

Revisiting How Exclusive is Exclusive Breastfeeding Practice as Determined by the Deuterium Dose-to-mother Technique: A Comparison of Methods of Assessment

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Abstract Exclusive breastfeeding (EBF) for the first 6 months is recommended by WHO and UNICEF as feeding practice in early infancy. This implies the choice of a robust method to ascertain that the mothers have really observed the recommendation. By analyzing secondary data from a breastfeeding study we conducted in Burkina Faso, we aimed to determine the accuracy of different ways to assess EBF. We examined EBF practice through maternal reports of 24 hours (24h recall) and the deuterium oxide dose-to-mother technique (DMT) cross-sectional and longitudinal measurements. We also used the DMT data to simulate the WHO indicator of EBF by cumulating the assessments from birth to 5 months. Then the different methods were compared using the McNemar test. The results showed that globally, the maternal report overestimated the EBF rate compared to the DMT with a difference of 19.17% (95% CI=11.29%-27.04%, $p=0.0000$, $n=40$). Using the DMT, there was a significant difference of 35.00% (95% CI =17.72%-52.28%, $p=0.0001$, $n=40$) between the cross-sectional measurement at 5 months and the longitudinal measurement since birth up to 5 months. Finally, the simulation of the WHO model showed a significant difference of 25.83% (95% CI = 17.17%-34.50%, $p=0.0000$, $n=120$) compared to the longitudinal assessment. Taken together, the study showed that the DMT gives a more realistic estimate of EBF practice according to the definition and the technique gives the best evaluation through a longitudinal measurement. The DMT can be used as a routine method for EBF assessment during nutritional surveys or intervention programs.

Keywords: exclusive breastfeeding, maternal report, dose-to-mother technique, cross-sectional measurement, longitudinal assessment, McNemar test

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1. Introduction

Exclusive breastfeeding (EBF) for the first 6 months is recommended by WHO and UNICEF as feeding practice in early infancy. Exclusive breastfeeding (EBF) means that the infant receives only breastmilk. No other liquid or solid is given, not even water, except for oral rehydration solution or drops/syrups of vitamins, minerals or

medicines [1]. Assessing objectively this important indicator of infant nutrition will help for better nutrition intervention. EBF is usually measured using the 24-hour recall. The indicator is defined as the percentage of infants 0-5 months of age who received only breastmilk during the previous day among the number of infants 0-5 months of age in the community [2-4].

Studies showed that other recall methods (recall since birth, repeated recall for seven days) are more accurate in determining the EBF rate than 24-hour recall [5-7]. Then,

as all these recall methods are based on maternal or caregiver reports, they could be subjected to social desirability bias. The deuterium oxide dose-to-mother technique [8] has been used to validate maternal report on exclusive breastfeeding. The method showed that there was a misreporting using 24-hour recall by revealing an important discrepancy between maternal report and the biological result [9-14].

In this work, we examined the evolution of exclusive breastfeeding practice, as recommended by the WHO. We analyzed secondary data of “Valley du Kou” breastfeeding study [15]. We compared the maternal report to the DMT, and also the cross-sectional assessment based on the DMT to the longitudinal one. The aim was to find the most accurate method that is closed to the exclusive breastfeeding definition according to the WHO recommendation.

2. Methods

2.1. The Original Study [15]

Forty-six mothers who agreed to exclusive breastfeed were followed with their babies from baby birth up to 6 months through 4 cross-sectional measurements (0-1 month, 2-3 months, 4-5 months and 6 months). At each evaluation a questionnaire was applied, anthropometric measurements were done in mother and her baby, hemoglobin level was measured in mother and, the deuterium oxide dose-to-mother technique was used to assess breastmilk intake and the intake of water from sources other than milk. Briefly, after anthropometric measurement and baseline saliva sample collection from the mother and her baby, an accurate dose of 30g of deuterium oxide (DO) was given to the mother. The mother fed the baby as usual and the baby received the deuterium from his mother through breastmilk. Saliva samples were collected from the mother and her baby at 1, 2, 3, 4, 13 and 14 days after dosing. The deuterium enrichment in saliva was analyzed by FTIR (Fourier Transformed Infrared Spectrometer). BM (breastmilk) and non-BM intake were calculated using a model of water turnover in the mother and her baby [16]. The infant was assessed to be exclusively breastfed if the non-BM $\leq$ 86.6 g/day [17].

2.2. Calculation of EBF Rate According to the Different Methods of Assessment

We classified breastfeeding practice according to four methods of assessment: 1- the Maternal Report of 24h (MR-24) also called 24-hour recall, assessed on day 14; 2- the DMT Current Status (DMT-CS) that gave the EBF rate based on DMT through a cross-sectional measurement done at a specific age (0-1month, 2-3 months or 4-5 months); 3- the DMT Cumulating Ages (DMT-CA), a cross-sectional assessment that compiles all ages between birth and 5 months as done for the WHO indicator; and 4 - the DMT Longitudinal Assessment (DMT-LA) from birth up to 5 months. Table 1 describes how we defined EBF and determined the indicators using those different approaches.

2.3. Statistical Analysis

Data were analyzed with Stata 13 (Stata Corporation Texas, USA). Out of the 46 mother-baby pairs initially present in the database, only those with complete and validated breastfeeding data for the 3 consecutive measurements (0-1 month, 2-3 months and 4-5 months) were considered for the final analysis [18].

After developing descriptive statistics, we used the McNemar test to compare the exclusive breastfeeding rate provided by the different methods of evaluation. The McNemar test [19], also called “Matched Case Control” test, can easily compare the result of two tests applied to the same population. It has been already used to compare methods of assessment of breastfeeding practice based on maternal report [7]. The choice between the chi-square p value and the exact binomial p value to make a decision after a McNemar test depended on the sum of the discordant pair in the contingency table. Based on Pembury-Smith and Ruxton’s guidance [20], an asymptotic chi-square approach was considered if the number of discordant pair is over 25, otherwise, this number was less than 25, the exact p value was chosen. The type 1 error was fixed at 0.05.

The MR-24 was first compared to the DMT-CS; after that, the DMT-CS and DMT-CA were compared to the DMT-LA. We restricted our comparisons to the 0-5 months age range and ignored 6 months results in order to adjust the calculation to the WHO’s EBF indicator [2].

3. Results

3.1. Participants’ Characteristics

From the 46 mother-baby pairs, 40 fitted with the requirements of complete data at the 3 consecutive assessments up to 5 months. Table 2 presents the subjects’ socio-anthropometric characteristics, and Table 3 summarizes their nutritional status at each measurement.

3.2. Comparison Between Different Methods of Assessment of Exclusive Breastfeeding

There was a significant difference of EBF rate between the MR-24 and the DMT at 0-1 month (20.00%, 95% CI=5.10%-34.90%, $p=0.0078$, $n=40$) and at 2-3 months (27.50%, 95% CI=11.16%-43.84%, $p=0.0010$, $n=40$). Only at 4-5 months, the difference was not significant. But globally, from birth up to 5 months, the total of assessment given by the MR-24 overestimated the EBF compared to the DMT with a significant difference of 19.17% (95% CI=11.29%-27.04%, $p=0.0000$, $n=120$). Using the DMT, the cross-sectional measurement at 4-5 months overestimated the EBF rate comparing to the longitudinal measurement since birth with a significant difference of 35.00% (95% CI=17.72%-52.28%, $p=0.0001$), as mentioned in Table 5. Finally, the simulation of WHO model with DMT showed a significant overestimation of 25.83% (95% CI=17.17%-34.50%, $p=0.0000$) compared to the longitudinal assessment, as shown in Table 6.

Table 1. EBF Assessment Methods and Calculation of the Different Indicators

Methods	Definition	Calculation of EBF rate under 6 months
MR-24	The infant received only breastmilk on the previous 24h according to the mother's declaration	(Infants 0-5 months of age who received only breastmilk during the previous day/Infants 0-5 months of age) x 100
DMT-CS	The non-breastmilk oral water intake is less than 86.6 g/day in a specific period	(Infants of a specific age with non-BM $\leq$ 86.6 g/day /Infants of that specific age) x 100
DMT-CA	The non-breastmilk oral water intake is less than 86.6 g/day at least once during the period under 6 months.	(Infants 0-5 months of age with non-BM $\leq$ 86.6 g/day/ Infants 0-5 months of age) x 100
DMT-LA	The non-breastmilk oral water intake is less than 86.6 g/day at each age under 6 months	(Same infants with non-BM $\leq$ 86.6 g/day at each age from birth up to 5 months/ Infants of 5 months of age) x 100

MR-24 = Maternal Report of 24h (24h recall); DMT-CS = Dose-to-Mother Technique giving Current Status; DMT-CA = Dose-to-Mother Technique Cumulating Ages; DMT-LA = Dose-to-Mother Technique Longitudinal Assessment; BM = breastmilk.

Table 2. Participants' General Socio-Anthropometric Characteristics at Inclusion (n=40)

Characteristics	Mean SD	Min-Max
Mother Age (years)	24.4 $\pm$ 5.1	17-40
Pregnancies	3.35 $\pm$ 1.90	1-9
Deliveries	3.05 $\pm$ 1.83	1-9
Children alive	2.65 $\pm$ 1.29	1-5
Baby birth weight (kg)	2.90 $\pm$ 0.42	1.69-3.55
Birth weight <2.5kg (%)	13.9	—
Baby Sex (M/F)	20/20	—

Table 3. Mothers And Babies' Nutritional Status and Breastmilk Intake at Each Assessment

Variables	<1 month	2-3 months	4-5 months
Mothers			
Weight (kg)	57.07 $\pm$ 7.29	56.20 $\pm$ 7.24	56.49 $\pm$ 7.94
MUAC (cm)	25.77 $\pm$ 2.15	25.82 $\pm$ 2.06	26.52 $\pm$ 2.21
Hb (g/dl)	10.91 $\pm$ 1.90	11.58 $\pm$ 1.22	12.23 $\pm$ 1.44
BMI (kg/m ²)	21.78 $\pm$ 2.27	21.44 $\pm$ 2.24	21.55 $\pm$ 2.58
TBW (kg)	31.96 $\pm$ 3.30*	31.52 $\pm$ 3.43	31.38 $\pm$ 3.24
FFM (kg)	43.65 $\pm$ 4.51*	50.56 $\pm$ 47.04	42.88 $\pm$ 4.4
FM (kg)	13.53 $\pm$ 5.56*	13.12 $\pm$ 4.93	13.61 $\pm$ 5.91
FMI (kg/m ²)	5.15 $\pm$ 2.02*	5.01 $\pm$ 1.87	5.19 $\pm$ 2.24
Babies			
Age at day 0	0.28 $\pm$ 0.16	2.31 $\pm$ 0.20	4.44 $\pm$ 0.27
Weight (kg)	3.01 $\pm$ 0.50	5.45 $\pm$ 0.82	6.54 $\pm$ 0.96
LAZ	-0.98 $\pm$ 1.19	-0.39 $\pm$ 1.11	-0.61 $\pm$ 1.12
WLZ	-0.58 $\pm$ 1.35	0.11 $\pm$ 1.22	-0.15 $\pm$ 1.20
WAZ	-0.99 $\pm$ 1.07	-0.29 $\pm$ 1.22	-0.58 $\pm$ 1.19
BM (g/day)	574.92 $\pm$ 202.49	846.97 $\pm$ 183.49	917.8 $\pm$ 183.71
non-BM (g/day)	38.42 $\pm$ 46.54	65.65 $\pm$ 165.83	7.17 $\pm$ 67.07

MUAC= mid- upper arm circumference; Hb= hemoglobin; BMI= body mass index; FMI= fat mass index; BM= breastmilk; non- BM= nonbreastmilk oral water intake; LAZ= length for age Z; WLZ= weight for length Z; WAZ= weight for age Z; *n=39 (1 outlier)

Table 4. Maternal Report Versus DMT-Current Status

	MR-24 (%)	DMT-CS (% (95% CI))	Difference (% (95% CI))	Exact McNemar P
0-1 month (n=40)	100	80.00 (64.03-89.99)	20.00 (05.10-34.90)	0.0078
2-3 months (n=40)	100	72.50 (56.07-84.48)	27.50 (11.16-43.84)	0.0010
4-5 months (n=40)	100	90.00 (75.35-96.36)	10.00 (-01.79-21.79)	0.1250
Total: 0-5 months (n=120)	100	80.83 (72.67-86.99)	19.17 (11.29-27.04)	0.0000

MR-24 = Maternal Report of 24h (24h recall)

DMT- CS= dose-to-mother technique giving a current status at a specific age

Table 5. DMT Current Status Assessment Versus DMT Longitudinal Assessment Since Birth

	DMT- CS % (95% CI)	DMT- LA % (95% CI)	Difference % (95% CI)	Exact McNemar P
0-1 month (n=40)	80.00 (64.03-89.99)	NA		
2-3 months (n=40)	72.50 (56.07-84.48)	62.50 (46.05-76.49)	10.00 (-01.80-21.80)	0.1250
4-5 months (n=40)	90.00 (75.35-96.36)	55.00 (38.93-70.09)	35.00 (17.72-52.28)	0.0001

DMT- CS= dose-to-mother technique giving a current status at a specific age

DMT- LA= dose-to-mother technique through a longitudinal assessment from birth up to a specific age

Table 6. DMT Cumulating Ages (WHO Model) Versus DMT Longitudinal Assessment

	DMT-CA ¹ % (95% CI)	DMT-LA ² % (95% CI)	Difference % (95% CI)	Exact McNemar P
0-1 month (n=40)	80.00 (64.03-89.99)	NA		
0-3 months (n=80)	76.25 (65.48-84.46)	62.50 (51.21-72.58)	13.75 (04.95-22.55)	0.0010
0-5 months (n=120)	80.83(72.67-86.99)	55.00 (45.90-63.77)	25.83 (17.17-34.50)	0.0000

¹This is a simulation of the WHO model by cumulating the measurements of different ages. The samples size (n=40, n=80 or n=120) are given in term of number of observations. The same infants (n=40) followed at different periods within a small time frame are assimilated to infants from different group age followed approximately at the same time.

²The longitudinal model is drawn from the sample size n=40 transformed to n=80 for 0-3 months and n=120 for 0-5 months by respectively duplicating and triplicating the observations of the longitudinal assessment since birth up to 2-3 months and up to 4-5 months presented in Table 5. The percentage of EBF given by the DMT-LA are the same in the 2 tables, but the CI are different.

DMT-CA= dose-to-mother technique cumulating ages at cross-sectional measurement. DMT-LA= dose-to-mother technique longitudinal assessment.

4. Discussion

Infant and young child feeding practices directly affect the health, development and nutritional status of children less than two years of age and ultimately impact child survival [4]. Evaluating well breastfeeding practice is very important for better nutrition intervention. The question on the assessment of exclusive breastfeeding has been discussed earlier and recently [5-7]. Ted Greiner's debate effectively covered the accuracies, benefits, drawbacks, and limitations of various methods for assessing EBF using maternal report [6]. The DMT helps to validate maternal reports [9,10,13,14,21] as an objective method for breastmilk intake and EBF assessment and it is recognized now as the gold standard for breastfeeding practice evaluation [22]. Recently, the technique has been updated on how to assess breastfeeding with more precision by facilitating data collection, management and validation [17,18].

Our study compared the results from several ways to assess EBF in surveys. We found that very early, in the 2 first weeks after birth, some mothers introduced in their babies' diet other sources of water than breastmilk contrary to their report and the difference was significant at 0-1 month (20.00%, $p=0.0078$) and at 2-3 months (27.50%, $p=0.0010$). So, using a 24-hour recall to measure a current status of breastfeeding may overestimate the proportion of exclusively breast-fed infants because some infants who are given other liquids irregularly may not have received them in the 24 hours before the survey [6]. In addition, contrary to the DMT, the maternal or caregiver report is subject to social desirability bias.

Unsurprising the EBF proportion based on DMT longitudinal assessment was significantly less than that given by the DMT cross-sectional measurement performed at that period. The example of 4-5 months that showed EBF was 90.00% at cross-sectional assessment and reduced significantly to 55.00% ($p=0.0001$) according to the longitudinal assessment since birth up to 5 months, revealed well that situation. Our results revealed that a single evaluation at a specific age does not assess that the mothers have really practiced exclusive breastfeeding before that time or after that time even if the evaluation uses the deuterium dilution method. So, the cross-sectional measurement using the DMT also overestimates the real proportions of EBF.

Finally, after drawing the model of WHO indicator, we clearly viewed that, according to the definition, only the longitudinal assessment gave the best evaluation of EBF. The DMT could be applied using the WHO indicator model that includes infants of different ages from birth up to 5 months in a cross-sectional evaluation. But since the method doesn't consider what happened to each infant before and after that single evaluation, there will be the same bias like the evaluation is done using maternal report with a single 24h recall, including then an overestimation.

Indeed, evaluation since birth could penalize, for example people with cultural practice of pre-feeding during the first 3 days after birth [6] even if they feed normally their babies immediately after that period and up to 6 months but, that occurs if the assessment stands on maternal report. The DMT takes 2 weeks for the evaluation and the calculation of fluids intake is the average of 14 days feeding practice. In one way, it could overcome the difficulty link to first days pre-feeding practice among people with cultural practice that not really influence the baby's normal growth. In another way, it permits detecting the babies who are truly exclusively breastfed but were declared by their mothers not to be so [9]. And the limit of 86.6 mg/day of non-breastmilk water intake admitted for EBF should cover the daily quantity of medicines in case some medications were given to the babies during sickness that could occur within the 2 weeks of evaluation.

The protocol of seven samples collection from each mother, and each baby was used in the study. A new protocol developed recently for EBF classification and still in investigation for milk intake assessment, involves only 3 samples collection that will be more field friendly [23]. The DMT is limited by the fact it can't be applied continually as after each dose it is necessary to wait for at least 45 days before starting another dosing, but it is the most accurate method for breastfeeding evaluation since now and it has the advantage to give at the same time the quantity of milk intake by the infants and the maternal body composition. The cost effectiveness hasn't been discussed here, but it is possible to introduce the technique as a routine assessment during national nutrition survey. Several countries could receive the technical support of the IAEA like Burkina Faso with local experts to conduct the study at the national level. Finally, the use of DMT to assess EBF practice can help to understand why infants are simultaneously assessed malnourished and reported exclusively breastfed by proving the misreporting on the feeding practice.

5. Conclusion

In our work, we reaffirmed the utility of the DMT to assess breastfeeding practice. We demonstrated that DMT is more accurate than maternal reports in evaluating EBF practice, and it is essential to use the technique through a longitudinal assessment. The procedure can be used in standard evaluation and provide further insight into the infant's feeding practice, as well as the factors contributing to the persistence of malnutrition in early childhood among particular communities.

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Authors contributions: CNMJD: designed the method, analyzed the data and wrote the first draft; SMAS gave advice and corrections on the method. All the authors contributed to the paper and approved the final version.

Competing Interest

The authors declare they have no conflicts of interest.

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