Breastfeeding, Overweight Status, and Inflammation

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2 Tables, 4 Figures

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Abstract

Breastfeeding confers a host of health benefits, including long-term protection from inflammation. Using data from the National Longitudinal Study of Adolescent to Adult Health (Add Health), we investigate overweight status from adolescence into young adulthood as a mediating pathway of the link between breastfeeding in infancy and inflammation in early adulthood. Results from pathway analyses in a structural equation modeling framework indicate that, in addition to a direct pathway linking breastfeeding and inflammation, indirect pathways through overweight status across adolescence into adulthood partially explains the association between breastfeeding and inflammation. Overweight status, moreover, links breastfeeding to inflammation not only through proximal timing of overweight status, but also through an indirect cascading process of overweight status over the life course that is evident in adolescence. Overall, this study highlights the importance of considering breastfeeding, overweight status and inflammation as dynamic life course processes contributing to development of health inequalities.

Keywords: breastfeeding, inflammation, overweight status, life course
Inflammation is an important biological process that connects early life experiences with a range of health outcomes later in life. For example, harmful childhood exposures to infections and stress contribute to higher inflammation levels in children (Dowd, Zajacova, and Aiello 2009; Broyles et al. 2012; McDade et al. 2013; Slopen et al. 2013), promoting biological processes that culminate in disease and poor health in later life (Crimmins and Finch 2006). The pathways through which childhood exposures promote inflammation thus contribute to the development of disadvantage and health disparities over the life course. In the present study, we examine an important parental practice that can potentially reduce children’s development of inflammation and ultimately reverberate into adulthood – infant breastfeeding. Being breastfed during infancy not only protects against infections (Jackson and Nazar 2006), but a longer duration of breastfeeding is also associated with lower levels of C-reactive protein (CRP), a key biomarker of inflammation, in early adulthood (Shanks and Lightman 2001; Williams, Williams, and Poulton 2006; Rudnicka, Owen, and Strachan 2007; McDade et al. 2014).

In this study, we revisit this association between breastfeeding in infancy and inflammation in early adulthood using the National Longitudinal Study of Adolescent to Adult Health (Add Health). We add to current understanding of this association by examining a potentially important biosocial pathway – weight status in adolescence and young adulthood. Breastfeeding is related to a lower risk of being overweight (McCory and Layte 2012; Metzger and McDade 2010; Owen et al. 2005). Being overweight, additionally, is associated with heightened CRP levels in adulthood (Hak et al. 1999; Visser et al. 1999). The role of breastfeeding in protecting against inflammation, coupled with the contribution of weight status to later life inflammation, suggests overweight status may thus be an especially important pathway through which breastfeeding is associated with inflammation. In examining the role of
overweight status, we pay special attention to the overweight status across adolescence into young adulthood to capture how overweight status at different points in the life course may serve as pathways through which breastfeeding influences inflammation in young adulthood. Although prior research makes clear that breastfeeding has long-term consequences for overweight status over the life, prior research is largely silent regarding whether overweight status at later stages of the life course operate as pathways linking breastfeeding to inflammation in young adulthood.

Given the multifaceted benefits of breastfeeding, not only for short-term nutrition promotion and infection protection but also for long-term weight and inflammatory processes, a more comprehensive understanding of the pathways through which breastfeeding impacts later life health will better inform policymakers and health care providers. Additionally, gaining a deeper understanding of overweight experiences as life course processes allows for more careful evaluation of intervention and the timing of intervention. Explicating how breastfeeding in infancy may indirectly impact inflammation in early adulthood through overweight status across adolescence into young adulthood therefore sheds light on crucial links that contribute to the development of health disparities in the short- and long-term.

Breastfeeding, Weight Status, and Inflammation

Breastfeeding is touted as the gold standard for feeding infants, with a host of advantages conferred in the short- and long-term (The American Academy of Family Physicians 2014; Horta and Victora 2013; U.S. Department of Health and Human Services 2011; Eglash, Montgomery, and Wood 2008). In the short-term, breastfeeding helps protect against infection and disease; and, in the long-term, being breastfed as an infant is associated with benefits to blood pressure, asthma, type-2 diabetes, cholesterol, and overweight and obesity (Horta and Victoria 2013; U.S. Department of Health and Human Services 2011). The advantages of breastfeeding that persist
across the life course, however, are subject to initiation and duration of breastfeeding ---
decisions conditioned by socioeconomic status (Heck et al. 2006; Beck et al. 1999; Hirschman
and Butler 1981). As such, breastfeeding represents a process that is both social and biological,
occurring during infancy, but having serious implications for health and well-being across the
life course.

Unpacking the association between breastfeeding and inflammation and identifying
mechanisms that relate these processes across the life course is important to elucidate ways in
which breastfeeding gets under the skin and inflammation is promoted across different life
course stages, thereby impacting inequalities in health. Given the metabolic implications of
breastfeeding and inflammation, overweight status appears to be a potential mechanism linking
breastfeeding to inflammation. Indeed, weight status later in life is connected to early life
factors, including breastfeeding (Salsberry and Reagan 2007). The protective nature of
breastfeeding against overweight status, moreover, extends across the life course (Horta and
Victoria 2013; Owen et al. 2005; Gillman et al. 2002), and is often attributed to the higher
protein intake and increased insulin response associated with breast milk (Horta and Victoria
2013). Individuals who are breastfed thereby develop heightened metabolic and hormonal
responses to feeding, which do not diminish later in life. The association between breastfeeding
and overweight status is a dose-response relationship, such that individuals who are breastfed for
longer periods of time enjoy decreased risk of being overweight as compared to individuals who
were not breastfed, and individuals who were breastfed for shorter durations (Harder et al. 2005).
At the same time, being overweight is associated with higher levels of inflammation across the
life course (Visser et al. 2001; Visser et al. 1999). Researchers speculate that this association
could be related to proteins released by adipose tissue that promote the production of CRP
(Visser et al. 2001). Indeed, a link between increased adiposity and higher CRP concentrations emerges as early as childhood (Dowd, Zajacova, and Aiello 2010). Overweight individuals, therefore, experience elevated inflammation as a function of their excess body fat.

In sum, breastfeeding and inflammatory processes are both linked to weight status. The protection against being overweight that is conferred to breastfed individuals may therefore be the same protection these individuals enjoy against inflammation in later life. The primary aim of this study is to test overweight status as a mediating pathway through which breastfeeding in infancy impacts inflammation in early adulthood. We ask – does being overweight during early adolescence, later adolescence, or during the transition into adulthood matter more (or less) in mediating the association between breastfeeding and inflammation? This timing approach seeks to highlight particular windows of vulnerability during which being overweight is particularly consequential for inflammation in early adulthood. Because we are able to assess how overweight status in early adolescence may launch a “chain of risk” of overweight status that persists into later parts of the life course, our study speaks to the long-term development of biological processes and highlights how the mediatory role of overweight status on the association between breastfeeding and inflammation develops across the early life course. In exploring our study aim, therefore, we conceptually capture alternative pathways between breastfeeding and inflammation through timing of overweight status and cumulative path of overweight status. In doing so, we are better equipped to understand breastfeeding, overweight status, and inflammation as dynamic processes that are active across the life course. Our hypothesis is that overweight status matters for the link between breastfeeding and inflammation not only for a given point in time, but also as a cumulative process that unfolds across the transition from adolescence to young adulthood.
Methods

Data and Sample

Add Health is a nationally representative survey that launched in 1994 with an in-school survey and followed adolescents into young adulthood through a series of four waves from 1995 to 2008 (Harris et al. 2009). The schools included in the study were selected by region, urbanicity, school size, school type, and racial composition based on a stratified sampling design. In-school data collection was done in 1994 when respondents were in grades 7–12 and was used to generate a nationally representative subsample of 20,745 students selected for Wave I in-home interviews in 1995. During Wave I in-home interviews, respondents’ parents also reported on a series of demographic and background characteristics. Additional in-home interviews of respondents were conducted in 1996 (Wave II; \( n = 14,738 \), with Wave I high school seniors excluded), 2001-2002 (Wave III; \( n = 15,197 \), with Wave I high school seniors brought back in), and 2007-2008 (Wave IV; \( n = 15,701 \)). The age ranges across waves were: 11 to 18 (Wave I), 12 to 18 (Wave II), 18 to 26 (Wave III), and 24 to 32 (Wave IV). During Wave IV, biological specimens were collected including whole blood, saliva, and cardiovascular and anthropometric measures (Whitsel et al. 2012).

The study sample is limited to respondents who were observed in all four waves of interviews, provided biological specimens for analyses (including CRP measurements), and had a valid longitudinal sampling weight. Among the 15,701 respondents that were observed through Wave IV, 9,421 had valid longitudinal sampling weights. To ensure measurement of CRP as a biomarker of chronic inflammation rather than acute inflammation in response to infection, our sample was further restricted to individuals who report no symptoms of infection, including cold or flu-like symptoms, fever, night sweats, nausea/vomiting/diarrhea, and/or frequent urination, in
the two weeks prior to biomarker specimen collection (McDade et al. 2014). Among the 9,421 respondents with valid sampling weights, 2,993 were excluded for reporting potential acute inflammation. Our analytical sample size was therefore 6,428 individuals. Sampling weights were used in all analyses to account for study design effects and to correct for differential attrition across waves. All item-level missingness was estimated through full information maximum likelihood (FIML) estimation techniques, as described below.

Measures

Univariate descriptive statistics for independent and dependent variables, mediating variables, and sociodemographic covariates are presented in Table 1.

< Table 1 approximately here >

Inflammation. The dependent variable in all analyses was inflammation, as measured by a marker of inflammation, C-reactive protein (CRP). Respondents in Wave IV were asked to provide a biological specimen sample that was analyzed for a host of biomarker levels, including CRP (Whitsel et al. 2012). A continuous variable was used to analyze CRP level, ranging upwards from 0.08 mg/L. Respondents were not included in the sample if they reported recent symptoms of infections, in order that CRP level reflect chronic (rather than acute) inflammation. The American Heart Association and Centers for Disease Control and Prevention (CDC) classify levels of CRP greater than 3 mg/L as high, and approximately 37% of the study sample had CRP levels that classified as such.

Breastfeeding. During the Wave I in-home parent interviews, parents reported the duration of time that the respondent was breastfed as an infant. Although these reports rely on retrospective report, maternal recall of the initiation and duration of breastfeeding is considered valid and reliable (Li, Scanlon, and Serdula 2005). A nominal variable was created to indicate
breastfeeding duration (0 = never, and 5 = 12 months or more), with each unit increase representing an additional three months of an infants’ breastfeeding. Respondents that were never breastfed as infants receive a score of zero. In all analyses, therefore, breastfeeding refers not only to whether or not the respondent was breastfed, but also to the duration of breastfeeding the individual experienced.

*Overweight status.* Self-reported height and weight at Waves I, II, and III were used to calculate body mass index (BMI) for each time point using the formula: \([\text{weight (kg)}]/[\text{height (m)}]^2\). The CDC sets thresholds for overweight and obesity based on BMI. For adolescents, overweight individuals are defined as having a BMI at or above the 85th percentile for age and gender. For adults, overweight individuals are defined as having a BMI of 25.0 or higher. Using BMI, therefore, binary variables (1 = overweight) were created to capture overweight status at Waves I, II, and III. For Waves I and II, the CDC’s adolescent standards were used, and for Wave III, the CDC’s adult standards were used.

Analyses consider overweight status in two ways. First, the timing of being overweight is considered by testing point-in-time indicators of being overweight as potential mediators of the association between breastfeeding and inflammation. Waves I and II capture two time points of overweight status across adolescence, and Wave III considers overweight status during the transition into adulthood. Figure 1 illustrates this conceptualization of overweight status. Per Figure 1, pathway 1, pathway 2, and/or pathway 3 could mediate the association between breastfeeding and inflammation. By testing each pathway, we are therefore better understanding which specific timepoint(s) of overweight status mediates the association between breastfeeding and inflammation.

*Figure 1 approximately here*
Second, the cumulative path of overweight status is examined via the pathway linking overweight status at Wave I to overweight status at Wave II to overweight status in Wave III. This pathway, illustrated in Figure 2, thus speaks to a cascading process of overweight status across adolescence into young adulthood. Overweight status at Wave I may be associated with overweight status at Wave II, which is in turn associated with overweight status at Wave III. This cumulative pathway across time is therefore also considered as a mediator of the association between breastfeeding in infancy and inflammation in young adulthood.

Covariates. Several controls were measured to account for sociodemographic position and possible spuriousness: gender (1 = female), age, race/ethnicity (non-Hispanic white, non-Hispanic black, non-Hispanic Asian, Hispanic, other/multi-racial), family structure (1 = lived with both biological parents at Wave I, 0 = other family form), family income at adolescence, and parent education (an ordinal variable ranging from 1, less than high school, to 5, post-college degree). Breastfeeding is not exogenous to parent’s education, however, and we therefore accounted for the link between parents’ education and breastfeeding in all analyses. Respondents’ birth weight was also a covariate in all analyses (deRosset and Strutz 2015).

Analytical Strategy

The primary goal of this study was to assess the mediation of the association between breastfeeding in infancy and inflammation in early adulthood by overweight status and determine how socioeconomic status conditions the mediated pathway. To address this goal, analyses were performed in three steps. The first step was to test the association between breastfeeding and inflammation (Model 1), confirming previous research showing that the longer an infant is breastfed, the lower their CRP levels are expected to be (e.g., McDade et al. 2014). The second
step was to introduce overweight status in a regression framework to evaluate the attenuation of
the association between breastfeeding and inflammation by overweight status. The third and
focal step was to test both direct and indirect pathways between breastfeeding and inflammation
in a structural equation framework. The mediation analyses highlight the significant pathways
between breastfeeding and inflammation through overweight status at Waves I, II, and III, testing
direct and indirect effects in a single model using path analysis. This method is preferred to
Baron and Kenny’s (1986) causal steps approach because a single model allows for a non-
significant correlation between the predictor and the outcome when testing indirect effects.
Indirect effects were tested using the Delta method and confirmed with Sobel tests.

Regression and mediation models were estimated using path analysis in a structural
equation framework in the statistical software program Mplus (Muthén and Muthén 2006).
FIML estimated exogenous variance for missingness, so that all cases in the sample were
retained even if they had missing data on individual variables. We also employed the cluster
feature in Mplus to account for students being nested within schools in the sampling frame, as
well as the longitudinal sampling weight to address differential probability of being included in
the frame and differential cross-wave attrition from the sample.

Results

Breastfeeding, Weight Status, and Inflammation

To test the general hypothesis of the mediation of the association between breastfeeding
and inflammation by weight status, a necessary first step was to examine the direct pathway
between breastfeeding and inflammation. Table 2 presents the direct pathway (Model 1), and
confirms the findings of previous researchers (i.e., McDade et al. 2014) that the longer an
individual is breastfed, the lower are their expected levels of CRP (standardized $b = -.072$; $p < .001$). This model is depicted graphically in Figure 3. The model also accounts for the impact of parents’ education on breastfeeding, and finds that higher educational attainment of parents is associated with longer duration of breastfeeding (standardized $b = .290$; $p < .001$).

Approximately 5% of the variance in CRP levels was explained in Model 1.

The next step of our analyses was to test whether overweight status acts as a mechanism linking breastfeeding in infancy to inflammation in early adulthood. Indeed, Model 2 of Table 2 shows that, when overweight status across adolescence into young adulthood is accounted for, the association between breastfeeding and inflammation is slightly attenuated, although still significant (standardized $b = -.059$; $p < .001$).

To further elucidate the indirect pathways through which breastfeeding acts on inflammation through overweight status and thereby address the primary question of this study, we proceeded to test the mediation of the relationship between breastfeeding and inflammation by overweight status in a single model, evaluating direct and indirect effects.

As shown in Figure 4, we confirmed that the direct pathway between breastfeeding and inflammation remained significant (standardized $b = -.050$; $p < .001$). Indirect pathways, however, also emerged. First, longer duration of breastfeeding was associated with lower likelihood of being overweight at Wave III (standardized $b = -.067$; $p < .001$); in turn, being overweight at Wave III was associated with higher levels of CRP in early adulthood (standardized $b = .116$; $p < .001$). Proximate overweight status --- being overweight during the
transition into adulthood (Wave III) --- is therefore a partial mediator of the association between breastfeeding and inflammation, controlling for overweight status earlier in the life course. Second, longer duration of breastfeeding was associated with lower odds of being overweight at Wave I (standardized $b = -.063; p < .001$); overweight status at Wave I, in turn, was associated with higher likelihood of being overweight at Wave II (standardized $b = .704; p < .001$), which was associated with higher likelihood of being overweight at Wave III (standardized $b = .517; p < .001$). Finally, being overweight at Wave III was significantly associated with higher CRP levels in early adulthood (standardized $b = .116; p < .001$). A pathway of overweight status across a significant part of the life course, therefore, stood out as an important mediator of the association between breastfeeding and inflammation. Breastfeeding is linked to overweight status in Wave I, which predicts overweight status across adolescence into adulthood, thereby impacting inflammation levels in early adulthood. Using the Delta method to test indirect effects, results indicated that overweight status at Wave III significantly mediated the association at $p < .05$, whereas the pathway of overweight status at Wave I to Wave II to Wave III mediated the association at $p < .01$. We confirmed significance of indirect effects with Sobel tests. The protective nature of breastfeeding against CRP, therefore, partially acts through the protective nature of breastfeeding against overweight status across the life course. No evidence of full mediation emerged for the indirect paths, however, as the direct path remained significant ($p < .001$). Overall, approximately 8% of the variance in CRP levels in early adulthood was explained in Model 2. As in all models, moreover, Model 2 accounts for the impact of parents’ education on breastfeeding, and finds that higher educational attainment of parents is associated with longer duration of breastfeeding (standardized $b = .278; p < .001$).
In sum, overweight status partially mediates the association between breastfeeding and inflammation, and two significant indirect pathways emerged. First, longer duration of breastfeeding is associated with lower likelihood of being overweight during the transition to adulthood (Wave III), which protects against increased CRP levels in early adulthood. This pathway highlights the importance of proximal timing of overweight status. Second, longer duration of breastfeeding is associated with lower likelihood of being overweight in early adolescence, which is associated with lower likelihood of being overweight in later adolescence, which translates to lower likelihood of being overweight during the transition to adulthood, which, in turn, protects against increased CRP levels in early adulthood. This second pathway highlights the importance of considering the cascade of overweight status across the life course.

**Discussion**

Inflammatory processes find their root in early life exposures, linking disadvantage across childhood into adulthood. Life course approaches emphasize the longer-term implications of early life experiences with later life health outcomes, which, in the case of inflammation, means considering how processes in infancy relate to inflammatory responses throughout different stages of the life course. Such an approach can elucidate how experiences in infancy get under the skin and promote (or hinder) healthy status (i.e., low levels of inflammatory markers) in adulthood. Breastfeeding in infancy is associated with incredible short- and long-term health benefits (e.g., Horta and Victoria 2013), including lower levels of inflammation in early adulthood (McDade et al. 2014). Working from a life course approach, therefore, we tested one potential mechanism (overweight status) relating breastfeeding in infancy and inflammation in
early adulthood, and examined how these pathways varied by socioeconomic status, ultimately informing how social and biological processes across the life course influence health disparities.

We found that overweight status partially mediated the association between breastfeeding in infancy and inflammation in early adulthood. Increased duration of breastfeeding was associated with protection against being overweight, which in turn, protected against elevated inflammatory biomarkers in early adulthood. Furthermore, the mediation was particularly salient for individuals who were overweight during the transition from adolescence into adulthood and for individuals who experienced being overweight across multiple life course stages. This pattern is very consistent with the concept of the “dynamic effect of early conditions” introduced by Salsberry and Reagan (2005). They argue that although early conditions such as breastfeeding may influence weight status in a temporally proximate way, early conditions may also independently influence weight status later in childhood by changing the probability of moving between weight states in later periods, conditional on prior weight.

Extending past research on the origins of health disparities through a life course lens allows us to probe mechanisms relating breastfeeding in infancy to inflammation in early adulthood and explain when and how overweight status mediates this pathway. Ultimately, however, three themes arise from the findings of this study that raise more questions, and consequently, call for future research. One such theme that emerged from our findings was the importance of considering overweight status as a life course process. By operationalizing overweight status over the life course, we were able to capture weight as a dynamic process that unfolds throughout development. We evaluated weight in adolescence and across the transition to adulthood, and confirmed two important indirect pathways of through which breastfeeding in infancy was related to inflammation in young adulthood. These pathways are not surprising,
given that overweight status in adolescence has been significantly associated with adult overweight status in past research (Harris 2010). Our findings thus confirm the necessity of a life course approach to weight. In our conceptualizations, however, we did not consider measures of early childhood weight status given data limitations. Early childhood weight status, though, has significant implications for weight across the life course (Nader et al. 2006), and overweight children are likely on trajectories that compound and magnify their exposure to being overweight. In picking up weight status in adolescence and following it through the transition into adulthood, we could therefore be missing an important component of both the timing and cumulative pathway of being overweight---early childhood. Future research should thus extend conceptualization of weight as a mediator between breastfeeding and inflammation by examining the extent to which early childhood weight determines how this mediation pathway unfolds.

Another emergent theme of this study consistent with past research is that pathway analyses supported breastfeeding as endogenous to socioeconomic status. Indeed, initiation and duration of breastfeeding are highly determined by socioeconomic status, particularly maternal education (Singh, Kogan, and Dee 2007; Scott and Binns 1999). Future research considering the relation between breastfeeding and inflammation should therefore do so in light of a more comprehensive environment that can directly and indirectly promote each of these sociobiological processes. Environmental challenges of the home, such as hygiene, presence of toxins, and cleanliness, or stressful and traumatic experiences that illicit biological responses, for example, could increase the salience of the tested pathways and are variable by socioeconomic status (Evans and Kantrowitz 2002). A more detailed look at family of origin and household measures during infancy, childhood, and adolescence would allow for a deeper comprehension
of how environments not only impact initiation and duration of breastfeeding, but also combine with breastfeeding to protect against inflammation or, conversely, stimulate inflammation.

A final issue sparked by this research is that breastfeeding impacts inflammation in direct and indirect ways, as was hypothesized by McDade and colleagues (2014) in their analyses of how birth weight and breastfeeding duration are related to CRP. Indirect pathways, or mechanisms relating these processes, are just beginning to be understood. Certainly, as the results of this study show, overweight status across the life course is one part of the story. Other mechanisms, however, are undoubtedly working in tandem with weight status, and this study is just a first pass at production of a better understanding of these complicated processes. Immune function, for example, may be another mechanism that is promoted by breastfeeding (Hanson 1998) and shapes inflammation throughout the life course (McDade 2012). Future work, therefore, should continue to unpack how breastfeeding gets under the skin, how inflammation has origins in early life exposure, and how these processes intertwine across the life course.

In conclusion, a life course approach to health disparities stresses that social and biological exposures in childhood have implications for later-life health and well-being (Montez and Hayward 2011). Using this approach to disentangle the roots of inflammation highlight how life course experiences promote inflammatory processes. Focusing on the association between breastfeeding and inflammation specifically allows us to drill into the mechanisms linking infant experiences to adult health outcomes. Elucidating socioeconomic differences, moreover, provides deeper knowledge on vulnerable populations. From a public health perspective, the importance of this research is threefold. First, understanding the early life origins of inflammation can help advocate for early intervention. Second, increasing knowledge about the benefits of breastfeeding and the ways breastfeeding influences later-life health outcomes can
further support movements to increase the prevalence of breastfeeding, especially among subgroups of the population for whom direct and indirect pathways linking breastfeeding to inflammation are most salient. Third, given the importance of overweight status at each time considered, our research suggests that interventions targeting weight at any point from adolescence across the transition to adulthood would be beneficial in suppressing the negative implications that being overweight has for inflammation. In conclusion, expanding our knowledge on the association between breastfeeding and inflammation and how overweight status is an indirect mechanism linking these experiences, we highlight how experiences and exposures across the life course compound and accumulate to impact biological processes such as inflammation.
References


Danese, Andrea, Terrie E. Moffitt, HonaLee Harrington, Barry J. Milne, Guilherme Polanczyk, Carmine M. Pariante, Richie Poulton, and Avshalon Caspi. 2009. “Adverse Childhood Experiences and Adult Risk Factors for Age-Related Disease: Depression, Inflammation,


McDade, Thomas W., Molly M. Metzger, Laura Chyu, Greg J. Duncan, Craig Garfield, and Emma K. Adam. 2014. “Long-term effects of birth weight and breastfeeding duration on


Table 1. Univariate descriptive statistics, full sample ($n = 6,428$)

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<th>Category</th>
<th>Mean</th>
<th>SD</th>
<th>Frequency</th>
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Table 2. Regression analysis of breastfeeding, overweight status, and inflammation on CRP levels.

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<td>-0.059 ***</td>
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<td></td>
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<td>(0.014)</td>
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<td></td>
<td></td>
<td>(0.034)</td>
</tr>
<tr>
<td>Overweight WII</td>
<td>0.080 **</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.031)</td>
</tr>
<tr>
<td>Overweight WIII</td>
<td>0.144 ***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.015)</td>
</tr>
<tr>
<td><strong>Covariates</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>0.167 ***</td>
<td>0.190 ***</td>
</tr>
<tr>
<td></td>
<td>(0.019)</td>
<td>(0.020)</td>
</tr>
<tr>
<td>Age</td>
<td>0.033</td>
<td>0.025</td>
</tr>
<tr>
<td></td>
<td>(0.021)</td>
<td>(0.021)</td>
</tr>
<tr>
<td>Adolescent family income</td>
<td>-0.030 *</td>
<td>-0.019 +</td>
</tr>
<tr>
<td></td>
<td>(0.014)</td>
<td>(0.011)</td>
</tr>
<tr>
<td>Birth weight</td>
<td>0.006</td>
<td>-0.014</td>
</tr>
<tr>
<td></td>
<td>(0.015)</td>
<td>(0.016)</td>
</tr>
<tr>
<td>Two biological parent household</td>
<td>0.004</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>(0.018)</td>
<td>(0.017)</td>
</tr>
<tr>
<td>Parent's education</td>
<td>-0.015</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>(0.017)</td>
<td>(0.016)</td>
</tr>
<tr>
<td>Race/ethnicity (ref: non-Hispanic white)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Hispanic black</td>
<td>0.081 **</td>
<td>0.063 *</td>
</tr>
<tr>
<td></td>
<td>(0.025)</td>
<td>(0.026)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>0.012</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>(0.014)</td>
<td>(0.014)</td>
</tr>
<tr>
<td>Asian</td>
<td>-0.046 ***</td>
<td>-0.043 ***</td>
</tr>
<tr>
<td></td>
<td>(0.009)</td>
<td>(0.010)</td>
</tr>
</tbody>
</table>

Note: n = 6,428; standardized beta coefficients shown; + p < .10, * p < .05, ** p < .01, *** p < .001
Figure 1. Conceptual model to test the timing of overweight status.
Figure 2. Conceptual model to test the cumulative pathway of overweight status.
Figure 3. Model 1, the direct effect of breastfeeding on inflammation.

Note: \( n = 6,428 \). Dashed lines represent insignificant pathways. Standardized coefficients shown. * \( p < .05 \), ** \( p < .01 \), *** \( p < .001 \). Model controls for gender, age, race/ethnicity, family structure, parents’ education, family income in adolescence, and birth weight. Covariate effects are not depicted. \( R^2 \) for inflammation = 0.049.
Figure 4. Model 2, mediation of the association between breastfeeding and inflammation by timing of overweight status.

Note: $n = 6,428$. Dashed lines represent insignificant pathways. Standardized coefficients shown. * $p < .05$, ** $p < .01$, *** $p < .001$. Model controls for gender, age, race/ethnicity, family structure, parents’ education, family income in adolescence, and birth weight. Covariate effects are not depicted. $R^2$ for inflammation = 0.082.