ASSOCIATIONS BETWEEN BREASTFEEDING AND CENTRAL ADIPOSITY 7-15 YEARS POSTPARTUM: DATA FROM THE POUCHMOMS STUDY

by

Gabrielle G. Snyder

BA, Dickinson College, 2003

BS, University of Pittsburgh, 2008

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This essay is submitted

by

Gabrielle G. Snyder

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April 20, 2015

and approved by

Essay Advisor:
Marnie Bertolet, PhD _____
Assistant Professor
Department of Epidemiology
Department of Biostatistics
Clinical and Translational Science Institute
Graduate School of Public Health
University of Pittsburgh

Essay Reader:
Janet Catov, PhD _____
Associate Professor
Department of Obstetrics, Gynecology, & Reproductive Sciences
Magee Womens Hospital
Department of Epidemiology
Graduate School of Public Health
University of Pittsburgh

Marnie Bertolet, Ph.D.

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ABSTRACT

Background: There is conflicting evidence regarding the relationship between breastfeeding (BF) and maternal waist circumference in the years after pregnancy. Abdominal obesity has been shown to be an important indicator of cardiometabolic dysfunction in later life.

Objective: We assessed postpartum waist circumference (WC) related to BF duration in a prospective cohort, 7-15 years postpartum.

Methods: This is a longitudinal analysis of 676 women enrolled in the Pregnancy Outcomes and Community Health (POUCH) pregnancy cohort and in the follow-up POUCHmoms study. History of BF duration for the POUCH pregnancy and all other pregnancies was self-reported at follow-up.

Results: Following the POUCH pregnancy, 61.8% of women in this study cohort breastfed at least once. Compared to women who did not breastfeed at all, women who breastfed for at least 6 months had smaller WC (-3.55 cm, 95% CI: (-6.03, - 1.06), p = 0.0052) adjusted for age, pre-pregnancy BMI, POUCH pregnancy gestational weight gain, POUCH pregnancy preterm birth, POUCH pregnancy gestational diabetes, parity, smoking, educational attainment, Medicaid status, race, diet quality score, and physical activity. BF for lesser durations had no significant impact on central adiposity at follow-up.

Conclusions: Results indicate that breastfeeding for greater than 6 months is associated with smaller central adiposity measured up to one decade after pregnancy. These findings may indicate the public health importance of BF promotion for long-term maternal health. Future analyses of BF duration for all pregnancies as a cumulative or per-pregnancy variable will improve the understanding the effects of multiple births, BF, socio-economic status, diet, and physical activity.

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PREFACE

I would like to thank Dr. Janet Catov for taking a chance on a first-year MPH student. I am immensely grateful for her on-going mentorship and support of this research.

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1.0 INTRODUCTION

There is conflicting evidence regarding the relationship between breastfeeding (BF) and maternal central adiposity in the years after pregnancy. The World Health Organization (WHO) recommends that exclusive BF for a minimum of 6 months is optimal for infants,[1] however an equivalently optimal duration for mothers to experience health benefits from BF has yet to be determined.

Normal pregnancy is accompanied by weight gain and retention postpartum, which may contribute to increased cardiovascular disease risk in later life.[2,3] Milk production and BF, however, requires mothers to expend up to 500 additional kcal/day and may promote healthy weight loss postpartum.[4] Previous studies on the effects of breastfeeding on maternal health have looked at a number of outcomes, including body mass index (BMI), skinfold thickness, waist circumference (WC), metabolic risk, and adipose tissue mobilization, and have led to the recognition that longer breastfeeding duration may lessen long-term weight retention following pregnancy.[5,6,7] There is some evidence that women who did not BF each child for at least three months or more had significantly more visceral fat than women who BF each child for three months or less.[8] Metabolically-active visceral adipose tissue has been associated with poor cardiovascular outcomes and studies have shown that BMI as a surrogate measurement may not be the best way to capture this type of body fat mass.[9,10] In particular, there is evidence that assessment of WC as a measure of central adiposity serves as a superior proxy for long-term CAD mortality risk, hypertension, dyslipidemia, and the metabolic syndrome, compared to overall adiposity measurement via BMI.[11,12] However, the possibility of reverse confounding by pre-pregnancy obesity, socioeconomic status, and overall healthy lifestyle continues to obfuscate associations between BF and maternal postpartum obesity.[13] Through detailed data collection and assessment, our study adds to the current body of evidence that BF >6 months following an index pregnancy has a persistent protective effect on maternal central adiposity, nearly one decade later, despite adjustment for other factors that influence central adiposity.

Several studies report improved long-term maternal health outcomes after 6 months BF duration, including greater postpartum weight loss and smaller WC.[14,15] In a systematic review of 45 observational studies, significant differences in weight change were most noticeable in women who BF >6 months and even more so if BF >12 months for a total lifetime duration.[16] An increasing linear dose-response relationship between waist circumference and BF has not been consistently observed in previous studies.[17] Longer durations of BF may also attenuate long-term maternal cardiovascular risk by reducing abdominal obesity and improving the blood pressure profile.[18]

The WHO recommends exclusive BF for a minimum of 6 months for infant health. Similar to these WHO recommendations, BF for a minimum of 6 months may be optimal for mothers to experience long-term health benefits. We hypothesize that, 7-15 years after delivery, women who breastfeed for >6 months will have a smaller WC compared to women who do not breastfeed.

2.0 SUBJECTS AND METHODS

2.1 STUDY POPULATION

Data from the Pregnancy Outcomes and Community Health (POUCH) study were collected in 52 clinics in five Michigan communities (1998-2004) to investigate biomarkers of multiple pathways to preterm delivery (PTD). Detailed pregnancy data were collected through structured interviews and medical record review at enrollment and after delivery. Gestational diabetes status (yes/no) was determined as a failed 3-hour glucose tolerance test, failed glucose screen (> 190 mg/dl) accompanied by a fasting glucose > 95 mg/dl, or specific diagnosis found in the medical records. Hypertension was defined as chronic (pre-existing), preeclampsia (gestational HTN and proteinuria), and gestational HTN (BP >140). Both pre-existing and pregnancy onset hypertension were included. Preterm birth (yes/no) included any birth prior to 37 weeks gestation. By design, African-American participants were oversampled (37%) for stratified analyses.[19] Biological samples and detailed assessment of data on the index pregnancy were collected on a subcohort of 1371 POUCH women.

At a follow-up visit 7-15 years after the POUCH study, 678 women from the POUCH subcohort returned as participants in the POUCHmoms study (2010-2014) that was designed to examine the association between PTD and long-term maternal cardiovascular disease risk. Post-pregnancy data were collected at this follow-up visit through self-report and direct measure. To investigate our hypothesis, we utilized data from POUCHmoms participants (Figure 1). Women who were pregnant, or within 6 months post-pregnancy at the time of the POUCHmoms recruitment, and women with invalid WC measurements were excluded.

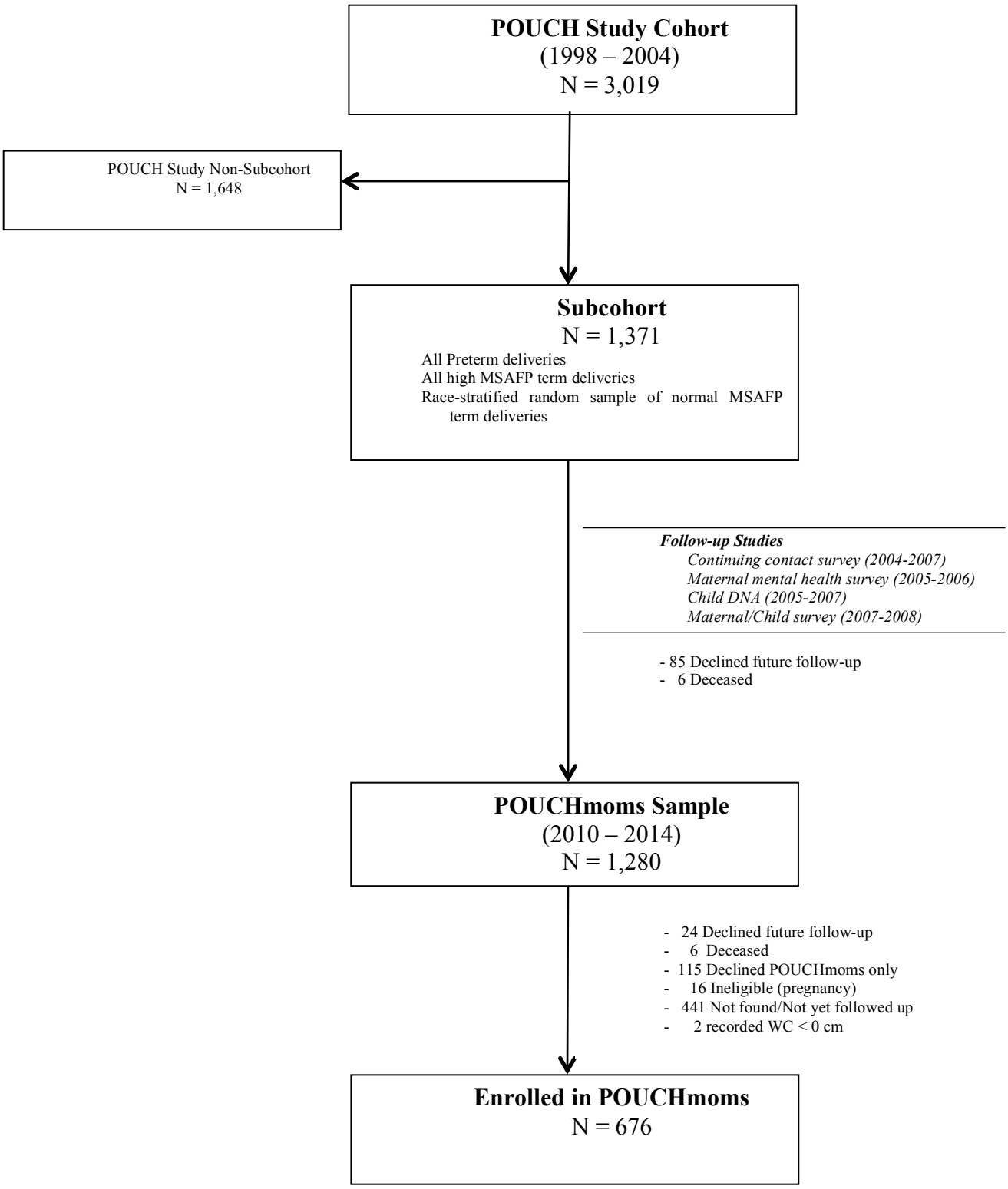

Figure 1: Flow chart of participants in POUCHmoms study, 2011-2014

2.2 BREASTFEEDING

Breastfeeding duration was collected as a self-reported continuous variable for the POUCH pregnancy at the follow-up visit. Participants were asked if they breastfed (yes/no) and the age of the infant, in months, when they stopped nursing. While we have BF information on all other pregnancies that had occurred through the follow-up period, we chose to focus on BF duration for the POUCH pregnancy, alone, because the clinical data collection for this pregnancy was based on chart review. Breastfeeding exposure of the POUCH child was stratified into 4 classes: none, >0-3 months, >3-6 months, and >6 months. Because the majority of prior research collects BF data as a categorical rather than a continuous duration, the creation of a categorical variable in this analysis would facilitate comparison to results of existing studies on BF and central adiposity.

2.3 WAIST CIRCUMFERENCE AT FOLLOW-UP

To assess long-term maternal health risk related to adiposity, this sub-study focused on waist circumference at follow-up, adjusting for pre-pregnancy BMI prior to the POUCH pregnancy. Pre-pregnancy weight was collected by self-report prior to the POUCH pregnancy and BMI was calculated as weight in kilograms divided by their height in meters squared. Waist circumference was used as a single continuous measure of central adiposity. An average of three WC measurements were collected using a Gulick tape measure, taken at the peak of expiration. BMI and WC measured at follow-up were checked for correlation (*rho* = 0.939, p<.0001) to confirm that pre-pregnancy BMI was a suitable proxy for pre-pregnancy WC adjustment in regression analyses. To explore clinically meaningful measure of body composition, WC >88cm was selected as a cut off point for central adiposity in women.[20]

Supplementary analyses considering BMI as an outcome are available at the end of this report (see Appendix).

2.4 COVARIATES

Variables collected during the POUCH pregnancy that were considered in this analysis included gestational weight gain (GWG) as defined by updated guidelines set forth by the Institute of Medicine,[21] hypertensive disorders of pregnancy and/or chronic hypertensive disorders, preterm birth, and gestational diabetes. At follow-up, maternal age, total number of live births to date, race, and educational attainment (<12 years of formal education, high school diploma, vocational training/some college, and college graduate) were assessed via a structured interview. A diet quality score was calculated from the Block Food Frequency Questionnaire, with a higher score indicating a higher quality diet.[22] An average number of hours of physical activity (leisure and occupational) per week were assessed via the Modified Activity Questionnaire.[23] Both smoking and cumulative Medicaid status were assessed by self-report before, during, and after the POUCH pregnancy at follow-up.

2.5 STATISTICAL ANALYSIS

We estimated the unadjusted associations of BF duration with pregnancy and lifestyle factors, SES, diet, and physical activity covariates using t-tests and ANOVA. Diagnostic testing of residuals for continuous WC were normally distributed and did not violate assumptions of linearity. Linear regression models were built to assess associations between BF duration for the POUCH pregnancy and measures of adiposity via WC and allowed for adjustment of potential confounders. A total of four models were used to estimate the effects of the covariates on the primary association of interest. Following initial adjustment of pre-pregnancy BMI to estimate crude WC at follow-up (Model 1), maternal age, and POUCH pregnancy covariates including GWG, preterm birth status, gestational diabetes, parity, and smoking were controlled for in the analyses (Model 2). Subsequent models took into account SES characteristics (educational attainment and Medicaid status) and race (Model 3), as well as diet quality score and average hours of physical activity per week (Model 4). BF exposure was considered as both a categorical and a continuous variable to assess impact on WC outcome. All tests were two-sided with a statistical significance level of 0.05 and analyses were performed using SAS (version 9.2; SAS Institute). Institutional review boards approved this study at the University of Pittsburgh and Michigan State University.

3.0 RESULTS

Socio-demographic, lifestyle, and POUCH pregnancy characteristics, by breastfeeding history are shown in Table 1 for the POUCHmoms subcohort participants. Overall, nearly two-thirds of the women breastfed for some duration. Specifically, 38.2% of the participants reported that they had not breastfed at all following the POUCH pregnancy, 22.0% reported BF for >0-3 months BF, 13.2% reported BF for >3-6 months, and 26.6% reported BF for >6 months. Mothers who breastfed were more likely to be older and to have lower BMI at follow-up, as well as smaller WC, hip circumference, and waist-hip-ratio (WHR) measurements. Additionally, these mothers had significantly higher diet quality scores and increased hours of physical activity per week, compared to women who did not breastfeed at all. African American women accounted for approximately 37% of this subcohort (58% were Caucasian, 5% were Asian and Native American), yet more than half (54.4%) did not breastfeed, compared to only 27.8% of Caucasian women who did not breastfeed (data not shown). Women with preterm birth had, on average, shorter BF durations.

In unadjusted analyses, the distribution of GWG category differed significantly between the four BF categories ($p = 0.0019$). Of those who breastfed >6 months, 10.3% had inadequate GWG at delivery, compared to 24.6%, 19.7% and 10.7% for those who breastfed none, >3-6, and >0-3 months, respectively. Alternatively, of those who breastfed for >6 months, 64.8% had excessive GWG at delivery, compared to 59.6%, 63.5% and 63.1% for those who breastfed none, >3-6, and >0-3 months, respectively. The duration of breastfeeding was significantly associated with the participants' Medicaid status ($p<.0001$). Of those who breastfed >6 months, 62% never received Medicaid, compared to 43.6% and 53.9% for participants who breastfed >0-3 and >3-6 months, respectively. Of those who did not breastfeed, 52.1% received Medicaid before, during, and after the POUCH pregnancy, compared to 12.8% who breastfed for >6 months. The duration of breastfeeding was significantly associated with education level ($p<.0001$). Of those who breastfed >6 months, 47.8% were college graduates, compared to 11.6%, 26.2% and 40.4% for those who breastfed none, >0-3, and >3-6 months, respectively. Finally, women who BF >6 months were

Table 1: Maternal characteristics during pregnancy and 7-15 years after delivery, according to breastfeeding duration

Characteristic	None (N = 258)	>0-3 months (N = 149)	>3-6 months (N = 89)	>6 months (N = 180)	p-value
Maternal age at Follow-up (yrs), mean, SD	36.3, 5.5	36.8, 5.6	38.5, 5.7	40.0, 5.5	<.0001
Delivery to Follow-up (yrs), mean, SD	11.4, 1.4	11.1, 1.4	10.8, 1.4	10.7, 1.4	<.0001
Maternal BMI at Follow-up, mean, SD	33.4, 9.7	31.5, 8.1	31.5, 8.5	29.1, 7.6	<.0001
Waist at Follow-up (cm), mean, SD	95.2, 18.7	91.5, 16.7	91.6, 17.5	86.5, 14.2	<.0001
Hip at Follow-up (cm), mean, SD	116.5, 19.2	113.8, 16.8	113.1, 18.0	108.9, 15.9	0.0002
WHR at Follow-up, mean, SD	0.81, 0.06	0.80, 0.06	0.81, 0.07	0.79, 0.05	0.0053
Diet Quality score, mean, SD	49, 10	54, 10	56, 11	57, 10	<.0001
MAQ: Avg activity hrs/wk, mean, SD	11.9, 15.2	12.0, 14.7	13.9, 13.9	16.2, 17.2	0.0211
Pre-Pregnancy BMI, n(column%)					
Normal weight, 18.5-24.9	112 (43.4)	70 (47.0)	46 (51.7)	104 (57.8)	0.2755
Overweight, 25-29.9	56 (21.7)	34 (22.8)	16 (18.0)	36 (20.0)	
Obese Class I, 30-34.9	41 (15.9)	22 (14.8)	13 (14.6)	22 (12.2)	
Obese Class II, 35-39.9	25 (9.7)	14 (9.4)	9 (10.1)	7 (3.9)	
Obese Class III, >=40	24 (9.3)	9 (6.0)	5 (5.6)	11 (6.1)	
GWG Category at delivery, n(column%)					0.0019
Inadequate	59 (24.6)	27 (19.7)	9 (10.7)	17 (10.3)	
Adequate	38 (15.8)	23 (16.8)	22 (26.2)	41 (24.8)	
Excessive	143 (59.6)	87 (63.5)	53 (63.1)	107 (64.8)	
Preterm birth, n(column%)	78 (30.2)	42 (28.2)	17 (19.1)	32 (17.8)	0.0105
African American Race, n(column%)	135 (52.3)	49 (32.9)	26 (29.9)	38 (21.1)	<.0001
Education level at Follow-up, n(column%)					<.0001
<12 Years	41 (15.9)	6 (4.0)	2 (2.2)	3 (1.7)	
HS Diploma	62 (24.0)	17 (11.4)	5 (5.6)	10 (5.6)	
Vocational Training/Some College	125 (48.4)	87 (58.4)	46 (51.7)	81 (45.0)	
College Graduate	30 (11.6)	39 (26.2)	36 (40.4)	86 (47.8)	
Cumulative Medicaid status, n(column%)					<.0001
Never On Medicaid	56 (21.8)	65 (43.6)	48 (53.9)	121 (67.2)	
Medicaid Before POUCH Only	54 (21.0)	33 (22.1)	20 (22.5)	27 (15.0)	
Medicaid After POUCH Only	13 (5.1)	12 (8.1)	5 (5.6)	9 (5.0)	
Medicaid Before/During and After POUCH	134 (52.1)	40 (26.2)	17 (18.0)	23 (12.8)	
Cumulative Smoking, n(column%)					<.0001
Never Smoked	108 (42.0)	77 (51.7)	56 (62.9)	125 (69.4)	
Former Smoker	28 (10.9)	25 (16.8)	12 (13.5)	28 (15.6)	
Current but not during POUCH Pregnancy	34 (13.2)	13 (8.7)	12 (13.5)	12 (6.7)	
Current and during POUCH Pregnancy	87 (33.9)	34 (22.8)	9 (10.1)	15 (8.3)	

more likely to have never smoked (69.4%) compared to 42.0%, 51.7%, 62.9% for those who breastfed none, >0-3, >3-6, and >6 months, respectively (p<.0001). Pre-pregnancy BMI was not associated with BF duration.

At follow-up, women with WC < 88cm breastfed for mean 8.20 months compared to women with WC > 88cm who breastfed for mean 6.29 months (p = 0.0018) (Table 2). Of those with higher central adiposity, 60.3% had excessive GWG, whereas only 14.8% and 17.8% had adequate and inadequate GWG, respectively (p = 0.0288). Furthermore, a substantial proportion were African American women (42.7%, p = 0.0019) and of lower SES in general (data not shown). Smaller WC was significantly associated with higher mean diet quality score (54 compared to 52, p = 0.0130) and higher mean physical activity (15.1 hrs/wk compared to 11.9 hrs/wk, p = 0.0083). It is worth noting that women who developed gestational diabetes were more likely to have central obesity greater than 88cm at follow-up. Based on unadjusted comparisons of the BF categories using ANOVA (data not shown), women BF >6 months versus women who did not breastfeed differed most significantly among all BF groups (F = 27.52, p<.0001). Additionally, BF >0-3 months and >3-6 months were significantly different from no BF at all (F = 5.47, p = 0.0196). Notably, no significant difference existed between >0-3 months and >3-6 months (F = 0.00, p = 0.9761). Based on mean and median WC, these results suggest that only BF >6 months is associated with WC below 88cm at follow-up (Figure 2).

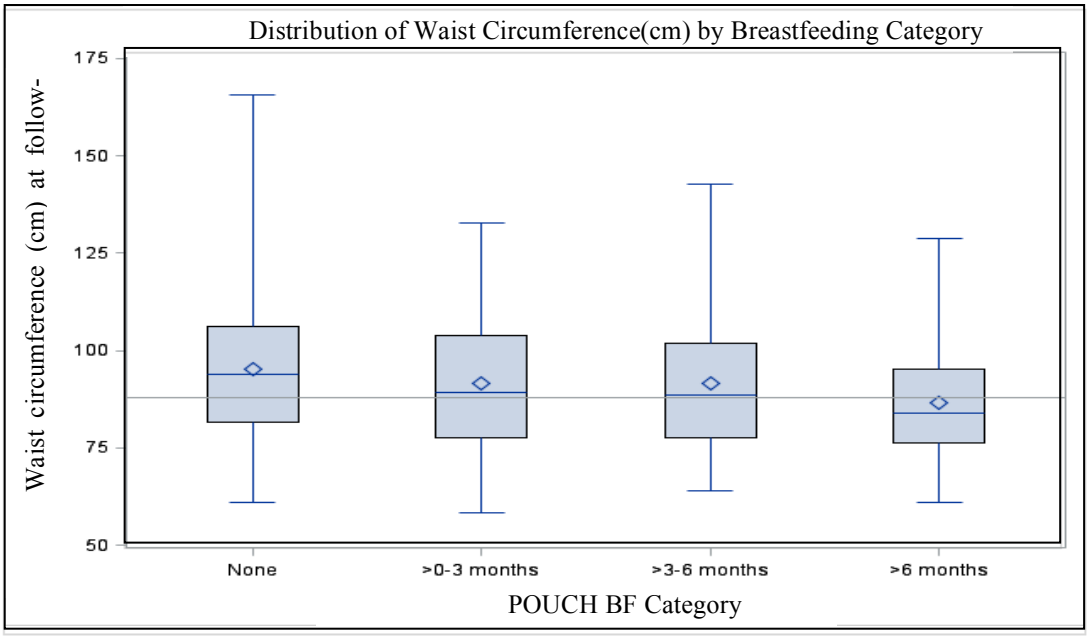

Figure 2: Comparative boxplot distributions about WC = 88cm, across breastfeeding groups, by waist circumference (cm)

Table 2: Maternal characteristics during pregnancy and 7-15 years after delivery, according to waist circumference (cm)

Characteristic	N	Waist < 88cm (N = 311)	Waist > 88cm (N = 365)	p-value
Maternal age at Follow-up (yrs), mean, SD	676	38.1, 5.8	37.3, 5.6	0.0690
Diet Quality Score, mean, SD	675	54, 11	52, 10	0.0130
MAQ: Avg activity hrs/wk, mean, SD	676	15.1, 16.4	11.9, 14.6	0.0083
Breastfeeding (months), mean, SD	418	8.20, 7.14	6.29, 5.21	0.0018
Pre-Pregnancy BMI, n(row%)				
Normal weight, 18.5-24.9	332	250 (75.3)	82 (24.7)	<.0001
Overweight, 25-29.9	142	54 (38.0)	88 (62.0)	
Obese Class I, 30-34.9	98	5 (5.1)	93 (94.9)	
Obese Class II, 35-39.9	55	0 (0)	55 (100)	
Obese Class III, >=40	49	2 (4.1)	47 (95.9)	
GWG Category at delivery, n(row%)				0.0288
Inadequate	112	47 (42.0)	65 (58.0)	
Adequate	124	70 (56.5)	54 (43.5)	
Excessive	390	170 (43.6)	220 (56.4)	
Gestational Diabetes, n(row%)	40	10 (25.0)	30 (75.0)	0.0060
African American Race, n(row%)	248	92 (37.1)	156 (62.9)	0.0019
Total Parity, n(row%)				0.0612
1	60	22 (36.7)	38 (63.3)	
2	259	128 (49.4)	131 (50.6)	
3	208	103 (49.5)	105 (50.5)	
4+	149	58 (38.9)	91 (61.1)	
Education level at Follow-up, n(row%)				<.0001
<12 Years	52	22 (42.3)	30 (57.7)	
HS Diploma	94	31 (33.0)	63 (67.0)	
Vocational Training/Some College	339	143 (42.2)	196 (57.8)	
College Graduate	191	115 (60.2)	76 (39.8)	
Cumulative Medicaid status, n(row%)				<.0001
Never On Medicaid	290	161 (55.5)	129 (44.5)	
Medicaid Before POUCH Only	134	61 (45.5)	73 (54.5)	
Medicaid After POUCH Only	39	13 (33.3)	26 (66.7)	
Medicaid Before/During and After POUCH	212	75 (35.4)	137 (64.6)	

In multivariate models of our continuous outcome variable, WC, we examined four linear regression models for BF as either a categorical or a continuous variable. Significant protective effects were seen consistently between BF >6 months and WC at follow-up, controlling for pre-pregnancy BMI, maternal age at follow up, GWG, preterm birth, total number of live births, smoking, educational attainment, Medicaid status, race, diet quality score,

and physical activity. Women who breastfed >6 months had 3.55 cm smaller WC (95% CI: (-6.03, - 1.06), p = 0.0052) compared to women who did not breastfeed at all following the POUCH pregnancy (Table 3). Breastfeeding for >3-6 months was unrelated to WC in any models. Following adjustment for pre-pregnancy BMI, BF >0-3 months was no longer associated with WC in subsequent models. In addition, there were no significant interactions between BF and GWG, smoking status, or parity through follow-up.

Table 3: Multivariate analyses of continuous waist circumference at follow-up by breastfeeding as a categorical variable for POUCH pregnancy

Breastfeeding Exposure Variable	Model 1 (N = 676)		Model 2 (N = 625)		Model 3 (N = 624)		Model 4 (N = 623)	
	β	p	β	p	β	p	β	p
Categorical								
None	Ref	NA	Ref	NA	Ref	NA	Ref	NA
>0-3 months	-2.20	0.0571	-1.84	0.1162	-1.12	0.3517	-0.88	0.4654
>3-6 months	-1.20	0.3855	-1.31	0.3542	-0.18	0.9002	-0.27	0.8520
>6 months	-4.95	<.0001	-5.52	<.0001	-4.21	0.0009	-3.55	0.0052

Model 1 - Crude change, adjusted for pre-pregnancy BMI

Model 2 - Adjusted for pre-pregnancy BMI, maternal age, GWG, preterm birth, GDM, parity, and smoking (lifestyle and pregnancy factors)

Model 3 - Adjusted for pre-pregnancy BMI, maternal age, GWG, preterm birth, GDM, parity, smoking, educational attainment, Medicaid status, race

Model 4 - Full model adjusted for pre-pregnancy BMI, maternal age, GWG, preterm birth, GDM, parity, smoking, educational attainment, Medicaid status, rac diet quality score, and physical activity

Similarly, the same multivariate analyses using BF as a continuous variable indicate associations between months of BF and WC at follow-up for all regression models (Table 4). Adjusting for all covariates, the association between BF and WC remained statistically significant (-0.19 cm, 95% CI:(-0.36, -0.02) p = 0.0267).

Table 4: Multivariate analyses of continuous waist circumference at follow-up by breastfeeding as a continuous variable for POUCH pregnancy

Breastfeeding Exposure Variable	Model 1 (N = 418)		Model 2 (N = 386)		Model 3 (N= 386)		Model 4 (N = 386)	
	β	p	β	p	β	p	β	p
Continuous (months)	-0.23	0.0053	-0.21	0.0121	-0.20	0.0181	-0.19	0.0267

Model 1 - Crude change, adjusted for pre-pregnancy BMI

Model 2 - Adjusted for pre-pregnancy BMI, maternal age, GWG, preterm birth, GDM, parity, and smoking (lifestyle and pregnancy factors)

Model 3 - Adjusted for pre-pregnancy BMI, maternal age, GWG, preterm birth, GDM, parity, smoking, educational attainment, Medicaid status, race

Model 4 - Full model adjusted for pre-pregnancy BMI, maternal age, GWG, preterm birth, GDM, parity, smoking, educational attainment, Medicaid status, rac diet quality score, and physical activity

A sensitivity analysis using maternal BMI at follow-up as the outcome provided comparable results (see Appendix).

4.0 DISCUSSION

We found that women who breastfed >6 months had significantly less central adiposity 7-15 years later compared to women who did not breastfeed at all, controlling for potential confounders. These results raise the possibility that BF duration of at least 6 months following pregnancy may be needed for improved long-term maternal central adiposity. Considering BF as a continuous variable also yielded significant results with respect to long-term maternal WC after accounting for possible confounders. As a unique strength if this study, BF duration collected as a continuous variable provided flexibility in exposure analysis and will help guide future analyses that examine the cumulative effects of the total number of live births, duration of BF per pregnancy, and aggregate BF for all pregnancies through follow-up. In this way, it will be possible to consider the influence of weight gain owing to additional pregnancies as well as fat tissue mobilization due to BF for each pregnancy.

While many prior studies have considered short-term weight loss as a result of BF, this study considers the long-term effects of BF with respect to maternal weight retention. Our findings are in agreement with a handful of previous studies that have looked at the relationship between BF and long-term weight retention, greater than 7-years postpartum, and seem to suggest that longer observational follow-up periods relate to more conclusive results. Fraser et al. showed that any BF following pregnancy attenuated overweight and central adiposity up to 16 years after pregnancy.[6] A study of the Danish National Birth Cohort found that BF was directly linked to lower 6-month postpartum weight, which was correlated with lower maternal WC, adjusted for pre-pregnancy BMI, 7 years later.[2] McClure et al. reveal similar findings in the WISH study, also at 7-year follow-up, in which women who breastfed 3 months or less had significantly more visceral fat deposits compared to women who breastfed >3 months.[24] Existing evidence suggests that greater durations of BF have been associated with decreased weight retention compared to no BF after a substantial amount of time (>7 years) has passed between pregnancy and follow-up.[3] Studies that have investigated weight retention after shorter postpartum periods, up to 3 years after delivery, have been less conclusive with respect to BF exposure.[15-17]

Pre-pregnancy weight and pregnancy weight gain have frequently been related to BF initiation and duration. Often, higher pre-pregnancy BMI is suggested as a reason why obese women tend to breastfeed for shorter periods of time. Higher GWG has also been associated with premature cessation of BF as well as lower rates of initiation.[25] In POUCHmoms, 57.8% of women had excessive GWG and, of those, 63.3% were able to BF for some period of time, with 27.4% BF >6 months. It is plausible that in this more contemporary cohort, such results may be explained by excessive GWG becoming more the norm. Detailed collection and inclusion of direct measures of diet quality score and average total hours of physical activity per week in our full model may also help to illuminate these associations.

Several limitations of this study deserve mention. Comparable to previous studies, white race, higher SES, better diet, and greater physical activity were highly associated with a woman's likelihood to breastfeed. As discussed by Stuebe and Rich-Edwards, these relationships may suggest that residual confounding in observational studies based on sociodemographic factors and healthy lifestyle choices is possible.[13] Also, imprecise recall within the POUCHmoms cohort for women BF >0 months but less than 6 months may have resulted in misclassification of the exposure variable when evaluated as a categorical variable. Reports on validity of self-reported BF practice years later depend largely on BF duration, the period of recall, and the social climate surrounding BF as an accepted custom. Maternal recall within three years of postpartum has been determined as reliable and valid among varied cohorts, and recall up to 20 years postpartum has also been validated when BF duration is long and occurs within a population where BF is commonplace.[26,27] Although BF rates in the US have increased over the past several years, perceptions of BF as an acceptable behavior remain low in general.[28] Therefore, misclassification within this cohort among women who breastfed >0-3 and >3-6 months due to poor maternal recall is plausible. Lastly, despite adjustment for parity through follow up, the total number of pregnancies a woman has may impact both her likelihood to breastfeed as well as the amount of gestational weight gained and retained postpartum for each pregnancy. With this in mind, selection of specific time points for assessment of maternal weight following BF may have impact results. Future studies are needed to take these factors into account.

Determining an appropriate outcome to assess both BF exposure and postpartum weight retention for this cohort is based on previous studies that hypothesized increased visceral fat mobilization from the waist as a result of BF.[8,29] Weight loss and weight maintenance studies have yet to agree upon the best metric to accurately capture weight change and body composition.[30] Moreover, future research should focus on not only postpartum BF duration

for a single index pregnancy but across all pregnancies to identify appropriate biomarkers of adiposity that contribute to poor health (inflammation, dyslipidemia, the metabolic syndrome, etc.).

Importantly, overweight and obesity have been shown to contribute significantly to the development of cardiovascular disease, which continues to be the primary cause of death among women in the US. In addition to diet, exercise, and overall lifestyle choices, the public health impact of BF duration following pregnancy may play a critical role in helping women to maintain long-term healthy weight goals that, in turn, influence cardiometabolic processes. In the interest of attenuating adverse cardiovascular outcomes, the biological mechanisms linking BF and maternal health deserve continued investigation.

In conclusion, this study found that BF >6 months was related to smaller WC, accounting for age, race, lifestyle factors, SES, diet, and physical activity, compared to women who did not BF at all. Categorical and continuous analysis of duration of BF may be equally important to understanding factors related to maternal central adiposity over time, and that a threshold effect may exist for BF >6 months. These conclusions may be important to consider when studying long-term maternal cardiovascular and metabolic health. Therefore, similar to WHO recommendations for infants, this study indicates that BF >6 months may be associated with smaller WC that persists up to one decade after pregnancy.

APPENDIX: SUPPLEMENTARY ANALYSIS—BMI AS OUTCOME

The same four linear regression models were performed on BMI as a continuous measure of overall adiposity with BF as a categorical and continuous primary independent variable. Results corroborate the significant association between BF exposure and adiposity, revealing a reduction of 1.53 kg/m^2 (95% CI: (-2.65, -0.41), p = 0.0075) in BMI for BF > 6 months, compared to no BF and adjusting for all covariates (Table 5).

Table 5: Multivariate analyses of continuous BMI at follow-up by breastfeeding as a categorical variable for POUCH pregnancy

Breastfeeding Exposure Variable	Model 1 (N = 676)		Model 2 (N = 625)		Model 3 (N = 624)		Model 4 (N = 623)	
	β	p	β	p	β	p	β	p
Categorical								
None	Ref	NA	Ref	NA	Ref	NA	Ref	NA
>0-3 months	-1.07	0.0447	-0.93	0.0794	-0.73	0.1790	-0.57	0.2885
>3-6 months	-0.57	0.3697	-0.56	0.3797	-0.20	0.7657	0.03	0.9591
>6 months	-2.28	<.0001	-2.27	<.0001	-1.80	0.0016	-1.53	0.0075

Additionally, analysis of BMI by BF as a continuous variable also shows a statistically significant decrease of 0.08 kg/m^2 (95% CI: (-0.16, -0.01), p = 0.0293) (Table 6).

Table 6: Multivariate analyses of continuous BMI at follow-up by breastfeeding as a continuous variable for POUCH pregnancy

Breastfeeding Exposure Variable	Model 1 (N = 418)		Model 2 (N = 386)		Model 3 (N = 386)		Model 4 (N = 386)	
	β	p	β	p	β	p	β	p
Continuous (months)	-0.11	0.0027	-0.09	0.0141	-0.09	0.0254	-0.08	0.0293

Model 1 - Crude change, adjusted for pre-pregnancy BMI

Model 2 - Adjusted for pre-pregnancy BMI, maternal age, GWG, preterm birth, GDM, parity, and smoking (lifestyle and pregnancy factors)

Model 3 - Adjusted for pre-pregnancy BMI, maternal age, GWG, preterm birth, GDM, parity, smoking, educational attainment, Medicaid status, race

Model 4 - Full model adjusted for pre-pregnancy BMI, maternal age, GWG, preterm birth, GDM, parity, smoking, educational attainment, Medicaid status, rac
diet score, and physical activity

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