HHS Public Access

Author manuscript

Subst Use Misuse. Author manuscript; available in PMC 2015 October 22.

Published in final edited form as:

Subst Use Misuse. 2015 ; 50(10): 1261–1273. doi:10.3109/10826084.2014.998234.

Growth Models of Maternal Smoking Behavior: Individual and Contextual Factors

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Abstract

Background—Persistent maternal smoking during pregnancy, reduction or cessation during pregnancy, and smoking initiation or resumption postpartum impel further research to understand these behavioral patterns and opportunities for intervention.

Objectives—We investigated heterogeneous longitudinal patterns of smoking quantity to determine if these patterns vary across three maternal age groups, and whether the influence of individual and contextual risk factors varies by maternal age.

Methods—Separate general growth mixture models were estimated for mothers ages 15–25, 26–35, and 36+, allowing different empirical patterns of an ordinal measure of smoking behavior at six time points, from preconception through child entry to kindergarten.

Results—We identify five classes for mothers ages 15–25, four classes for ages 26–35, and three classes for ages 36+. Each age group presents classes of nonsmokers and persistent heavy smokers. Intermediate to these ends of the spectrum, each age group exhibited its own smoking classes characterized by the extent of pregnancy smoking reductions and postpartum behavior. In all three age groups, class membership can be distinguished by individual sociodemographic and behavioral characteristics. Co-resident smokers predicted nearly all smoking classifications across age groups, and selected neighborhood characteristics predicted classification of younger (15–25) and older (36+) mothers.

Conclusions—The design, timing, and delivery of smoking prevention and cessation services, for women seeking to become pregnant and for women presenting for prenatal or pediatric care, are best guided by individual characteristics, particularly maternal age, preconception alcohol consumption, and postpartum depression, but neighborhood characteristics merit further attention for mothers at different ages.

Introduction

Given the documented harmful effects of maternal smoking to women themselves (U.S. DHHS, 2001) and their children (U.S. DHHS, 2006), prenatal and postpartum smoking abstinence and cessation are important targets for women (e.g., Healthy People 2020). Although smoking rates decline from 22% in the first trimester to 14% by the second

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trimester of pregnancy, by the time the child is 18 months old maternal smoking rates (30%) rebound close to rates of their childless peers (33%) (Substance Abuse and Mental Health Services Administration, 2009). Further, while the smoking rate among all women of reproductive age (WRA) fell from 30.7% to 26.7% between 2002 and 2010, the rate among pregnant women failed to decline significantly (from 18.0% to 16.3%) over the same period (Substance Abuse and Mental Health Services Administration, 2011).

Recent studies have enhanced our understanding of longitudinal profiles of maternal smoking during and following pregnancy. Among British mothers in the early 1990s (with child surviving to one year of age), approximately 33% were smokers from 3 months prior to conception through 33 months postpartum (Munafo, Heron, & Araya, 2008). Nearly 18% of the sample persisted in smoking throughout the study period, and about 10% who smoked prior to conception quit at some point during pregnancy and then resumed smoking by 8 months post-delivery. Less than 4% quit during pregnancy and stayed quit through the study period. Mothers of a 2001 U.S. birth cohort showed similar patterns, although the initial smoking rate was slightly lower (23%), and 5% of the sample *initiated* smoking following the pregnancy (Mumford, Hair, Yu, & Liu, 2013). While efforts to effect behavioral change are often concentrated during pregnancy when smoking cessation interventions are moderately successful (Lumley et al., 2009), the rate of relapse post-delivery requires further investigation to inform effective design and targeting of ongoing prevention and cessation efforts (Colman & Joyce, 2003; Phillips et al., 2010).

Overall, consistent with life course theory (Elder, 1998) as well as empirical evidence for maternal alcohol consumption (Jagodzinski & Fleming, 2007; Meschke, Holl, & Messelt, 2013), the literature indicates that maternal age is correlated with different patterns of adult mothers' perinatal smoking. Younger pregnant women and recent mothers exhibit more instability of smoking behavior (characterized by quitting and relapsing) than older mothers. Younger mothers are more likely to smoke before (Tong et al., 2011) and during pregnancy (Crozier et al., 2009; Lu, Tong, & Oldenburg, 2001; Pevalin, Wade, Brannigan, & Sauve, 2001; Substance Abuse and Mental Health Services Administration, 2007), and are more likely to smoke a greater amount than older mothers (Martin et al., 2002). Further, mothers ages 20–29 are more likely to quit during pregnancy than mothers ages 30 and older (Colman & Joyce, 2003; Kahn, Certain, & Whitaker, 2002), and postpartum resumption of smoking behavior is more likely for mothers ages 20–24 (Tong et al., 2009). Current smoking among recent mothers ages 18–25 exceeds that of recent mothers ages 26–44 (Substance Abuse and Mental Health Services Administration, 2007). Despite this evidence, there has been no research investigating differences in developmental patterns of maternal smoking by age group, nor regarding how relevant personal and contextual characteristics associated with mothers' smoking behavior may differ between maternal age groups. These are gaps that are critical to designing effective smoking prevention and cessation services.

In addition to targeting maternal age groups, prevention and cessation efforts benefit from identifying malleable risk factors. Maternal behaviors that predict perinatal smoking include limited or no breastfeeding (Hauge, Torgersen, & Vollrath, 2012; Kendzor et al., 2010; L. T. Martin et al., 2008; Page, Padilla, & Hamilton, 2012) and alcohol consumption (Holtrop et al., 2010; Martin et al., 2008). Maternal depression predicts smoking during pregnancy

(Hauge et al., 2012; Linares Scott, Heil, Higgins, Badger, & Bernstein, 2009) and postpartum (Munafo et al., 2008). While some research has found current maternal employment to be a protective characteristic (Havens, Simmons, Shannon, & Hansen, 2009), other studies found no association with smoking during pregnancy (Gilman, Breslau, Subramanian, Hitsman, & Koenen, 2008). Additional correlates (documented in a multitude of studies) before, during and/or after pregnancy include education, income, marital status, and race/ethnicity (Holtrop et al., 2010; Lu et al., 2001; Page et al., 2012).

While the accepted wisdom is that individual characteristics are key proximal determinants of health essential to ecological models, contextual characteristics likely play some role (Macintyre, Ellaway, & Cummins, 2002; Pickett & Pearl, 2001). Glass and McAtee (2006) characterize the development of health actions or behaviors over the stream of time — potentially marked and influenced by turning points such as pregnancy and the transition to parenthood (Rutter, 1996) as well as individual age (Pickett & Pearl, 2001) — with social structures influencing the quality, direction, and intensity of health behaviors. Stressful economic conditions such as individual and area unemployment and poverty are fundamental mechanisms by which neighborhood contexts may influence smoking behavior (Kendzor et al., 2012; Lantz & Pritchard, 2010; Nkansah-Amankra, 2010; Schempf, Strobino, & O'Campo, 2009). Although maternal smoking during pregnancy moderates the effect of neighborhood variables on child outcomes (Nkansah-Amankra, 2010; Rich-Edwards, Buka, Brennan, & Earls, 2003), few neighborhood studies of pregnant women are designed to focus on maternal smoking behavior as a risk factor in their own health profiles. Embedded within the broader community context, household context is known to shape individual smoking profiles (Gage, Everett, & Bullock, 2007). Smoking by a partner or other household members (Gage et al., 2007; Kahn et al., 2002; Martin et al., 2008; Page et al., 2012; Park, Tudiver, Schultz, & Campbell, 2004) has consistently been shown to increase the likelihood of smoking during pregnancy.

While the above cited body of literature is informative, there remain crucial research gaps. First, studies of maternal smoking behavior usually focus on smoking during pregnancy, with a few studies including the postpartum period immediately after the delivery of the child. Despite the secondhand smoke risks for children (Datta et al., 2006; DiFranza, Masaquel, Barrett, Colosia, & Mahadevia, 2012), only a few studies extend examination of maternal smoking into the early parenting years (Kahn et al., 2002; Mumford et al., 2013; Munafo et al., 2008). Further, past studies have tended to examine all adult mothers as a group (Holtrop et al., 2010; Mumford et al., 2013) and/or included age as a covariate (e.g., Maxson, Edwards, Ingram, & Miranda, 2012; Page et al., 2012), limiting the ability to detect important differences in the developmental patterns of maternal smoking as well as risk factors of perinatal smoking by maternal age. Additionally, no studies to our knowledge have examined the ecological context of mothers' longitudinal smoking behavior. Moreover, only a handful of studies examine *quantity smoked* during pregnancy (Kandel, Griesler, & Schaffran, 2009; Pickett, Wakschlag, Dai, & Leventhal, 2003; Pickett, Wakschlag, Rathouz, Leventhal, & Abrams, 2002; Schempf et al., 2009; Troe et al., 2008), none of which examined preconception or postpartum smoking behavior. Studies that have included postpartum smoking did not examine patterns of quantity smoked (Colman & Joyce, 2003;

Fingerhut, Kleinman, & Kendrick, 1990; Kahn et al., 2002; Mumford et al., 2013; Munafo et al., 2008). Finally, most studies use a convenience sample, limiting the generalizability of study results.

In an attempt to address these gaps, the purpose of the current study is to provide a broader picture of women's longitudinal smoking patterns (taking into account quantity smoked), and the individual and contextual correlates thereof, from preconception through entry of the child to kindergarten separately for three groups of mothers who gave birth at different ages, with the benefit of a large nationally representative study sample. The separation of maternal age groups not only allows us to study how patterns of maternal smoking differ, but also facilitates detection of how individual and neighborhood characteristics differentially distinguish longitudinal maternal smoking patterns across age groups.

Methods

Data and Sample

The study sample comes from the Early Childhood Longitudinal Study (ECLS-B), nationally representative of the 2001 U.S. birth cohort. Data on 10,700 children and their parents were collected when the child was approximately 9 months old (baseline) and follow-up surveys were conducted at 2 years (2003–04), 4 years (2005–06, preschool sample), and 5 or 6 years of age (2006–07, samples allowing for staggered entry into kindergarten). At baseline, respondents were queried about their behavior in the three months prior to conception and during the third trimester of pregnancy. A sample of 9,150 cases (counts rounded to the nearest 50 in compliance with the ECLS-B confidentiality rules per National Center for Education Statistics, accessed June 8, 2012) were selected based on the following criteria. First, to collect pre-childbirth smoking behavior, only biological mothers were included. Second, the respondent had a valid measure on at least one of the six smoking measures. Third, the respondent had valid measures on all the covariates included in the analysis. We grouped respondents by baseline maternal age as follows: ages 15 to 25, 26 to 35, and age 36 or older. This categorization was motivated by theoretical reasoning, closely matches the typical categorization used in past empirical studies on maternal perinatal substance use (Meschke et al., 2013; Turney, 2012), and considered the empirical distribution of the sample. An attrition analysis conducted separately for each age group revealed no substantial differences between selected and unselected subjects on self-reported smoking behavior or covariates included in the analysis (detailed results available upon request).

Outcome variables: Longitudinal measures of maternal smoking

Those respondents who reported having ever smoked 100 cigarettes at the baseline interview were asked about average daily quantity smoked in terms of cigarettes per day (CPD) for the six time periods of the study. For the preconception and third trimester retrospective measures, respondents were prompted to think about the specified three-month periods. Post-delivery of the child, smoking measures are current reports of 'how many cigarettes or packs per day' the respondent reports smoking. To manage the low response frequency of higher smoking quantities likely to pose problems for model estimation (e.g. over 90% of

women in the youngest age group smoked zero or only one CPD during pregnancy, and this percentage is larger for the two older age groups) while still maintaining an ordinal scale, a four-level categorical ordinal variable was created for each of the six time points: never smokers (0); very light smokers (Husten, 2009) who smoked ≤5 CPD (1); smokers of 6–10 CPD (2); and smokers of >10 CPD (3).

Individual-level covariates

Mother's *race* was coded as white (0); black (1); Hispanic (2); Asian-American or other (3) (Ebrahim & Gfroerer, 2003; Yang, Shoff, Noah, Black, & Sparks). Mother's *household income* was coded as <100% of the federal poverty threshold (0); 100–130% of the federal poverty threshold (1); 130–185% of the threshold (2); and greater than 185% of the federal poverty threshold (3), reflecting common federal aid eligibility requirements and prior maternal smoking research (Mumford et al., 2013). Mother's *education* at baseline was coded as less than a high school diploma (0); high school graduate (1); or some college (2); with a college or graduate degree (3) (Kandel et al., 2009; Patterson, Seravalli, Hanlon, & Nelson, 2012). Mother's *marital status* at baseline was coded as married or living together (1) or other relationship status (0) (Carmichael & Ahluwalia, 2000). We distinguished past year *employment status* as not employed (0) compared to part-time (1) and full-time (2) schedules (Cooklin, Donath, & Amir, 2008). Maternal *postpartum depression* at baseline is measured by a modified 12-item version of the Center for Epidemiologic Studies Depression Scale (CES-D) (Radloff, 1977). Following Paulson et al. (2009), a binary depression indicator was coded "moderate to severe depression" (1) if a total score (the average of all responses for individuals who answered at least nine out of 12 items) was at least 10. Preconception *alcohol use* was coded as an indicator of consumption (1) or not (0) (Pevalin et al., 2001). A categorical variable distinguishes having *breastfed* the child for 6 months or less (1); >6 months (2); or not at all (0) (Ogbuanu, Glover, Probst, Liu, & Hussey, 2011).

Contextual covariates

We included an indicator for the presence of one or more additional household smokers (coded as 1) as identified by CDC's maternal health indicators for pregnancy (Prevention, 2011). Regarding community context, ECLS-B respondents are coded by zip code. To access summary Census measures (consistent with neighborhood research of birth outcomes (Messer et al., 2006)), we assigned a 2000 U.S. Census tract ID to each sample respondent. Using MapInfo Pro, we determined the geographic center of each ZIP code and applied a geographic merge of the ZIP code centroid and the 2000 Census Tract boundaries. Our primary focus was the economic conditions of the neighborhood, captured through Census tract-level measures of the percentage of (a) households reporting income below the federal poverty level; (b) residents age 25 or older reporting a high school education or less; and (c) unemployment among residents age 16 or older. As additional proxies of household economic constraints, we also include the percentage (e) of female-headed households and (f) reporting a residential move within the past year. These measures were dichotomized at the weighted median for each maternal age group. Individual and contextual sample characteristics are reported in Table 1.

Analytic strategy

We used general growth mixture modeling (GGMM) (Muthén, 2004) to empirically identify developmental trajectories of maternal cigarette smoking before, during and after pregnancy. GGMM uses a categorical latent class variable in combination with continuous growth factors to explore population heterogeneity in the change process of the outcome of interest, i.e., whether the study population consists of two or more discrete classes of individuals with varying growth trajectories (Muthén, 2004; Petras & Masyn, 2010). Analyses were conducted separately for each age group.

In order to determine the functional form for individual change in our ordered categorical smoking outcome (Masyn, Petras, & Liu, 2013), we first estimated a series of growth models with fixed or random intercept, linear and nonlinear slopes (Petras & Masyn, 2010). The origin of time was set at the baseline (i.e., 9 months after delivery) interview in order to accommodate inclusion of covariates measured at that time point. Thus, the methods support the association of baseline covariates with subsequent smoking measures (Biesanz, Deeb-Sossa, Papadakis, Bollen, & Curran, 2004). We compared these preliminary models for model fit, parsimony and interpretability, with final model selection based on theoretical reasoning as well as standard criteria recommended by Masyn et al. (2013) such as the Bayesian Information Criterion (BIC) (Schwarz, 1978) and the Lo-Mendell-Rubin (LMR) likelihood ratio chi-square test (Lo, Mendell, & Rubin, 2001). We found that a functional form with a random intercept and a random slope achieved optimal fit for all three age groups. Heterogeneity in the longitudinal development of maternal smoking was then explored by estimating models with increasing numbers of classes. Once the best fitting GGMM model was selected, we modeled the association of individual and contextual covariates with class membership, via categorical logistic regression (Long & Cheng, 2004).

We accounted for missing data on smoking measures over time through full information maximum likelihood (FIML) estimation (Arbuckle, 1996; Schafer & Graham, 2002). Among the approximately 9,050 mothers included in the final analysis, over 60% had valid information on all six smoking measures and 20% missed only one smoking measure. Complex sampling design was accounted for by computing robust standard errors using a sandwich estimator (White, 1980). Results were weighted to represent the 2001 birth cohort. Separate analyses for each age group were conducted using Mplus version 6.12 (Muthén & Muthén, 1998–2012).

Results

Patterns of smoking across three age groups

As shown in Table 2, older mothers were less likely to smoke than younger mothers across the study period. Mothers of all three age groups reduced smoking substantially during pregnancy, but relapsed to various degrees after child delivery. For mothers 15–25, the percentage of very light smokers (≤5 CPD) 5–6 years post-delivery is as high as their preconception rates, while the percentage smoking >5 CPD never fully rebounded postpartum. Likewise, the rates of mothers ages 26+ smoking >5 CPD also never fully returned to preconception rates. The rate of very light smoking among mothers ages 36+

fluctuated within a tight range over the full study period. For the most part, declines in the proportion of mothers smoking >10 CPD from preconception through the study period were greater than declines in the proportion of mothers smoking 6–10 CPD. For example, the proportion of mothers ages 26–35 reporting 6–10 CPD declined 15% between preconception and the child's entry to preschool, whereas the proportion of this age group reporting >10 CPD declined 32% over the same period, suggesting overall reductions in quantity smoked.

Profiles of smoking behavior for three age groups

Fit indices for models with different number of classes are presented in Table 3. The selection of the best solution is based on statistical criteria (e.g. the diminishing return of reduction in BIC with additional parameters) as well as substantive considerations. A 5-class solution was selected for age group 15–25 (LL=−10890.987 (31), BIC=22034.504); a 4-class solution was selected for age group 26–35 (LL=−7946.09 (25), BIC=16102.04); and a 3-class solution was selected for age group 36+ (LL=−1827.227 (19), BIC=3790.788). As shown in Figure 1, a "*nonsmoker*" class was identified for all three age groups, with different class proportions (ages 15–25: 56.7%; ages 26–35: 79.3%; ages 36+: 86.5%). In each age group, mothers with a significant likelihood of ongoing heavy smoking were classified as "*persistent heavy smokers*" (with a tendency for reduced smoking during pregnancy). Across age groups, about 70–80% of the members in the persistent heavy smoker class smoked >10 CPD and an additional 10–30% smoked between 6 and 10 CPD preconception and after delivery (lower percentages were observed during pregnancy).

Between nonsmokers and persistent heavy smokers, each age group exhibit related intermediate smoking patterns with slight variations characterized by the extent of their smoking reductions during pregnancy and the patterns followed postpartum. "*Moderate smokers*" (with a strong tendency to reduce smoking during pregnancy) constituted 15.7% of mothers ages 15–25 and 7.7% of mothers ages 26–35. Among mothers ages 36+, this class is termed "*moderate reducers*" (7.6%) to reflect a tendency for smoking reduction and cessation throughout the study period, following significant reductions during pregnancy. The postpartum pattern of moderate reducers (ages 36+) is mirrored by a class of "*temporary quitters*" (8.7%) among mothers ages 26–35, whose cessation during pregnancy is much more prominent. For the youngest age group exhibiting very little smoking during pregnancy, two opposing patterns are evident: "*delayed initiators*" (10.9%) who for the most part adopt smoking behavior after the child is born, and "*motherhood-inspired quitters*" (5.9%) who largely quit during pregnancy, may smoke lightly while the child is very young, but tend to have fully quit smoking by the time the child is entering preschool.

Covariate effects for three age groups

Table 4 presents the role of individual and neighborhood covariates associated with being assigned to the smoking classes versus the non-smokers class as the reference on an odds ratio scale. Among the individual sociodemographic characteristics, as expected, a college education, being married or cohabiting with a partner, and being non-White tends to be protective in terms of smoking classification. An indicator of adolescent mothers (ages 15–17) illustrates that this characteristic is protective for moderate smoking compared to nonsmoking (AOR=0.34), but does not distinguish the other smoking classes from

nonsmokers. Household income effects are apparent only for the youngest mothers, in the expected direction. And among these youngest mothers, part-time employment predicts moderate smoking behavior (AOR=1.48). Moderate/severe depression, by contrast, exhibited stronger effects for older mothers. Depression increases the odds of being classified as persistent heavy smokers for mothers ages 36+ and as moderate smokers for mothers ages 15–35, although the size of these effects varies. Being depressed at baseline for the two younger age groups increased the odds of being in the moderate smoker class by less than two-fold (age 15–25: AOR=1.48; age 26–35: AOR=1.94), while the strength of this association between depression and persistent heavy smoking is more than twice that for the oldest age group (AOR=4.5).

Behavioral covariate effects are consistently in the expected direction. Reported breastfeeding for more than six months was a significant protective characteristic for maternal smoking for all three age groups with various levels of strength. Likewise, preconception alcohol consumption was a consistent risk factor for maternal smoking in all age groups. However, while younger mothers were less likely to drink alcohol before pregnancy compared to older mothers (see Table 2), preconception drinking tended to have a stronger negative influence on their smoking behavior. Mothers ages 15–25 who drank before pregnancy were over five times as likely to be assigned to the persistent smokers class compared to those who did not (AOR=5.29). This association is weaker for mothers 26–35 (AOR=2.2) and non-significant for those who gave birth at age 36 or older.

The contextual predictors can be interpreted and compared across age groups in a similar pattern. For all three age groups, living with one or more other smokers in the home significantly increases the odds of being classified in any smoking class, except for the parenting-inspired quitters ages 15–25. The strength of the association varies across age groups, with effects generally larger for persistent smokers. Significant neighborhood-level covariates distinguish the youngest mothers and the oldest mothers, but not mothers ages 26–35. Mothers ages 15–25 living in neighborhoods with more unemployment were less likely to be heavy smokers (AOR=0.6). For mothers ages 36+, living in neighborhoods with more poverty and female-headed households were less likely to be moderate (AOR=0.2) or heavy smokers (AOR=0.42), respectively. By contrast for these older mothers, living in a neighborhood with a higher proportion of residents having at most a high school education increases the odds of being a persistent heavy smoker over nine-fold (AOR=9.05).

Discussion

Overall, the aggregate smoking rates among mothers of a national representative birth cohort show higher rates of smoking at younger ages over a 6-year span from preconception to child's kindergarten entry, consistent with preconception data from the Pregnancy Risk Assessment Monitoring System (Tong et al., 2011). Our analyses revealed different class structures across maternal age groups. Younger mothers are more likely to smoke before pregnancy and to return to preconception level after child delivery, as shown in other research (Crozier et al., 2009; Lu et al., 2001; Pevalin et al., 2001; Substance Abuse and Mental Health Services Administration, 2007; Tong et al., 2011). While population trends indicate declines in smoking among WRA over the past decade (Hayes, Fan, Smith, &

Bombard, 2011), tobacco marketing targeting different age groups may further impact age-specific trends (Tong et al., 2009).

The difference in class structures by maternal age groups is also reflected in the percentage of the sample assigned to each class across the three age groups. The probability of mothers ages 15–25 being classified in a smoking pattern was at least twice that of mothers ages 26 and older. In addition, two unique classes emerged for mothers ages 15–25: those who appeared inspired by pregnancy and parenting an infant to successfully stay quit as the child develops, and those who initiated smoking following childbirth. Nearly 11% of younger mothers who tended to be nonsmokers prior to the pregnancy adopted smoking behavior postpartum, a finding consistent with past studies of their peers (Webb, Culhane, Mathew, Bloch, & Goldenberg, 2011). This pattern has important implications for primary *prevention* services during pregnancy and early pediatric care contacts, as well as for extending the evaluation of smoking cessation interventions beyond pregnancy and the six-month postpartum period.

Second, our results indicate that in some instances individual predictors of heterogeneous patterns vary across maternal age groups. For example, we found that drinking alcohol before pregnancy has a stronger relationship with persistent smoking for younger mothers than for older mothers. While prior research has linked alcohol consumption with perinatal smoking (Holtrop et al., 2010; Martin et al., 2008), our finding of an age difference is consistent with general population data on the diminishing association between smoking and drinking with advancing age (Falk, Yi, & Hiller-Sturmhofel, 2006). Conversely, we found that the association between persistent smoking and postpartum depression became stronger as mothers age. A positive relationship between depression and smoking is consistent with past research (Hauge et al., 2012; Linares Scott et al., 2009; Munafo et al., 2008), but our study extends the literature by distinguishing the differential strength of association across age groups.

Third, we found that neighborhoods with low average educational attainment were associated with persistent smoking behavior before, during and after pregnancy for mothers ages 36 and older. This is consistent with the general finding that disadvantaged neighborhoods are associated with significantly greater probability of smoking in a middle-aged Australian population and reduced likelihood of smoking cessation over time (Turrell, Hewitt, & Miller, 2012). However, some neighborhood characteristics that might be considered to be disadvantageous had protective effects for smoking behavior among mothers ages 15–25 (neighborhoods with more unemployment) and mothers ages 36+ (neighborhoods with more poverty and female-headed households). It is important to note that these relationships hold while controlling for an array of individual covariates including personal SES as well as other neighborhood contextual variables. These results bear further investigation, principally in terms of personal economic constraints, as well as potentially different cultural norms within neighborhoods of these descriptions. For example, research has shown associations between neighborhood walkability and interpersonal civility (Messer, Vinikoor-Imler, & Laraia, 2012) as well as perceived safety (Patterson et al., 2012) with maternal smoking behaviors. Our results highlight the importance of avoiding

assumptions about the nature of perceived advantages and disadvantages in neighborhood research.

Limitations

Although the ECLS-B self-reported measures of smoking have no biological verification, reports of perinatal and maternal smoking behavior are highly correlated with smokers' urinary cotinine levels (Ashford et al., 2010; Patterson et al., 2012; Pickett, Kasza, Biesecker, Wright, & Wakschlag, 2009) as well as urinary cotinine measures from co-resident children (Ino, Ohtani, & Yoshimi, 2011). However, data for the preconception and pregnancy time points (collected at the baseline interview, or approximately 9 months post-childbirth) may be subject to recall bias. Our data did not support linkage to block-level Census data; however, the distinction of area measurement at the tract vs. block level did not impact the positive relationship between neighborhood and pregnancy smoking (Messer et al., 2012). Further research to distinguish the impact of block-level measurements is warranted.

Implications

The finding that maternal smoking behavior in the perinatal period varies with maternal age indicates that prevention and treatment efforts need to reflect the different life stages of mothers. Several additional implications can be drawn from this research. First, it is concerning that a sizable group of women smoke persistently (with a high likelihood of smoking 6–10 or >10 CPD) across the perinatal and early parenthood period, especially given the consistent dose-response relationship for both maternal and child health outcomes (Clifford, Lang, & Chen, 2012; U.S. DHHS, 2006) and the risks of even light smoking for numerous poor health outcomes (Schane, Ling, & Glantz, 2010). The individual and contextual variables found to predict class membership (with variation in significance and strength across age groups) inform the early identification of these women. Further, prevention and cessation for women seeking to get pregnant and those presenting for prenatal or pediatric care can be guided by these individual and contextual characteristics to inform the design, timing, and delivery. Of particular interest to these goals are preconception alcohol consumption and postpartum depression, which distinguish mothers' smoking behavior at different ages and serve both as identifying characteristics to target mothers at risk of persistent smoking and malleable characteristics for direct interventions. Although national rates of postpartum depression are similar for adult mothers across the reproductive age span (Vesga-Lopez et al., 2008), pregnancy rates have been increasing among older mothers (Ventura, Curtin, Abma, & Henshaw, 2012). Thus, cessation treatment for older mothers in particular may benefit from a comprehensive care approach involving mental health services for the benefit of both maternal and infant outcomes (Goler et al., 2012).

Second, it would be fruitful to identify and to develop effective prevention strategies for the group of young mothers (age 15–25) who initiated smoking after delivery. Multiple characteristics (race, marital status, income, preconception drinking, breastfeeding behavior, and co-resident smokers) distinguish delayed initiators from non-smokers. Young mothers who drank alcohol before pregnancy were three times as likely, and those who breastfed

their child longer than 6 months were half as likely, to follow the pattern of delayed initiation. In addition, whites were at a much higher risk to follow this pattern than nonwhites. Such information may help clinicians identify likely members of this class during gynecological or perinatal care visits. While the development of postpartum cessation services is important and encouraging (Winickoff et al., 2005; Winickoff et al., 2010), attention to postpartum prevention is also warranted.

Third, living with smoking household members consistently increased the likelihood of following a persistent smoking trend and leads to a higher risk of returning to smoking after delivery. The literature on interventions for partners of pregnant women, which include a broad array of designs, shows mixed results (Hemsing, Greaves, O'Leary, Chan, & Okoli, 2012). Refined approaches that access co-resident smokers' motivation to support their partner's and their own cessation efforts, in addition to extending the timeframe of efforts through early childhood parenting, may make greater headway (Duckworth & Chertok, 2012; Gage et al., 2007). Overall, while we found that individual characteristics are consistent correlates of maternal perinatal smoking behavior — suggesting the importance of continued public health efforts targeting individual behavior and clinical support tailored to the individual — household level and neighborhood level contextual effects merit more attention for distinct maternal age groups.

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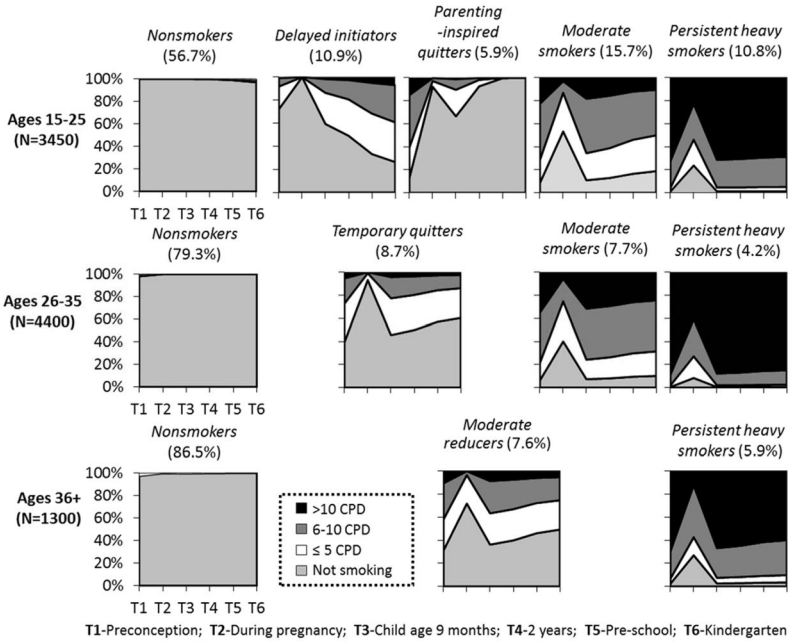

Figure 1.
Predictive smoking behavior conditional class solutions, by maternal age

Table 1

Weighted distribution of individual and contextual covariates, by maternal age Early Childhood Longitudinal Study-Birth Cohort (ECLS-B)

	Age 15–25 (N=3400)	Age 26–35 (N=4400)	Age 36+ (N=1300)	p-value
White	49.4%	64.1%	70.1%	<0.001
Black	20.3%	10.5%	9.8%	<0.001
Hispanic	25.4%	18.8%	14.7%	<0.001
Asian-American or other	4.9%	6.6%	5.3%	<0.001
Married or living together	65.3%	90.2%	92.6%	<0.001
Less than a high school diploma	33.0%	9.8%	6.3%	<0.001
High school gradute	38.9%	23.3%	17.3%	<0.001
Some college	24.2%	32.5%	26.7%	<0.001
Having a college degree or above	3.9%	34.4%	49.7%	<0.001
Not employed	52.9%	43.8%	43.1%	<0.001
Part-time employment	18.3%	21.6%	22.0%	<0.001
Full-time employment	28.8%	34.6%	34.9%	<0.001
Moderately/severely depressed	22.4%	13.6%	12.7%	<0.001
Houshold income <100% poverty line	38.2%	14.9%	10.7%	<0.001
Household income 100–130% poverty line	17.2%	8.8%	6.0%	<0.001
Household income 130–185% poverty line	15.9%	10.9%	8.1%	<0.001
Household income above 185% poverty line	28.8%	65.4%	75.3%	<0.001
Ever breast fed child	59.0%	74.0%	78.4%	<0.001
Drink alcohol before pregnancy	31.3%	42.0%	49.9%	<0.001
Other smokers in household	37.4%	19.2%	18.2%	<0.001
% below poverty in neighborhood	50.3%	50.0%	50.0%	<0.001
% high school or less in neighborhood	50.0%	49.9%	50.2%	<0.001
% moved within past year in neighborhood	50.0%	50.0%	50.0%	<0.001
% female headed households in neighborhood	49.8%	50.0%	49.9%	<0.001
% unemployed in neighborhood	50.0%	50.0%	50.2%	<0.001

Table 2

Weighted distribution of smoking behavior (6 time points), by maternal age Early Childhood Longitudinal Study-Birth Cohort (ECLS-B)

	Age 15–25 (N=3400)	Age 26–35 (N=4400)	Age 36+ (N=1300)	p-value
3 months before pregnancy				
Non-smoker	64.7%	81.2%	86.5%	<0.001
Smoking ≤ cigarettes per day (CPD)	8.5%	4.9%	3.6%	<0.001
Smoking 6–10 CPD	13.4%	6.0%	4.6%	<0.001
Smoking >10 CPD	13.4%	7.9%	5.3%	<0.001
Last 3 months of pregnancy				
Non-smoker	84.1%	91.0%	93.4%	<0.001
Smoking ≤5 CPD	8.0%	4.0%	2.8%	<0.001
Smoking 6–10 CPD	5.1%	2.9%	3.1%	<0.001
Smoking >10 CPD	2.9%	2.1%	0.7%	<0.001
9 months post-partum				
Non-smoker	70.7%	84.5%	89.2%	<0.001
Smoking ≤5 CPD	8.1%	4.7%	3.4%	<0.001
Smoking 6–10 CPD	11.6%	5.3%	3.2%	<0.001
Smoking >10 CPD	9.6%	5.5%	4.2%	<0.001
2 years post-partum				
Non-smoker	70.6%	85.1%	90.1%	<0.001
Smoking ≤5 CPD	8.2%	4.3%	2.4%	<0.001
Smoking 6–10 CPD	12.1%	5.0%	3.9%	<0.001
Smoking >10 CPD	9.1%	5.7%	3.6%	<0.001
Child in Preschool				
Non-smoker	70.1%	86.0%	90.2%	<0.001
Smoking ≤5 CPD	8.0%	3.5%	1.6%	<0.001
Smoking 6–10 CPD	11.9%	5.1%	3.7%	<0.001
Smoking >10 CPD	10.1%	5.4%	4.5%	<0.001
Child in Kindergarten				
Non-smoker	70.5%	88.3%	90.8%	<0.001
Smoking ≤5 CPD	8.7%	3.1%	3.0%	<0.001
Smoking 6–10 CPD	11.7%	3.5%	2.8%	<0.001
Smoking >10 CPD	9.2%	5.2%	3.4%	<0.001

Table 3

Determining the number of classes in GGMM, by maternal age

Model	Log Likelihood	# of free parameters	BIC[a]	VLMR-LRT[b] P-value
Ages 15–25, N=3450				
1-class	−15745.173	7	31547.369	N/A
2-class	−11713.949	13	23533.797	0.3333
3-class	−11164.301	19	22483.379	0
4-class	−10993.005	25	22189.663	0
5-class	−10890.987	31	22034.504	0.7602
6-class	−10817.664	37	21936.734	0.2398
Age 26–35, N=4400				
1-class	−13361.81	7	26782.39	N/A
2-class	−8603.746	13	17316.62	0
3-class	−8090.027	19	16339.55	0
4-class	−7946.09	25	16102.04	0
5-class	−7896.197	31	16052.62	0.2873
6-class	−7859.964	37	16030.52	0
Age 36+, N=1300				
1-class	−3088.367	7	6226.963	N/A
2-class	−1957.712	13	4008.705	0.0007
3-class	−1827.227	19	3790.788	0.6765
4-class	−1797.673	25	3774.734	0.1176
5-class	−1770.275	31	3762.99	0.7602
6-class	−1749.586	37	3764.664	0.0668

[a] Bayesian Information Criterion.

[b] Lo-Mendell-Rubin likelihood ratio chi-square test.

Table 4

Adjusted Odds Ratios of Maternal Smoking Class Membership for Individual and Contextual Covariates, ECLS-B

	Ages 15–25, N=3450				Ages 26–35, N=4400			Ages 36+, N=1300	
	Delayed initiators (10.9%)	*Parenting-inspired quitters* (5.9%)	*Moderate smokers* (15.7%)	*Persistent heavy smokers* (10.8%)	*Temp-orary quitters* (8.7%)	*Moderate smokers* (7.7%)	*Persistent heavy smokers* (10.8%)	*Moderate reducers* (7.6%)	*Persistent heavy smokers* (5.9%)
Age 15–17	–	–	0.34*	–	n/a	n/a	n/a	n/a	n/a
Some college	–	–	0.32**	0.28**	–	0.35*	0.27**	–	–
College or graduate degree	fixed	–	0.12**	Fixed	0.41**	0.12**	0.03**	–	–
Married or living together	0.62*	0.48*	–	0.54*	0.49*	0.28**	0.34*	–	0.00**
Part-time employed	–	–	1.58*	–	–	–	–	–	–
Full-time employed	–	–	–	–	–	–	–	–	–
Black	0.46*	–	0.22**	0.03**	–	0.30*	0.02**	–	–
Hispanic	0.23**	0.32**	0.12**	0.03**	–	0.05**	0.00**	–	0.01**
Asian or Other	–	–	–	0.37**	–	–	–	–	–
Depression	–	–	1.48*	–	–	1.94**	–	–	4.50*
Income 100–130% poverty	0.61*	–	–	–	–	–	–	–	–
Income 130–185% poverty	–	–	–	–	–	–	–	–	–
Income >185% poverty	–	–	–	0.43**	–	–	–	–	–
Breastfed child <6 months	–	–	–	–	–	–	0.46**	–	–
Breastfed child >6 months	0.42**	0.40*	0.27**	0.19**	–	0.33**	–	–	0.03**
Drinking before pregnancy	2.90**	4.00**	2.83**	5.29**	3.06**	1.93**	2.20**	2.80*	–
Others smoking in household	1.75*	–	4.55**	5.21**	5.13**	8.53**	9.10**	4.94**	583.47**
% below poverty	–	–	–	–	–	–	–	0.20*	–
% high school or less	–	–	–	–	–	–	–	9.05**	–
% moved in past year	–	–	–	–	–	–	–	–	–
% female headed households	–	–	–	–	–	–	–	–	0.42*
% unemployed	–	–	–	0.60*	–	–	–	–	–

Non-significant results not displayed.

* <0.05

** <0.01