster care; or if they were treated unfairly or judged based on their race or ethnic group. We also created a sum of the number of adverse childhood experiences reported. Maternal depression was measured using a binary indicator for whether the mother reported feeling sad or hopeless almost every day for 2 or more weeks in a row in the past 12 months (adapted from the CDC's Youth Risk Behavior Standard High School Survey; CDC, 2011).

Sexual Risk Behaviors. We included several predictors that involved risky sexual behaviors, including age at sexual initiation, a continuous variable in years; a binary indicator for ever having a sexually transmitted disease or infection if mothers reported ever being told by a doctor that they had chlamydia, gonorrhea, genital herpes, syphilis, HIV infection or AIDS, human papilloma virus, or trichinosis; a binary indicator for using birth control at sexual initiation if mothers reported using or having their first sexual partner use any form of birth control the first time they had sexual intercourse; number of unprotected sexual intercourse occasions, a continuous variable of the number of times they reported having sexual intercourse without using any form of birth control in the 3 months before they found out they were pregnant; and a binary indicator for whether they reported they had accessed birth control in the past 12 months.

Substance Use. Binary indicators for recent smoking, alcohol use, and drug use were based on individual survey items that asked the respondent how many days she had engaged in each activity in the past 30 days (adapted from measures on the CDC's Youth Risk Behavior Standard High School Survey; CDC, 2011). Mothers were coded as "yes" for each respective indicator if they reported smoking, having at least one drink of alcohol, or using marijuana or any other type of illegal drug on one or more days.

Attitudes and Intentions. Two dummy variables were used to measure intentions to have sex and use contraception: (a) Mothers who reported they did not plan to have sexual intercourse in the next 12 months and (b) mothers who reported they planned to have sexual intercourse and definitely or probably planned on using a LARC were compared separately to (c) mothers who reported they planned to have sexual intercourse but did not plan to use a LARC. Two dummy variables were used to measure mothers' attitudes about their current or most recent pregnancy: (a) Mothers who reported that they wanted to be pregnant sooner or at the time of the most recent pregnancy and (b) mothers who reported they were unsure about what they wanted were compared separately to (c) mothers who reported not wanting to be pregnant at the time of the most recent pregnancy. We included three dummy variables to measure attitudes toward future pregnancy based on a question asking how the mother would feel if she got pregnant again before turning 20. Mothers who reported they (a) did not know how they would feel were compared separately to three groups of mothers: mothers who said they would feel (b) happy, (c) upset, or (d) both happy and upset.

Knowledge of Contraceptives. We included four factors that reveal knowledge about contraceptives: knowledge of condoms, knowledge of birth control pills, knowledge of IUDs, and knowledge of other hormonal methods. These were developed based on a series of true/false items used in Power to Decide's Fog Zone Survey (Kaye et al., 2009). For example, to reflect knowledge about condoms, mothers were asked if it is okay to use the same condom; if condoms have an expiration date; if, when putting on a condom, it is important to leave space at the tip; if it is okay to use petroleum jelly or Vaseline as a lubricant when using latex condoms; if it is important for the man to pull out right after ejaculation; and if wearing two latex condoms will provide extra protection. All topic areas included five true/false items, with the exception of knowledge of condoms, which included six items. Each knowledge factor was scored as the average of all items a mother answered correctly in each topic area, with responses of "do not know" or "missing" coded as incorrect.

Relationship Predictors

At the relationship level, we included a binary indicator for whether mothers were in a relationship with the baby's father if the mother reported currently being married to, in a serious romantic relationship with, or in a casual romantic relationship with the baby's father. Whether mothers were accepting of IPV was measured based on mothers' average responses to two 4-point scale items (1 = *strongly disagree*; 4 = *strongly agree*), "There are times when hitting or pushing is okay in a relationship" and "People who make their partner jealous deserve to be hit or pushed," from a scale that was modified from the Acceptance of Couple Violence Questionnaire (Foshee et al., 1998). We included a binary indicator of whether the mother was ever fearful of IPV if the mother reported being fearful at least one time in her life that someone she was dating might physically hurt her.

Family Predictors

At the family level, we included binary indicators for having a mother figure if the mother reported that she has someone in her life right now who cares for her as a mother figure, and likewise

for having a father figure if she reported that someone in her life right now cares for her as a father figure. We then included binary indicators for whether the teen mother lives with her mother figure some or all of the time and whether the teen mother lives with her father figure some or all of the time. We included binary indicators for whether teen mothers reported their mother figure would disapprove if the teenager got pregnant again before age 20 and whether her father figure would disapprove if she got pregnant again before age 20.

Community or Environmental Predictors

Relational support was measured based on the average of three 4-point Likert scale variables (1 = *strongly disagree*; 4 = *strongly agree*) measuring the mother's relationship with a trusted adult: "There is an adult whom I can count on when things go wrong," "There is an adult who helps me make good decisions," and "There is an adult who encourages me to do my best." Higher scores indicate more relational support. Whether the mother moved at least once in the past 12 months was measured using a binary indicator. Mothers were asked how many times they had experienced crimes throughout their life (0 = *never*, 1 = *once*, 2 = *two or three times*, 3 = *four or more times*), including hearing gunshots, witnessing shooting, and being robbed or mugged. These were based on items adapted from National Survey of Children's Exposure to Violence (Finkelhor et al., 2009). Scores were based on averaged responses, with higher scores indicating more frequent experiences of crime. We also included measures of the services teen mothers received in the past 12 months; for youth to receive services, services must be available in their community, the teen must know about the services, and the teen must decide to take them up. Mothers were asked if they attended classes on contraception services, defined as individual or group classes or sessions on methods of birth control or where to get birth control. The average number of educational services was based on whether mothers reported receiving any of the following: GED preparation, programs to prepare for a high school diploma, standardized achievement test preparation, college preparation activities, help finding financial aid, or another education-related service.

Analytic Approach

Identifying Predictors of Repeat Teen Pregnancy

To address the first research question and identify significant predictors of repeat teen pregnancy within 24 months of study entry, we used logistic regression with backward-stepwise variable selection to identify variables that effectively predict repeat pregnancy. Logistic regression with backward-stepwise selection aims for a balance between model performance and model complexity by using an iterative process to remove redundant variables that do not contribute enough to improving the prediction of repeat pregnancy. We used the backward-stepwise variable selection so we could examine a broad set of theoretically important predictors and remove predictors that were uninformative or redundant.

Prior to conducting the logistic regression, we conducted a test for multicollinearity between predictor variables and examined the variance inflation factor. No variables had a variance inflation factor higher than 10, suggesting multicollinearity was not a substantial issue. We then predicted repeat teen pregnancy based on all 47 theoretically selected predictors and sequentially removed predictors that

had the least impact on model performance to identify all the factors that are strongly predictive of repeat pregnancy. The Akaike information criterion (AIC) was used to evaluate which predictors to include. The AIC score is a metric to evaluate the information loss by a given model. It considers the trade-off between the goodness of fit of the model and the simplicity of the model, with a lower AIC score indicating a better balance of the two. At each step, a variable is chosen to be removed if doing so minimizes the AIC score when comparing to the prior model. The process of backward-stepwise selection ends if dropping any variable will result in an increase in AIC.

To interpret the significant predictors of repeat pregnancy, we conducted another logistic regression with the predictors selected by the backward selection, as well as treatment status and preselected background characteristics as key control variables that have been related to repeat teen pregnancy, including age, whether the participant was pregnant (vs. parenting), and whether the participant was Hispanic/Latina (vs. any other race/ethnicity). We controlled for treatment status, even though treatment did not affect repeat pregnancy (Zief et al., 2020), to ensure that the experience of being in the intervention was controlled for. We present the amount of variance explained by the logistic regression model using McFadden's R^2 .

Evaluating the Accuracy of Predicting Repeat Teen Pregnancy

To address the second research question about assessing how accurately we can predict having a repeat teen pregnancy within 24 months of study entry, we compared the accuracy of two analytic approaches including all 47 predictors described earlier: (a) the logistic regression model and (b) a random forest model. Including more predictors yields more information to identify mothers who are likely to experience a repeat pregnancy. We used a random forest model in addition to the logistic regression to account for more complex and nonlinear associations between the predictors and the outcome. A random forest is a tree-based machine learning algorithm that first develops numerous decision trees (known as an ensemble), with each tree generated from a bootstrap sample (that is, a sample with replacement from the data set) of the data based on a random subset of the input variables to avoid overfitting the model (Breiman, 2001). The final prediction of the outcome for a given case is based on the majority "vote" among these decision trees. That is, a teen mother would be predicted to experience a repeat pregnancy if the majority of the decision trees predict a repeat pregnancy.

To compare how well we can predict repeat pregnancy using the logistic and random forest models, we used a randomly selected 80% of the sample for "training," that is, for developing the predictive model. Using the training sample, we determined the functional form as well as coefficients of each predictor for the

logistic regression model. Similarly, the specification of the random forest model was determined through the training sample. We then used the remaining 20% of the sample for "testing." This sample was held out to test the performance of the model because it had not been used to develop the predictive model, so it guards against overfitting the model to the data. Model performance was evaluated by applying the logistic regression and random forest models with all 47 variables developed in the training sample to the testing sample and assessing the "area under the curve," which is a typical measure used in predictive analytics that describes the probability that a mother with a repeat pregnancy is more likely than one without to have been predicted to have a repeat pregnancy by the model. If the model were guessing by chance, it would be equal to .5.

Sensitivity Analysis

We conducted the same set of analyses predicting rapid repeat pregnancies (repeat pregnancies occurring within 24 months of the prior birth) to assess whether predictors were more accurate when predicting births occurring within a shorter time frame. The sample for analysis was nearly identical, except that 12 participants did not fully complete the 24-month follow-up survey and so did not have a survey completion date to use to calculate the months between their index birth and the repeat pregnancy ($N = 933$). Analyses were also nearly identical, except that we did not include whether a mother was pregnant or parenting at baseline as a predictor because 96% of mothers with a rapid repeat pregnancy were pregnant at baseline.

Results

Descriptive Results

In the analytic sample, 12.6% of mothers had experienced a repeat pregnancy and 4.8% of mothers had experienced a rapid repeat pregnancy by the time of the 12-month survey (see Table 1). By the 24-month survey, cumulatively, 26.1% of mothers had experienced a repeat pregnancy (the primary outcome variable) and 11.9% of mothers had experienced a rapid repeat pregnancy (the outcome variable for the sensitivity analyses) during the study period.

Means and standard deviations for all predictors for mothers who did and did not have a rapid repeat pregnancy or any repeat pregnancy are shown in Table 2. At baseline, compared to mothers who did not have a repeat pregnancy, mothers who had any repeat pregnancy during the study period were significantly more likely to be older, to have experienced two adverse childhood experiences (had a parent or guardian with a serious drinking or drug

Table 1
Frequency of Repeat Pregnancy

Type of repeat pregnancy	Repeat pregnancy by 12-month survey <i>N</i> (%)	Repeat pregnancy by 24-month survey <i>N</i> (%)	No repeat pregnancy <i>N</i> (%)
Any repeat pregnancy	119 (12.6%)	249 (26.3%)	696 (73.7%)
Rapid repeat pregnancy	45 (4.8%)	111 (11.9%)	822 (88.1%)

Note. Repeat pregnancies by the 24-month survey include repeat pregnancies at 12 months.

Table 2*Baseline Descriptive Statistics for Teen Mothers Who Do and Do Not Have a Repeat Pregnancy*

Predictor	Rapid repeat pregnancy (N = 111)		No rapid repeat pregnancy (N = 822)		Sig. ^a	Any repeat pregnancy (N = 249)		No repeat pregnancy (N = 696)		Sig. ^a
	M or %	SD	M or %	SD		M or %	SD	M or %	SD	
Individual predictors										
Treatment	59%		53%			54%		53%		
Age in years	17.35	0.97	17.29	1.07		17.53	0.95	17.22	1.07	*
Hispanic/Latina	77%		88%		*	84%		87%		
Pregnant at baseline	96%		41%		*	43%		49%		
Enrolled in school	91%		88%			87%		89%		
Has high school diploma or GED	10%		10%			10%		9%		
Grades in school	5.20	1.77	5.43	1.77		5.40	1.81	5.42	1.75	
Expects to complete college	63%		62%			61%		62%		
Repeated a grade	10%		9%			10%		8%		
Was ever suspended or expelled	48%		39%			44%		38%		
Resiliency skills	3.25	0.29	3.28	0.31		3.25	0.30	3.29	0.31	
Went hungry because they could not afford food	15%		15%			18%		14%		
Parent or guardian got divorced or separated	52%		48%			52%		47%		
Parent or guardian got in trouble with the law or went to jail	33%		28%			28%		28%		
Parent or guardian had a serious drinking or drug problem	37%		21%		*	29%		20%		*
Parent or guardian was mentally ill or suicidal	21%		12%		*	17%		11%		*
Saw or heard parents/guardians hit each other	19%		15%			19%		14%		
Was in foster care	14%		9%			12%		9%		
Were treated unfairly or judged because of race or ethnic group	5%		7%			6%		7%		
Maternal depression	23%		16%			20%		15%		
Age at sexual initiation	14.74	1.37	14.84	1.24		14.80	1.31	14.84	1.24	
Had a sexually transmitted disease	13%		11%			14%		10%		
Used birth control at sexual initiation	68%		67%			63%		68%		
Number of unprotected sexual intercourse occasions in the three months before getting pregnant	8.65	14.40	5.09	10.88	*	6.94	12.74	4.95	10.78	
Accessed birth control in the past 12 months	31%		49%		*	47%		47%		
Smoked in past 30 days	1%		3%		*	4%		3%		
Used alcohol in past 30 days	2%		5%		*	5%		5%		
Used drugs in past 30 days	5%		4%			5%		4%		
Do not plan to have sexual intercourse in next 12 months	42%		42%			35%		44%		*
Plan to have sexual intercourse and use a LARC in next 12 months	29%		39%		*	35%		38%		
Wanted to be pregnant sooner at the time of the most recent pregnancy	13%		9%			12%		9%		
Unsure of when they wanted to be pregnant at the time of the most recent pregnancy	35%		37%			40%		36%		
Would be happy if pregnant again before turning 20	21%		17%			24%		15%		*
Would be upset if pregnant again before turning 20	8%		8%			7%		8%		
Would be both happy and upset if pregnant again before turning 20	14%		20%			17%		20%		
Knowledge of condoms	0.70	0.21	0.67	0.21		0.68	0.22	0.67	0.22	
Knowledge of birth control pills	0.56	0.28	0.53	0.28		0.55	0.28	0.53	0.28	
Knowledge of IUDs	0.43	0.30	0.44	0.28		0.46	0.28	0.43	0.28	
Knowledge of other hormonal methods	0.64	0.25	0.62	0.24		0.63	0.24	0.62	0.24	
Relationship predictors										
In a relationship with baby's father	68%		65%			65%		65%		
Accepting of IPV	1.35	.47	1.37	.48		1.36	0.47	1.37	0.48	
Ever fearful of IPV	11%		8%			10%		7%		
Family predictors										
Has mother figure	90%		96%			92%		96%		*
Has father figure	73%		73%			70%		73%		
Lives with mother figure	77%		83%			74%		85%		*
Lives with father figure	53%		51%			50%		51%		
Mother figure would disapprove of another pregnancy before age 20	24%		30%			27%		30%		
Father figure would disapprove of another pregnancy before age 20	27%		27%			26%		27%		
Community or environmental predictors										
Relational support	3.45	0.54	3.49	0.50		3.42	0.54	3.51	0.49	*
Moved in past 12 months	61%		54%			61%		53%		*
Number of times experienced crimes	1.41	.47	1.32	.47		1.39	0.51	1.31	0.46	*
Attended classes on contraception services	59%		65%			64%		65%		
Number of educational services received	1.09	1.37	1.03	1.35		0.94	1.21	1.06	1.39	

Note. LARC = long-acting reversible contraceptive; IUD = intrauterine device; IPV = intimate partner violence.

^a Significant differences were measured with a two-sided *t* test of means.

* $p < .05$.

Table 3
Odds Ratios for Baseline Predictors of Repeat Teen Pregnancy Selected by Backward Selection Logistic Regression

Predictor	Rapid repeat teen pregnancy				Any repeat teen pregnancy			
	OR	Lower CI	Upper CI	Sig.	OR	Lower CI	Upper CI	Sig.
Individual predictors								
Treatment ^a	1.48	1.01	2.16	*	1.19	0.90	1.57	
Age in years ^a	1.12	0.96	1.31		1.21	1.08	1.36	**
Hispanic/Latina ^a	0.58	0.37	0.93	*	0.78	0.53	1.15	
Pregnant at baseline ^b					0.80	0.60	1.06	
Was ever suspended or expelled					1.22	0.92	1.63	
Higher resiliency skills	0.65	0.38	1.12		0.52	0.35	0.78	**
Parent got in trouble with the law or went to jail					0.80	0.57	1.12	
Parent had a serious drinking or drug problem	1.84	1.21	2.78	**	1.60	1.12	2.28	*
Were treated unfairly or judged because of race or ethnic group	0.71	0.33	1.52					
Age at sexual initiation	0.95	0.81	1.11		0.90	0.79	1.01	
Accessed birth control in the past 12 months	0.44	0.30	0.66	***				
Unsure if they wanted to be pregnant for most recent pregnancy					1.16	0.87	1.54	
Would be happy if pregnant again before 20					1.35	0.95	1.93	
Would be both happy and upset if pregnant again before 20	0.69	0.41	1.17					
Do not plan to have sexual intercourse in next 12 months					0.63	0.44	0.91	*
Plan to have sex and use an LARC in next 12 months	0.53	0.35	0.81	**	0.53	0.37	0.77	**
Knowledge of IUDs	1.07	0.56	2.04					
Relationship predictors								
Acceptance of IPV	0.74	0.50	1.09					
Family predictors								
Has mother figure	0.36	0.18	0.69	**				
Lives with mother figure					0.62	0.44	0.87	**
Community or environmental predictors								
Number of times experienced crimes	1.34	0.93	1.94		1.19	0.89	1.60	

Note. The grey shaded cells were not selected for one of the models based on the AIC in the backward selection regression model. LARC = long-acting reversible contraceptive; IUD = intrauterine device; IPV = intimate partner violence; CI = confidence interval; OR = odds ratio; sig. = significance.

^a These control variables were included in analyses regardless of whether they were selected based on the AIC in the backward selection logistic regression models. ^b Being pregnant at baseline was not included as a predictor of rapid repeat pregnancy because nearly all mothers who had a rapid repeat pregnancy were pregnant at baseline.

* $p < .05$. ** $p < .01$. *** $p < .001$.

problem or who was mentally ill or suicidal), to have had more unprotected sexual intercourse occasions in the 3 months before getting pregnant, to plan to have sexual intercourse in the next 12 months, to report they would be happy if they got pregnant again before turning 20, to have moved in the past 12 months, and to have experienced crime more times. Mothers who had any repeat pregnancy during the study period were significantly less likely to have a mother figure, live with a mother figure, and have relational support than mothers who did not have a repeat pregnancy.

Significant Predictors of Repeat Teen Pregnancy

Based on the backward selection logistic regression model using the full data set, 11 predictors of having a repeat pregnancy within 24 months of study entry were identified as improving predictiveness and model fit (based on the AIC metric described in the “Method” section). These 11 predictors were included in the predictive model along with treatment, age, Hispanic/Latina ethnicity, and pregnancy status (see Table 3). Of these, having a parent with a serious drinking or drug problem when the mother was a child was associated with significantly greater odds of a repeat teen pregnancy ($OR = 1.60$).¹ Being older was also associated with significantly greater odds of a repeat teen pregnancy ($OR = 1.21$). Not planning to have sex in the next 12 months or planning to have sex and definitely or probably planning on using a LARC were both associated with lower odds of having a

repeat pregnancy ($OR = .63$ and $OR = .53$) compared to planning to have sex but not planning to use a LARC. Higher resiliency skills were associated with significantly lower odds of having a repeat pregnancy ($OR = .52$). Finally, living with a mother figure was associated with significantly lower odds of having a repeat pregnancy ($OR = .62$) compared to not having a mother figure or having a mother figure but not living with her. We used McFadden’s R^2 to examine the amount of variance in repeat teen pregnancy explained by the model. This value was equal to .05, indicating that these 11 predictors only explain 5% of the variance in repeat pregnancy.

Accuracy of Predicting Repeat Teen Pregnancy

In analyses testing the performance of models with all 47 theoretically selected predictors of repeat pregnancy in the testing data, both the logistic regression and random forest had low accuracy, as reflected by low area under the curve estimates, which describe the probability that a mother with a repeat pregnancy is more likely to be predicted to have a repeat pregnancy than a mother without a repeat pregnancy. For the logistic regression, this number was .60, and for the random forest model, this number was

¹ We conducted a sensitivity analysis using the sum of adverse childhood experiences instead of the binary indicators, and the sum of adverse childhood experiences was not selected as improving predictiveness and model fit.

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.63; if the model were guessing by chance, it would be equal to .50, so this is only a bit better than chance. Therefore, although the random forest model could include complex and nonlinear associations between the predictors and repeat pregnancy, this did not help improve the accuracy of predicting repeat pregnancy.

Sensitivity Analyses Predicting Rapid Repeat Pregnancy

Similar to the main results, some significant predictors of rapid repeat pregnancy were identified, but the ability to accurately predict rapid repeat pregnancy was limited. Eleven predictors were selected by the backward selection logistic regression model as improving predictiveness and model fit, and were included as predictors along with treatment, age, and Hispanic/Latina ethnicity. Some of the significant predictors of rapid repeat pregnancy were consistent with the predictors of any repeat pregnancy: Having a parent with a serious drinking or drug problem when the mother was a child was associated with significantly greater odds of a rapid repeat teen pregnancy ($OR = 1.84$), and planning to have sex and definitely or probably planning on using a LARC was associated with lower odds of having a rapid repeat pregnancy ($OR = .53$) compared to not planning to have sex or planning to have sex but not planning to use a LARC. Having a mother figure was associated with significantly lower odds of having a rapid repeat pregnancy ($OR = .36$) compared to not having a mother figure. There were also some unique predictors of rapid repeat pregnancy. Being in the treatment group was associated with greater odds of having a rapid repeat pregnancy ($OR = 1.48$).² Being Hispanic/Latina was associated with lower odds of having a rapid repeat pregnancy ($OR = .58$). Accessing birth control in the 12 months prior to the baseline was associated with lower odds of having a rapid repeat pregnancy ($OR = .44$).

However, consistent with the main results, the predictors of rapid repeat pregnancy that were identified as improving predictiveness and model fit in the backward selection regression model only explained 7% of the variance in whether mothers had a rapid repeat pregnancy. Similarly, in models with all predictors conducted in the testing data, both the logistic regression and random forest model had low accuracy as reflected by low area under the curve estimates. For the logistic regression, this number was .71, and for the random forest model, this number was .68.

Discussion

This study examined social ecological predictors of repeat pregnancy and how accurately repeat pregnancy could be predicted for a sample of predominantly Hispanic/Latina teen mothers, who have been found to be more likely to experience repeat pregnancy than other mothers (Patel et al., 1997; Pfitzner et al., 2003). Overall, across the 24-month study period, more than one quarter of teen mothers had a repeat pregnancy when they were younger than 21. From a set of 47 theoretically important predictors, some significant predictors of having a lower likelihood of repeat pregnancy were identified: not having a parent with a serious drinking or drug problem when the teen mother was a child (a measure of ACEs), being younger, living with a mother figure, intending to abstain from sex or use a LARC, and having greater resiliency skills. However, the accuracy of predicting repeat pregnancy was low, even when using all 47 predictors and random forest predictive analytic techniques.

We describe the implications of these findings. Some of the significant predictors of repeat pregnancy are not modifiable (such as experiences of ACEs and age), although these factors could possibly be used to modify program content, such as differentiating programming by age. Therefore, we focus on describing past research and potential implications related to the predictors of repeat pregnancy that are potentially modifiable through a program—including contraceptive intentions, resiliency skills, and living with a mother figure—although living with a mother is harder to influence. We then discuss the nonsignificant predictors and the challenge of accurately predicting repeat pregnancy for teen mothers. Finally, we describe the limitations of this research and next steps for research.

Potentially Modifiable Predictors of Repeat Pregnancy

Mothers who intended to abstain from sex in the next 12 months or who intended to use a LARC had lower odds of having a repeat pregnancy. A robust body of literature supports the association between contraceptive use and decreased likelihood of repeat pregnancy (Baldwin & Edelman, 2013; Damle et al., 2015; Isquick et al., 2017; Maravilla et al., 2017; Raneri & Wiemann, 2007; Tocce et al., 2012), but the current study shows that contraceptive intentions are associated with decreased likelihood of repeat pregnancy as well. The role of intentions as a determinant of repeat pregnancy is consistent with a larger body of public health and social science research revealing that intentions are robust correlates of future behavior (Bouris et al., 2012; Bui & Goodson, 2007; Webb & Sheeran, 2006). By focusing on mothers' intentions to use contraception, programs may be able to reduce repeat pregnancies and births. Indeed, a randomized controlled trial of an intervention that uses motivational interviewing to change contraceptive intentions and encourage the use of contraception found that the intervention substantially decreased repeat pregnancies and births among teen mothers (Stevens et al., 2017).

Mothers with greater resiliency skills also had a lower likelihood of a repeat pregnancy, which is consistent with resiliency frameworks that suggest that by building problem-solving and planning skills, young people can improve their social, academic, and health outcomes (Bernard, 2004). By helping youth build their problem-solving and planning skills, programs may be able to reduce the likelihood of repeat teen pregnancies, although causal research is needed to support this.

Finally, teen mothers who lived with a mother figure were less likely to have a repeat pregnancy than teen mothers who did not have a mother figure at all or who were not living with the mother figure they did have. This is consistent with past research that found having strong ties to parents (Reese & Halpern, 2017) and perceptions of higher levels of parental monitoring (Crosby et al., 2002) were associated with lower likelihood of repeat pregnancy. Interestingly, there were no associations between repeat pregnancy and living with a father figure. One study showed that living with a father figure decreased the likelihood of initial teen births (Dorsey, 2020); however, this study did not examine the relative influence of living with a mother or father figure. Support from mothers may be particularly protective. For example, having a higher-quality relationship with

² Finding that rapid repeat pregnancies are higher in the treatment group could be because more mothers in the AFLP-PYD group withdrew from programming than those in the AFLP group who also received case management programming (Zief et al., 2020).

mothers, but not fathers, was associated with teen girls' sexual behavior (Nogueira Avelar e Silva et al., 2016). Although family living situations may not be easily modifiable, programs for teen mothers that include a focus on parental support or that include teen mothers' parents could reduce the likelihood of repeat pregnancy (Reese & Halpin, 2017). Such programs could be particularly important for Hispanic/Latina teens, for whom familial influences on sexual behaviors are particularly strong (Bouris et al., 2012). Indeed, a randomized trial of a home visiting program that included a focus on helping teen mothers improve their relationship with their own mother did decrease repeat births (Black et al., 2006). More causal research is needed, but contraceptive intentions, resiliency skills, and support from a mother figure could be areas for programs to focus on as they work to reduce repeat pregnancies or births.

Challenges in Predicting Repeat Pregnancy

Many of the other predictors that were included based on theory were not significantly associated with the likelihood of teen mothers experiencing a repeat pregnancy. Although the social ecological model suggests that family, relationship, and community or environmental predictors contribute to teen mothers' likelihood of experiencing repeat pregnancy, most significant predictors were at the individual level. Only one family predictor (living with a mother figure) was significantly associated with decreased likelihood of having a repeat pregnancy, and no relationship or community or environmental predictors were significantly associated with repeat pregnancy. This is in contrast with other studies that have identified significant predictors at these levels (Raneri & Wiemann, 2007; Maravilla et al., 2017). As we will discuss more in the "Limitations" section, this could be due to the specific predictors included in the current study, the fact that predictors in this study were measured at baseline, or the unique sample of mothers included here.

Despite using random forest methods that allow for complex, nonlinear prediction of repeat pregnancy, the accuracy of predicting both any repeat pregnancy and rapid repeat pregnancy was low. Correlations between the theoretically selected predictors and repeat pregnancy were weak, indicating there was limited signal in the data (results available from the first author by request). Related research that used predictive analytics to predict unintended births (Kranker et al., 2020) found area under the curve statistics similar to those in the current study, suggesting that it could be difficult to predict these types of outcomes. Nonetheless, this study makes an important contribution because few prior studies have examined how accurately repeat pregnancy could be predicted based on the significant predictors identified. More research is needed to understand key predictors of repeat pregnancy because accurately identifying mothers at risk of repeat pregnancy could be useful for program practitioners who could then focus services on mothers most in need.

Limitations

Although this research adds to the current literature by exploring predictors of repeat pregnancy for a sample of predominantly Hispanic/Latina mothers, the current study has some limitations. First, some potentially important predictors were not measured, including socioeconomic status, relationship with a new partner

(Raneri & Wiemann, 2007), acculturation (Aparicio et al., 2016), and connection to religion (Reese & Halpern, 2017). Second, although many predictors were measured using multi-item scales, measures of some predictors were limited. For example, maternal depression was measured with a single item. Nonetheless, the models included a wide range of potential predictors, including some theoretically important predictors that have been understudied, such as ACEs. Third, predictors were measured at program enrollment, 12 or 24 months before repeat pregnancy was measured. Although, this ensured that predictors preceded the observed repeat pregnancies, past research has found that predictors with close temporality are more likely to impact repeat pregnancy (Raneri & Wiemann, 2007). Nonetheless, focusing on baseline predictors provides information about whether risk for repeat pregnancy could be identified at the start of an intervention. Fourth, the associations identified may not be causal. For example, this study shows that contraceptive intentions are associated with lower likelihood of repeat pregnancy, but it does not show that changing mothers' intentions around getting a LARC would cause fewer repeat pregnancies. In fact, mothers who are more motivated to avoid a repeat pregnancy may intend to get a LARC, suggesting the reverse causal direction. Fifth, although this study included a relatively large sample of teen mothers, a larger sample may be needed to ensure the primary benefits of the random forest model are realized, such as allowing for multiple interactions between variables. Sixth, this was not a representative sample of teen mothers in the United States; the program participants were in California and were primarily Hispanic/Latina. Nonetheless, it provides information about predictors of repeat pregnancy among Hispanic/Latina mothers who may be particularly likely to experience repeat pregnancies. More research is needed to predict repeat pregnancy more accurately among these mothers.

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Received May 22, 2021

Revision received February 22, 2022

Accepted April 11, 2022 ■