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Breast-feeding Duration, Age of Starting Solids, and High BMI Risk and Adiposity in Indian Children

Abstract

This study utilized data from a prospective birth cohort study on 568 Indian children, to determine whether a longer duration of breast-feeding and later introduction of solid feeding was associated with a reduced higher body mass index (BMI) and less adiposity. Main outcomes were high BMI (>90th within-cohort sex-specific BMI percentile) and sum of skinfold thickness (triceps and subscapular) at age 5. Main exposures were breast-feeding (6 categories from 1-4 to ≥21 months) and age of starting regular solid feeding (4 categories from ≤3 to ≥6 months). Data on infant feeding practices, socioeconomic and maternal factors were collected by questionnaire. Birthweight, maternal and child anthropometry were measured. Multiple regression analysis which accounted for potential confounders, demonstrated a small magnitude of effect for breast-feeding duration or introduction of solid feeds on the risk of high BMI but not for lower skinfold thickness. Breast-feeding duration was strongly negatively associated with weight gain (0-2 years) (adjusted $\beta = -0.12$ SD 95% CI: −0.19 to −0.05 per category change in breast-feeding duration, $p=0.001$) and weight gain (0-2 years) was strongly associated with high BMI at 5 years (adjusted OR = 3.8, 95 % CI: 2.53 to 5.56, $p<0.001$). In our sample, findings suggest that longer breast-feeding duration and later introduction of solids has a small reduction on later high BMI risk and a negligible effect on skinfold thickness. However, accounting for sampling variability, these findings cannot exclude the possibility of no effect at the population-level.

Keywords

Breast-feeding duration; Complementary feeds; Childhood body mass index; Adiposity; Infant weight gain; India

INTRODUCTION

Childhood overweight/obesity is an important public health issue for high-income countries like Europe and North America. Despite India's high prevalence of cardiovascular and metabolic diseases, primary prevention, particularly during childhood and adolescence, has failed to become a priority. India is still striving to address the seemingly intractable problems of endemic infant and child under-nutrition, micronutrient deficiencies and preventable infectious diseases (Arnold et al., 2009; Nongkynrih et al., 2004; Boutayeb, 2006; Chakravarty & Ghosh, 2000; Pasricha & Biggs, 2010). However, its recent economic growth has resulted in urban areas undergoing a rapid nutrition transition, where increasing childhood adiposity and early infant under-nutrition coexist (Griffiths & Bentley, 2001; Sawaya et al., 1995; Popkin et al., 1996).

A recent study conducted in Delhi schoolchildren reported that in high income students the prevalence of overweight and obesity was 6.8% and 15.3% respectively (Kaur et al., 2008). Being overweight or obese in childhood increases the risk of being overweight/obese in

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adulthood (Parsons et al., 1999; Power & Parsons, 2000; Garn & LaVelle, 1985). Furthermore, higher levels of BMI in childhood are associated with higher prevalence of cardiometabolic risk factors (Freedman et al., 1999; Chu et al., 1998) and greater risk of developing atherosclerosis-related vascular changes during childhood itself (Woo et al., 2004; Pena et al., 2006). Therefore, effective interventions are required, not only to lower the risk of higher BMI levels in childhood and the development of adverse cardiometabolic profiles, but also contribute to the lowering of the future burden of cardio-metabolic disease in India (Wild et al., 2004; Reddy, 2007) given the tracking of higher levels of BMI through to adolescence and adulthood.

Several systematic reviews and observational studies have suggested an association between breast-feeding and a later introduction of regular solid (complementary) feeds on the later risk of childhood overweight/obesity and adiposity (Gillman et al., 2007; Kramer, 1981; Wilson et al., 1998; Arenz et al., 2004; Owen et al., 2005b; Harder et al., 2005; Burke et al., 2005; Shields et al., 2006; Mayer-Davis et al., 2006; Weyermann et al., 2006). Additionally, there is some evidence of a dose-response effect with breast-feeding duration. However, these associations are reported from studies predominantly conducted in high-income countries and could result from confounding by socioeconomic factors (Heck et al. 2006; Bolling K 2007). In such settings, mothers who choose to initiate and continue breast-feeding tend to have higher incomes and greater educational attainment, than those who do not breast-feed or ceased breast-feeding early (Hoddinott & Pill, 1999). Therefore, a subsequent lower prevalence of higher BMI levels and adiposity in later childhood may reflect a “healthier” environment which avoids energy-dense grains, fats, and sugars and promotes physical activity, rather than an effect of breast-feeding. Studies conducted in low-middle income settings may help to resolve the confounding issues, since in these populations breast-feeding may have different relationships with socioeconomic status (Owen et al., 2005b).

For the last fifteen years, India’s average breast-feeding duration metrics has remained fairly constant. The median duration of exclusive breast-feeding is approximately two months, with predominant breast-feeding (either exclusive breast-feeding or receiving breast milk and plain water and/or non-milk liquids only) median duration is slightly over 5 months (International Institute for Population Sciences (IIPS) and ORC Macro, 2001). Median duration of any breast-feeding is approximately between 24-25 months (International Institute for Population Sciences (IIPS) and ORC Macro, 2001; Arnold et al., 2009). Similar to other countries, India’s infant feeding practices differ by socioeconomic position. Two recent nationally representative cross-sectional surveys, the National Family Health Surveys, NFHS 2 (1998-1999) and NFHS-3 (2005-2006), demonstrated that mother’s residing in urban areas, having increasingly higher household income and greater years of schooling were more likely to stop breast-feeding within the first two years (Malhotra et al., 2008). The most recent survey demonstrated that the median duration of any breast feeding decreases with maternal years of schooling from 24.1 months (mothers with 5-7 years of completed education) to 20.6 months (mothers with 12 or more years of completed education) and increasing household wealth index, from 27.7 months (lowest quintile) to 20.8 months (highest wealth quintile) (Arnold et al., 2009).

We have examined the hypothesis that a longer duration of breast-feeding and later introduction of regular solid feeds are associated with a lower risk of high BMI and reduced adiposity at five years of age. This was due to the lack of prospective studies in settings undergoing the initial stages of the nutrition transition (Araújo et al. 2006). Based on growth studies during the early years of life (0-24 months) comparing breast fed and formula fed infants, it has been suggested that lower growth (Robinson & Godfrey, 2008; Dewey, 1998; Baird et al., 2008; Kramer et al., 2004) is a possible mechanism of breast-feeding duration effect on later childhood anthropometry. Therefore, we have also explored whether growth (birth to 2 years) is a potential mediator of the proposed relationship between breast-feeding duration and child BMI and adiposity at 5 years.

MATERIALS & METHODS

Study Design and Participants

We used data from the Mysore Parthenon Study (initiated 1997-1998), a prospective birth cohort study of pregnancy-related maternal risk factors and later infant and child health (Hill et al., 2005; Krishnaveni et al., 2005). 830 eligible mothers, living in Mysore city or surrounding rural villages booking consecutively into the antenatal clinic of the Holdsworth Memorial Hospital (HMH) and those that satisfied the recruitment criteria (willingness to participate, gestational age <30 weeks and no history of diabetes prior to the pregnancy) were enrolled into the study. Further details of the study design methodology and HMH patient-base are provided elsewhere (Krishnaveni et al., 2005). 663 women delivered normal live born babies at HMH. Follow-up information was obtained for 585 children at one, two and five years (Figure 1). Study attrition was mainly due to refusal to participate and death. 568 children had complete breast-feeding data and 5-year outcomes.

The HMH Research Ethics Committee approved this study and verbal informed consent was obtained from parents and children. Applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed.

Measurements

Main Exposures—Total duration of breast-feeding and age at starting regular solid foods in months were the two main exposures. Information on breast-feeding was obtained by interviewer-administered questionnaire at one, two and three years. The same set of questions was asked at each timepoint: How was the baby fed from birth (breast, bottle, breast+bottle or other)? ; If breast-fed, was the baby still being breast-fed?; If no longer breast-fed, what was the age (months) at which breast-feeding stopped? At the age of one year, mothers were asked the following question regarding the introduction of solid foods to their infant at the age of 1 year: “Has the baby started taking solid foods regularly? If yes at what age (months) was it started.” This question ascertains the first time solid foods were introduced as a regular part of the infant’s diet (our exposure of interest) rather than the time when the child first consumed solid food.

Breast-feeding duration was categorised as follows: 1-4, 5-8, 9-12, 13-16, 17-20 and ≥21 months. Categories were chosen based on (1) the need to have duration categories of equal length for the ease of interpretation of the regression analysis, (2) comparison with the other studies, and (3) statistical reasons which included having sufficient observations in each bin, and the ability to adequately perform departure of linearity testing. Age at starting regular solid foods had 4 categories: ≤3, 4, 5, ≥6 months).

Outcome Measures—The main study outcomes at 5 years were presence or absence of “high body mass index” (BMI, weight/height^2) and sum of subscapular and triceps skinfold thickness. High BMI was defined as a sex-specific BMI greater than the within-cohort 90th percentile. Using this definition 58/568 (10.2%) of children were classified as having a high BMI.

High BMI was chosen as a study outcome despite being below the International Obesity Task Force (IOTF) cut-offs for overweight/obesity. In our sample, very few children were overweight (0.7%) or obese (0.2%). It is reasonable to use higher BMI levels in preschool children rather than IOTF cut-offs, given that the population where the sample was obtained, is undergoing the early stages of the nutrition transition, in addition to a high prevalence of infant and childhood under-nutrition. Furthermore, using this outcome will include a broad group of preschool children who are likely to develop cardiometabolic risk factors in later childhood.

Anthropometry was performed by one of 6 trained field workers using standardised methods. Weight was measured to the nearest 100 g using a digital weighing scale (Seca, Germany). Standing height was measured to the nearest mm using a wall-mounted stadiometer (Microtoise, CMS Instruments, UK). Triceps and subscapular skinfolds were measured to the nearest 1 mm using Harpenden callipers (CMS Instruments, UK); the average of three readings was used. As skinfold thickness measurements were skewed, they were log-transformed for analysis.

Other Measures—At baseline, the family's socioeconomic status (SES) and religion, family history of diabetes, and maternal education attained was recorded. SES was assessed by the Kuppuswamy score, a standardised SES questionnaire for Indian urban populations (Kuppuswamy, 1962). At 30±2 weeks gestation, women had a 100-g, 3-hour, oral glucose tolerance test (OGTT). Gestational diabetes mellitus (GDM) was diagnosed using the Carpenter and Coustan criteria (Carpenter & Coustan, 1982), the method chosen for clinical use in the hospital.

The babies were weighed to the nearest 10 g by one of four trained observers within 72-hours of birth, using a digital weighing scale (Seca, Germany). The children were subsequently followed up annually. 1 year follow-up was on the child's first birthday (± 4 weeks) for children born at term and on the anniversary of the expected date of delivery (± 4 weeks) for preterm children. Follow-up visits from 2-5 years were on the child's birthday (± 4 weeks) for all children.

Weight gain (birth to 2 years) was derived from conditional weight gain z-scores, calculated as standardised residuals from the regression of weight at age 2 on birthweight and gestational age. Weight gain from birth to 2 years rather than 1 year was used as a proxy for child growth, since that a high proportion of children were breastfed beyond 1 year (64%, 363/568). Low BMI and stunting were defined as BMI and height two standard deviations or more below the median, using the WHO reference (www.who.int/childgrowth). We defined indicators of household nutritional status at 5 years follow-up, using maternal BMI constructed from maternal weight and height measurements and number of children in a household (proxied by parity at baseline) given by maternal report. These indicators are an imperfect measure of the average household nutritional status from birth to 5 years. However, previous research in low-middle income settings has demonstrated maternal nutritional status as a potential determinant of childhood nutritional status (Rahman et al., 1993), and number of children per household influencing childhood nutritional status by reducing scarce family resources for maintaining adequate nutrition (Bronte-Tinkew & DeJong, 2004; Heaton et al., 2005).

STATISTICAL METHODS

We first examined bivariate associations of breast-feeding duration (six categories) and age at starting solid feeds (four categories) with covariates and outcomes. Associations between the main exposures and outcomes (high BMI, sum of skinfolds) were approximately linear across the categories (departure from linearity test, p=0.515 [high BMI], p=0.265 [sum of skinfolds]) therefore we assumed a linear trend across exposure categories for regression modelling (Figure 2). Logistic and ordinary least squares regression (OLS) were used to examine the associations with high BMI and skinfold thickness, respectively. Additionally, OLS was used to conduct supplementary analysis on the effect of breast-feeding duration on the mean BMI of children at 5 years of age.

For the ease of interpretation, we present the results of the regression analyses for skinfold thickness (outcome), as the expected change, expressed as a percentage, in geometric mean sum of skinfold thickness (mm) per one-unit category increase in exposure. This percentage change is estimated by the expression: $100(e^{change}-1)$, where "e^{change}" is the exponentiated regression coefficient for breast feeding duration when a natural log transformation of the outcome has been used.

Multiple regression analysis was based on an *a priori* conceptual framework. This framework was constructed from subject matter knowledge on the relationships between covariates, main exposures and outcomes, organized in blocks of variables which followed a socioeconomic-biologic axis. Our conceptual framework provides a visual representation of the interrelationships among factors thought to influence 5-year child outcomes (Figure 3) (Victora et al., 1997). Individual-level socioeconomic covariates are considered distal factors, which have a direct effect on individual behavioural/biological mechanisms. Additionally, our framework assumes that child outcomes at 5 years are affected by gender and current age at follow-up.

There are four blocks of variables: socioeconomic characteristics, household nutritional status, birth outcomes and infant feeding practices. Blocks are used to enter specific covariates into regression models in chunks. Covariates were only entered as confounders in regression models if they were: [1] considered *a priori*; or [2] had ≥5% change in estimate between the crude and adjusted estimates. For both exposures we adjusted for urban dwelling, SES, maternal education, birthweight and gestational age (*a priori confounders)*, maternal BMI at 5-year follow-up and family history of diabetes (confounders by criteria [2]). Variables not included in the models were religion, gestational diabetes and parity. Six successive regression models were fitted based on the order of blocks, where later models included all variables from previous models. The first model assessed socioeconomic characteristics. Model 2 included socioeconomic characteristics and added household nutritional status at 5 years. This approach was continued until Model 6, the final model, which demonstrated the effect of infant feeding practices on 5-year child outcomes controlling for socioeconomic characteristics, household nutritional status at 5 years, family history of diabetes, birth outcomes, other infant feeding practices, child age and gender.

Weight gain (birth to 2 years) was considered a mediator (intermediate variable) between the potential causal association of breast-feeding duration and 5-year outcomes. Accordingly, weight gain was not adjusted for in the main analysis (Models 1-6). The presence of mediation was assessed by comparing the breast-feeding duration effect estimate for model 6 before and after adjustment for weight gain. A reduction in the effect estimate was suggestive of mediation.

Differences in association by gender and prematurity status (*a priori* effect modifiers) as well as other covariates, were investigated using Mantel- Haenszel stratified analysis, comparing stratum specific ORs and 95% CI, and inspecting for trends across strata. A χ^2 test of homogeneity was also used as statistical guidance for the presence of effect modification. There was no evidence of effect modification by either gender or prematurity status. STATA v10 was used for all analyses.

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RESULTS

Characteristics of the children and parents are summarised in Table 1. Almost all mothers initiated breast-feeding, with 89% (504/568) of infants breast fed for at least 6 months. The median breast-feeding duration was 12 months, whilst the median age for starting solids was 4 months. The mean BMI of the children was 13.6 kg/m^2 (SD 1.12). Low BMI prevalence (<-2SD, WHO reference) was 10.6% and 23.1% at 1 and 5 years of age, respectively. At 5 years, 10.1% of children were stunted (<-2SD for height, WHO reference). The prevalence of high BMI was not considered since this outcome is defined as a sex-specific BMI greater than the within-cohort 90^{th} percentile. That is 10% of children at 5 years with the greatest (sex-specific) BMI were classified as having “high BMI”.

Tables 2 and 3 present socioeconomic characteristics, history of diabetes, birth outcomes, household nutritional status and 5-year child outcomes by the duration of breast-feeding and age of starting solids. Compared with children who were breast-fed for longer, infants having shorter breast-feeding duration were more likely to be urban residents, Muslim and live in households with two or more siblings (Table 2). No associations were observed between breast-feeding duration and SES, maternal education and maternal BMI at 5 years. Whilst infants having either a short or long breast-feeding duration had higher birthweight, there was no association with prematurity status.

A later introduction of solid feeding was associated with urban residence, lower SES and maternal educational attainment (Table 3). Hindu mothers typically introduced solids later compared to mother’s following Islam or “other” religions.

Associations of Breast-Feeding Duration with High BMI and Sum of Skinfolds Thickness at 5 years

The proportion of children having high BMI at 5 years was lower in children breast fed for a longer duration (≥18 months: 10%, 11/110) compared to children breast fed for a shorter duration (<6 months: 17 %, 11/64), with weak statistical evidence of a dose-response effect (p_{trend}=0.07) (Table 2). A longer duration of breast-feeding was associated with smaller sum of skinfold thickness at 5 year, with weak evidence of a dose-response effect (p_{trend}=0.07).

Increasing breast-feeding duration (4-month duration categories: 1-4, 5-8, 9-12, 17-20 and 21+) was weakly associated with a lower risk of high BMI at 5 years (OR=0.87, 95% CI: 0.69 to 1.10, p=0.26, Table 4). A one category increase in breast-feeding duration resulted in a 13% reduction in high BMI risk at 5 years. Successive introduction of confounding variables (Models 1-5) made negligible difference to the size of the unadjusted effect estimate. Adjusting for urban dwelling, kuppaswamy score, maternal education, birthweight, gestational age, family history of diabetes and 5- year maternal BMI, child gender and current age (Model 6) made no substantial difference to these findings, with the confidence intervals to wide to exclude the possibility of no effect (aOR=0.87, 95% CI: 0.68 to 1.11, p=0.26). Multiple linear regression analysis estimated a reduction of mean BMI by 0.04 (kg/m^2) per one-category increase in breast-feeding duration, adjusting for an identical set of covariates included in Model 6, the final logistic regression model (95% CI:-0.12 to 0.04, p=0.33).

There was no evidence of an important effect of breast-feeding duration on the geometric mean sum of skinfold thickness (mm) with weak statistical evidence of an association (% change −0.9, 95% CI: −2.5 to 0.8, p=0.31). This is interpretable as the percentage change in the expected geometric mean value of the sum of skin folds, per category increase in breast-feeding duration. After adjustment for potential confounders, there was no change in the effect estimate and the lack of statistical evidence of an association remained.

Associations of Age of Starting Regular Solid feeding with High BMI and Sum of Skinfolds Thickness at 5 years

Children who were introduced to solids later tended to have a lower risk of high BMI, although there was weak evidence of a statistical association (p=0.21, Table 3).

The regression analysis demonstrated (Table 4) that a later age of starting regular solid feeding was associated with a lower risk of high BMI (OR=0.79, 95% CI: 0.58 to 1.07, p=0.14). A one category increase in the age solids were introduced resulted in a 21% reduction in high BMI risk at 5 years. However, after accounting for sampling variability, there was weak statistical evidence of an association. After the adjustment for confounding factors in an identical manner to breast-feeding duration, there was negligible change in the effect estimate and the weak statistical evidence of the association remained. Multiple linear regression analysis, adjusting for an identical set of variables, estimated mean BMI decreases by 0.07 kg/m^2 per one-category increase in age of starting regular solid feeding (95% CI: − 0.17 to −0.03, p=0.15).

A one-category increase in age of starting regular solid feeding was associated with a small reduction in sum of skinfolds, compared to a lower category of duration (% difference: −2.2, 95% CI: −4.3 to 0.0, p=0.05, Table 4). On adjustment for socioeconomic characteristics, this association was attenuated and accounting for sampling variability there was no statistical evidence of an association. The final model (Model 6) demonstrated that a one-category increase in the age of starting regular solids resulted in a 1.7% reduction in sum of skinfold thickness, with weak statistical evidence of an effect (95% CI: −3.7 to 0.4, p=0.11).

Breast Feeding Duration, Weight Gain (birth to 2 years), High BMI and Sum of Skinfolds Thickness at 5 years

Breast-feeding duration was strongly negatively associated with weight gain (0-2 years) (β= −0.12 SD 95% CI: −0.19 to −0.05 per category change in breast-feeding duration, p=0.001). After adjustment for breast-feeding duration and confounding variables (Model 6 variables), weight gain was strongly positively associated with high BMI at 5 years (aOR = 3.75, 95 % CI: 2.53 to 5.56, p<0.001) and sum of skinfolds (adjusted % change = 10.0, 95% CI: 7.9 to 12.2). The inclusion of weight gain attenuated the overall effect of breast-feeding duration on high BMI. The protective effect estimate (odds ratio) of breast-feeding duration (per category increase) was reduced from 0.87 (95% CI: 0.69 to 1.10) to 1.02 (95% CI: 0.77 to 1.35). The skinfold association was attenuated from −0.9% (95% CI: −2.5 to 0.8) to 0.4%, (95% CI: −1.1 to 1.9).

DISCUSSION

We used data from a birth cohort study in South Indian children, to evaluate whether a longer duration of breast-feeding, and the age an infant regularly starts solid feeding, reduced the risk of high BMI and skinfold thickness at 5 years of age. Based on our sample, there was a small magnitude of effect for the unadjusted association of a longer duration of breast-feeding on reducing the risk of high BMI. After adjusting for several important confounding variables, the breast-feeding effect estimate remained unchanged. The final model which included all potential confounding covariates (Model 6), estimated a 13% reduction in the risk of high BMI per duration of breast feeding category. This finding suggests a potential public health benefit for promoting longer breast-feeding duration, but given the confidence interval of the adjusted effect estimate, we cannot exclude the possibility of no effect. Additionally, our study found no evidence of an important size of exposure effect on skinfold thickness.

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There is a paucity of literature in LMICs investigating this potential association. In these settings prospective observational studies with infant feeding data, have tended to evaluate adult cardiometabolic risk factors as an outcome rather than childhood BMI (Fall et al., the COHORTS group, 2010). Our findings differ from two similar studies conducted in Brazil and Chile, which demonstrated no evidence of a protective effect of breast-feeding on overweight at 4 years of age (Araújo et al., 2006; Corvalan et al., 2009). There have been mixed results from systematic reviews and recent studies in high-income countries (Arenz et al., 2004; Hediger et al., 2001; Owen et al., 2005b; Harder et al., 2005; Burke et al., 2005; Shields et al., 2006; Mayer-Davis et al., 2006; Weyermann et al., 2006) and the few studies conducted on direct adiposity measures (Baranowski et al., 1990; Neutzling et al., 2009). A North American study directly evaluating childhood adiposity using DXA measurements in 5-year old children, demonstrated no association with breast-feeding duration (Burdette et al., 2006). Furthermore PROBIT, a cluster randomized control trial in Belarus, evaluated whether a breast-feeding promotion intervention to increase breast-feeding duration and exclusivity would result in reduced later childhood anthropometry. Their findings indicated there was little evidence of a reduction in BMI or skinfold thickness in children at 6 years of age (Kramer et al., 2007).

In our study, the effect of a longer duration of breast-feeding on mean BMI was very small, with no strong evidence of a statistical association. Notwithstanding small sample size considerations, this finding is consistent with other studies that suggest that breast-feeding may lower the risk of higher BMI levels rather than shifting down (movement to the left along the X-axis) the entire BMI distribution (Owen et al., 2005a; Toschke et al., 2008). Similarly, the effect of longer duration of breast-feeding on sum of skinfolds was very small, with weak statistical evidence of an effect. Studies that have measured skinfold thickness in children have demonstrated mixed results (Bergmann et al., 2003; Bogen et al., 2004; Zive et al., 1992; Kramer et al., 2007). The lack of an association of either public health or statistical importance, may reflect that the long lag period between exposure and outcome, is outside the exposure’s biological range of effect. That is, infant feeding practices are more likely to be biologically associated to subcutaneous adiposity in the earlier years of life rather than at preschool age. Furthermore, as South Asian populations are known to have increased abdominal fat deposition compared with white Caucasians (McKeigue et al., 1991) the lack of an observed effect observed could potentially be due to breast-feeding influencing central adiposity (e.g. intra-abdominal fat) more than subcutaneous fat, which would not be assessed with skinfold measurements.

Both infant-feeding exposure effects had a similar low magnitude of association, that is protective odds ratios in the range of 0.77-0.91 (corresponding to risk odd ratios: 1.1-1.3). However, compared with an increase in breast-feeding duration, a later age for starting regular solid feeding had a greater sized reduction in high BMI risk, with the confidence intervals too wide to exclude the possibility of no effect. Additionally, there was no evidence of an association between a later start of solids and skinfold thickness at 5 years. Previous findings regarding our results are mixed. Whilst some studies have reported lower rates of obesity in children who started solids later (Reilly et al., 2005; Wilson et al., 1998), others have reported no association (Kramer, 1981; Burdette et al., 2006; Zive et al., 1992) or greater adiposity associated with delayed introduction of solids (Agras et al., 1990). Future research could be used to help resolve this issue. Firstly, the age of starting regular solid feeding is a simple exposure and ignores the dynamics of nutrition during the period of 6-24 months which is likely to influence later child anthropometry. Firstly, utilizing detailed infant feeding measures such as the WHO Infant and Young Complementary Feeding (IYCF) indicators (WHO, 2008) in a longitudinal study design may help. Secondly, studies need to be conducted in settings of relatively high child overweight/obesity prevalence, in order to describe changing dietary patterns during infancy and its relation to later body composition.

There are only a few studies which report the effect of adjusting for weight gain during the early years of life on the associations between infant feeding and later BMI or adiposity (van Rossem et al., 2010; Lamb et al., 2010). Our qualitative mediational analysis agrees with these studies by suggesting that weight gain (birth to 2 years) is a mediator of the relationship between breast-feeding duration and risk of high BMI. We observed that a longer breast-feeding duration is strongly associated with slower weight gain between 0-2 years and that weight gain is strongly associated with high BMI. When weight gain(0-2 years) is controlled for, the breast-feeding duration effect estimate was attenuated. Within the literature, robust findings are that breast-feeding is associated with lower weight gain compared with formula feeding infants (Griffiths et al., 2009; Kramer et al., 2007; Dewey et al., 1992) and that lower weight gain during the early years of life is associated with a lower later BMI (Ong et al., 2002; Monteiro & Victora, 2005; Baird et al., 2005; Stettler, 2007; Wells et al., 2005; Griffiths et al., 2010). Primary studies evaluating the size of the mediated effect using path analysis will provide further insight into the potential mechanism between breast-feeding duration and levels of preschool BMI.

In this sample, under-nutrition (low BMI and stunting) had a greater prevalence than high BMI at 5 years (23% had a BMI <-2 SDs below WHO median, 10.1% had a height <-2 SDs below WHO median). There was no association with these outcomes and infant feeding practices (results not shown). The lower prevalence of overweight/obesity in this population may undermine our decision to investigate high BMI risk. However, in an Indian population where overweight and obesity emerges from a context of infant under-nutrition, we think it is important to examine the role of infant feeding practices on later childhood adiposity. Underscoring this approach is that (1) BMI tracks through the life-course such that children with higher BMI levels are more likely to be overweight/obese adolescents and adults compared to thinner children (Singh et al., 2008) and (2) upward crossing of BMI percentiles during childhood, even within the normal range of BMI, is associated with an increased risk of adult type 2 diabetes and metabolic syndrome (Fall et al., 2008; Sachdev et al., 2009).

Particular strengths of our study include the use of skinfold thickness, a direct measure of adiposity, as well as BMI, and that it adds to the small number of studies on this subject from low-middle income countries. Additionally, a conceptually designed analysis was used to adjust for potential confounding and identify potential mediating factors. However in interpreting our findings, a few methodological issues require consideration. This was a relatively small observational study. As such, it may lack the statistical power to detect small sized infant feeding effects on the outcome. Given that infant feeding practices were not randomly assigned to children, there is likely to be an unobserved systematic allocation of exposure assignment. So whilst adjusting for several important confounding variables, we cannot exclude the possibility that there were remaining systematic differences in children with varying infant feeding practices. For example, even within SES strata maternal infant feeding practices and related child care attitudes may vary (Bentley et al., 2003; Sharps et al., 2008).

Due to exposure misclassification and the absence of exclusive breast-feeding data, the magnitude of the protective effect of increasing breast-feeding duration could have been underestimated (towards null results). The ascertainment of breast-feeding duration based on maternal recall at one year is considered to be reasonably accurate (Kark et al., 1984). However, since we ascertained breast-feeding data at 12, 24, 36 months follow-up, this may have increased the tendency of “heaping” (digit preference)- a specific form of recall bias,

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which is suggested by observation of a large peak in breast-feeding duration at 12 months. Alternatively, such a peak may represent true breast-feeding duration behaviour due to local breast-feeding norms. The effect of starting solid feeding may also be underestimated, as the lack of information on the type and quality of feeds maybe more strongly related to its long-term effects on body composition than the age at which solids was started. We observed a lack of association between infant feeding practices and socioeconomic status. As diet and physical activity is typically related to socioeconomic status, it is unlikely that the absence of this covariate data for children at 5 years will strongly confound the association between infant feeding practices and 5-year outcomes.

In a sample of South Indian preschool children, this cohort study demonstrates findings suggestive that a longer duration of breast-feeding is associated with a small reduction in the risk of high BMI at 5 years. Additionally, an earlier introduction of solid feeding may slightly increase the risk of high BMI. After accounting for sampling variability, these findings cannot exclude no effect as a possibility at the population-level. We have shown qualitatively that a longer duration of breast-feeding is associated with slower weight gain from birth to 2 years, which in turn is associated with a reduced risk of high BMI. Consideration our own findings that infant feeding practices have a low magnitude of effect, and previous meta-analyses (Owen et al., 2005b; Harder et al., 2005), the promotion of current WHO guidelines on infant feeding may offer only a fairly small role in the prevention of overweight/obesity in preschool children. Rather, for India to effectively avoid the alarming trends of child overweight/obesity prevalence seen in other fast growing LMIC economies (Jiang et al., 2006; Luo & Hu, 2002; Wang & Lobstein, 2006), this will depend on how the country develops its own long-term, multi-level strategies to address the major determinants of child overweight/obesity at the population-level: the increasing consumption of high energy dense diets and reduced physical activity.

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Abbreviations

aOR	adjusted odds ratio
BMI	body mass index
CI	confidence interval
LMIC	Low-middle income country
OR	odds ratio
SD	standard deviation
SES	socioeconomic status

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KEY MESSAGES

- In a cohort of South Indian children, excluding bias, per category increases in both infant feeding practices (duration of breast-feeding, timing of the introduction of solid feeds) demonstrated a small effect on the risk of high BMI at 5 years. However, given the confidence interval of the adjusted effect estimates, we cannot exclude the possibility of no effect at the population level.
- Infant feeding practices were not associated with important sized effects on subcutaneous adiposity.
- Assuming a causal association between the exposure and outcome, weight gain (birth to 2 years) is likely to be a mediator of the proposed relationship between breast-feeding duration and risk of high BMI at 5 years.
- Promoting and advocating for the maintenance of current WHO guidelines on infant feeding practices may have a small role in the prevention of higher levels of BMI in preschool children. However, to effectively avoid following the trends of child overweight/obesity prevalence observed in other fast growing LMIC economies, will depend on how effectively India develops long-term, multi-level strategies which addresses the major determinants of child overweight/obesity at the population-level: the increasing consumption of high energy dense diets and reduced physical activity.

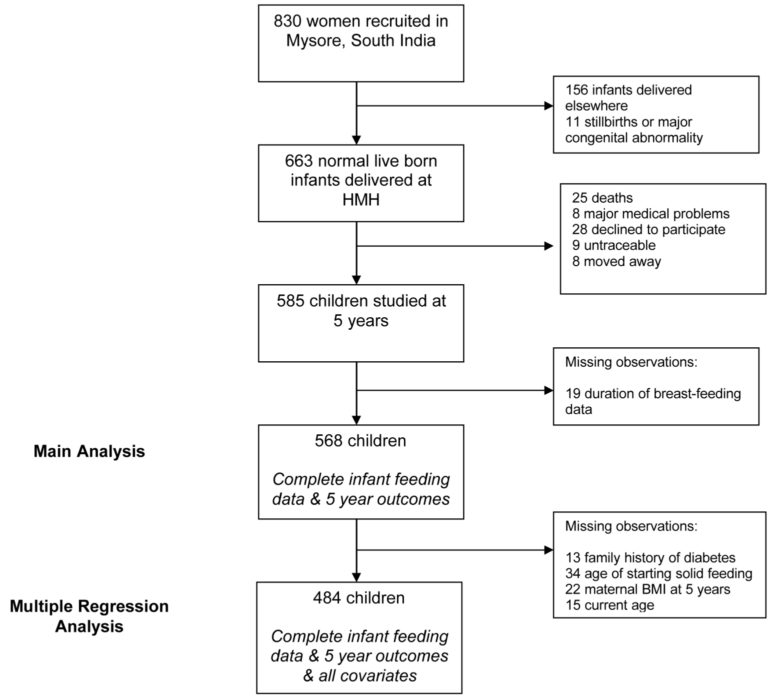

Figure 1.
Cohort Flow Chart

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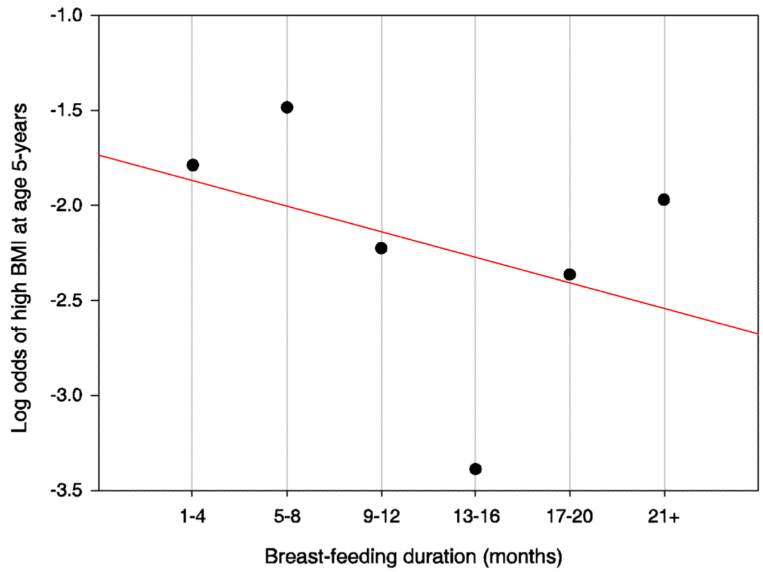

Figure 2.
Observed and predicted log odds of high BMI at age 5. This plot shows the linearity of the relationship between breastfeeding and high BMI at age 5.

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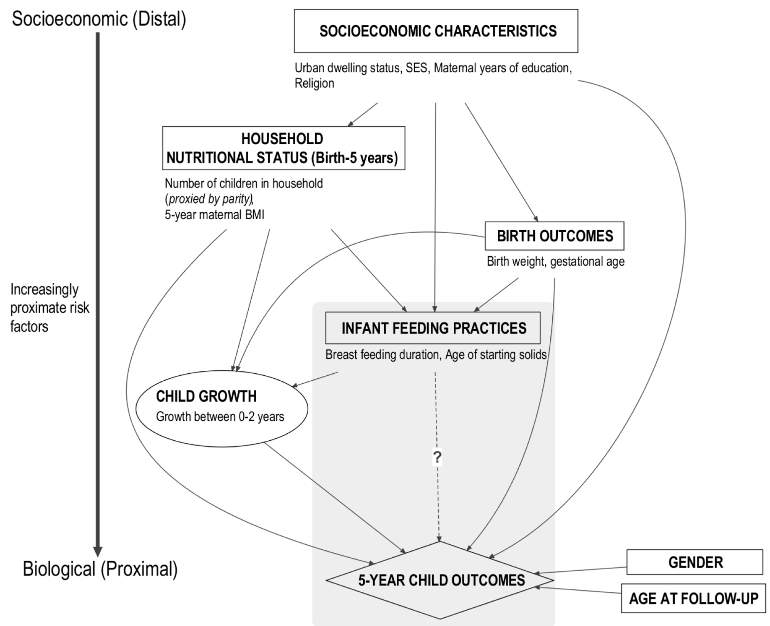

Figure 3.
Conceptual Framework for Examining the Potential Association between Infant Feeding Practices and 5 Year Child Study Outcomes at 5 years, High BMI and Adiposity, for Multiple Regression Analyses

TABLE 1
Characteristics of the Sample in Mysore, South India, 1997-2003

Data are presented as mean and SD unless otherwise stated.

Variable	n	Boys (n=272)	Girls (n=296)	Both sexes
Level 1: Socioeconomic characteristics				
Urban dwelling status	568	195 (72)	226 (76)	421 (74)
Kuppuswamy score median IQR)	568	33 (29,38)	34 (30, 38)	34 (30,38)
Maternal education (years), *n (%)*				
Illiterate (0)	568	5 (1.8)	7 (2.4)	12 (2.1)
Primary school (1-4)		18 (6.6)	10 (3.4)	28 (4.9)
Middle School (5-7)		48 (17.7)	36 (12.2)	84 (14.8)
High School (8-10)		98 (36.0)	131 (44.3)	229 (40.3)
High 2° School Certificate (11-12)		65 (23.9)	60 (20.3)	125 (22.0)
Degree (13-15)		31 (11.4)	42 (14.2)	73 (12.9)
Professional (16+)		7 (2.6)	10 (3.4)	17 (3.0)
Religion, *n (%)*				
Hindu	568	145 (53.3)	175 (59.1)	320 (56.3)
Muslim		99 (36.4)	99 (33.5)	198 (34.9)
Other		28 (10.3)	22 (7.4)	50 (8.8)
Level 2: Family & Maternal Gestational Diabetes				
Gestational Diabetes, *n (%)*	524	13 (4.9)	22 (7.7)	35 (6.3)
Family History of Diabetes, *n (%)*	555	52 (20)	60 (21)	112 (21)
Level 3: Birth Outcomes				
Birth weight (g)	568	2909 (466)	2834 (411)	2870 (441)
Gestational age (weeks) median (IQR)	568	39.1 (38.1, 40.0)	39.4 (38.6, 40.1)	39.3 (38.4, 40.1)
Prematurity (<37 weeks), *n (%)*	568	26 (9.6)	25 (8.5)	51 (9.0)
Level 4: Infant feeding practices				
Breast-feeding duration (months), *n (%)*	568			
1-4		20 (7.4)	22 (7.4)	42 (7.4)
5-8		42 (15.4)	34 (11.5)	76 (13.4)
9-12		109 (40.1)	138 (46.6)	247 (43.5)
13-16		44 (16.2)	48 (16.2)	92 (16.2)
17-20		33 (12.1)	37 (12.5)	70 (12.3)
21+		24 (8.8)	17 (5.7)	41 (7.2)
Age started regular solids (months), *n (%)*	532			
≤3		46 (18.0)	55 (19.9)	101 (19.0)
4		93 (36.3)	109 (39.5)	202 (38.0)
5		79 (30.9)	66 (23.9)	145 (27.2)
≥6		38 (14.8)	46 (16.7)	84 (15.8)
Level 5: Household nutritional status				
Maternal BMI at 5 years (kg/m^2)	543	23.3 (4.4)	23.8 (4.6)	23.6 (4.5)
Parity, *n (%)*	568			

Variable	n	Boys (n=272)	Girls (n=296)	Both sexes
No children		135 (49.6)	154 (52.0)	289 (50.9)
One child		90 (33.1)	90 (33.1)	190 (33.5)
2 or more children		47 (17.3)	47 (17.3)	89 (15.7)
Childhood outcomes measures at 1 and 2 yrs of age				
Weight (kg) at 1 year	532	8.7 (1.1)	8.1 (1.0)	8.4 (1.1)
Weight (kg) at 2 year	549	10.8 (1.2)	10.2 (1.2)	10.5 (1.2)
BMI <-2SD (WHO reference) at 1 year, *n (%)*	529	33 (12.9)	23 (8.4)	56 (10.6)
BMI <-2SD (WHO reference) at 2 years, *n (%)*	549	12 (4.5)	9 (3.2)	21 (3.8)
Childhood outcomes measures at 5 yrs of age				
Height (cm)	568	106.4 (4.3)	105.0 (4.3)	105.7 (4.3)
Weight (kg)	568	15.4 (1.9)	15.0 (2.0)	15.2 (2.0)
BMI <-2SD (WHO reference), *n (%)*	568	60 (22.5)	68 (23.7)	128 (23.1)
Height <-2SD (WHO reference), *n (%)*	568	21 (7.9)	35 (12.2)	56 (10.1)
BMI (kg/m^2)	568	13.6 (1.04)	13.6 (1.21)	13.6 (1.12)
High BMI n (%)	568	28 (10.3)	30 (10.1)	58 (10.2)
Skinfolds (mm) (median, IQR):				
Subscapular	568	5.3 (4.8, 6.2)	6.0 (5.1, 7.6)	5.6 (4.9, 7.0)
Triceps	568	7.2 (6.3, 8.4)	8.1 (7.0, 9.8)	7.7 (6.6, 8.9)
Sum of skinfolds	568	12.5 (11.1, 14.4)	14.4 (12.3, 17.3)	13.5 (11.7, 15.8)

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TABLE 2

Relationship of Breast-feeding Duration by Covariates and 5 year Child Outcomes in Mysore, South India, 1997-2003

Data are presented as mean and SD unless otherwise stated.

Variable	n	Breast-feeding Duration (months)* <6 (n=64)	6-11 (n=141)	12-17 (n=253)	18+ (n=110)	p†
Level 1: Socioeconomic Characteristics						
Urban Dwelling, *n (%)*	568	55 (86.0)	98 (69.5)	178 (70.4)	90 (81.8)	<0.001 ga
Kuppuswamy score	568	33.6 (6.4)	34.8 (5.6)	33.9 (6.3)	33.8 (7.3)	0.83
Maternal Education (years)	568	10.4 (3.5)	10.9 (3.5)	10.4 (3.4)	10.3 (3.8)	0.94
Religion, *n (%)*						
Hindu	320	17 (26.6)	86 (61)	164 (64.8)	53 (48.2)	
Muslim	198	41 (64.1)	46 (32.6)	72 (28.5)	39 (35.5)	<0.001 ga
Other	50	6 (9.4)	9 (6.4)	17 (6.7)	18 (16.4)	
Level 2: Family & Gestational History of Diabetes						
Family History of Diabetes, *n (%)*	555	16 (25.4)	27 (19.7)	46 (18.6)	23 (21.5)	0.15
Gestational diabetes, *n (%)*	538	4 (6.3)	2 (1.4)	15 (5.5)	14 (12.7)	0.01
Level 3: Birth Outcomes						
Birth weight (g)	568	2913 (419)	2805 (415)	2837 (442)	3005 (451)	0.05 ga
Prematurity, *n (%)*	568	4 (6.3)	15 (10.6)	23 (9.1)	9 (8.2)	0.95
Level 4: Infant Feeding Practices						
Age of starting solids (months), *n (%)*						
≤3	101	13 (21.7)	28 (21.0)	43 (18.2)	17 (16.7)	
4	202	32 (53.3)	48 (35.8)	88 (37.3)	34 (33.3)	0.16ga
5	145	11 (18.3)	37 (27.6)	69 (29.2)	28 (27.5)	
≥6	84	4 (6.7)	21 (15.7)	36 (15.3)	23 (22.6)	
Level 5: Household Nutritional Status						
Maternal BMI at 5 years (kg/m^2)	543	23.9 (4.9)	23.1 (4.1)	23.4 (4.3)	24.5 (5.1)	0.33
Parity, *n (%)*						
No children	289	34 (53.1)	80 (56.7)	130 (51.4)	45 (40.9)	0.02ga
One child	90	16 (25.0)	45 (31.9)	85 (33.6)	44 (40.0)	

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Variable	n	Breast-feeding Duration (months)*				P†
		<6 (n=64)	6-11 (n=141)	12-17 (n=253)	18+ (n=110)	
2 or more children	89	14 (21.9)	16 (11.4)	38 (15.0)	21 (19.1)	
Main Outcomes at 5 years of age						
High BMI (>90th percentile), *n (%)*	568	11 (17.2)	19 (13.5)	17 (6.7)	11 (10.0)	0.08
Skinfolds (mm) geometric mean (+/− 1SD)						
Subscapular	568	6.3 (4.6, 8.5)	6.0 (4.5, 8.0)	5.9 (4.6, 7.6)	5.9 (4.6, 7.6)	0.07
Triceps	568	8.3 (6.2, 11.1)	7.8 (6.1, 10.0)	7.6 (6.2, 9.5)	7.7 (6.0, 9.9)	0.12
Sum of skinfolds	568	14.6 (11.0, 19.4)	13.9 (10.8, 17.8)	13.6 (11.0, 16.8)	13.7 (10.8, 17.3)	0.07

*The data are shown in 4 categories for economy of presentation, but all statistical tests used the 6 categories described in Methods.

†Test of linear trend using breast-feeding duration in 6 categories, unless the test for a departure from linear trend was significant, in which case this is a likelihood ratio test or a χ^2 test of general association (ga).

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TABLE 3

Relationship of Age of Starting Regular Solid Feeding by Covariates and 5-year Child Outcomes in Mysore, South India, 1997-2003

Data are presented as mean and SD unless otherwise stated.

Variable	n	Age Started Regular Solids (months)				P *
		≤3 (n=100)	4 (n=201)	5 (n=145)	≥6 (n=83)	
Level 1: Socioeconomic Characteristics						
Urban Dwelling, *n (%)*	532	75 (74.3)	166 (82.2)	107 (73.8)	56 (66.7)	0.03ga
Kuppuswamy score	532	34.6 (6.4)	34.5 (6.0)	33.5 (6.3)	33.2 (6.9)	0.05
Maternal Education (years)	532	10.5 (3.6)	11.2 (3.1)	10.0 (3.8)	10.0 (3.7)	0.01 ga
Religion, *n (%)*						
Hindu	294	57 (56.4)	84 (41.6)	101 (69.7)	52 (18)	
Muslim	188	26 (25.7)	97 (48.0)	39 (26.9)	26 (14)	<0.001 ga
Other	50	18 (17.8)	21 (10.4)	5 (3.5)	6 (7.1)	
Level 2: Family & Gestational History Diabetes						
Family History of Diabetes, *n (%)*	521	22 (22.2)	43 (21.1)	25 (17.9)	13 (15.7)	0.61ga
Gestational diabetes, *n (%)*	503	5 (5.0)	17(7.9)	4 (2.8)	6 (7.1)	0.76 ga
Level 3: Birth Outcomes						
Birth weight (g)	532	2946 (397)	2901 (434)	2797 (433)	2854 (488)	0.03
Prematurity, *n (%)*	532	7 (6.9)	17 (8.4)	13 (9.0)	10 (11.9)	0.25
Level 4: Infant Feeding Practices						
Breast-feeding duration (months)						
<6	60	13 (12.9)	32 (15.8)	11 (7.6)	4 (4.8)	0.16ga
6-11	134	28 (27.7)	48 (23.8)	37 (25.5)	21 (25.0)	
12-17	236	43 (42.6)	88 (43.6)	69 (47.6)	36 (42.9)	
18+	102	17 (16.8)	34 (16.8)	28 (19.3)	23 (27.4)	
Level 5: Household Nutritional Status						
Maternal BMI at 5 years (kg/m^2)	509	23.5 (4.1)	23.7 (4.1)	23.1 (4.8)	24.3 (5.2)	0.58
Parity, *n (%)*						
No children	267	60 (59.4)	104 (51.5)	67 (46.2)	36 (42.9)	0.32ga
One child	181	30 (29.7)	67 (33.2)	51 (35.2)	33 (39.3)	

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Variable	n	Age Started Regular Solids (months)				P *
		≤3 (n=100)	**4 (n=201)**	**5 (n=145)**	**≥6 (n=83)**	
2 or more children	84	11 (10.9)	31 (15.4)	27 (18.6)	15 (17.9)	
Main Outcomes at age 5 years						
High BMI (>90th percentile), *n (%)*	532	12 (11.9)	24 (11.9)	11 (7.6)	7 (8.3)	0.21
Skinfolds (mm) geometric mean (+/− 1SD)						
Subscapular	532	6.1 (4.7, 8.0)	6.0 (4.6, 7.9)	5.8 (4.5, 7.7)	5.9 (4.6, 7.7)	0.19
Triceps	532	8.1 (6.1, 10.6)	8.0 (6.2, 10.2)	7.5 (6.0, 9.5)	7.6 (6.1, 9.5)	0.02
Sum of skinfolds	532	14.3 (11.1, 18.5)	14.1 (11.1, 17.8)	13.5 (10.7, 16.9)	13.6 (10.9, 16.9)	0.05

* Test of linear trend using age of starting regular solids in 4 categories, unless the test for a departure from linear trend was significant, in which case this is a likelihood ratio test for continuous variables or a χ^2 test for categorical variables, of a general association (ga).

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TABLE 4

Associations between Breast-feeding Duration and Age of Starting Solid Feeding with High BMI (sex-specific BMI >90th centile) and Sum of Skinfolds at 5 years in Mysore, South India, 1997-2003

Odds ratios and % change in sum of skinfolds are for a one category increase in breast-feeding (1-4, 5-8, 9-12, 13-16, 17-20 and 21+ months) and introduction of solids (≤3, 4, 5, 6+ months). To allow coefficients to be compared, all results are reported from the sample with complete data by each exposure (Final Model, n=484).

Model*	**High BMI**		**Sum of Skinfolds†**	
	OR (95% CI)	***p value***	**% change**	***P value***
Breast Feeding Duration				
Unadjusted association for Breast-feeding Duration Effect	0.87 (0.69 to 1.10)	0.26	−0.9 (−2.5 to 0.8)	0.31
Model 1: Socioeconomic Characteristics	0.88 (0.69 to 1.11)	0.27	−0.8 (−2.5 to 0.8)	0.33
Model 2: Model 1 + Household Nutritional Status	0.85 (0.67 to 1.07)	0.17	−1.0 (−2.6 to 0.7)	0.24
Model 3: Model 2 + Family History of Diabetes	0.85 (0.67 to 1.07)	0.17	−1.0 (−2.6 to 0.7)	0.25
Model 4: Model 3 + Birth Outcomes	0.84 (0.66 to 1.07)	0.17	−0.8 (−2.4 to 0.7)	0.37
Model 5: Model 4 + Age of Starting Solid Feeds	0.87 (0.68 to 1.11)	0.25	−0.6 (−2.2 to 1.1)	0.48
Model 6: Model 5 + Child Gender and Current Age	0.87 (0.68 to 1.11)	0.26	−0.6 (−2.2 to 1.0)	0.47
Age of Starting Solid Feeds	**OR (95% CI)**	***p value***	**% difference**	***P value***
Unadjusted association for Age of Starting Solid Feeds Effect	0.79 (0.58 to 1.07)	0.14	−2.2 (−4.3 to 0.0)	0.05
Model 1: Socioeconomic Characteristics	0.79 (0.58 to 1.08)	0.15	−1.8 (−3.9 to 0.4)	0.10
Model 2: Model 1 + Household Nutritional Status	0.77 (0.56 to 1.06)	0.10	−1.9 (−4.1 to 0.2)	0.08
Model 3: Model 2 + Family History of Diabetes	0.77 (0.56 to 1.05)	0.10	−1.9 (−4.0 to 0.2)	0.08
Model 4: Model 3 + Birth outcomes	0.75 (0.56 to 1.05)	0.09	−0.9 (−2.6 to 0.7)	0.26
Model 5: Model 4 + Breast-feeding Duration	0.77 (0.56 to 1.08)	0.14	−1.8 (−3.9 to 0.4)	0.11
Model 6: Model 5 + Child Gender and Current Age	0.78 (0.56 to 1.09)	0.15	−1.7 (−3.7 to 0.4)	0.11

*Variables included in final regression models: Socioeconomic characteristics (Block 1): Urban dwelling status, Kuppaswamy score, Maternal education; Household Nutritional Status (Block 2): Maternal BMI at 5-year follow-up; Family History of Diabetes; Birth Outcomes (Block 3): Birthweight, Gestational age; Infant feeding practices (Block 4): Either Breast-feeding duration or Age of Starting Solid Feeds, Child Gender; Current Age at Follow-Up.

†Estimated percentage change in the geometric mean of sum of skinfold thickness (SSF) (subscapular and triceps) for a per category increase in exposure.