Published in final edited form as:
Int J Pediatr Obes. 2011 June ; 6(0): e415–e422. doi:10.3109/17477166.2010.524700.

IS THE ASSOCIATION OF BREASTFEEDING WITH CHILD OBESITY EXPLAINED BY INFANT WEIGHT CHANGE?

Lenie van Rossem, MSc[a,b], **Elsie M. Taveras, MD, MPH**[c,d], **Matthew W. Gillman, MD SM**[c,e], **Ken P. Kleinman, ScD**[c], **Sheryl L. Rifas-Shiman, MPH**[c], **Hein Raat, MD PhD**[b], and **Emily Oken, MD, MPH**[c]

[a]The Generation R Study Group, Erasmus MC-University Medical Centre Rotterdam, Dr. Molewaterplein 50, 3015 GE, Rotterdam, the Netherlands [b]Department of Public Health, Erasmus MC-University Medical Centre Rotterdam, Dr. Molewaterplein 50, 3015 GE, Rotterdam, the Netherlands [c]Obesity Prevention Program, Department of Population Medicine, Harvard Pilgrim Health Care Institute and Harvard Medical School, 133 Brookline Ave, Boston, MA 02215 [d]Center for Child Health Care Studies, Department of Population Medicine, Harvard Pilgrim Health Care Institute and Harvard Medical School, 133 Brookline Ave, Boston, MA 02215 [e]Department of Nutrition, Harvard School of Public Health, Boston, Massachusetts

Abstract

Objective—Breastfeeding and infant weight change are both associated with adiposity. We examined the extent to which infant weight change mediates the association between breastfeeding and adiposity at age 3 years.

Methods—We studied 884 children in a prospective cohort study. We determined breastfeeding status at 6 months. Our primary outcomes at 3 years were body mass index (BMI) *z* score and the sum of subscapular and triceps skinfold thicknesses (SS + TR); we also assessed obesity. We defined infant weight change as change in weight-for-age *z* score between birth and 6 months. We performed multivariable regression analyses.

Results—At age 6 months, 25.0% of infants were fully breastfed. At age 3 years, mean (SD) BMI *z* score was 0.45 (1.03). In linear regression analyses adjusted for mother's educational level, race/ethnicity, smoking, BMI, pregnancy weight gain and birth weight (adjusted for gestational age), the BMI *z* score of fully breastfed children was 0.17 (95% CI:−0.43, 0.09) units lower than never breastfed children. After additional adjustment for infant weight change, the estimate was attenuated (−0.03, 95% CI: −0.27, 0.20). Adjustment for infant weight change only modestly attenuated estimates for SS + TR (from −1.48 (95% CI: −2.52, −0.44) to −1.16 mm (95% CI: −2.18, −0.14)), and for the odds of being obese (from 0.21 (95% CI: 0.07, 0.68) to 0.29 (95% CI: 0.08, 1.05)).

Conclusion—Infant weight change between birth and 6 months mediates associations of breastfeeding with BMI, but only partially with indicators of child adiposity.

Keywords

body mass index; breastfeeding; infant weight change; obesity; overweight

Corresponding author: L. van Rossem, MSc, The Generation R Study Group, Erasmus MC-University Medical Centre Rotterdam, PO BOX 2040 (Room Ae-003), 3000 CA Rotterdam, the Netherlands, l.vanrossem@erasmusmc.nl, Telephone: +31 10 704 34 05 Fax: +31 10 704 46 45.

Conflict of Interest: None

INTRODUCTION

Several reviews and meta-analyses of observational studies have concluded that breastfeeding protects against the development of overweight and obesity.(1–4) However, the mechanisms underlying the protective effect of breastfeeding on obesity are unclear. One of the proposed mechanisms is behavioral. Breastfed children may have learned better to self-regulate their energy-intake than formula-fed children.(5–6) However, in a previous study we did not find a strong mediating effect of maternal feeding restriction on the association between breastfeeding and adiposity.(7)

Another proposed mechanism involves infant growth rate: infants who gain weight more rapidly have a higher risk for developing obesity, an association that has been reported in a number of observational studies over the past 4 decades and summarized in recent meta-analyses(8–11). Breast-fed children generally grow slower during infancy.(12) Many studies have looked at infant feeding or infant growth in relation to adiposity, but few have been able to separate the two effects. The aim of the present study was to examine the extent to which infant weight change mediates the association between breastfeeding and adiposity. We hypothesized that the association of breastfeeding with adiposity at age 3 years would be attenuated by adjusting for infant weight change in the first 6 months after birth.

METHODS

Study Design and Participants

Study subjects were participants in Project Viva, a prospective, observational cohort study of perinatal factors and maternal and child health.(13) We recruited women who were attending their initial prenatal visit at one of 8 urban and suburban obstetrical offices of a multi-specialty group practice located in eastern Massachusetts between April 1999 and July 2002. Details of recruitment and retention procedures are available elsewhere.(13)

Of the 2 128 women who delivered a live infant, 1 579 were eligible for 3-year follow up by virtue of having completed prenatal nutritional assessments and consenting for their children to be followed up. We collected follow-up information on 1 405 children (66% of 2 128), including in-person examinations on 1 294 (61%). For this analysis, we excluded 36 participants who were missing the main outcome (child body mass index [BMI] at age 3 years) and 325 participants who were missing the main exposure (breastfeeding status at six months) or mediator (change in weight-for-age *z* score between birth and 6 months). We excluded 15 infants whose gestational age at birth was <34 weeks, as well as those with missing information on maternal BMI (n=4), smoking status (n=19), education (n=1), and pregnancy weight gain (n=10). Thus, our study population consisted of 884 mother-infant pairs.

Compared with those lost to follow-up, included mothers were slightly older at study enrollment (32.7 years vs. 31.2 years), had higher educational attainment (74% vs. 58% completed college), and had a slightly lower pre-pregnancy BMI (24.4 kg/m^2 vs. 25.2 kg/m^2). More included than excluded children received full breastfeeding for 6 months (25% vs. 17%).

The human subjects committees of participating institutes approved the study protocols and all mothers provided written informed consent. All procedures were in accordance with the ethical standards for human experimentation established by the Declaration of Helsinki.

Measurements

Main exposures—Our main exposure was type of infant feeding during the first 6 months of life, which we assessed by interview at 6 months postpartum. We grouped women into 4 categories: 'never breastfed' (mothers who had fed their infants only formula since birth), 'any breastfeeding for less than 6 months' (mothers who had initiated breastfeeding, but discontinued it completely before 6 months), 'any breastfeeding for 6 months' (mothers who had fed both breastmilk and formula at 6 months after birth), and 'full breastfeeding for 6 months' (mothers who fed their infant only breastmilk during the first six months after birth: this category includes both predominantly and exclusive breastfeeding(14)). We did not consider solids or liquids other than breastmilk and formula when defining these categories.

A secondary exposure was a continuous measure of breastfeeding duration. At 1 year postpartum, we asked the women who reported that they had breastfed their infants the following: "How old was your child when you stopped breastfeeding?" We truncated breastfeeding duration at 6 months to correspond to our hypothesized mediator, infant weight change between birth and 6 months of age.

Outcome measures—Trained Project Viva research assistants weighed children at 3 years with a digital scale (model 881; Seca, Hamburg, Germany) and measured height with a Shorr measuring board (Shorr Productions, Olney, MD). They measured skinfold thicknesses by using Holtain calipers (Holtain, Crosswell, United Kingdom). Research assistants performing all measurements followed standardized techniques and participated in bi-annual in-service training to ensure measurement validity. We calculated BMI *z* scores using US national reference data (www.cdc.gov/nccdphp/dnpa/growthcharts).(15)

Our main outcomes at 3 years of age were age- and sex-specific BMI *z* score, and the sum of subscapular and triceps skinfold thicknesses, a measure of subcutaneous adiposity (SS + TR).(16) We used obesity, defined as BMI for age and sex $\geq 95^{th}$ percentile, as a secondary outcome in the analyses. We used BMI 5^{th} – 85^{th} percentile as the comparison. We also showed obesity prevalence according to the classification of the International Obesity Task Force.(17)

Mediator—We used the change in weight-for-age *z* score from birth to 6 months as an indicator of infant weight change. We used *z* scores because these measures can be interpreted independently of sex and age. We abstracted birth weight from hospital medical records. Project staff members weighed infants at 6 months and, on a subset, measured length at birth and 6 months of age as described above. We calculated weight-for-age *z* scores at birth and 6 months by using US national reference data.(15)

Other measures—Through a combination of questionnaires and interviews, we obtained information on mother's age, educational level, race/ethnicity, and smoking status during pregnancy. Mothers reported their pre-pregnancy body weight and height which we used to calculate BMI. We calculated total pregnancy weight gain by subtracting self-reported pre-pregnancy weight from the last clinically-measured prenatal weight. We determined birth weight for gestational age *z* score using a US national reference.(18)

Statistical Analyses

In bivariate analyses, we assessed characteristics of participants by breastfeeding status at 6 months. To calculate unadjusted trend *P* values across breastfeeding categories, we used Mantel-Haenszel Chi-Square for categorical characteristics and linear regression for continuous characteristics, with breastfeeding categories coded as 1 to 4.

Using multivariable linear and logistic regression, we assessed the effect of breastfeeding on child adiposity measures at age 3 years independent of covariates. In our model building strategy, we first included variables of a priori interest based on previously identified associations with early childhood obesity(19–20) namely maternal smoking, pre-pregnancy BMI, gestational weight gain, and educational level, which we used as an indicator of socioeconomic position, and birth weight adjusted for gestational age. We also included mother's race/ethnicity as it is associated with both breastfeeding and adiposity. Then we added each other possible confounder separately to that model. We considered country of birth, marital status, and maternal age at enrollment, but none of these covariates changed the estimates, and were therefore not included in the analyses. We entered covariates as continuous variables in the models, except for sex (male, female), educational level (less than high school, some college, BA/BS, graduate school), smoking status (never, former, during pregnancy), race/ethnicity (white, black, Hispanic, other). We report 3 models in this paper. In model 1 we report the association between breastfeeding and adiposity adjusted for child's sex and age at outcome assessment. Model 2 is additionally adjusted for maternal educational level, race/ethnicity, smoking status during pregnancy, prepregnancy BMI, and pregnancy weight gain, and birth weight adjusted for gestational age. In model 3 we added the mediator infant weight change. We report regression estimates (β) or odds ratios (OR) and 95% confidence intervals (CI) for the main predictors. We conducted all analyses with SAS 9.1 (SAS Institute, Cary, NC).

RESULTS

Sample characteristics

Participant characteristics are summarized in Table 1. At 6 months postpartum, 9.2% of mothers had never breastfed fed their infants, whereas 25.0% had fed their infants breastmilk with no formula (Table 1). Mean (SD) duration of any breastfeeding was 4.3 (2.3) months. At age 3 years, mean (SD) child BMI *z* score was 0.45 (1.03) units, sum of subscapular plus triceps skinfold thicknesses was 16.7 (4.0) mm, 3.4% of children were obese according to the definition of the IOTF, this was 9.2% according to the criteria of the CDC (Table 1).

Associations of breastfeeding and infant weight change with adiposity measures

Whereas weight-for-age *z* score increased between birth and 6 months for both never breastfed infants (mean increase 0.43 [SD 0.94] units) and infants that were breastfed for less than 6 months (0.49 [SD 1.03]), fully breastfed infants hardly changed in weight-for-age *z* score (−0.03 [SD 1.07]) (Table 1). On unadjusted analyses, for each unit increase in weight-for-age *z* score between birth and 6 months, age 3 year BMI *z* score increased by 0.24 units (95% CI 0.18, 0.30), SS + TR increased by 0.57 mm (95% CI 0.32, 0.81), and the odds ratio for obesity was 2.05 (95% CI 1.62, 2.60).

Compared to never breastfed children, mean BMI *z* score at 3 years was lower in fully breastfed children (β = −0.27, [95% CI −0.53, −0.01]) and children that were given any breastfeeding for 6 months (β = −0.31, [95% CI −0.57, −0.05]), but did not differ for children that were given breastfeeding for less than 6 months (β = 0.03, [95% CI −0.22, 0.27]). Compared with never breastfed children, the prevalence of obesity was lower in the fully breastfed children group (OR = 0.14, [95% CI 0.04, 0.41]), but not in the children that were given any breastfeeding for less than 6 months or for 6 months (Table 2, model 1). SS + TR showed a similar pattern as BMI *z* score (Table 2, model 1).

Multivariable estimates were attenuated slightly after adjustment for confounders: BMI *z* score (β = −0.17 units, [95% CI −0.43, 0.09]); SS + TR (β = −1.48 mm, [95% CI −2.52,

−0.44]). Children who received any breastfeeding for 6 months also had somewhat lower BMI *z* score and lower SS + TR than never breastfed infants (Table 2, model 2). When we considered breastfeeding duration as a continuous measure, for each month that a child was breastfed until age 6 months, the decrement in BMI *z* score was 0.04 units (95% CI −0.07, −0.01) and the decrement in SS + TR was 0.19 mm (95% CI −0.31, −0.07) (Table 3). For each month that a child was breastfed, odds of being obese was reduced by 14% (95% CI 6–22%).

Mediating effect of Infant Weight Change

After we added infant weight change to the multivariable model, effect estimates for BMI *z* score were attenuated among fully breastfed children (from β= −0.17, [95% CI −0.43, 0.09] to β= −0.03, [95% CI −0.27, 0.20]) and children that were given any breastfeeding for 6 months (from β= −0.20, [95% CI −0.46, 0.05] to β= −0.06, [95% CI −0.29, 0.17] (Table 2, model 3), each compared with never breastfed children. The odds ratio for obesity among fully breastfed children was modestly attenuated after we added infant weight change to the model (from OR = 0.21, [95% CI 0.07, 0.68] to OR = 0.29, [95% CI 0.08, 1.05]), as was the estimate for SS + TR (from β= −1.48, [95% CI −2.52, −0.44] to β= −1.16, [95% CI −2.18, −0.14]). Infant weight change was an independent predictor of all adiposity measures (Table 2).

Considering breastfeeding duration, estimates for BMI *z* score for each month that a child was breastfed were attenuated (from β= −0.04, [95% CI −0.07, −0.01] to β= −0.01, [95% CI −0.04, 0.02]) after we added infant weight change to the multivariate model (Table 3). Estimates for SS + TR attenuated from β= −0.19 (95% CI −0.31,−0.07) to β= −0.13 (95% CI −0.25, −0.01) (Table 3), and adiposity attenuated from OR=0.93 (95% CI 0.79–1.10) to OR=0.99 (95% CI 0.83–1.18).

We saw similar results when we adjusted for change in weight for length (data not shown).

DISCUSSION

In this longitudinal study of over 800 infants in the US, we found that breastfeeding until 6 months of age was associated with a lower BMI *z* score, lower skinfold thicknesses, and lower odds of obesity at age 3 years. Infant weight gain was a strong independent predictor of these outcomes and fully mediated the associations of breastfeeding with BMI *z* score, but only partially with sum of skinfold thicknesses and odds of being obese.

Our finding that breastfeeding in the first 6 months of life is associated with lower adiposity at age 3 years is consistent with a large body of epidemiologic evidence summarized in recent systematic reviews and meta-analyses.(1, 3–4) However, one review(21) concluded that the association between breastfeeding and mean BMI is likely to be confounded by socio-economic status, maternal smoking and maternal BMI. Also, a large breastfeeding promotion intervention trial did not find a protective effect of breastfeeding on obesity.(22) It should be noted that this trial included only mothers that initiated breastfeeding and thus evaluated the consequences of longer breastfeeding duration, not the effects of breastfeeding relative to formula feeding. Residual confounding by lifestyle-related factors may explain the association between breastfeeding and obesity.

However, several behavioral and biological mechanisms have been proposed to explain the observed protective effect of breastfeeding on future obesity.(5–6, 23) There is some support for the mechanisms in animal data, but there is a lack of experimental data in humans to support mechanistic hypotheses.(24) First, whereas formula fed children may be encouraged to take in more or less volume than they would otherwise, breastfed children may better

NIH-PA Author Manuscript
NIH-PA Author Manuscript

learn to self-regulate their energy intake by internal satiety cues. This enhanced self-regulation may persist beyond the breastfeeding period. Second, breastfed children may consume less protein than formula fed children. High protein intake in formula fed children may lead to higher insulin levels which subsequently stimulate greater adipose tissue deposition.(25) Third, breastfed children may be differently exposed to leptin, a hormone contained in breastmilk but not formula.(6) Breastmilk leptin may influence growth in infants.(23)

Few studies(26) have examined whether early infant weight change may mediate the observed relationship between breastfeeding and obesity. Breastfeeding may lead to less infant weight gain which in turn may lead to lower adiposity. Scholtens *et al.*(26) found that mean BMI and overweight prevalence at 7 years of age were lower among breastfed children. However, adjustment for BMI at 1 year of age attenuated the observed associations (from $\beta = -0.12$, 95% CI: [−0.34, 0.10] to $\beta = -0.01$, 95% CI [−0.22, 0.19] for children who were breastfed for at least 16 weeks compared to never breastfed children).(26) In our study, breastfeeding was still associated with SS + TR and obesity with confidence limits that excluded the null value for SS + TR even after adjustment for infant weight gain from birth to 6 months. A first possible explanation is that obesity and SS + TR may reflect body fatness better than BMI, which incorporates both fat and lean mass.(27–28) This is in line with other studies that found breastfeeding associated with fat mass, but not with BMI.(29–30) Another possible explanation may be that infant weight change in the first 6 months after birth is more associated with lean mass than fat mass (31) and therefore mediates the association between breastfeeding and BMI, but not fully between breastfeeding and obesity. However, other studies have reported rapid infant weight gain to be mainly associated with fat mass.(32)

We did not find an effect of breastfeeding or infant weight change on central adiposity, measured as the subscapular to triceps skinfold ratio (data not shown).(33–34) Rapid infant weight gain has been found to be positively associated with central obesity among older children.(32, 35)

Strengths of this study included research standard measures of growth at ages 6 months and 3 years. We were able to use several indicators of adiposity including measurement of skinfold thicknesses. We assessed breastfeeding during infancy, before outcomes were assessed, minimizing the likelihood of bias, and we were able to account for a wide variety of important confounders. Self-reported information on breast-feeding duration is valid and reliable when recalled within 3 years.(36)

However, some limitations should be considered when interpreting the results. Although we accounted for measured confounders, residual confounding may remain. Thus, the protective effect of breastfeeding on overweight may be due to confounding or selection bias.(2, 21, 25) Also, the association between breastfeeding and infant weight change may be subject to reverse causality; mothers may choose to switch from breastfeeding to formula feeding if their infant is growing quickly and seems very hungry. Thus, those infants who grow slower were able to be exclusively breastfed for 6 months. On the other hand, it is also possible that mothers whose infants grow slower may discontinue breastfeeding, because they feel not confident that the baby is satisfied with breastfeeding only.(37) Furthermore, most of the measures were self-reported. However, we expect that any misclassification would have been nondifferential, and may therefore have attenuated the results. Lastly, adiposity is more accurately measured by methods such as dual-energy X-ray absorptiometry (DXA) or densitometry than by using BMI.(27)

We performed an in-person study visit during infancy only at age 6 months, and therefore we were not able to directly compare our results with other studies such as Stettler *et al.*.(38) It may be that another time period for infant weight change has a more relevant critical window. However, it should be noted that four months was also an arbitrary timepoint, as that was the age at which Stettler *et al* had data available. Further research with multiple research quality assessments of infant growth will be helpful in ascertaining the periods of growth during infancy that have the greatest influence of obesity risk. Also, it may be that weight-for-age is not the best measure of adiposity gain.

Fully breastfed children in our study may already have received complementary feeding before 6 months of age. Complementary feeding before 4 months of age may have an effect on developing adiposity.(39) We repeated our analyses with age of introduction of solids as a confounder, but results were similar (data not shown). We did not measure body composition at birth, which may be a stronger confounder than birth weight adjusted for gestational age. Loss to follow-up might have introduced selection bias, for example if non-participants fully breastfed their infants and these infants were more often overweight at age 3. Although children lost to follow-up were more often formula-fed, we have no evidence that they differ in weight status. Lastly, the mothers in this study may not fully represent the general population as they were generally well educated and all resided in Massachusetts.

Conclusion

Our findings suggest that infant weight change may be in the intermediate pathway between breastfeeding and later size. Because the attenuation of effect was only modest for indicators of adiposity, infant weight change does not appear to be the only mechanism by which breastfeeding protects against adiposity. Future research may search for additional pathways that explain the association between breastfeeding and obesity.

Acknowledgments

We thank all the participants and staff of Project Viva. LvR is supported by a grant from The Netherlands Organization for Health Research and Development (ZonMW), no. 7110.0002, and by a fund of the Trustfonds (Erasmus University Rotterdam, the Netherlands). Project Viva was supported by grants from the U.S. National Institutes of Health (HD 34568, HL 64925, HL 68041), and by the Harvard Pilgrim Health Care Foundation.

Abbreviations

BMI	body mass index
SS + TR	sum of subscapular and triceps skinfold thicknesses
OR	odds ratio
CI	confidence interval

REFERENCES

1. Arenz S, Ruckerl R, Koletzko B, von Kries R. Breast-feeding and childhood obesity--a systematic review. Int J Obes Relat Metab Disord. 2004 Oct; 28(10):1247–1256. [PubMed: 15314625]
2. Cope MB, Allison DB. Critical review of the World Health Organization's (WHO) 2007 report on 'evidence of the long-term effects of breastfeeding: systematic reviews and meta-analysis' with respect to obesity. Obes Rev. 2008 Nov; 9(6):594–605. [PubMed: 18554244]
3. Harder T, Bergmann R, Kallischnigg G, Plagemann A. Duration of breastfeeding and risk of overweight: a meta-analysis. Am J Epidemiol. 2005 Sep 1; 162(5):397–403. [PubMed: 16076830]

4. Owen CG, Martin RM, Whincup PH, Smith GD, Cook DG. Effect of infant feeding on the risk of obesity across the life course: a quantitative review of published evidence. Pediatrics. 2005 May; 115(5):1367–1377. [PubMed: 15867049]

5. Singhal A, Lanigan J. Breastfeeding, early growth and later obesity. Obes Rev. 2007 Mar; 8(Suppl 1):51–54. [PubMed: 17316302]

6. Dewey KG. Is breastfeeding protective against child obesity? J Hum Lact. 2003 Feb; 19(1):9–18. [PubMed: 12587638]

7. Taveras EM, Rifas-Shiman SL, Scanlon KS, Grummer-Strawn LM, Sherry B, Gillman MW. To what extent is the protective effect of breastfeeding on future overweight explained by decreased maternal feeding restriction? Pediatrics. 2006 Dec; 118(6):2341–2348. [PubMed: 17142517]

8. Baird J, Fisher D, Lucas P, Kleijnen J, Roberts H, Law C. Being big or growing fast: systematic review of size and growth in infancy and later obesity. BMJ (Clinical research ed. 2005 Oct 22.331(7522):929.

9. Monteiro PO, Victora CG. Rapid growth in infancy and childhood and obesity in later life--a systematic review. Obes Rev. 2005 May; 6(2):143–154. [PubMed: 15836465]

10. Ong KK, Loos RJ. Rapid infancy weight gain and subsequent obesity: systematic reviews and hopeful suggestions. Acta Paediatr. 2006 Aug; 95(8):904–908. [PubMed: 16882560]

11. Eid EE. Follow-up study of physical growth of children who had excessive weight gain in first six months of life. British medical journal. 1970 Apr 11; 2(5701):74–76. [PubMed: 5420235]

12. Nommsen-Rivers LA, Dewey KG. Growth of breastfed infants. Breastfeed Med. 2009 Oct 4. (Suppl 1):S45–S49. [PubMed: 19827923]

13. Gillman MW, Rich-Edwards JW, Rifas-Shiman SL, Lieberman ES, Kleinman KP, Lipshultz SE. Maternal age and other predictors of newborn blood pressure. J Pediatr. 2004 Feb; 144(2):240–245. [PubMed: 14760269]

14. Cattaneo, A. Definitions of breastfeeding recommended by WHO. EUPHIX EBR, <http://www.euphix.org> EUphact\ Determinants of health\ Health behaviours\ Breastfeeding. 2008 Apr 28.

15. [Accessed December 8, 2009] 2000 CDC Growth Charts: United States. Available at www.cdc.gov/nccdphp/dnpa/growthcharts/ [database on the Internet] [cited December 8, 2009]. Available from: www.cdc.gov/nccdphp/dnpa/growthcharts/sas.htm

16. Freedman DS, Mei Z, Srinivasan SR, Berenson GS, Dietz WH. Cardiovascular risk factors and excess adiposity among overweight children and adolescents: the Bogalusa Heart Study. The Journal of pediatrics. 2007 Jan; 150(1):12–17. e2. [PubMed: 17188605]

17. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ (Clinical research ed. 2000 May 6; 320(7244):1240–1243.

18. Oken E, Kleinman KP, Rich-Edwards J, Gillman MW. A nearly continuous measure of birth weight for gestational age using a United States national reference. BMC Pediatr. 2003 Jul 8.3:6. [PubMed: 12848901]

19. Dubois L, Girard M. Early determinants of overweight at 4.5 years in a population-based longitudinal study. Int J Obes (Lond). 2006 Apr; 30(4):610–617. [PubMed: 16570091]

20. Moschonis G, Grammatikaki E, Manios Y. Perinatal predictors of overweight at infancy and preschool childhood: the GENESIS study. Int J Obes (Lond). 2008 Jan; 32(1):39–47. [PubMed: 18059407]

21. Owen CG, Martin RM, Whincup PH, Davey-Smith G, Gillman MW, Cook DG. The effect of breastfeeding on mean body mass index throughout life: a quantitative review of published and unpublished observational evidence. Am J Clin Nutr. 2005 Dec; 82(6):1298–1307. [PubMed: 16332664]

22. Kramer MS, Matush L, Vanilovich I, et al. A randomized breast-feeding promotion intervention did not reduce child obesity in Belarus. J Nutr. 2009 Feb; 139(2):417S–421S. [PubMed: 19106322]

23. Bartok CJ, Ventura AK. Mechanisms underlying the association between breastfeeding and obesity. Int J Pediatr Obes. 2009; 4(4):196–204. [PubMed: 19922033]

24. Ozanne SE, Hales CN. Lifespan: catch-up growth and obesity in male mice. Nature. 2004 Jan 29; 427(6973):411–412. [PubMed: 14749819]
25. Koletzko B, von Kries R, Monasterolo RC, et al. Can infant feeding choices modulate later obesity risk? Am J Clin Nutr. 2009 May; 89(5):1502S–1508S. [PubMed: 19321574]
26. Scholtens S, Gehring U, Brunekreef B, et al. Breastfeeding, weight gain in infancy, and overweight at seven years of age: the prevention and incidence of asthma and mite allergy birth cohort study. American journal of epidemiology. 2007 Apr 15; 165(8):919–926. [PubMed: 17277294]
27. Freedman DS, Wang J, Ogden CL, et al. The prediction of body fatness by BMI and skinfold thicknesses among children and adolescents. Ann Hum Biol. 2007 Mar-Apr;34(2):183–194. [PubMed: 17558589]
28. Wells JC. A Hattori chart analysis of body mass index in infants and children. Int J Obes Relat Metab Disord. 2000 Mar; 24(3):325–329. [PubMed: 10757626]
29. Robinson SM, Marriott LD, Crozier SR, et al. Variations in infant feeding practice are associated with body composition in childhood: a prospective cohort study. J Clin Endocrinol Metab. 2009 Aug; 94(8):2799–2805. [PubMed: 19435826]
30. Toschke AM, Martin RM, von Kries R, Wells J, Smith GD, Ness AR. Infant feeding method and obesity: body mass index and dual-energy X-ray absorptiometry measurements at 9–10 y of age from the Avon Longitudinal Study of Parents and Children (ALSPAC). Am J Clin Nutr. 2007 Jun; 85(6):1578–1585. [PubMed: 17556696]
31. Victora CG, Sibbritt D, Horta BL, Lima RC, Cole T, Wells J. Weight gain in childhood and body composition at 18 years of age in Brazilian males. Acta Paediatr. 2007 Feb; 96(2):296–300. [PubMed: 17429924]
32. Chomtho S, Wells JC, Williams JE, Davies PS, Lucas A, Fewtrell MS. Infant growth and later body composition: evidence from the 4-component model. Am J Clin Nutr. 2008 Jun; 87(6):1776–1784. [PubMed: 18541568]
33. Deurenberg P, Pieters JJ, Hautvast JG. The assessment of the body fat percentage by skinfold thickness measurements in childhood and young adolescence. Br J Nutr. 1990 Mar; 63(2):293–303. [PubMed: 2334665]
34. Okosun IS, Liao Y, Rotimi CN, Dever GE, Cooper RS. Impact of birth weight on ethnic variations in subcutaneous and central adiposity in American children aged 5–11 years. A study from the Third National Health and Nutrition Examination Survey. Int J Obes Relat Metab Disord. 2000 Apr; 24(4):479–484. [PubMed: 10805505]
35. Wells JC, Chomtho S, Fewtrell MS. Programming of body composition by early growth and nutrition. Proc Nutr Soc. 2007 Aug; 66(3):423–434. [PubMed: 17637095]
36. Li R, Scanlon KS, Serdula MK. The validity and reliability of maternal recall of breastfeeding practice. Nutr Rev. 2005 Apr; 63(4):103–110. [PubMed: 15869124]
37. Kramer MS, Matush L, Bogdanovich N, et al. Health and development outcomes in 6.5-y-old children breastfed exclusively for 3 or 6 mo. Am J Clin Nutr. 2009 Oct; 90(4):1070–1074. [PubMed: 19710187]
38. Stettler N, Zemel BS, Kumanyika S, Stallings VA. Infant weight gain and childhood overweight status in a multicenter, cohort study. Pediatrics. 2002 Feb; 109(2):194–199. [PubMed: 11826195]
39. Wilson AC, Forsyth JS, Greene SA, Irvine L, Hau C, Howie PW. Relation of infant diet to childhood health: seven year follow up of cohort of children in Dundee infant feeding study. BMJ (Clinical research ed. 1998 Jan 3; 316(7124):21–25.

NIH-PA Author Manuscript
NIH-PA Author Manuscript

Table 1

Characteristics of 884 mother-infant pairs in Project Viva according to infant feeding method during 6 months after birth

		N	%	Breastfeeding (bf) dose/duration during 6 months (%)				*P* for trend
				Never breastfed *N*=81 (9%)	**Any bf <6 months** *N*=341 (39%)	**Any bf for 6 months** *N*=241 (27%)	**Full bf for 6 months** *N*=221 (25%)	
Maternal characteristics								
Age at enrollment (years)	*<25*	56	6	9	11	4	1	0.001
	25–35	550	62	63	60	63	64	
	≥35	278	31	28	29	33	35	
Educational level	*High school or less*	52	6	10	8	5	2	<0.0001
	Some college	177	20	40	25	13	12	
	BA/BS	328	37	35	40	37	33	
	Graduate school	327	37	16	26	45	52	
Race /ethnicity	*Black*	89	10	7	13	10	6	0.02
	Hispanic	46	5	5	6	7	2	
	Other	77	9	2	11	8	9	
	White	672	76	85	69	76	83	
Smoking during pregnancy	*Smoker*	82	9	14	15	6	3	0.04
	Former smoker	180	20	23	19	23	19	
	Never	622	70	63	66	71	68	
Prepregnancy BMI, kg/m^2	*< 25*	580	66	51	62	71	71	<0.0001
	25–30	195	22	31	23	18	22	
	≥ 30	109	12	19	16	11	6	
Excessive pregnancy weight gain (2009 Institute of Medicine category)		527	60	65	60	59	57	0.22
Child characteristics								
Male		442	50	49	50	51	50	0.83

		N	%	Breastfeeding (bf) dose/duration during 6 months (%)				*P* for trend
				Never breastfed ***N*=81 (9%)**	**Any bf <6 months** ***N*=341 (39%)**	**Any bf for 6 months** ***N*=241 (27%)**	**Full bf for 6 months** ***N*=221 (25%)**	
Birth weight-for-gestational age *z* score, mean (SD)		0.25 (0.93)		0.20 (0.95)	0.20 (0.93)	0.21 (0.93)	0.38 (0.91)	0.04
Change in weight-for-age *z* score between birth and 6 months, mean (SD)		0.24 (1.09)		0.43 (0.94)	0.49 (1.03)	0.05 (1.16)	−0.03 (1.07)	<0.0001
Age 3 anthropometric characteristics								
BMI *z* score, mean (SD)		0.45 (1.03)		0.58 (1.19)	0.61(1.01)	0.28 (1.10)	0.33 (0.86)	0.0003
BMI categories IOTF	*normal*	749	85	83	81	85	91	0.0008
	overweight	105	12	11	13	13	9 1	
	obese	30	3	6	5	2	91	
BMI percentiles	*< 5^{th}*	20	2	2	1	4	2	<0.0001
	5^{th}–85^{th}	632	71	63	69	74	76	
	85^{th}–95^{th}	151	17	21	18	12	19	
	≥ 95^{th}	81	9	14	12	10	2	
Skinfold thicknesses (mm, mean (SD)) Sum of subscapular and triceps		16.7 (4.0)		17.8 (4.5)	17.2 (4.2)	16.1 (3.9)	16.1 (3.5)	<0.0001

BMI = Body Mass Index

NIH-PA Author Manuscript
NIH-PA Author Manuscript

Table 2

Multivariable-adjusted estimates of adiposity measures at 3 years of age according to type of infant feeding during 6 months, among 884 mother-child pairs in Project Viva

	BMI *z* score (*N* = 884)		SS + TR (*N* = 843)		BMI >95th percentile[1] (*N* = 713)	
	β	*95% CI*	β	*95% CI*	β	*95% CI*
Model 1: adjusted for child's age and sex						
Never breastfed	ref (0.0)	ref	ref (0.0)	ref	ref (1.00)	ref
Any breastfeeding for less than 6 months	0.03	−0.22, 0.27	−0.56	−1.53, 0.40	0.80	0.39, 1.67
Any breastfeeding for 6 months	−0.31	0.57, −0.05	−1.68	−2.67, −0.68	0.61	0.28, 1.33
Full breastfeeding for 6 months	−0.27	0.53, −0.01	−1.61	−2.62, −0.59	0.14	0.04, 0.41
Model 2: model 1 + mother's educational level, race/ethnicity, smoking status during pregnancy, BMI, and pregnancy weight gain and birth weight adjusted for gestational age						
Never breastfed	ref (0.0)	ref	ref (0.0)	ref	ref (1.00)	ref
Any breastfeeding for less than 6 months	0.08	−0.16, 0.32	−0.33	−1.30, 0.63	0.90	0.40, 2.03
Any breastfeeding for 6 months	−0.20	−0.46, 0.05	−1.50	−2.52, −0.48	0.88	0.37, 2.10
Full breastfeeding for 6 months	−0.17	−0.43, 0.09	−1.48	−2.52, −0.44	0.21	0.07, 0.68
Model 3: model 2 + change in infant weight-for-age *z* score between birth and 6 months						
Never breastfed	ref (0.0)	ref	ref (0.0)	ref	ref (1.00)	ref
Any breastfeeding for less than 6 months	0.05	−0.17, 0.27	−0.32	−1.27, 0.62	0.85	0.33, 2.18
Any breastfeeding for 6 months	−0.06	−0.29, 0.17	−1.18	−2.18, −0.18	1.44	0.53, 3.96
Full breastfeeding for 6 months	−0.03	−0.27, 0.20	−1.16	−2.18, −0.14	0.29	0.08, 1.05
Change in infant weight-for-age *z* score	0.44	0.38, 0.51	0.89	0.60, 1.17	4.30	3.02, 6.14

[1] The odds on which the odds ratios are based, is a comparison between obese and normal weight children, overweight children were not included.

BMI = Body Mass Index; SS + TR = Sum of subscapular and triceps skinfold thicknesses

Table 3

Multivariable adjusted adiposity estimates at 3 years of age according to breastfeeding duration until 6 months among 877 children in Project Viva

	BMI *z* score (*N* = 877)		**SS + TR (*N* = 837)**		**BMI >95th percentile (*N* = 708)**	
	β	***95% CI***	β	***95% CI***	***OR***	***95% CI***
Model 1: adjusted for child's age and sex	−0.06	−0.09, −0.03	−0.22	−0.33, −0.11	0.86	0.78, 0.94
Model 2: adjusted for confounders*	−0.04	−0.07, −0.01	−0.19	−0.31, −0.07	0.92	0.82, 1.02
Model 3: model 2 + change in infant weight-for-age *z* score between birth and 6 months	−0.01	−0.04, 0.02	−0.13	−0.25, −0.01	0.98	0.87, 1.11
Change in infant weight-for-age *z* score	0.45	0.38, 0.51	0.91	0.63, 1.19	4.21	2.97, 5.96

* model 2 was adjusted for all variables in model 1 + mother's educational level, race/ethnicity, smoking status during pregnancy, BMI, and pregnancy weight gain and birth weight adjusted for gestational age