ORIGINAL INVESTIGATION

Maternal Body Mass Index Moderates the Influence of Smoking Cessation on Breast Feeding

Drina Vurbic MA^{1,2}, Stephen T. Higgins PhD^{1,2}, Stephanie R. McDonough BA², Joan M. Skelly MS³, Ira M. Bernstein MD⁴

¹Department of Psychiatry, University of Vermont, Burlington, VT; ²Department of Psychology, University of Vermont, Burlington, VT; ³Department of Medical Biostatistics, University of Vermont, Burlington, VT; ⁴Department of Obstetrics, Gynecology, and Reproductive Sciences, University of Vermont, Burlington, VT

Corresponding Author: Stephen T. Higgins, PhD, Department of Psychiatry, University of Vermont, UHC Campus, Room 3100B Old Hall, 1 S. Prospect St, Burlington, VT 05401. Telephone: 802-656-9614; Fax: 802-656-9628; E-mail: stephen.higgins@uvm.edu

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ABSTRACT

Introduction: Smoking cessation is associated with greater breast feeding in newly postpartum women, while being overweight or obese is associated with lower rates of breast feeding. The purpose of this study is to examine whether the increases in breast feeding associated with smoking cessation are moderated by maternal body mass index (BMI). To our knowledge, the interaction of maternal smoking status and overweight/obesity on breast feeding has not been previously reported.

Methods: Participants ($N = 370$) were current or recent smokers at the start of prenatal care who participated in controlled trials on smoking cessation or relapse prevention during/after pregnancy. Study participants were followed from the start of prenatal care through 24 weeks postpartum. Smoking status was biochemically verified, and maternal reports of breast feeding were collected at 2-, 4-, 8-, 12-, and 24-week postpartum assessments.

Results: Women who reported postpartum smoking abstinence or had a normal/underweight prepregnancy BMI (<25) were more likely to be breast feeding at the time that smoking status was ascertained (odds ratio [OR] = 3.02, confidence interval [CI] = 2.09–4.36, and $OR = 2.07$, $CI = 1.37$ – 3.12 , respectively). However, smoking status and BMI interacted such that (a) normal/underweight women showed a stronger association between smoking abstinence and breast feeding ($OR = 4.58$, $CI = 2.73$ – 7.66) than overweight/obese women ($OR = 1.89$, $CI = 1.11$ – 3.23), and (b) abstainers showed an association between normal/underweight BMI and breast feeding ($OR = 3.53$, $CI = 1.96$ – 6.37), but smokers did not ($OR = 1.46$, $CI = 0.88$ – 2.44).

Conclusions: Overweight/obesity attenuates the positive relationship between smoking abstinence and greater breast feeding among newly postpartum women.

INTRODUCTION

A large number of epidemiological studies link breast feeding to numerous positive health outcomes for infants and mothers (see American Academy of Pediatrics [AAP], 2012; Ip et al., 2007). For instance, breast-fed infants have reduced risk and severity of several types of infections and illnesses, such as respiratory and urinary tract infections (Lopez-Alarcon, Villalpando, & Fajardo, 1997; Mårild, Hansson, Jodal, Odén, & Svedberg, 2004), childhood leukemia and lymphomas (Bener, Denic, & Galadari, 2001), and type-II diabetes (Owen, Martin, Whincup, Smith, & Cook, 2006). Mothers who breast feed have decreased risk for ovarian and breast cancers (Collaborative Group on Hormonal Factors in Breast Cancer, 2002; Rosenblatt & Thomas, 1993) and quicker return to prepregnancy body weight (Dewey, Heinig, & Nommsen, 1993). Driven by these findings, multiple public health organizations including the World Health Organization (WHO) and

AAP now recommend that women breast feed exclusively through 6 months postpartum, and great efforts are being made to increase breast-feeding rates globally (AAP, 2012; WHO, 2008).

Despite ongoing efforts to promote breast feeding in the United States, current breast-feeding rates still fall below established recommendations. The most recent national estimates of U.S. breast-feeding rates indicate that approximately 16.3% of infants are exclusively breast fed through the first 6 months of life, while a national rate of 25.5% is the goal of the Healthy People 2020 initiative (Centers for Disease Control and Prevention [CDC], 2013; U.S. Department of Health and Human Services, 2010). While there is considerable room for improvement generally, the risk for inadequate breast feeding is increased in certain groups of women. Women who smoke, for instance, are less likely to initiate breast feeding and wean earlier than nonsmoking women (Amir & Donath, 2002; Horta, Kramer, & Platt, 2001; Liu, Rosenberg, & Sandoval, 2006;

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Lopez, Gaalema, & Higgins, 2013). This relationship is dose dependent and thus particularly strong among heavier smokers (Liu et al., 2006).

The CDC recommends breast feeding even among smokers as the health benefits of breast feeding are generally thought to exceed the risks from nicotine exposure in breast milk (CDC, 2010). There is evidence that breast feeding may even provide children protection against some of the adverse health effects associated with maternal smoking (Batstra, Neeleman, & Hadders-Algra, 2003; Woodward, Douglas, Graham, & Miles, 1990). For example, Woodward and colleagues (1990) reported that the rate of acute respiratory illness among children with smoking mothers was lower for those who had been breast fed. Increasing breast-feeding rates in this population may thus be especially important. Recently, it has been reported that an intervention that used financial incentives to increase smoking cessation among pregnant and newly postpartum women also significantly increased breast-feeding rates (Higgins et al., 2010; see Higgins et al., 2012 for a review). In that study, women provided with monetary-based incentives for smoking abstinence were significantly less likely to be smoking and more likely to be breast feeding at 8 and 12 weeks postpartum compared with women assigned to a control condition. Those who successfully abstained from smoking also maintained higher breast-feeding rates through 24 weeks postpartum—12 weeks after the active treatment period had concluded. The findings are especially promising because the study population was comprised largely of women who were economically disadvantaged, which is another risk factor for inadequate breast feeding (Heck, Braveman, Cubbin, Chávez, & Kiely, 2006; Taylor, Risica, Geller, Kirtania, & Cabral, 2006; Thulier & Mercer, 2009). Moreover, they suggest that the benefits gained from quitting smoking were greater than any disadvantages that might have been expected from abstinence-related increases in weight gain (see Aubin, Farley, Lycett, Lahmek, & Aveyard, 2012). It may be important to note, however, that a previous investigation found no evidence of excessive weight gain in women receiving this treatment (Washio et al., 2011; see also Rode, Kjærgaard, Damm, Ottesen, & Hegaard, 2013).

In the last decade, excess weight has emerged as another important risk factor for low breast-feeding rates. Like smokers, women with excess prepregnancy or postpartum weight initiate breast feeding at lower rates and wean earlier than their normal weight counterparts (Donath & Amir, 2008; Li, Jewell, & Grummer-Strawn, 2003; Oddy et al., 2006; Wojcicki, 2011). Also similar to smoking, risks for overweight and obesity among U.S. women are associated with socioeconomic disadvantage, especially lower educational attainment (Ogden, Lamb, Carroll, & Flegal, 2010). To our knowledge, whether smoking and excess weight interact to increase risk for inadequate breast-feeding outcomes has not been reported. Previous studies have uncovered interactive effects of smoking and excess weight on cardiovascular risk (Akbaratabtoori, Lean, & Hankey, 2005) and overall mortality risk (Koster et al., 2008). We therefore sought to examine how these two characteristics interact on risk for inadequate breast feeding among a cohort of participants in controlled clinical trials on smoking cessation and relapse prevention in newly postpartum women. We hypothesized that excess weight (i.e., overweight and obesity) would reduce the beneficial effect of smoking cessation among abstainers and potentially add further detriment among smokers. Thus, we expected that breast feeding would be most

prevalent among normal or underweight abstainers and least prevalent among overweight or obese smokers.

METHODS

Participants

Participants ($N = 370$) were women who were current or recent smokers enrolled in controlled clinical trials investigating the effectiveness of monetary-based incentives to support smoking abstinence. Four of the trials examined the efficacy of incentives in promoting smoking cessation among women still smoking at the start of prenatal care ($N = 253$), while the remaining three trials examined relapse prevention among women who were smokers at conception but had quit smoking prior to initiating prenatal care ($N = 117$). All trials were conducted in a university-based outpatient research clinic and approved by the local institutional review board. Participants were recruited from local obstetric clinics and the Federal Special Supplemental Nutrition Program for Women, Infants and Children in Burlington, VT. To be eligible for inclusion, participants had to report currently smoking (cessation trials) or recently quitting smoking (relapse prevention trials) at the first prenatal care visit with consistent biochemical verification, reside within the county in which the clinic is located with no plans to leave the area for 6 months following delivery, and speak English. Exclusion criteria included incarceration, previous participation in a trial on incentives for smoking abstinence or living with a trial participant, current opioid substitution therapy, current use of psychotropic medications other than antidepressants, being greater than 25 weeks gestation, and living in a group residence (see Higgins et al., 2010, 2012 for more details).

During recruitment, women receiving prenatal care at participating clinics were given a brief questionnaire regarding basic sociodemographics and smoking status, including age, race, years of education, estimated gestational age, and smoking status. Those who endorsed smoking in the past 7 days (cessation trials) or who reported quitting smoking upon becoming pregnant (relapse prevention trials) were then invited to complete a detailed assessment evaluating inclusion and exclusion criteria and biochemical verification of smoking status. Eligible participants were later excluded if they failed to deliver a live infant ($N = 35$) or had missing body mass index (BMI) or breast-feeding data ($N = 57$).

Assessment of Smoking, Weight, and Breast-Feeding Status

At the trial intake assessment and all subsequent assessments, participants provided both breath and urine specimens for biochemical verification of smoking status via breath carbon monoxide and urine cotinine levels and completed questionnaires examining sociodemographics, smoking history and current smoking behavior, smoking environment, and motivation, confidence, and intentions to quit smoking. Appropriately modified versions of this battery were completed twice more before delivery (approximately one month following intake and again after 28 weeks gestation) and at five postpartum assessments (2, 4, 8, 12, and 24 weeks after delivery). At each postpartum assessment, women also answered a yes–no self-report item

asking whether they were breast feeding. This item did not ask about exclusive or other categories of breast feeding. For the statistical analyses, women were categorized into four subgroups at each postpartum assessment according to their smoking status (abstainers vs. smokers) and weight status (normal/underweight vs. overweight/obese). Smoking status was determined at each assessment by urine cotinine assay (abstainers ≤ 80 ng/ml; smokers > 80 ng/ml). Weight status was assessed once using prepregnancy BMI (kg/m^2) calculated from body weights and heights obtained from their medical records (normal/underweight < 25 ; overweight/obese ≥ 25). Prepregnancy BMI is a standard measure used to examine weight-related postpartum outcomes and has been reliably associated with inadequate breast feeding (Li et al, 2003; Oddy et al., 2006; Wojcicki, 2011).

Treatment

The main treatment conditions have been described previously (Higgins et al., 2012). Briefly, participants in the first three smoking cessation trials and the relapse prevention trials were assigned to an abstinence-contingent incentive or control condition. In the active treatment conditions, women earned vouchers exchangeable for retail items contingent on biochemically verified abstinence from recent smoking. In the control condition, women received vouchers of comparable monetary value but delivered independent of smoking status and in amounts designed to keep the total voucher values comparable across treatment conditions. The incentive program was in place from study initiation through 12 weeks postpartum in all but the most recent relapse prevention trial where duration was increased to 24 weeks in one experimental condition. In addition to the voucher-based incentives, participants in both treatment conditions received usual care for smoking cessation provided through their obstetric clinics, which typically involved discussion with their provider regarding the benefits of quitting smoking during pregnancy. Research staff did not attempt to monitor or influence those clinic practices or otherwise discuss breast feeding with participants.

Statistical Methods

Demographic and smoking characteristics of study participants were summarized using means and standard deviations for continuous variables and percentages for categorical variables. Distributions of these characteristics were compared between the dichotomized levels of prepregnancy BMI (normal/underweight and overweight/obese) using *t* tests for continuous variables and chi-square tests for categorical variables. The association between postpartum smoking status and prepregnancy BMI on breast-feeding status over five postpartum assessments was analyzed using repeated measures for categorical data based on generalized estimating equations utilizing a logistic link function (SAS PROC GENMOD). Initially, stepwise logistic regressions were conducted at each assessment with smoking status, dichotomized BMI, and the interaction forced into the model and baseline characteristics examined as potential predictors of breast-feeding status. Educational attainment and marital status were determined to be significant predictors of breast-feeding status and included as covariates in the repeated measures analysis noted above. Repeated measures analysis was also conducted including the

three-way interaction between smoking status, BMI, and time in order to obtain the estimated proportions of breast feeding at each assessment adjusted for the covariates. Reported statistical significance and odds ratios (ORs) are adjusted for educational attainment and marital status. Breast-feeding status was imputed for one or more assessments for 47 women for whom prior or subsequent data allowed for reasonable estimation. Only one woman out of 370 was observed to stop breast feeding and start at a later date; thus, women were assumed not to be breast feeding when missing assessments followed assessments where they reported discontinuing breast feeding. In instances where missing assessments were followed by a subsequent assessment where women reported breast feeding, they were assumed to be breast feeding at the earlier assessments. The number of data points imputed were 13/370 (3.5%) at 2 weeks, 6/370 (1.6%) at 4 weeks, 17/370 (4.6%) at 8 weeks, 14/370 (3.8%) at 12 weeks, and 20/370 (5.4%) at 24 weeks. All analyses were performed using SASv.9 statistical software (SAS Institute, Cary, NC). Statistical significance was determined based on $\alpha = 0.05$.

RESULTS

Participant Characteristics

Participants were largely socioeconomically disadvantaged Caucasian women with a high school diploma or lower educational level (Table 1). A majority of women were unmarried and lacked private insurance. Smoking onset occurred at approximately 15 years of age, and prepregnancy smoking rate was just under one pack per day. Slightly more than half of the sample (56.5%) was classified as normal/underweight based on prepregnancy BMI ($M = 21.22$, $SD = 2.15$; overweight/obese $M = 32.33$, $SD = 5.33$). There were no significant differences between BMI categories in other characteristics assessed at baseline. The number of participants per subgroup at each postpartum assessment are shown in Table 2.

Worth noting is that we compared baseline characteristics among the 370 women included in the study to the 57 women who were excluded due to missing data. The only significant difference was mean gestational age at study, which was lower among those included compared with those excluded (10.3 vs. 12.3 weeks, $p = .01$). We know of no rationale why that difference would introduce bias into the relationships described below.

Relationships Between Breast-Feeding Status, Smoking Status, BMI, and Time

Odds ratios (ORs) and 95% confidence intervals (CI) for the relationships between breast-feeding status, smoking status, and BMI are shown in Table 3. Breast-feeding status varied significantly by smoking status and BMI (Figure 1A and 1B, respectively). Smokers were significantly less likely to breast feed than abstainers ($\chi^2(1) = 34.87$, $p < .001$), and overweight/obese women were significantly less likely to breast feed than normal/underweight women ($\chi^2(1) = 11.94$, $p < .001$).

There was a significant interaction between smoking status and BMI ($\chi^2(1) = 5.48$, $p = .02$). The source of this interaction is evident in Figure 2A, which shows the proportions of breast feeding among the four smoking status $\times$ BMI subgroups.

Maternal BMI moderates the influence of smoking cessation on breast feeding

Table 1. Participant Baseline Characteristics

	Overall	Overweight/obese (N = 161)	Normal/underweight (N = 209)	p value
Demographics				
Age (years)	24.6 (5.2)	25.1 (5.2)	24.2 (5.3)	.13
% Caucasian	95	97	94	.16
Education				.89
% > 12 years of education	30	30	30	
% = 12 years of education	47	48	46	
% < 12 years of education	23	22	24	
Weeks pregnant at baseline	10.3 (4.6)	10.5 (5.4)	10.1 (4.0)	.46
% First pregnancy	61	59	63	.44
% Married	26	27	25	.59
% With private insurance	31	32	30	.68
% Working outside of home	57	57	56	.89
Smoking characteristics				
Age first started smoking	15.2 (3.1)	15.2 (3.3)	15.3 (2.9)	.93
Cigarettes per day pre-pregnancy	16.6 (9.5)	17.1 (10.0)	16.2 (9.1)	.37
% Living with another smoker	75	75	74	.83
% With no smoking allowed in home	55	52	58	.27
% With none or few friends or family who smoke	29	25	32	.15
% Attempted to quit pre-pregnancy	70	70	71	.72
Number of quit attempts during pregnancy	1.0 (1.9)	0.9 (1.5)	1.1 (2.2)	.20
Nicotine withdrawal questionnaire total score	1.5 (0.8)	1.5 (0.8)	1.5 (0.8)	.80
Psychiatric symptoms				
Stress rating	5.3 (2.6)	5.4 (2.6)	5.3 (2.5)	.71
Beck Depression Inventory	10.1 (6.8)	10.4 (6.8)	10.0 (6.8)	.60
% History of depressive symptoms	35	35	34	.85

Note. Values represent means (SD) unless otherwise indicated. *p* values correspond to *t* tests for comparisons of means and chi-square tests for comparisons of proportions (percents).

Table 2. Participants per Subgroup

Postpartum assessment	Abstainers		Smokers	
	Normal/underweight	Overweight/obese	Normal/underweight	Overweight/obese
2 weeks	96	81	100	75
4 weeks	91	76	110	81
8 weeks	77	65	124	93
12 weeks	71	53	132	105
24 weeks	51	47	148	109

Two aspects of the interaction are notable. First, the difference in breast-feeding rates by BMI category is significant among women who abstained from smoking ($\chi^2(1) = 17.59$, $p < .001$), but not among smokers ($\chi^2(1) = 2.10$, $p = .15$). Second, although breast feeding was more prevalent among abstainers compared to smokers in both BMI categories, the difference was greater among normal/underweight women ($\chi^2(1) = 33.49$, $p < .001$) than overweight/obese women ($\chi^2(1) = 5.52$, $p < .05$). Accordingly, the normal/underweight women who abstained from smoking had the highest probability of breast feeding (Figure 2A, left), whereas overweight/obese smokers had the lowest (Figure 2A, right). These same relationships were noted independent of whether analyses were conducted with or without imputed values for incomplete breast-feeding datasets. When the imputed datapoints were excluded, there were again significant main effects of smoking status ($\chi^2(1) = 35.24$, $p < .001$), and BMI ($\chi^2(1) = 11.52$, $p < .001$), and a significant interaction between them, ($\chi^2(1) = 5.77$, $p = .02$).

These relationships between smoking status, BMI, and breast feeding did not interact with whether women had participated in our relapse prevention trials conducted with women who had already quit smoking prior to entering prenatal care or cessation trials conducted with those who were still smoking at the start of prenatal care (not shown). Smokers were significantly less likely to breast feed than abstainers ($\chi^2(1) = 31.13$, $p < .001$) with no significant interaction with trial type ($\chi^2(1) = 1.90$, $p = .17$) and overweight/obese women were significantly less likely to breast feed than normal/underweight women ($\chi^2(1) = 7.06$, $p = .008$) with no significant interaction with trial type ($\chi^2(1) = 0.04$, $p = .84$).

As expected, there were robust decreases in breast-feeding rates across time ($\chi^2(4) = 154.97$, $p < .0001$), with no significant interactions of time and smoking status or BMI. That is, breast-feeding probabilities declined as an orderly function of time across the 24-week postpartum period, with the influence of smoking status and BMI remaining evident throughout (Figure 2B).

DISCUSSION

The purpose of this study was to explore the interactive effects of smoking and maternal overweight/obesity, which have previously been identified as important independent risk factors for inadequate breast feeding. The results provide evidence that smoking and excess weight have interactive effects that may present unique challenges in efforts to

raise breast-feeding rates, particularly in populations where both risk factors are highly prevalent. For example, smoking and overweight/obesity are overrepresented and the prevalence of adequate breast feeding is underrepresented among economically disadvantaged women (Chilcoat, 2009; Heck et al., 2006; Taylor et al., 2006; Thulier & Mercer, 2009; Wadden, Brownell, & Foster, 2002). The need to decrease smoking in this population to raise breast-feeding levels has

Table 3. Relationship Between Smoking Status, Body Mass Index (BMI), and Breast Feeding

Predictor variable	OR	95% CI	p value
Main effects model ^a			
Smoking status			
Smoker	ref		
Abstainer	3.02	2.09–4.36	<.001
Prepregnancy BMI			
Overweight/obese	ref		
Normal/underweight	2.07	1.37–3.12	<.001
Interaction model ^a			
Simple effects of smoking status			
Overweight/obese			
Smoker	ref		
Abstainer	1.89	1.11–3.23	.02
Normal/underweight			
Smoker	ref		
Abstainer	4.58	2.73–7.66	<.001
Simple effects of BMI			
Smokers			
Overweight/obese	ref		
Normal/underweight	1.46	0.88–2.44	.15
Abstainers			
Overweight/obese	ref		
Normal/underweight	3.53	1.96–6.37	<.001

Note. ^aAdjusted for education and marital status. OR = odds ratio; CI = confidence interval.

Figure 1. Adjusted proportions of breast feeding according to smoking status (A) and prepregnancy BMI (B) across the 24-week postpartum assessment period. Asterisks denote significant differences between conditions at $p < .001$.

Figure 2. The number of participants per smoking status $\times$ BMI subgroup at each postpartum assessment. Individual assessments were excluded if missing smoking or breast-feeding data could not be imputed. Adjusted proportions of breast feeding among the four smoking status $\times$ BMI subgroups. Probabilities are presented for entire the 24-week postpartum assessment period (A) and for each assessment time (B). Simple effects of smoking status and BMI are indicated. Asterisks denote significant differences between subgroups at $p < .05$.

been discussed, the challenges of overweight/obesity less so, and the combined challenge to our knowledge even less or not at all. The present results suggest that the overrepresentation of overweight/obesity will dampen, although not eliminate, the increases in breast feeding associated with smoking abstinence, and the presence of smoking appears to have the potential to eliminate any benefit of reducing the prevalence of overweight/obesity on breast feeding in this population. These findings reveal important links between smoking

status, maternal BMI, and breast feeding that should be recognized in efforts to increase breast feeding in economically disadvantaged women, and underscore the potential need for interventions that reduce the prevalence of both problems, while also seeking to encourage breast feeding among smokers and overweight/obese women.

A growing body of research exploring risk factors for low levels of breast feeding has suggested that the pathways between smoking, maternal BMI, and inadequate breast feeding are

complex. Both risk factors likely involve social/cultural, behavioral, and physiological determinants that may present obstacles to breast feeding (Amir & Donath, 2002, 2007; Donath & Amir, 2004; Lopez et al., 2013; Nommsen-Rivers, Chantry, Pearson, Cohen, & Dewey, 2010; Rasmussen & Kjolhede, 2004; Walker, 2006). The present results demonstrating interactions between smoking status and overweight/obesity add further complexity to our current understanding of the pathways linking them to inadequate breast feeding. The evidence clearly suggests caution in looking for a simple explanation for what is almost surely a multiply determined outcome.

It should be noted that prepregnancy BMI is known to play a role in gestational weight gain, which is also associated with the likelihood of breast feeding (Hilson, Rasmussen, & Kjolhede, 2006). However, it is unlikely that differences in gestational weight gain would produce the pattern of results reported above. We have previously reported that lower prepregnancy BMI was associated with greater gestational weight gain in women enrolled in two of our smoking cessation trials (Washio et al., 2011). If anything, greater weight gain among normal/underweight women might be expected to diminish the differences in breast-feeding behavior between weight categories observed in this study. Future studies should, however, examine whether gestational weight gain or postpartum weight change affects smoking status, breast feeding, and/or the association between them. Additionally, although BMI is generally a reliable indicator of body fatness, the use of more precise measures in future studies on this topic such as dual energy X-ray absorptiometry may provide even more reliable data and perhaps greater insights into some of the mechanisms involved in the relationships between maternal weight and breast feeding. Other methodological issues deserving further investigation in future studies on this topic are associations between breast feeding and maternal BMI using postpartum in addition to prepregnancy BMI measures, and examination of the influence of maternal BMI as a continuous variable or as four categorical variables (underweight, normal, overweight, obese) rather than the two (underweight/normal, overweight/obese) categories that were investigated in this study. These were not investigated in this study because we did not obtain postpartum BMI measurements and our focus in this initial study was on examining relationships between smoking status and excess weight rather than with maternal BMI more generally in predicting the likelihood of breast feeding.

Overall, smoking and overweight/obesity are widely regarded as two of the greatest public health concerns in the United States and other industrial countries (Danaei et al., 2009; Jia & Lubetkin, 2010) and may both play prominent roles in socioeconomic inequalities in health outcomes (Fors, Agahi, & Shaw, 2013). Previous studies have uncovered combined effects of these variables on cardiovascular risk (Akbarbartoort et al., 2005) and overall mortality risk (Koster et al., 2008), underscoring the need to understand how these factors interact. However, despite the well-established association of both smoking status and prepregnancy or postpartum maternal BMI with breast feeding, surprisingly little research has been reported examining their interactive effects. The present results begin to characterize this relationship, and suggest that efforts to raise breast-feeding rates among disadvantaged women will have to address the additional barriers posed by comorbid maternal smoking and overweight/obesity.

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DECLARATION OF INTERESTS

None declared.

REFERENCES

- Akbarbartoort, M., Lean, M. E., & Hankey, C. R. (2005). Relationships between cigarette smoking, body size and body shape. *International Journal of Obesity* (2005), 29, 236–243. doi:10.1038/sj.ijo.0802827
- American Academy of Pediatrics (AAP). (2012). Breastfeeding and the use of human milk. *Pediatrics*, 129, e827–e841. doi:10.1542/peds.2011–3552
- Amir, L. H., & Donath, S. M. (2002). Does maternal smoking have a negative physiological effect on breastfeeding? The epidemiological evidence. *Birth* (Berkeley, Calif.), 29, 112–123. doi:10.1046/j.1523-536X.2002.00152.x
- Amir, L. H., & Donath, S. (2007). A systematic review of maternal obesity and breastfeeding intention, initiation and duration. *BMC Pregnancy and Childbirth*, 7, 1–14. doi:10.1186/1471-2393-7-9
- Aubin, H. J., Farley, A., Lycett, D., Lahmek, P., & Aveyard, P. (2012). Weight gain in smokers after quitting cigarettes: Meta-analysis. *BMJ (Clinical research ed.)*, 345, e4439. doi:http://dx.doi.org/10.1136/bmj.e4439
- Batstra, L., Neeleman, J., & Hadders-Algra, M. (2003). Can breast feeding modify the adverse effects of smoking during pregnancy on the child's cognitive development? *Journal of Epidemiology and Community Health*, 57, 403–404. doi:10.1136/jech.57.6.403
- Bener, A., Denic, S., & Galadari, S. (2001). Longer breastfeeding and protection against childhood leukaemia and lymphomas. *European Journal of Cancer (Oxford, England: 1990)*, 37, 234–238. doi:10.1016/S0959-8049(00)00339-7
- Centers for Disease Control and Prevention (CDC). (2010). Breastfeeding frequently asked questions. Retrieved from www.cdc.gov/breastfeeding/faq
- Centers for Disease Control and Prevention (CDC). (2013). Breastfeeding among U.S. children born 2000–2009, CDC National Immunization Survey. Retrieved from www.cdc.gov/breastfeeding/data/NIS_data/index.htm
- Chilcoat, H. D. (2009). An overview of the emergence of disparities in smoking prevalence, cessation, and adverse consequences among women. *Drug and Alcohol Dependence*, 104, S17–S23. doi:10.1016/j.drugalcdep.2009.06.002
- Collaborative Group on Hormonal Factors in Breast Cancer. (2002). Breast cancer and breastfeeding: Collaborative reanalysis of individual data from 47 epidemiological studies in 30 countries, including 50302 women with breast cancer and 96973 women without the disease. *Lancet*, 360, 187–195. doi:10.1016/S0140-6736(02)09454-0
- Danaei, G., Ding, E. L., Mozaffarian, D., Taylor, B., Rehm, J., Murray, C. J., & Ezzati, M. (2009). The preventable causes of death in the United States: Comparative risk assessment of

- dietary, lifestyle, and metabolic risk factors. *PLoS Medicine*, 6, 1–23. doi:10.1371/journal.pmed.1000058
- Dewey, K. G., Heinig, M. J., & Nommsen, L. A. (1993). Maternal weight-loss patterns during prolonged lactation. *American Journal of Clinical Nutrition*, 58, 162–166. Retrieved from <http://ajcn.nutrition.org/content/58/2/162.full.pdf+html>
- Donath, S. M., & Amir, L. H. (2004). The relationship between maternal smoking and breastfeeding duration after adjustment for maternal infant feeding intention. *Acta Paediatrica (Oslo, Norway: 1992)*, 93, 1514–1518. doi:10.1111/j.1651-2227.2004.tb02639.x
- Donath, S. M., & Amir, L. H. (2008). Maternal obesity and initiation and duration of breastfeeding: Data from the longitudinal study of Australian children. *Maternal & Child Nutrition*, 4, 163–170. doi:10.1111/j.1740-8709.2008.00134.x
- Fors, S., Agahi, N., & Shaw, B. A. (2013). Paying the price? The impact of smoking and obesity on health inequalities in later life. *Scandinavian Journal of Public Health*, 41, 134–141. doi:10.1177/1403494812468966
- Heck, K. E., Braveman, P., Cubbin, C., Chávez, G. F., & Kiely, J. L. (2006). Socioeconomic status and breastfeeding initiation among California mothers. *Public Health Reports*, 121, 51–59. Retrieved from www.ncbi.nlm.nih.gov/pmc/articles/PMC1497787
- Higgins, S. T., Washio, Y., Heil, S. H., Solomon, L. J., Gaalema, D. E., Higgins, T. M., & Bernstein, I. M. (2012). Financial incentives for smoking cessation among pregnant and newly postpartum women. *Preventive Medicine*, 55, S33–S40. doi:10.1016/j.ypmed.2011.12.016
- Higgins, T. M., Higgins, S. T., Heil, S. H., Badger, G. J., Skelly, J. M., Solomon, L. J., Washio, Y., & Preston, A. M. (2010). Effects of cigarette smoking cessation on breastfeeding duration. *Nicotine & Tobacco Research*, 12, 483–488. doi:10.1093/ntr/ntq031
- Hilson, J. A., Rasmussen, K. M., & Kjolhede, C. L. (2006). Excessive weight gain during pregnancy is associated with earlier termination of breast-feeding among White women. *The Journal of Nutrition*, 136, 140–146.
- Horta, B., Kramer, M., & Platt, R. (2001). Maternal smoking and the risk of early weaning: A meta-analysis. *American Journal of Public Health*, 91, 304–307. doi:10.2105/AJPH.91.2.304
- Ip, S., Chung, M., Raman, G., Chew, P., Magula, N., DeVine, D., ... Lau, J. (2007). Breastfeeding and maternal and infant health outcomes in developed countries. *Evidence Report/Technology Assessment*, 1–186. Retrieved from www.ncbi.nlm.nih.gov/books/NBK38337
- Jia, H., & Lubetkin, E. I. (2010). Trends in quality-adjusted life-years lost contributed by smoking and obesity. *American Journal of Preventive Medicine*, 38, 138–144. doi:10.1016/j.amepre.2009.09.043
- Koster, A., Leitzmann, M. F., Schatzkin, A., Adams, K. F., van Eijk, J. T. M., Hollenbeck, A. R., & Harris, T. B. (2008). The combined relations of adiposity and smoking on mortality. *The American Journal of Clinical Nutrition*, 88, 1206–1212. doi:10.3945/ajcn.2008.26298
- Li, R., Jewell, S., & Grummer-Strawn, L. (2003). Maternal obesity and breast-feeding practices. *The American Journal of Clinical Nutrition*, 77, 931–936. doi:10.1038/oby.2009.182
- Liu, J., Rosenberg, K. D., & Sandoval, A. P. (2006). Breastfeeding duration and perinatal cigarette smoking in a population-based cohort. *American Journal of Public Health*, 96, 309–314. doi:10.2105/AJPH.2004.060798
- Lopez, A. A., Gaalema, D. E., & Higgins, S. T. (2013). Maternal smoking and inadequate breastfeeding. In S. Zibadi, R. R. Watson, & V. R. Preedy (Eds.), *Handbook on dietary and nutritional aspects of human breastmilk*. Wageningen, The Netherlands: Wageningen Academic Publishers.
- Lopez-Alarcon, M., Villalpando, S., & Fajardo, A. (1997). Breast-feeding lowers the frequency and duration of acute respiratory infection and diarrhea in infants under six months of age. *Journal of Nutrition*, 127, 436–443. Retrieved from <http://jn.nutrition.org/content/127/3/436.long>
- Mårild, S., Hansson, S., Jodal, U., Odén, A., & Svedberg, K. (2004). Protective effect of breastfeeding against urinary tract infection. *Acta Paediatrica (Oslo, Norway: 1992)*, 93, 164–168. doi:10.1111/j.1651-2227.2004.tb00699.x
- Nommsen-Rivers, L. A., Chantry, C. J., Peerson, J. M., Cohen, R. J., & Dewey, K. G. (2010). Delayed onset of lactogenesis among first-time mothers is related to maternal obesity and factors associated with ineffective breastfeeding. *The American Journal of Clinical Nutrition*, 92, 574–584. doi:10.3945/ajcn.2010.29192
- Oddy, W. H., Li, J., Landsborough, L., Kendall, G. E., Henderson, S., & Downie, J. (2006). The association of maternal overweight and obesity with breastfeeding duration. *The Journal of Pediatrics*, 149, 185–191. doi:10.1016/j.jpeds.2006.04.005
- Ogden, C. L., Lamb, M. M., Carroll, M. D., & Flegal, K. M. (2010). *Obesity and socioeconomic status in adults: United States, 2005–2008 (NCHS Data Brief No. 50)*. Hyattsville, MD: National Center for Health Statistics. Retrieved from <http://cdc.gov/nchs/data/databriefs/db50.pdf>
- Owen, C. G., Martin, R. M., Whincup, P. H., Smith, G. D., & Cook, D. G. (2006). Does breastfeeding influence risk of type 2 diabetes in later life? A quantitative analysis of published evidence. *The American Journal of Clinical Nutrition*, 84, 1043–1054. doi:10.3945/ajcn.111.033035
- Rasmussen, K. M., & Kjolhede, C. L. (2004). Prepregnant overweight and obesity diminish the prolactin response to suckling in the first week postpartum. *Pediatrics*, 113, 465–471. doi:10.1542/peds.113.5.e465
- Rode, L., Kjærgaard, H., Damm, P., Ottesen, B., & Hegaard, H. (2013). Effect of smoking cessation on gestational and postpartum weight gain and neonatal birth weight. *Obstetrics & Gynecology*, 122, 618–625.
- Rosenblatt, K. A., & Thomas, D. B. (1993). Lactation and the risk of epithelial ovarian cancer. The WHO Collaborative Study of neoplasia and steroid contraceptives. *International Journal of Epidemiology*, 22, 192–197. doi:10.1093/ije/22.2.192
- Taylor, J. S., Risica, P. M., Geller, L., Kirtania, U., & Cabral, H. J. (2006). Duration of breastfeeding among first-time mothers in the United States: Results of a national survey. *Acta Paediatrica (Oslo, Norway: 1992)*, 95, 980–984. doi:10.1080/08035250600750064
- Thulier, D., & Mercer, J. (2009). Variables associated with breastfeeding duration. *Journal of Obstetric, Gynecologic, and Neonatal Nursing: JOGNN/NAACOG*, 38, 259–268. doi:10.1111/j.1552-6909.2009.01021.x
- U.S. Department of Health and Human Services. (2010). *Healthy People 2020: Maternal, Infant, and Child Health*. Retrieved from <http://healthypeople.gov/2020/topicsobjectives2020/objectiveslist.aspx?topicId=26>
- Wadden, T. A., Brownell, K. D., & Foster, G. D. (2002). Obesity: Responding to the global epidemic. *Journal of Consulting and Clinical Psychology*, 70, 510–525. doi:10.1037//0022-006X.70.3.510
- Walker, M. (2006). Influence of the maternal anatomy and physiology on lactation. In *Breastfeeding management for the clinician: Using the evidence* (pp. 51–82). Sudbury, MA: Jones and Bartlett.
- Washio, Y., Higgins, S. T., Heil, S. H., Badger, G. J., Skelly, J., Bernstein, I. M., ... Hanson, J. D. (2011). Examining maternal weight gain during contingency-management

- treatment for smoking cessation among pregnant women. *Drug and Alcohol Dependence*, 114, 73–76. doi:10.1016/j.drugalcdep.2010.08.012
- World Health Organization (WHO). (2008). Strengthening action to improve feeding of infants and young children 6–23 months of age in nutrition and child health programmes. Report of proceedings, Geneva. October 6–9, 2008. Retrieved from http://whqlibdoc.who.int/publications/2008/9789241597890_eng.pdf
- Wojcicki, J. M. (2011). Maternal prepregnancy body mass index and initiation and duration of breastfeeding: A review of the literature. *Journal of Women's Health* (2002), 20, 341–347. doi:10.1089/jwh.2010.2248
- Woodward, A., Douglas, R. M., Graham, N. M., & Miles, H. (1990). Acute respiratory illness in Adelaide children: Breast feeding modifies the effect of passive smoking. *Journal of Epidemiology and Community Health*, 44, 224–230. doi:10.1136/jech.44.3.224