Early Infant Feeding and Body Composition In Pre-School Children

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Abstract: *Objective:* The purpose of this study was to examine the association between early infant feeding and childhood adiposity.

Method: This was a cross-sectional study of 29 pre-school age (4 to 6 years) children and their mothers. Mothers were interviewed using a structured questionnaire to assess early infant feeding practices, while the children's body composition was measured using the BOD POD Pediatric Option Body Composition System.

Results: The mean age of the children was 4.9 ± 0.8 years, 82.8% Caucasian and 17.2% Black/African American, while 65.5% were female. None of the mothers reported alcohol consumption or smoking during the pregnancy with the child. Of the 29 children in the study, 41.4% were exclusively breastfed for at least 3 months, 48.3% mix-fed and 10.3% exclusively formula-fed. Although we found significant differences in BMI-for-age z-score ($p = 0.033$) and BMI-percentile-for-age ($p = 0.023$), there was no significant differences in fat mass and percent fat mass between the groups. Formula-fed children tended to have slightly higher fat-free mass and percent fat-free mass than both mix-fed and exclusively breastfed children although these differences were not statistically significant.

Conclusions: Our findings suggest that the direction of the association between early infant feeding and childhood obesity may be dependent on the indicators used to assess obesity.

Keywords: Adiposity, BOD POD, body composition, exclusive breastfeeding, mix-feeding, obesity, pre-school children.

1. INTRODUCTION

Overweight and obesity are the result of "caloric imbalance"–too few calories expended for the amount of calories consumed–and may also result from eating habits, genetic, behavioral, and environmental factors as well as lack of physical activity [1].

Obesity in childhood is not a benign condition, despite the popular belief that overweight/obese children outgrow the condition. The longer a child stays overweight / obese, the more likely the child is to be overweight or obese during adolescence and adulthood [2]. Obesity in childhood is associated with a wide range of serious health complications and an increased risk of premature onset of chronic diseases [3].

2. OVERWEIGHT AND OBESITY SITUATION

Reports by the World Health Organization [4] and the International Obesity Task Force [5] suggest that the prevalence of obesity is high and increasing in all age groups and most countries worldwide, with these trends being observed from very early life [6].

Data from the National Center for Health Statistics [7] in the United States show that childhood obesity has more than doubled in children and quadrupled in adolescents in the past 30 years. Findings from studies by Ogden and colleagues between 2011 and 2012 also support these findings and they also found that in the year 2012, the percentage of children aged 6-11 years in the United States who were obese increased from 7% in 1980 to nearly 18% [8].

3. CHILDHOOD FEEDING PRACTICES

A review by Anzman *et al*, [9] suggested that one factor that has been linked to early growth is the first decision parents make about feeding their infants: whether to breast-fed or formula feed. They also reported that during the early months after birth, the growth rate of breast-feed infants slows relative to formula-fed infants, and their trajectories tend to track at lower levels during later infancy.

A study by Daniels and colleagues [1] found that childhood obesity can adversely affect almost every organ system and often has serious consequences, including hypertension, dyslipidemia, insulin resistance or diabetes, fatty liver disease, and psychosocial complications. Overweight/obese children have also been found to be at least twice more likely to be deficient in certain micronutrients, particularly iron, than their normal weight counterparts [10]). Other complications that could arise as a result of childhood obesity include acceleration in the timing of the larche and menarche in girls [11].

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Although breastfeeding has been reported to reduce the likelihood of overweight/obesity in young children [12], these studies have either used BMI-for-age or skin fold measurements to assess overweight and obesity [13-16] which are not very accurate methods of measuring total body adiposity. This situation has resulted in mixed reporting of the association between breastfeeding and childhood obesity. Measuring adiposity using a valid body composition methodology in studies examining the role of breastfeeding in the obesity epidemic is likely to provide additional evidence of the influence of breastfeeding on obesity, particularly in childhood.

Although there are numerous techniques and equipment for body composition measurement such as underwater weighing, dual energy X-ray absorptiometry, bio-electric impedance and deuterium dilution, the air-displacement plethysmography (ADP) technique has been evaluated and shown to be accurate, easy and a convenient means of measuring total body adiposity in infants, children, and adults [17-20].

The objective for this study was to assess the relationship between infant feeding (exclusive breastfeeding, mixed feeding and exclusive formula feeding) and childhood adiposity among pre-school children. We hypothesized that children who were exclusively breastfed for at least three (3) months will have different adiposity compared to children who were mixed or formula fed.

3. METHODS AND DESIGN

3.1. Study Design

This was a cross-sectional study conducted in 2013 to determine the relationship between early infant feeding practices and adiposity of pre-school age children. Mothers aged 18 years or older and their children 4 to 6 years, residing in the Athens Area and surrounding communities of the State of Georgia were recruited to participate in the study. All interested participants (mother-child pairs) who met the inclusion and exclusion criteria were scheduled and reported to the Maternal and Child Nutrition Research Lab, Department of Foods and Nutrition, University of Georgia for the consent process. Inclusion criteria included 1) child born full term (>37 weeks gestation), 2) normal birth weight (>2.5kg), 3) between 4 and 6 years old, 3) absence of conditions that limit/restrict mobility, 4) able to sit in the BOD POD for the duration of the body composition measurement, and 5) parent's ability to accompany their child to the research laboratory and complete the questionnaire, children born premature, with congenital malformation or spent extensive time in the neonatal intensive care (NICU), and on steroid medication were excluded. Participants (mothers) provided a written consent before being enrolled in the study. The study protocol was reviewed and approved by the Institutional Review Board of the University of Georgia.

Mothers were interviewed as part of data collection using a structured questionnaire, and the child's body composition measurement conducted thereafter using the BOD POD Pediatric Option body composition system. Mothers received a hardcopy of the body composition results of the child and $25 compensation for their time and participation.

3.2. Measures

3.2.1. Anthropometric Measurement

After the child changed into the recommended outfit (one-piece swimsuit for girls or spandex shorts for boys) and a tight fitting swim cap, his/her height was measured *via* a standing stadiometer (SECA 214) to the nearest millimeter. On the day of measurement, the weighing scale connected to the BOD POD was calibrated using known weights and volume phantom per the manufacturer's protocol. Mothers were instructed not to let the child eat or drink anything at least 2 hours before reporting to the research lab. Child's weight was measured to the nearest 0.01kg. BMI-percentile-for-age and BMI z-score were calculated using the Baylor College of Medicine BMI calculator (https://www.bcm.edu/cnrc-apps/bodycomp/bmiz2.html).

3.2.3. Body Composition Measurement

Each day, before data collection began, the BOD POD Pediatric Option body composition system was calibrated according to the manufacturer's protocol (COSMED Inc., Concord, CA, USA). The BOD POD was calibrated by measuring the empty chamber with the Pediatric Seat secured to the test chamber, followed by adding the calibration cylinder (19.977 Liters) according to the manufacturer's protocol. Testing procedures for the body composition measurement were explained to the child in the presence of his or her mother.

The subject's information, consisting of study ID, date of birth, gender, height and ethnicity, was subsequently entered into the computer while the BOD

POD went through a 2-point calibration. First, the volume of the test chamber of the BOD POD was measured with only the Pediatric Seat inside. Then, the 19.977 Liters calibration cylinder was placed on the Pediatric Seat in the BOD POD with the door closed. The child's weight as described above was measured during the 2-point calibration and automatically captured into the BOD POD computer system. The calibration cylinder was removed and the child was asked to enter the BOD POD, seated and secured in the Pediatric Seat. The child was then instructed to sit very still, not to talk or laugh, and to breathe normally. Then the door to the test chamber of the BOD POD was closed for the body volume measurement. A total of 3 body volume measurements were conducted during a test session with each lasting about 50 seconds with the BOD POD door opened in between measurements. The three body volumes were to be within 0.2% or 150mL of each other. If the three body volume measurements were not in the required range, the entire test session was repeated. After successful body volume measurements, the child was asked to step out of the BOPD POD while the computer system used the predicted thoracic gas volume (TGV) to estimate the child's body composition (fat mass, fat free mass, percent fat mass and percent fat free mass).

Fat mass index (FMI) and fat-free mass index (FFMI) were computed as fat mass divided by height-squared and fat-free mass divided by height-squared, respectively.

3.2.4. Data Collection

Additional data was obtained from the mother using a questionnaire in a face-to-face interview format. Questions asked included gestational age at delivery, birth weight and length, maternal age, education, maternal weight and height, alcohol use and smoking, early infant feeding practices, timing of introduction and types of complementary foods fed. Exclusive breastfeeding was assessed using the since birth definition. Mothers were asked how long since birth did the infant receive breast milk as the only source of nutrition. We also use the timing of introduction of complementary food to ascertain the true duration of exclusive breastfeeding. Infants who received any other source of nourishment in addition to breast milk are classified as mix-fed, irrespective of the frequency of age.

3.2.5. Statistical Analysis

Descriptive statistics was used to describe participant's characteristics with results presented as frequencies and percentages for categorical variables and means for continuous variables. Pearson Chi-square test was used to explore the differences between groups (e.g., exclusively breast-fed, mix-fed and formula-fed). The level of statistical significance was set at $P<0.05$.

4. RESULTS

A total of 29 mother-child pairs participated in the study. There were no statistical differences in maternal age, education and weight status. Most (65.5%) of the children in the study were female and 82.8% were Caucasian with the remaining 17.2% being Black/African American. The mean age of the participating children was 4.9±0.8 (range: 4 to 6) years. None of the mothers reported smoking or consuming alcohol during the pregnancy with the child. Average maternal age at birth of child was 28.7±4.7 (range: 21 to 40) years while age at test date was 33.9±4.9 (range: 25 to 47) years. The average maternal BMI was 25.5±5.8 (range: 18.6 to 38.0)kgm^{-2}. Out of the 29 children who participated in the study, two-fifths (41.4%) were exclusively breastfed for at least 3 months while 48.3% were mix-fed and 10.3% were formula-fed in the early life. Duration of exclusive breastfeeding ranged from 0.5 months to 6 months (Table **1**). Average age of introduction of complementary food was 4.9±1.6 (range: 0.5–9.0) months. Only 10.3% of the children were reported to have changed their diet significantly in the past year. Some of the reasons given for dietary change included a recent gluten allergy (1/3), family's preference for a whole food or macrobiotic diet (1/3), and the family becoming pescetarian (1/3).

Table 1: Participant Characteristics

Characteristics	Mean ± SD
Birth weight (kg)	3.47 ± 0.09
Birth length (cm)	51.31 ± 0.50
Current weight (kg)	19.76 ± 0.61
Current height (cm)	112.78 ± 1.44
Percent fat mass (%FM)	15.93 ± 1.17
Percent fat free mass (%FFM)	84.07 ± 1.17
Fat mass (kg)	3.11 ± 0.24
Fat free mass (kg)	16.63 ± 0.59
Fat mass index (FMI)	2.48 ± 0.20
Fat free mass index (FFMI)	12.99 ± 0.25

Table 2: Child Anthropometrics and Body Composition by Type of Early Infant Feeding

	Mode of Feeding			
	EBF	**MF**	**FF**	**p-Value**
Birth Weight (Kg)	3.58 ± 0.28	3.55 ± 0.45	2.63 ± 0.33	<0.001
Birth Length (cm)	52.99 ± 2.11	50.66 ± 2.31	47.63 ± 1.91	<0.002
Current Weight (kg)	19.37 ± 3.02	19.42 ± 3.52	27.74 ± 2.33	<0. 037
Current Height (cm)	114.03 ± 7.44	110.48 ± 8.18	118.53 ± 1.99	<0.874
% FM	17.04 ± 6.70	16.12 ± 5.91	10.57 ± 5.46	<0.713
% FFM	82.96 ± 6.70	83.88 ± 5.91	89.43 ± 5.46	<0.713
FM	3.28 ± 1.45	3.12 ± 1.26	2.40 ± 1.20	<0.757
FFM	16.09 ± 2.97*	16.31 ± 3.18	20.34 ± 2.43*	<0.861

EBF=Exclusive Breast-Feeding; MF=Mix-Feeding; FF=Formula Feeding; *p=0.041.

4.1. Anthropometry and Body Composition by Type of Early Infant Feeding

Table **1** presents the anthropometric and body composition profile of the children. Their reported mean birth weight was 3.47±0.9kg with exclusively breast-fed and mix-fed children weighing slightly more at birth than their formula-fed counterparts (Table **2**). Similar trend was observed for birth length (Table **2**). We did not observe any significant difference in the children's current weight and height, irrespective of type of early infant feeding (Table **2**). Although we did not observe any statistically significant differences in %FM, %FFM, FM and FFM by type of early infant feeding (Table **2**), there was a significant difference in BMI-for-age z-score (p=0,033) and BMI-for-age percentile (p=0.023) with formula-fed infants having slightly higher values than their exclusively breast-fed and mix-fed counterparts (Table **3**). Children who were either exclusively breast-fed or mix-fed by 3 months of age tended to have slightly higher %FM and FM while their counterparts who were formula-fed had higher %FFM and FFM. Children who were formula-fed had slightly higher BMI z-score, BMI percentile and FFMI compared to children who were either exclusively breast-fed or mix-fed within the first 3 months after delivery (Table **3**).

5. DISCUSSION

Our study findings show that exclusively breast-feeding for at least 3 months is associated with lowest weight among preschoolers, although not statistically different from children either mix-fed or formula-fed. Other studies with much larger sample size have reported similar findings [21]. Several studies have attributed these findings to less energy intake, as well as less protein intake by exclusively breast-fed as compared to formula-fed infants [21-24]. Whilst some studies support our findings that exclusive breast-feeding is protective against rapid weight gain in children [25], others have reported no protective effect [26].

Although we did not observe statistically significant difference in measures of body composition by type of early infant feeding, children who were exclusively breast-fed had slightly higher fat mass (FM) and %FM

Table 3: Markers of Childhood Adiposity by Type of Early Infant Feeding

Weight Status	Mode of Feeding		
	EBF	**MF**	**FF**
BMI Z-Score	- 0.54 ± 1.30*	0.35 ± 0.61*	0.59 ± 0.75
BMI Percentile	38.28 ± 28.04[¥]	61.23 ± 0.17[¥π]	68.83 ± 23.06[π]
FMI	2.56 ± 1.6	2.57 ± 0.99	1.70 ± 0.83
FFMI	12.28 ± 1.37[ab]	13.27 ± 1.01[a]	14.47 ± 1.55[b]

BMI: body mass index; FMI: fat mass index; FFMI: fat free mass index.

*p=0.033; [¥]p=0.023; [π]p=0.041; [a]p=0.045; [b]p=0.031.

compared to their formula-fed counterparts. Similar findings have been reported by [21], who observed higher fat mass and percentage fat mass in breast-fed than formula-fed infants at 3 and 9 months, but no differences at 12 and 24 months of age. This is however contradictory to findings by Bellù *et al,* [27], who used total body electric conductivity (TOBEC) as a tool to measure the body composition of breast-fed as well as formula-fed infants who were 12 months old. They reported lower weight as well as body fat mass among breast-fed children compared to their formula-fed counterparts. Other studies have reported significantly higher fat mass, but not percentage fat mass among formula-fed girls [23].

Many studies over the past years have suggested that breastfeeding offers long-term protection against obesity, and the degree of protection increases with greater duration of exclusive breastfeeding [16]. In the current study, BMI z-score was highest for formula–fed children, whilst the exclusively breastfed group had the lowest BMI z-score. Similarly, formula-fed children had the highest BMI-percentiles, whilst exclusive breastfeeding children recorded the least. Consistent with our findings is a cross sectional study done in Bavaria in South Germany which involved 134,577 children within the ages of 5-6 years of age. They found that prolonged exclusive breastfeeding reduced the risk of being obese or overweight, which they attributed to the composition of breast milk as the contributing factor. They reported the prevalence of obesity among formula-fed children who had never been breast-fed to be 4.5% as compared to 2.8% in exclusively breastfed children [28]. Similar findings were also reported by Yan *et al,* [29] in which a systematic review (meta-analysis) comprising of 226,508 participants from 12 countries showed that breast-feeding was associated with a significantly reduced risk of obesity in children.

CONCLUSION

Overall, our results suggest that exclusive breastfeeding may be protective against body weight and obesity assessed as BMI but not fat mass or percent fat mass. There is therefore a need for adequately powered prospective studies that monitors early infant feeding practices, timing and introduction of complementary foods on weight and adiposity in later childhood.

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