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Concordance of the Deuterium Dose to Mother Method and 24-Hour Recall to Measure Exclusive Breastfeeding at 6 Weeks Postnatally in Rural/Urban Setting in Jamaica

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Abstract

Introduction The 2030 health agenda for the United Nations Sustainable Development Goals promote exclusive breastfeeding (EBF) for the first 6 months of life as a central step towards ensuring the survival of infants. As Jamaica attempts to achieve this goal, monitoring the rates of EBF is desirable. Currently, EBF rate is measured by questionnaires which are subject to recall and social desirability biases. We determined the rate of EBF using the Deuterium-oxide dose-to-mother (DTM) method and 24-h recall. The concordance of both methods and urban–rural differences of EBF were evaluated. Additionally, the growth of infants who were exclusively breastfed was compared to the infants who were mixed-fed.

Methods Sixty-one healthy mother–child pairs were followed from birth. EBF was measured at 6 weeks. Growth was determined using standard anthropometric measurements. Differences in means were assessed by independent t-test or ANOVA. The agreement between the DTM and 24-h recall method was assessed with the kappa statistic. Differences in anthropometry and location were determined using a repeated measure model approach.

Results Thirty (49%) women exclusively breastfed their infants with mean breast milk intake of 1024.3 ± 256.9 g/day. There was moderate agreement between the methods (Agreement 69%, kappa 0.37, $p = 0.002$). Rural women (65%) were more likely to practice exclusive breastfeeding. There was no significant difference between the growth of the exclusively breastfed infant and mixed-fed infants.

Conclusion EBF rate was successfully measured using the DTM method. Women from urban settings are less likely to practice EBF. Further research may be needed to gain an in-depth understanding of the factors affecting breastfeeding practices in urban Jamaica.

Keywords Breastfeeding · Deuterium-oxide dose-to-mother method · Infant growth · Jamaica

Significance Statement

What is known Current methods of measuring breastfeeding in Jamaica is subject to recall bias and may fail to determine the true prevalence of exclusive breastfeeding. A quantitative reliable method is needed to give a true picture of the current rate of exclusive breastfeeding.

What this study adds This study demonstrated the successful use of the safe and reliable deuterium-oxide dose-to-mother method to determine exclusive breastfeeding and to quantitatively measure breastmilk intake in Jamaica.

Introduction

Breast milk is accepted as the best source of nutrition for the young infant with benefits that are both immediate and long-term. Exclusive breastfeeding (EBF) is practised when the infant is fed with breast milk and no other solids or liquids including water with the exception of oral rehydration salts, medicines and vitamin or mineral supplements (WHO, 2008). Exclusive breastfeeding is of importance in low- and middle-income countries where the occurrence of infectious

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diseases is high and poor sanitation and lack of potable water are quite widespread (Victora et al., 2016a, 2016b). The practice of breastfeeding (BF) has the possibility to avert over 800,000 deaths in children 5 years and under in developing nations (Black et al., 2013) with the effect being more evident if the infant is exclusively breastfed (Mihrshahi, 2008). Exclusive or predominantly breastfed infants are less likely to be stunted and are at a reduced risk of developing lower respiratory and gastrointestinal illnesses (Duijts et al., 2009) and chronic non-communicable diseases later in life (Bernardo et al., 2013; Rudnicka et al., 2007) compared to infants who receive little or no breast milk during infancy. This effect is likely to be mediated by differences in early growth of the infants based on breast milk and mixed milk intake. However, in Jamaica, it is unclear as previous studies that examined the relationship between early growth and chronic non-communicable disease did not explore the relationship with breastfeeding (Boyne et al., 2010; Forrester et al., 1996; Lawrence-Wright et al., 2011).

Breastfeeding is also beneficial to the health of the lactating woman. Women who practise exclusive breastfeeding are more likely to have their uterus returning to its normal size and there is less postpartum blood loss (Dieterich et al., 2013). Exclusively lactating women also experience lactational amenorrhea; the period in which there is no menstruation due to the hormonal effects of breastfeeding, thereby preserving iron stores (Dieterich et al., 2013). Breastfeeding may also increase the likelihood of weight loss in women who had gained excess weight during pregnancy, reducing the risk of obesity and the likelihood of developing type-2 diabetes and hypertension (Williams et al., 2014). Therefore, promoting exclusive breastfeeding could be a key strategy used to curb the debilitating effects of the double burden of disease in a country experiencing nutrition transition, such as Jamaica.

The recommendation by the World Health Organisation (WHO) is that all infants be exclusively breastfed for the first 6 months of life with continued breastfeeding for up to 2 years with appropriate complementary feeding (WHO, 2001). While the rate of initiation for exclusive breastfeeding is high, most women struggle to meet this requirement and often the rate of exclusive breastfeeding declines substantially in the first few months postpartum (Chatman et al., 2004). Currently, the rate of exclusive breastfeeding in Jamaica is measured using questionnaires administered to the mothers of infants between the ages of 0 to 6 months at the health clinics during routine health checks. The limitation of this method is it can be affected by recall. Additionally, the desire of the mothers to appease healthcare professionals often results in a higher reporting of breastfeeding than what is being practised (Mulol & Coutsoudis, 2018). Previous studies in Jamaica that have reported BF prevalence, utilized questionnaires and reported rates of 30% in urban areas at 6 weeks (Kurzewski, 2005) and 22.2% in the rural areas at 6 months (Chatman et al., 2004). However, whether the differences in BF patterns are reliable at post-delivery between urban and rural women is unknown. The deuterium-oxide dose-to-mother method (DTM) is a quantitative assessment of the volume of milk ingested by an infant thus providing an objective measure of breastfeeding practice (IAEA, 2010; Lokonon et al., 2020; Mulol et al., 2020). The 2030 health agenda for the United Nations Sustainable Development Goals promote breastfeeding as a central and practical step towards protecting the survival of infants and women through exclusive breastfeeding. As the Jamaican government attempt to achieve this goal, monitoring and assessing the rates of exclusive breastfeeding is desirable. Therefore, the primary goals of this study were, to determine the prevalence of EBF utilizing the deuterium-oxide dose-to-mother method at 6 weeks post-delivery, to determine whether there were urban–rural differences and to determine concordance by the methods used and to determine the exclusive breastfeeding rates. The secondary goal was to compare the growth of infants fed exclusively with breastmilk and infants who are mixed-fed (both formula and breast milk) at 6 weeks.

Method

Subjects and Participation

Jamaica is a Caribbean Island Nation classified as an upper middle-income country (UMIC) with a population of approximately 2.9 million, of which 937,700 resides in the urban capital of Kingston. Manchester is a parish located in the central area of the island with a population of approximately 91,000. Participants were chosen from Kingston and Manchester as the high population density would provide good representation of both rural and urban Jamaica. The study design was longitudinal and observational. The deuterium-oxide dose-to-mother protocol was conducted in the Manchester parish capital at the Mandeville Health Centre, in Health Centres across the neighbouring parishes of Clarendon and St Elizabeth and at the study site located at the Caribbean Institute for Health Research, Tropical Metabolism Research Unit (CAIHR-TMRU), The University of the West Indies, Kingston Jamaica.

Eligible individuals were identified through the hospital admission records from the maternity wards of the University Hospital of the West Indies in the parish of Kingston and the Mandeville Hospital in the Parish of Manchester, Jamaica. Individuals were approached and invited to participate. Informed consent was received from persons willing to participate until the required number for the study was achieved. Prior to enrolment, the eligibility of the

mother-infant pairs to participate in the study was verified using a wellness questionnaire. Eligibility criteria included mothers between the ages of 18 to 40 years with singleton termed births (37 to 42 weeks gestation) and infants with Apgar scores of 8 to 10. Exclusion criteria included women who had a complicated pregnancy or presented with any infectious diseases, chronic illness or genetic disorders that would prevent breastfeeding and infants with congenital disorders, or any defect that would interfere with their ability to feed, were premature or admitted to the neonatal nursery during the first week of life.

One hundred and twenty-nine women were approached to be enrolled in the study, (Fig. 1), of these, 107 mothers gave informed consent. Of this total, 34 mothers could not continue due to personal reasons; 4 were relocated to other areas and 2 cited health reasons and withdrew their consent. DTM protocol was conducted in 67 mothers at 6 weeks of which 61 had evaluable data.

This study was funded by a grant from the Office of Graduate Studies and Research, University of the West Indies (UWI), Mona Campus and the International Atomic Energy Agency, (IAEA). Ethical approval was granted by the University Hospital of the West Indies, University of the West Indies, Faculty of Medical Sciences, (UHWI/UWI/FMS) Ethics committee and the Ministry of Health Ethics Board, Jamaica. This study was performed in accordance with the standard established in the Declaration of Helsinki (1964) ("Declaration of Helsinki (1964)," 1996) and all its later amendments. All participants gave a signed informed consent before being enrolled in the study. Subsequently, the mothers of the infant completed an interviewer-administered questionnaire that sought to obtain information on breastfeeding practice and socio-economic status.

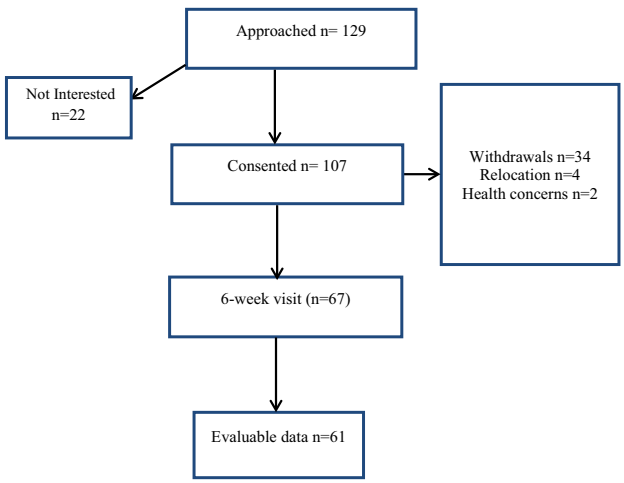

Fig. 1 Flowchart of recruitment, participation and follow-up of study participants

Feeding Practice by Questionnaire

The infants' mothers were interviewed on a weekly basis by telephone from birth to 6 weeks. The main aims of the interview were to determine the breastfeeding practice and to describe the infant's dietary intake and wellness status. On each occasion, the participants were asked whether they were breastfeeding, how often they breastfed and for how long during each feed. If breastmilk was not the only food given, then each responder would be asked to share details about the additional foods that were given such as, vitamins or mineral supplements, sweetened wa*ter (lemonade) or glucose, flavoured or p*lain water, fruit juice, *tea,* infant formula, *Canned "t*inned", powdered or fresh milk (cow's milk) *or soy "milk", solid or semi-solid food or oral rehydration s*alts (ORS) etc. The information would then be coded, and each participant classified based on the WHO criteria for exclusive breastfeeding.

Feeding Practice by Direct Measurement

Milk intake was measured quantitatively using the DTM method at 6 weeks postnatal age (IAEA, 2010). This technique also facilitates the determination of non- breast milk intake thereby allowing exclusive breastfeeding to be estimated. Deuterium oxide is also called heavy water, it occurs naturally in the environment at approximately 150 parts per million in water and it is also found in the human body (IAEA, 2010; Mulol et al., 2020). Therefore, pre-dose saliva samples were collected from the mother and the infant prior to administering the deuterium oxide to adjust for background enrichment. At the beginning of the protocol (Day0), the mother of the infant consumed a weighed enriched dose (30 g 99.9% D2O; Sigma-Aldrich Corp) of deuterium oxide. The deuterium oxide mixes with the mother's body water and forms a part of her saliva and breastmilk. Deuterium oxide can only be passed from the mother to the infant through the mother's milk. If the infant receives breastmilk, the deuterium from the milk also mixes with the infant's body water and forms a part of the saliva. Post-dose saliva samples were then collected from the mother and infant on days 1, 2, 3, 4, 13 and 14. The saliva samples were obtained by placing a small sterile cotton ball into the mouth of the mother and allowing it to remain until saturated (IAEA, 2010). The infants' mouths were swabbed with sterile cotton until saturated; the cotton wool was then transferred to 20 ml syringes where the saliva sample was expressed into collecting tubes. The saliva samples were collected at least one hour after the mother and infant had eaten. As best as possible, the samples were collected at the same time on each day during the collection period. Saliva samples were then stored at − 20 °C until they were analysed. Infants' body weights

were measured again on day 14 to monitor growth during the 2-week period of the DTM protocol (IAEA, 2010).

Deuterium enrichment was determined from the saliva samples of the mother and infant by Fourier-transform infrared spectroscopy (FTIR) according to standard instructions outlined by the manufacturer (Agilent 4500 Tumbl-IR, Agilent Germany). Samples were measured twice or until a coefficient of variation of less than 1% was achieved (IAEA, 2010). The average of the two values was used to determine deuterium enrichment. Quantitative determination of water intake from breastmilk and other sources was determined based on the theory of the two compartment model (IAEA, 2010). In the two-compartment model, enrichment values measured from the mother and infant over the 2-week period were used to generate curves by fitting the measures into equations using the Solver function of Microsoft Excel® (IAEA, 2010). The Solver function uses non-linear regression to compute, by repeated measures, the value of the constants that decrease the sum of the squares of the differences between actual measured and expected values both for mother and infant data. This produced values for both the labelled (from breastmilk) and non-labelled water. An infant was classified as exclusively breastfed if the intake of non-labelled water was less than or equal to 87 g/day. Infants with intakes greater than 87 g/day of non-breast milk water were classified as non-exclusive breastfed (mixed-fed) (IAEA, 2010).

Anthropometry

The length and weight of each mother-infant pair were measured by standard anthropometric methods and recorded on the day of the deuterium study. For infants, birth anthropometry was extracted from hospital records. Gender-specific z-scores for length/height-for-age, and head circumference-for-age were calculated using the World Health Organization (WHO) growth charts as reference.

Statistical Analysis

Values are expressed as frequencies, proportions, and means with standard deviations as appropriate. Differences in group means were assessed by independent t-test or ANOVA and associations between categorical variables by Chi-square statistic. The agreement between the deuterium-based classification of breast milk intake and questionnaire-based classification was assessed with the kappa statistic. To determine whether there were differences in anthropometry by feeding mode, location and gender, a repeated measure model approach was used with repeated factor anthropometric measures and gender, location and feeding mode, the between factors. All statistical analyses were performed using the STATA version 14©, StataCorp, College Station, Texas, USA.

Results

Maternal Characteristics

Of the total 61 women who completed the DTM protocol, 35 were from the urban area and 26 from the rural area. The mean age was 28.6 ± 6.2 years and there was no significant difference in womens' age by location. Similarly, there were no significant differences in womens' weight, height, or BMI fat mass by location (Table 1). However, there were significant associations between income level, employment status, parity and educational level and location with urban women having greater than expected income level, educational attainment, and lower parity than rural women. Women who are employed and are becoming first time mothers are significantly less likely to breastfeed.

A significantly higher proportion of rural women 65% (17/26) practised exclusive breastfeeding, compared with urban women 37% (13/35). The overall exclusive breastfeeding proportion for this sample was 49%. However, based on mothers' report, 47% practised exclusive breastfeeding (Table 2). There was moderate agreement between the breastfeeding classification by the DTM method and the 24-h recall (Agreement 69%, kappa 0.37, $p = 0.0016$). Within location, there were no significant differences in anthropometry between the women who exclusively breastfed compared to women who did not (Table 1).

Milk Intake

The mean overall intake of human milk in the infants was 901.9 g/day and the mean total intake of water from other sources was 231.5 g/day. As expected, the mean intake of breast milk was 1024.3 ± 256.9 g/day in the exclusively breastfed infants which was significantly greater than the mean of 783.4 ± 341.4 g/day milk intake in the 29 infants who were not exclusively breastfed (Table 3). Infants of rural mothers consumed on average more breast milk compared with infants of urban mothers (1042 g/d ± 221 g/d vs 798 g/d ± 351 g/d, $p < 0.003$). However, there was no difference in milk intake by gender (Male vs Female, 962 g/d ± 330 g/d vs 847 g/d ± 313 g/d, $p = 0.16$)) or employment status of the women (employed vs unemployed, Fig. 2).

Infant Growth

As expected, there were significant increases in absolute weight, height, and head circumference values from birth to the 6-weeks. There was positive change in z-score from

Table 1 Maternal anthropometric characteristics for rural and urban mothers and by feeding type

Anthropometric and Socio-demographic characteristics	Rural (n = 26)		Urban (n = 35)		All (n = 61)	P value
	EBF (n = 17)	NEBF (n = 9)	EBF (n = 13)	NEBF (n = 22)		
	Mean ± sd	Mean ± sd	Mean ± sd	Mean ± sd	Mean ± sd	
Age (years)	30.4 ± 6.7	27.1 ± 6.1	29.2 ± 5.4	28 ± 6.4	28.8 ± 6.2	0.5
Weight (kg)	64.8 ± 13.4	66.4 ± 15.1	76.3 ± 22.7	65.6 ± 12	67.7 ± 15.9	0.2
Height (cm)	161.9 ± 7.4	162.7 ± 13.1	166.6 ± 7.2	161.3 ± 7.1	162.8 ± 8.4	0.3
BMI (kg/m^2)	24.5 ± 3.9	25.3 ± 6.1	27.4 ± 7.4	25.1 ± 3.5	25.5 ± 5	0.5
Fat free mass kg	39.3 ± 5.1[a]	38.7 ± 4.3[a]	52.9 ± 10.6[b]	48 ± 7.1[b]	44.6 ± 9	< 0.001
Fat mass kg	24.6 ± 10	27.7 ± 11.7	21.1 ± 15.2	21.4 ± 14.4	23.5 ± 12.7	0.6
Fat mass %	37.2 ± 8.7[a]	40.2 ± 8.6[a]	26.1 ± 10.9[b]	28.7 ± 11.8[a]	32.9 ± 11.3	< 0.004
Income level						< 0.001
< $20,000	10	6	0	0	16	
$20–60,000	3	3	1	8	15	
> $60,000	2	0	8	12	22	
Employment status						< 0.006
Employed	8	2	12	15	37	
Unemployed	8	7	1	7	23	
Marital status						0.08
Unmarried	9	9	11	16	45	
Married	7	0	2	6	15	
Educational level						< 0.02
Secondary/primary	13	9	5	15	42	
Tertiary	3	0	8	7	18	
Parity						< 0.001
Primigravida			10	10	20	
Multigravida	17	9	3	12	41	

EBF exclusive breastfeeding, *NEBF* non-exclusive breastfeeding

[a]Significant difference between location

[b]Significant difference within location

Table 2 Agreement between Deuterium-oxide dose-to-mother method and the 24-h recall

24-h recall	Stable isotope method		Total
	EBF	Mixed feeding	
EBF	20	9	29
Mixed feeding	10	22	32
Total	30	31	61

DTM dose to mother, EBF breastfeeding. Agreement 69%, kappa 0.37, p = 0.0016, Sensitivity to identify Exclusive BF = 66.7% 95 CI 47.2% to 82.7%, Specificity for Exclusive BF = 71% 95 CI 52% to 86%

birth to six weeks for weight-for-age, but this was only significant for the urban exclusively breastfed infants (Fig. 3). There was no significant difference in length-for-age z-score change between birth and the 6 weeks by location and feeding mode. However rural infants had significantly lower head circumference z-scores at 6 weeks relative to birth but there was no difference in head circumference z-score change for urban infants (Fig. 3). Additionally, there was a significant positive association between milk intake and weight-for-age z-score adjusting for weight-age z-score measurement at birth with a 100 g/d increase in milk intake associated with a 0.14 weight-for-age z-score increase at 6 weeks (Fig. 4). In contrast, there was no association of milk intake with head circumference or length-for-age (Fig. 4).

Discussion

In the present study, the prevalence of exclusive breastfeeding was determined using the deuterium-oxide dose-to-mother method. Previous studies in Jamaica, have demonstrated an exclusive breastfeeding prevalence of 30% in urban areas at 6 weeks (Kurzewski, 2005) and 22.2% in the rural areas at 6 months (Chatman et al., 2004) using

Table 3 Anthropometric and milk intake of infants by location and Breastfeeding status

Anthropometry and Milk intake in infants	Birth				6 weeks			
	Rural		Urban		Rural		Urban	
	EBF	NEBF	EBF	NEBF	EBF	NEBF	EBF	NEBF
Female to male ratio	9:8	5:4	6:7	12:10				
Age (months)					1.6 ± 0.3	1.6 ± 0.1	1.8 ± 0.3	1.7 ± 0.2
Weight (kg)	3.3 ± 0.5	3.3 ± 0.5	3.4 ± 0.3	3.2 ± 0.4	5.1 ± 0.6	5.2 ± 1.2	5.5 ± 0.7	5.1 ± 0.7
Height (cm)	50.5 ± 3.4	50 ± 1.9	50.5 ± 1.9	48.3 ± 2.8	56.8 ± 2.6	57.4 ± 2.5	57 ± 2.1	55 ± 2
Head Circumference (cm)	34.1 ± 1	33.1 ± 1.5	33.9 ± 1.4	34 ± 1.4	36.7 ± 1.5	36.1 ± 1.4	38.5 ± 2.2	38.3 ± 1.6
Milk Intake (g/d)					1076.5 ± 208.7	976.8 ± 240.4	956 ± 304.1	704.3 ± 349.2
Milk Intake (g/kg/d)					211.2 ± 30.3	189.9 ± 34.3	173.9 ± 47.1	136.5 ± 63.6
Non-Breast Milk Intake (g/d)					20.8 ± 30	209.1 ± 66.6	22.6 ± 29.2	526.9 ± 512.7

EBF exclusive breastfeeding, *NEBF* non-exclusive breastfeeding

Fig. 2 Comparison of milk intake by gender and employment status

recall. The DTM method demonstrated that approximately, 49% of mothers practised exclusively breastfeeding at 6 weeks with geographical locale being a major determinant. Reports of large differences in exclusive breastfeeding by geographical location observed in this study are similar in Niger where only 15.8% of urban mothers practised EBF and 54.4% of rural mothers practised EBF (Hitachi et al., 2019). Urbanisation and modernisation in developing countries over the last few decades have been reported to be contributing factors of low breastfeeding rates (Oakley et al., 2017; Victora et al., 2016a, 2016b). This study was no exception as the findings demonstrated that mothers from the urban area were less likely to exclusively breastfeed their infants. Urbanisation is positively associated with employment, higher educational attainment and income (Narayan, 2016). Whereas higher educational attainment and wealth have been positively associated with better breastfeeding behaviours (Victora et al., 2015), mothers' employment is associated with a lower likelihood of breastfeeding (Victora et al., 2016a, 2016b). The demands associated with employment, oftentimes deny mothers the opportunity to breastfeed or express breast milk for the infant (Victora et al., 2016a, 2016b). In addition, infant formula is readily available in urban areas and the ability to purchase infant formula is often viewed as being in a higher social class or having greater wealth (Patel et al., 2010; Rahman & Akter, 2019). In this study, mothers from the urban area were more likely to be employed, had attained higher education, and had higher income compared to the mothers of the rural area. Contrary to the findings of this study, urbanisation was positively associated with exclusive breastfeeding in women living in the sub-urban areas of Malawi (Kamudoni et al., 2007). However, in the study conducted in Malawi, rural women were more likely to give birth outside of a health care facility. Rural women in Malawi were also less likely to benefit from the education and support for exclusive breastfeeding provided by the health care facilities and are more likely to introduce alternate foods at an earlier age (Kamudoni et al., 2007). Based on the foregoing, it is evident that the sociodemographic factors affecting breastfeeding initiation and duration may vary in the degree and direction of influence depending on the country's social and health infrastructure. In Jamaica, there is no disparity

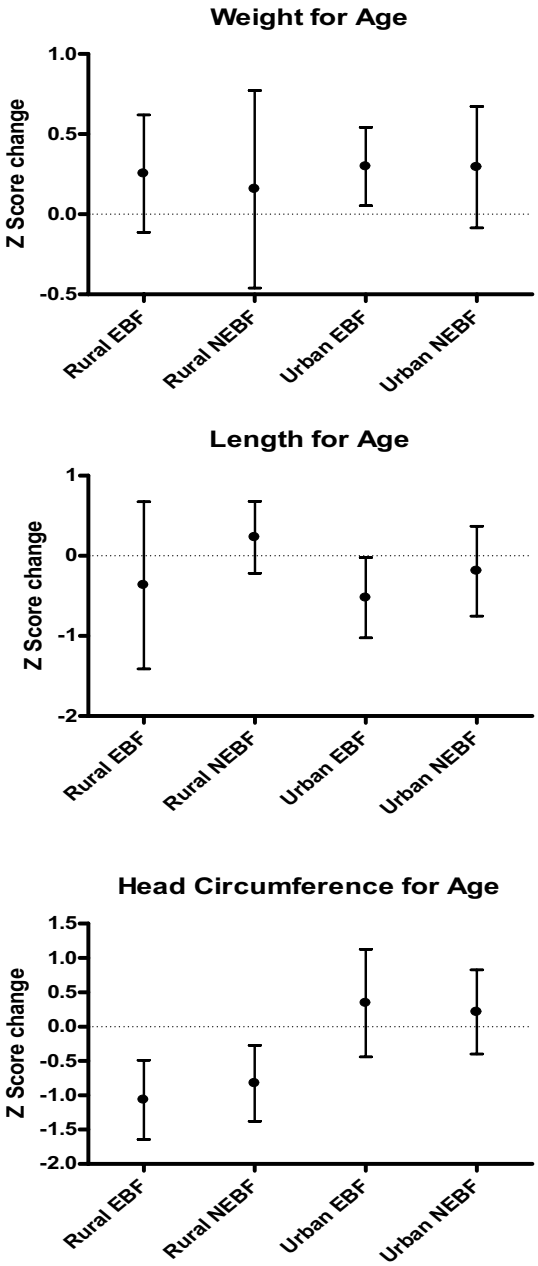

Fig. 3 Z-score change in anthropometry for Rural and Urban infants from birth to 6 weeks by feeding group

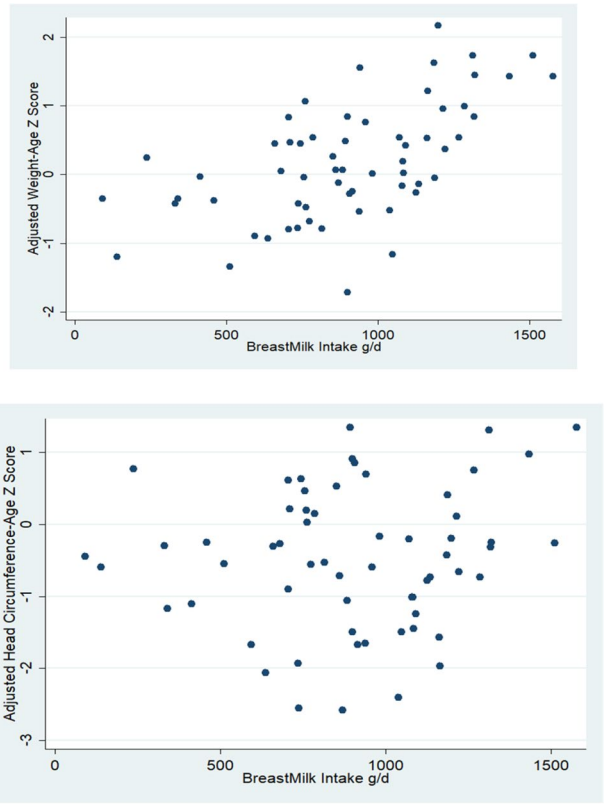

Fig. 4 Variation of Anthropometry z-score with breastmilk intake at 6 weeks adjusting for birth anthropometry

in the availability of support for breastfeeding or health facility in the rural and urban areas (UNICEF, 2013).

Exclusive breastfeeding at 6 weeks was significantly higher in women who are multiparous compared to primiparous women. Multiparous women with previous breastfeeding experience have a greater understanding of breastfeeding and are more likely to overcome the challenges often encountered with the practice compared to primiparous women (Hackman, 2015). In addition, parity is strongly associated with delayed onset of milk production after childbirth; 33% of primiparous women are more likely to experience delay compared to 5% of multiparous women (Dewey et al., 2003). Parity may have contributed to the difference in rates of exclusive breastfeeding observed by location, as in the current study, all the women from the rural area were multiparous.

One major advantage of using the deuterium-oxide dose-to-mother technique is the ease at which the quantity of human milk and non-breast milk water intake is estimated to objectively determine breastfeeding practices. Based on the DTM method, exclusive breastfeeding was classified based on the quantity of non-breast milk water received by the infant. Infants who received ≤ 87 g/day of non-breast milk were classified as exclusively breastfed (Liu et al., 2019a). Forty-nine per cent (49%) of the infants in the study were identified as exclusively breastfed based on this classification. Proportionally, this was comparable to the 47% of exclusive breastfeeding classified by mothers' recall. This present finding contrasts with the findings of previous studies that have investigated the agreement between self-reported breastfeeding practices and the DTM (Medoua et al., 2012; Motswagole et al., 2015; Mulol & Coutsoudis, 2018). Typically, recall methods are often subjected to self-reported biases and may not reliably estimate exclusively

breastfeeding rates. This is especially common in instances where there are programs aimed at behavioural changes for breastfeeding practice (Lokonon et al., 2020; Moore, 2007; Mulol & Coutsoudis, 2018). The recall method is likely to overestimate the true estimate of EBF, as mothers are likely to respond in ways that are viewed more favourably by healthcare professionals (Hebert et al., 2008; Mulol & Coutsoudis, 2018). Furthermore, the true rate can be missed if additional foods were given a few days before the recall. However, in this current study, a similar proportion of mothers reported practising exclusive breastfeeding by recall compared to the DTM method. The observed concordance between the two methods could be attributable to recency bias. Maternal recall of breastfeeding duration and initiation was found to be valid and reliable if the time of recall was within a period of 3 years or less, compared to a longer period of recall (Li et al., 2005). In the present study, the women were interviewed every week from one week postpartum until the DTM protocol was administered.

The mean values of breastmilk intake determined in the women who practised EBF were significantly different from the women who practised mixed feeding. However, the range of values was comparable to findings of similar studies in settings of similar socioeconomic climate such as Bangladesh (Moore, 2007) and Brazil (HAISMA, 2003).

A secondary outcome of the present study was to compare the differences in growth of the exclusively breastfed infants with infants who were mixed-fed at 6 weeks. During the study period, there was no significant difference in growth between infants who were exclusively breastfed or mixed-fed. Unlike previous studies that demonstrated a difference in growth between formula-fed infants and breastfed infants at one month (Agostoni et al., 1999) and six to eight weeks (Ziegler, 2006) of age, this study did not show any significant difference in the weight-for-age or length-for-age between the two groups of infants. All the infants in this study received breast milk and so the quantity of the different foods received in the mixed-fed group may not be sufficient to produce a significant difference in the growth variables as seen in the above-mentioned studies (Agostoni et al., 1999; Ziegler, 2006). In addition, the 6-week period may have been too short to observe any noticeable differences in the growth patterns between the two groups of infants. Furthermore, the sample size may have been too small to detect any measurable significant difference.

Limitations

In the current study, the use of the deuterium-oxide dose-to-mother technique was successfully used to determine breastmilk intake and to determine breastfeeding practices. Currently, the DTM method is considered to be the gold standard due to its non-invasive nature and ease of administration, however, there are a few limitations that need to be highlighted. The technique requires that saliva samples are collected over two weeks before classification can be determined. This classification may not be generalizable on a long-term basis as the choice of feeding may change thereafter. To compensate for this weakness, a concordance test with the 24-h recall was performed in this study to assist with generalizability.

Conducting the study protocol can prove to be quite costly and labour intensive as it involves purchasing the deuterium oxide for dose and administration, collection of seven post-dose saliva samples and analysis of samples in duplicate. This could be a disadvantage for large studies or studies with limiting funding. However, subsequent to the collection of the data for this current study, a field-friendly protocol was developed by Lui et al. (2019b). In this protocol, three samples are required, that is, one pre-dose and two post-dose samples with sampling days options of, days 7 to 9 or days 13 and 14 (Liu et al., 2019b) instead of seven post-dose samples required in the full protocol. The field-friendly protocol provides a 95% sensitivity and specificity when compared to the full protocol and offers an objective and reliable technique that is suitable for use as a validation tool for the recall methods commonly used in large studies and surveys (Liu et al., 2019b). In addition, the DTM method can be used to quantify both milk intake and non-breast milk water intake and can be employed to determine the intake of other nutritional indices (Lopez-Teros et al., 2017) or environmental contaminants (IAEA, 2010).

The findings of the study highlighted the relationship between sociodemographic factors and breastfeeding practices with rural–urban differences. However, the current findings may not be generalizable as households within both study sites tend to have a higher income than most other regions in Jamaica. Nevertheless, the study sites are densely populated with many individuals representing every economic and social stratum. The differences observed in feeding practices may also need further investigation to gain more in-depth knowledge of the factors. In the interim, immediate action may be needed for the urban population.

In addition, the study was limited to determining exclusive breast milk intake in infants at 6 weeks rather than at 6 months; the period recommended by the WHO for exclusive breastfeeding practice. In this study 6 weeks was chosen to maximise the portion of women who were likely to exclusively breastfeed as previous studies using recall had recorded a great decline beyond 6 weeks (UNICEF, 2013).

Conclusion

Consistent with previous literature, the findings of the study highlighted the sociodemographic effects of breastfeeding and the disparity of exclusive breastfeeding rates

between urban and rural Jamaican mothers. Currently, there are programs to create awareness of the health benefits of breastfeeding both for expectant mothers and the public. However, individualised breastfeeding education and support may be necessary to strengthen the existing strategies, especially among women who will give birth for the first time, are urban dwellers and are employed on a full-time basis. This support should begin during gestation and continue during the early postpartum period. Primiparous women are less confident with the practice of breastfeeding and are often not convinced that breastmilk is enough to meet the nutritional needs of the infant. Additionally, increasing the number of health care facilities certified as Baby-Friendly may also help in increasing the rates of exclusive breastfeeding. Hospitals that are certified as Baby-Friendly do not accept infant formulas, teats and feeding bottles, and staff are trained in lactational management (Lopes Sda et al., 2013). Moreover, studies have shown that early initiation and exclusivity rates of breastfeeding were higher in hospitals certified as Baby Friendly with the higher rates persisting regardless of sociodemographic factors (Merewood et al., 2005; Merten et al., 2005).

Finally, intervention programmes to promote and protect breastfeeding practices such as educational support and a designated safe and quiet area to facilitate the expression of breast milk at places of employment should also be considered. Breastfeeding can be successful for mothers who are professionally employed if adequate support is provided. A study conducted in the USA showed that the employer-sponsored lactation program for working mothers that facilitated milk expression by providing a private room with equipment for expressing breast milk, and a certified breastfeeding consultant, had more women exclusively breastfeeding for 6 months compared to the employers who did not provide these facilities (Ortiz et al., 2004).

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Data Availability The datasets used and/or analysed during the current study are available upon reasonable request from the corresponding author.

Code Availability Not applicable.

Declarations

Conflict of interest The authors wish to declare that there are no known conflict of interest associated with this publication and that the financial support received for this work did not influence the outcome.

Ethical approval Ethical approval was granted by the Ethics Committee of the University Hospital of the West Indies, University of the West Indies, Faculty of Medical Sciences, (UHWI/UWI/FMS) Kingston, and the Ministry of Health Ethics Board, Jamaica.

Consent to Participate Informed consent was obtained from the individuals who participated in the study.

Consent for Publication The participants consented to publishing their individual data in journal articles.

References

Agostoni, C., Grandi, F., Gianni, M. L., Silano, M., Torcoletti, M., Giovannini, M., & Riva, E. (1999). Growth patterns of breast fed and formula fed infants in the first 12 months of life: An Italian study. *Archives of Disease in Childhood, 81*(5), 395–399.

Bernardo, H., Cesar, V., World Health Organization. (2013). *Long-term effects of breastfeeding: A systematic review*. World Health Organization.

Black, R. E., Victora, C. G., Walker, S. P., Bhutta, Z. A., Christian, P., de Onis, M., Ezzati, M., Grantham-McGregor, S., Katz, J., Martorell, R., Uauy, R., & Maternal and Child Nutrition Study Group (2013) Maternal and child undernutrition and overweight in low-income and middle-income countries. *The Lancet*, *382*(9890), 427–451. https://doi.org/10.1016/S0140-6736(13)60937-X

Boyne, M. S., Osmond, C., Fraser, R. A., Reid, M., Taylor-Bryan, C., Soares-Wynter, S., & Forrester, T. E. (2010). Developmental origins of cardiovascular risk in Jamaican children: The Vulnerable Windows Cohort Study. *British Journal of Nutrition, 104*(7), 1026–1033. https://doi.org/10.1017/S0007114510001790

Chatman, L. M., Salihu, H. M., Roofe, M. E., Wheatle, P., Henry, D., & Jolly, P. E. (2004). Influence of knowledge and attitudes on exclusive breastfeeding practice among rural Jamaican mothers. *Birth, 31*(4), 265–271. https://doi.org/10.1111/j.0730-7659.2004.00318.x

Declaration of Helsinki. (1964, 1996). *BMJ 313*(7070), 1448. https://doi.org/10.1136/bmj.313.7070.1448a

Dewey, K. G., Nommsen-Rivers, L. A., Heinig, M. J., & Cohen, R. J. (2003). Risk factors for suboptimal infant breastfeeding behavior, delayed onset of lactation, and excess neonatal weight loss. *Pediatrics, 112*(3 Pt 1), 607–619. https://doi.org/10.1542/peds.112.3.607

Dieterich, C. M., Felice, J. P., O'Sullivan, E., & Rasmussen, K. M. (2013). Breastfeeding and health outcomes for the mother-infant

dyad. *Pediatric Clinics of North America, 60*(1), 31–48. https://doi.org/10.1016/j.pcl.2012.09.010

Duijts, L., Ramadhani, M. K., & Moll, H. A. (2009). Breastfeeding protects against infectious diseases during infancy in industrialized countries. A systematic review. *Maternal & Child Nutrition, 5*(3), 199–210. https://doi.org/10.1111/j.1740-8709.2008.00176.x

Forrester, T. E., Wilks, R. J., Bennett, F. I., Simeon, D., Osmond, C., Allen, M., & Scott, P. (1996). Fetal growth and cardiovascular risk factors in Jamaican schoolchildren. *BMJ, 312*(7024), 156–160. https://doi.org/10.1136/bmj.312.7024.156

Hackman, N. M. S., Beiler, E. W., Rose, J. S., Paul, C. M., & Ian, M. (2015). Breastfeeding outcome comparison by parity. *Breastfeeding Medicine, 10*(3), 156–162. https://doi.org/10.1089/bfm.2014.0119

Haisma, H., Coward, W. A., Albernaz, E., et al. (2003). Breast milk and energy intake in exclusively, predominantly and partially breast-fed infants. *European Journal of Clinical Nutrition, 57*, 1633–1642.

Hebert, J. R., Hurley, T. G., Peterson, K. E., Resnicow, K., Thompson, F. E., Yaroch, A. L., & Nebeling, L. (2008). Social desirability trait influences on self-reported dietary measures among diverse participants in a multicenter multiple risk factor trial. *Journal of Nutrition, 138*(1), 226S-234S. https://doi.org/10.1093/jn/138.1.226S

Hitachi, M., Honda, S., Kaneko, S., & Kamiya, Y. (2019). Correlates of exclusive breastfeeding practices in rural and urban Niger: A community-based cross-sectional study. *International Breastfeeding Journal, 14*(1), 32. https://doi.org/10.1186/s13006-019-0226-9

IAEA. (2010). *Stable Isotope Technique to Assess Intake of Human Milk in Breastfed Infants. International Atomic Energy Agency (IAEA), Human Health Series No. 7, Vienna, Austria* Retrieved from https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1429_web.pdf

Kamudoni, P., Maleta, K., Shi, Z., & Holmboe-Ottesen, G. (2007). Infant feeding practices in the first 6 months and associated factors in a rural and semiurban community in Mangochi District Malawi. *Journal of Human Lactation, 23*(4), 325–332. https://doi.org/10.1177/0890334407307567

Kurzewski, K., & Gardner, J. (2005). Breastfeeding patterns among six-week-old term infants at the University Hospital of the West Indies. *West Indian Medical Journal, 54*(1), 28–33.

Lawrence-Wright, M. B., Boyne, M. S., Osmond, C., Fraser, R. A., Soares-Wynter, S., Thame, M., & Forrester, T. E. (2011). The effect of feto-maternal size and childhood growth on left ventricular mass and arterial stiffness in Afro-Caribbean children. *Journal of Human Hypertension, 25*(7), 457–464. https://doi.org/10.1038/jhh.2010.84

Li, R., Scanlon, K. S., & Serdula, M. K. (2005). The validity and reliability of maternal recall of breastfeeding practice. *Nutrition Reviews, 63*(4), 103–110. https://doi.org/10.1111/j.1753-4887.2005.tb00128.x

Liu, Z., Diana, A., Slater, C., Preston, T., Gibson, R. S., Houghton, L., & Duffull, S. B. (2019a). Development of a nonlinear hierarchical model to describe the disposition of deuterium in mother-infant pairs to assess exclusive breastfeeding practice. *Journal of Pharmacokinetics and Pharmacodynamics, 46*(1), 1–13. https://doi.org/10.1007/s10928-018-9613-x

Liu, Z., Diana, A., Slater, C., Preston, T., Gibson, R. S., Houghton, L., & Duffull, S. B. (2019b). Development of a parsimonious design for optimal classification of exclusive breastfeeding. *CPT: Pharmacometrics & Systems Pharmacology, 8*(8), 596–605. https://doi.org/10.1002/psp4.12428

Lokonon, J. H. F., Hounkpatin, W. A., & Idohou-Dossou, N. (2020). Participation in the "nutrition at the Centre" project through women's group improved exclusive breastfeeding practices, as measured by the deuterium oxide dose-to-mother technique. *International Breastfeeding Journal, 15*(1), 58. https://doi.org/10.1186/s13006-020-00302-y

Lopes Sda, S., Laignier, M. R., Primo, C. C., & Leite, F. M. (2013). Baby-friendly hospital initiative: Evaluation of the ten steps to successful breastfeeding. *Revista Paulista De Pediatria, 31*(4), 488–493. https://doi.org/10.1590/s0103-05822013000400011

Lopez-Teros, V., Limon-Miro, A. T., Astiazaran-Garcia, H., Tanumihardjo, S. A., Tortoledo-Ortiz, O., & Valencia, M. E. (2017). "Dose-to-mother" deuterium oxide dilution technique: An accurate strategy to measure vitamin A intake in breastfed infants. *Nutrients, 9*(2), 169. https://doi.org/10.3390/nu9020169

Medoua, G. N., Sajo Nana, E. C., Ndzana, A. C., Makamto, C. S., Etame, L. S., Rikong, H. A., & Oyono, J. L. (2012). Breastfeeding practices of Cameroonian mothers determined by dietary recall since birth and the dose-to-the-mother deuterium-oxide turnover technique. *Maternal & Child Nutrition, 8*(3), 330–339. https://doi.org/10.1111/j.1740-8709.2011.00293.x

Merewood, A., Mehta, S. D., Chamberlain, L. B., Philipp, B. L., & Bauchner, H. (2005). Breastfeeding rates in US Baby-Friendly hospitals: Results of a national survey. *Pediatrics, 116*(3), 628–634. https://doi.org/10.1542/peds.2004-1636

Merten, S., Dratva, J., & Ackermann-Liebrich, U. (2005). Do baby-friendly hospitals influence breastfeeding duration on a national level? *Pediatrics, 116*(5), e702-708. https://doi.org/10.1542/peds.2005-0537

Mihrshahi, S., Oddy, W., Peat, J. K., et al. (2008). Association between infant feeding patterns and diarrhoeal and respiratory illness: A cohort study in Chittagong. *Bangladesh. International Breastfeeding Journal, 3*, 28.

Moore, S. E., Prentice, A. M., Coward, W. A., et al. (2007). Use of stable-isotope techniques to validate infant feeding practices reported by Bangladeshi women receiving breastfeeding counseling. *The American Journal of Clinical Nutrition, 84*(4), 1075–1082.

Motswagole, B., Matenge, S., Mongwaketse, T., Bogopa, J., Kobue-Lekalake, R., Mosetlha, K., & Kwape, L. (2015). Application of the deuterium-oxide dose-to-mother technique to determine the exclusivity of breastfeeding in women in Kanye, Botswana. *South African Journal of Clinical Nutrition, 28*(3), 128–133. https://doi.org/10.1080/16070658.2015.11734547

Mulol, H., & Coutsoudis, A. (2018). Limitations of maternal recall for measuring exclusive breastfeeding rates in South African mothers. *International Breastfeeding Journal, 13*(1), 19. https://doi.org/10.1186/s13006-018-0159-8

Mulol, H., Coutsoudis, A., Amoussa Hounkpatin, W., Urio, E., Kenguela Wabolou, P., Sissinto, Y., & El-Kari, K. (2020). Is exclusive breastfeeding an option or a necessity in Africa? A pooled study using the deuterium oxide dose-to-mother technique. *Journal of Public Health in Africa, 11*(1), 932–932. https://doi.org/10.4081/jphia.2020.932

Narayan, L. (2016). Relationship between urbanisation and economic growth: A causality analysis for India. *Indian Journal of Economics and Development, 12*, 237. https://doi.org/10.5958/2322-0430.2016.00131.1

Oakley, L., Baker, C. P., Addanki, S., Gupta, V., Walia, G. K., Aggarwal, A., & Kinra, S. (2017). Is increasing urbanicity associated with changes in breastfeeding duration in rural India? An analysis of cross-sectional household data from the Andhra Pradesh children and parents study. *British Medical Journal Open, 7*(9), e016331. https://doi.org/10.1136/bmjopen-2017-016331

Ortiz, J., McGilligan, K., & Kelly, P. (2004). Duration of breast milk expression among working mothers enrolled in an employer-sponsored lactation program. *Pediatric Nursing, 30*(2), 111–119.

Patel, A., Badhoniya, N., Khadse, S., Senarath, U., Agho, K. E., & Dibley, M. J. (2010). Infant and young child feeding indicators and determinants of poor feeding practices in India: Secondary data analysis of National Family Health Survey 2005–06. *Food*

and Nutrition Bulletin, 31(2), 314–333. https://doi.org/10.1177/156482651003100221

Rahman, A., & Akter, F. (2019). Reasons for formula feeding among rural Bangladeshi mothers: A qualitative exploration. *PLoS ONE, 14*(2), e0211761. https://doi.org/10.1371/journal.pone.0211761

Rudnicka, A. R., Owen, C. G., & Strachan, D. P. (2007). The effect of breastfeeding on cardiorespiratory risk factors in adult life. *Pediatrics, 119*(5), e1107-1115. https://doi.org/10.1542/peds.2006-2149

UNICEF. (2013). *Jamaica Multiple Indicator Cluster Survey 2011: Final Report.* Retrieved from https://www.unicef.org/jamaica/reports/jamaica-multiple-indicator-cluster-survey-mics-2011

Victora, C. G., Bahl, R., Barros, A. J., Franca, G. V., Horton, S., Krasevec, J., & Rollins, N. C. (2016a). Breastfeeding in the 21st century: Epidemiology, mechanisms, and lifelong effect. *Lancet, 387*(10017), 475–490. https://doi.org/10.1016/s0140-6736(15)01024-7

Victora, C. G., Bahl, R., Barros, A. J. D., França, G. V. A., Horton, S., Krasevec, J., & Rollins, N. C. (2016b). Breastfeeding in the 21st century: Epidemiology, mechanisms, and lifelong effect. *The Lancet, 387*(10017), 475–490. https://doi.org/10.1016/S0140-6736(15)01024-7

Victora, C. G., Horta, B. L., Loret de Mola, C., Quevedo, L., Pinheiro, R. T., Gigante, D. P., & Barros, F. C. (2015). Association between breastfeeding and intelligence, educational attainment, and income at 30 years of age: A prospective birth cohort study from Brazil. *The Lancet Global Health, 3*(4), e199–e205. https://doi.org/10.1016/S2214-109X(15)70002-1

WHO. (2001). *Report of the expert consultation on the optimal duration of exclusive breastfeeding. Report of an Expert Consultation 28–30 March 2001*. Retrieved from https://www.who.int/nutrition/publications/infantfeeding/WHO_NHD_01.09/en/

WHO. (2008). *Indicators for assessing infant and young child feeding practices. Part 1: definitions.* Retrieved from https://www.who.int/maternal_child_adolescent/documents/9789241596664/en/

Williams, C. B., Mackenzie, K. C., & Gahagan, S. (2014). The effect of maternal obesity on the offspring. *Clinical Obstetrics and Gynecology, 57*(3), 508–515. https://doi.org/10.1097/GRF.0000000000000043

Ziegler, E. E. (2006). Growth of breast-fed and formula-fed infants. *Nestlé Nutrition Institute Workshop Series: Pediatric Program, 58*, 51–59. https://doi.org/10.1159/000095010 discussion 59-63.