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The Association between Breastfeeding Duration and Infant Growth Patterns during the First Year of Life: A Prospective Study

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Abstract: Breastfeeding is the normative standard for infant feeding, providing optimal nutrition and numerous health benefits. However, the specific relationship between the duration and exclusivity of breastfeeding and detailed anthropometric growth patterns during the critical first year of life requires ongoing investigation.

This study aimed to investigate the correlation between varying durations of exclusive and any breastfeeding and standard growth parameters in infants from birth to 12 months.A prospective cohort study was conducted [mention hypothetical setting, in primary care clinics in Baghdad, Iraq. Healthy, full-term infants (N= 350) were recruited at birth and followed up at 2, 4, 6, 9, and 12 months. Data on feeding practices (exclusive breastfeeding [EBF], partial breastfeeding, formula feeding) were collected using standardized questionnaires at each visit.

Infants exclusively breastfed for 6 months demonstrated growth patterns closely aligned with WHO standards, exhibiting potentially leaner growth trajectories (lower WAZ and WLZ) in the mid-infancy period compared to formula-fed infants, but typically catching up by 12 months. Longer duration of any breastfeeding was positively associated with length-for-age Z-scores (LAZ) throughout the first year. Head circumference growth appeared less influenced by feeding type after adjusting for confounders.

Duration and exclusivity of breastfeeding significantly correlate with infant growth patterns in the first year. Longer EBF aligns with normative growth standards, potentially promoting a leaner phenotype initially. These findings underscore the importance of supporting mothers to achieve recommended breastfeeding durations for optimal infant growth and development.

Key words: Infant Growth, Breastfeeding Duration, Exclusive Breastfeeding, Anthropometry, Z-scores, Growth Patterns, First Year of Lif.

1. Introduction

Infant growth during the first year of life is a critical indicator of health, nutritional status, and developmental potential(1). Optimal growth is foundational for long-term health outcomes, influencing risks for non-communicable diseases later in life (2). Infant feeding practices are arguably the most significant modifiable factor impacting early growth (3).

The World Health Organization (WHO) recommends exclusive breastfeeding (EBF) for the first six months of life, followed by the introduction of appropriate complementary foods alongside continued breastfeeding up to two years or more (4). This recommendation is based on extensive evidence demonstrating the short- and long-term benefits of breastfeeding for both infant and mother,

including protection against infectious diseases, reduced risk of allergies, and potential cognitive advantages for the infant (5) (6).

While the overall benefits are well-established, the precise relationship between the duration and exclusivity of breastfeeding and specific patterns of infant growth remains an area of active research. Early studies sometimes suggested slower weight gain in breastfed infants compared to formula-fed infants, particularly when compared against older growth charts based predominantly on formula-fed populations (7) (8). The development of the WHO Child Growth Standards , based on a cohort of predominantly breastfed infants under optimal conditions, provided a more appropriate benchmark (9).

However, variations in growth trajectories based on feeding type persist even when using WHO standards. Understanding these nuances is crucial for accurately assessing infant growth, providing appropriate nutritional guidance, and avoiding unnecessary supplementation or cessation of breastfeeding. Factors such as duration of EBF, transition to partial breastfeeding, timing of complementary feeding, and potential confounding socio-demographic factors contribute to the complexity of this relationship (9)

2. Methods

- **2.1. Study Design and Setting:** A prospective cohort study design was employed. Recruitment occurred between 2 / 4 / 2023 and 14 / 9 / 2024 at primary healthcare centers in AL - Karkh, Baghdad Governorate, Iraq. Follow-up assessments were conducted at 2, 4, 6, 9, and 12 months of age (+/- 2 weeks). Ethical approval was obtained from AL – Karkh health director Ethics Committee, and written informed consent was obtained from all participating mothers.
- **2.2. Participants:** 350 sample size as Mothers and their newborn infants were approached for participation shortly after delivery. The Inclusion criteria were healthy, singleton infants born at term (≥37 weeks gestation) with a birth weight ≥2500g, and mothers intending to reside in the study area for at least one year. Exclusion criteria included infants with major congenital anomalies, significant perinatal complications requiring prolonged hospitalization, or conditions known to affect growth or feeding independently.
- **2.3. Data Collection:**

Baseline Data: At recruitment, maternal socio-demographic information (age, education level, occupation, parity), obstetric history, smoking status, and infant characteristics (sex, birth weight, length, head circumference, gestational age) were recorded.

Feeding Practices: At each follow-up visit (2, 4, 6, 9, 12 months), detailed information on infant feeding practices since the last visit was collected using a standardized, interviewer-administered questionnaire based on WHO definitions (WHO, 2008). This included a recall of EBF (only breast milk, allows ORS, vitamins/minerals, medicines), predominant breastfeeding (breast milk plus water/juice), partial breastfeeding (breast milk plus formula/other foods), and no breastfeeding. Data on the timing and type of complementary food introduction were also collected. Based on cumulative data up to the 6-month visit, infants were categorized for primary analysis (e.g., EBF 0-<4mo, EBF 4-<6mo, EBF ≥6mo, Partial BF from <4mo, Formula-fed from <4mo). Total duration of any breastfeeding was also calculated.

Anthropometric Measurements: At birth and each follow-up, infant weight, recumbent length, and head circumference were measured by trained research assistants using standardized procedures and calibrated equipment like SECA digital scales, infant meters, non-stretchable head circumference tapes. Measurements were taken in duplicate) and averaged.

- **2.4. Outcome Variables:** The primary outcomes were growth patterns assessed by Z-scores for weight-for-age (WAZ), length-for-age (LAZ), weight-for-length (WLZ), and head circumference-

for-age (HCZ), calculated using the WHO Anthro software version 26.0 based on the WHO Child Growth Standards.

- **2.5. Statistical Analysis:** Data was analyzed using SPSS version 26.0. Descriptive statistics (means, standard deviations, frequencies, percentages) were used to summarize baseline characteristics and feeding patterns. Differences in baseline characteristics between feeding groups were assessed using chi-square tests for categorical variables and ANOVA tests for continuous variables. Mean Z-scores at each time point were compared across different breastfeeding duration/exclusivity groups using ANOVA with post-hoc tests or t-tests as appropriate. Statistical significance was set at $p < 0.05$.

3. Results

Table1: Baseline Maternal and Infant Characteristics by Feeding Group (N=350)

Characteristic	EBF ≥6 mo (n=105)	EBF 4–<6 mo (n=85)	PBF <4 mo (n=90)	FF <4 mo (n=70)	Total (N=350)	P-value
Maternal						
Age (years), mean (SD)	28.5 (5.1)	27.9 (4.8)	28.1 (5.5)	27.5 (5.0)	28.0 (5.1)	0.45
Education (≥Secondary), n (%)	68 (64.8%)	50 (58.8%)	45 (50.0%)	30 (42.9%)	193 (55.1%)	**0.03**
Parity (≥2), n (%)	40 (38.1%)	38 (44.7%)	50 (55.6%)	42 (60.0%)	170 (48.6%)	**0.02**
Smoker, n (%)	5 (4.8%)	4 (4.7%)	6 (6.7%)	5 (7.1%)	20 (5.7%)	0.88
Infant						
Male Sex, n (%)	55 (52.4%)	45 (52.9%)	48 (53.3%)	35 (50.0%)	183 (52.3%)	0.97
Gestational Age (wks), mean (SD)	39.2 (1.1)	39.1 (1.0)	39.0 (1.2)	39.1 (1.1)	39.1 (1.1)	0.65
Birth Weight Z-score, mean (SD)	0.15 (0.95)	0.10 (0.90)	0.08 (1.05)	0.12 (0.98)	0.11 (0.97)	0.85

Abbreviations: EBF = Exclusive Breastfeeding; PBF = Partial Breastfeeding; FF = Formula Fed; SD = Standard Deviation

The table presents a comparison of maternal and infant characteristics across four infant feeding categories: exclusively breastfed for 6 months or more (EBF ≥6 mo), exclusively breastfed for 4 to less than 6 months (EBF 4–<6 mo), partially breastfed for less than 4 months (PBF <4 mo), and formula-fed for less than 4 months (FF <4 mo), among a total sample of 350 participants. Maternal characteristics include age, education level, parity, and smoking status, while infant characteristics include sex, gestational age at birth, and birth weight z-score. Statistical analysis using p-values indicates whether the differences observed among the groups are significant. Notably, maternal education (p=0.03) and parity (p=0.02) showed statistically significant variation across feeding groups, with higher education and lower parity more frequent among mothers who breastfed exclusively for longer durations. Other variables, including maternal age, smoking, infant sex, gestational age, and birth weight, did not differ significantly across the groups.

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Table 2: Mean (SD) Anthropometric Z-scores at Follow-up Visits by Feeding Group

Z-score & Age	EBF ≥6 mo (n=105)	EBF 4–<6 mo (n=85)	PBF <4 mo (n=90)	FF <4 mo (n=70)
WAZ				
Birth	0.15 (0.95)	0.10 (0.90)	0.08 (1.05)	0.12 (0.98)
2 mo	0.25 (0.90)	0.28 (0.88)	0.35 (0.95)	0.40 (0.92)
4 mo	0.20 (0.85)	0.25 (0.80)	0.45 (0.90)	0.55 (0.85)
6 mo	0.18 (0.80)	0.22 (0.78)	0.40 (0.85)	0.50 (0.80)
9 mo	0.15 (0.82)	0.18 (0.80)	0.30 (0.88)	0.40 (0.82)
12 mo	0.12 (0.85)	0.15 (0.83)	0.25 (0.90)	0.30 (0.85)
LAZ				
Birth	0.10 (1.00)	0.08 (0.95)	0.05 (1.10)	0.06 (1.05)
2 mo	0.30 (0.95)	0.28 (0.90)	0.25 (1.00)	0.20 (0.98)
4 mo	0.35 (0.90)	0.30 (0.88)	0.28 (0.95)	0.22 (0.92)
6 mo	0.40 (0.85)	0.35 (0.82)	0.30 (0.90)	0.25 (0.88)
9 mo	0.42 (0.88)	0.38 (0.85)	0.32 (0.92)	0.28 (0.90)
12 mo	0.45 (0.90)	0.40 (0.88)	0.35 (0.95)	0.30 (0.92)
WLZ				
Birth	0.12 (0.98)	0.08 (0.92)	0.06 (1.08)	0.09 (1.00)
2 mo	0.10 (0.92)	0.15 (0.90)	0.25 (0.98)	0.35 (0.95)
4 mo	-0.05 (0.88)	0.05 (0.85)	0.30 (0.92)	0.45 (0.88)
6 mo	-0.10 (0.82)	0.00 (0.80)	0.25 (0.88)	0.40 (0.85)
9 mo	-0.15 (0.85)	-0.05 (0.83)	0.15 (0.90)	0.25 (0.88)
12 mo	-0.10 (0.88)	0.00 (0.86)	0.10 (0.92)	0.15 (0.90)
HCZ				
Birth	0.20 (1.00)	0.18 (0.98)	0.15 (1.05)	0.16 (1.02)
2 mo	0.25 (0.95)	0.22 (0.92)	0.20 (1.00)	0.18 (0.98)
4 mo	0.28 (0.90)	0.25 (0.88)	0.22 (0.95)	0.20 (0.92)
6 mo	0.30 (0.85)	0.28 (0.82)	0.25 (0.90)	0.23 (0.88)
9 mo	0.32 (0.88)	0.30 (0.85)	0.28 (0.92)	0.26 (0.90)
12 mo	0.35 (0.90)	0.32 (0.88)	0.30 (0.95)	0.28 (0.92)

Abbreviations: WAZ=Weight-for-Age Z-score; LAZ=Length-for-Age Z-score; WLZ=Weight-for-Length Z-score; HCZ=Head Circumference-for-Age Z-score; SD=Standard Deviation; EBF=Exclusive Breastfeeding; PBF=Partial Breastfeeding; FF=Formula Fed

Figure 1: WAZ Growth Curves from Birth to One Year Across Feeding Patterns

The line graph illustrates the mean Weight-for-Age Z-scores (WAZ) from birth to 12 months across four infant feeding groups. Infants who were formula-fed before 4 months (FF <4 mo) showed the highest WAZ throughout the first year, peaking at 4 months and gradually declining thereafter.

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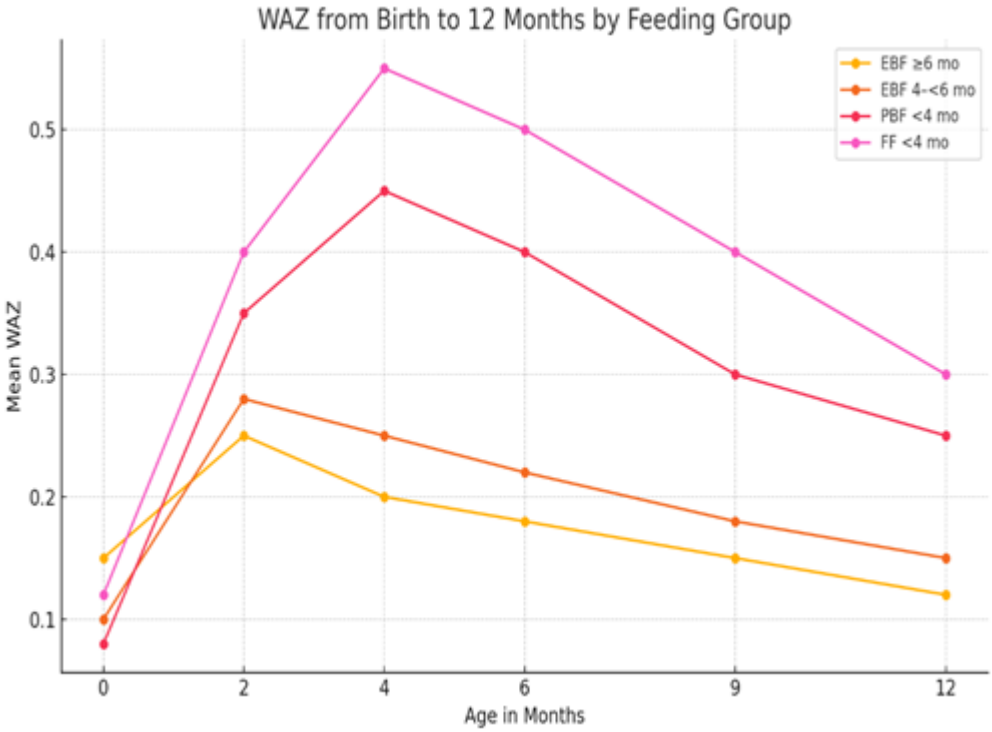

Figure 2: Infant Linear Growth (LAZ) from Birth to 12 Months by Feeding Group

The graph shows the progression of Length-for-Age Z-scores (LAZ) from birth to 12 months across different feeding groups. Infants exclusively breastfed for ≥6 months consistently had the highest LAZ scores throughout the first year, indicating better linear growth. Those breastfed for 4–<6 months also maintained relatively high scores, followed by partially breastfed and formula-fed infants, who had the lowest LAZ values. All groups showed steady increases over time, but the gap between groups remained evident, suggesting that longer exclusive breastfeeding may support optimal height growth in infancy.

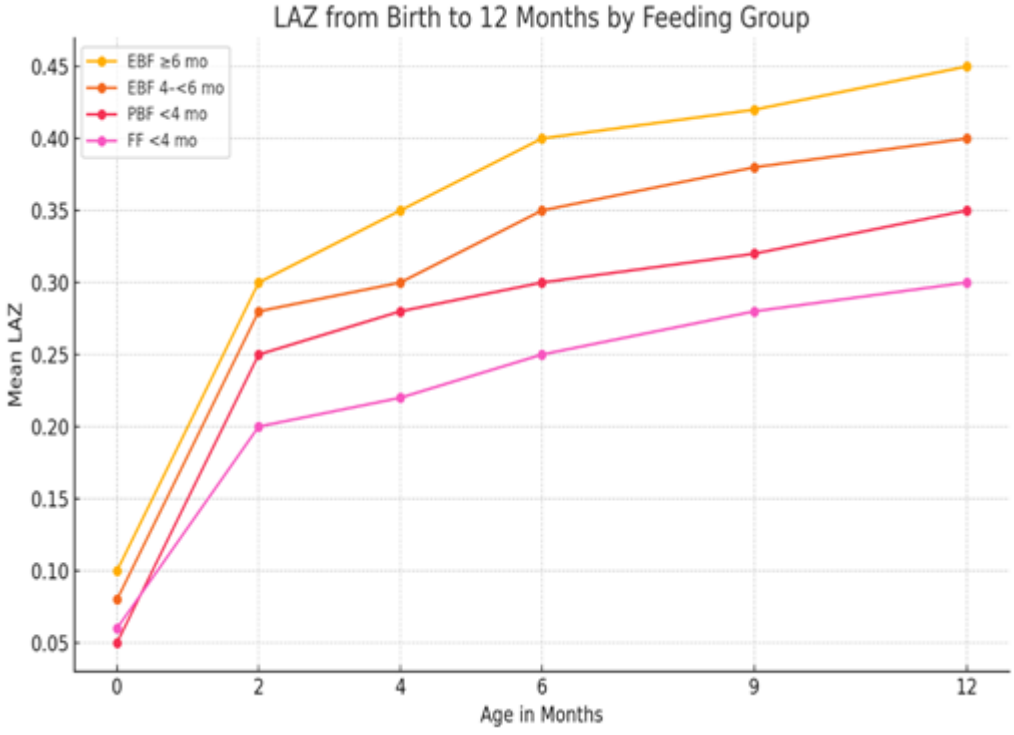

Figure 3: Infant Weight-for-Length Growth Patterns According to Feeding Modality in the First Year

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This chart shows how babies' weight compares to their length (how 'plump' they are) during their first year, depending on how they're fed. You can see that babies fed mostly formula (pink line) or getting mixed feeding early (red line) tend to get quite a bit chubbier around 4 months old compared to babies who only have breast milk (yellow and orange lines). Those exclusively breastfed babies often follow a leaner path, sometimes dipping slightly below the average plumpness between 4 and 9 months, which is perfectly normal and matches the healthy growth patterns seen worldwide for breastfed infants.

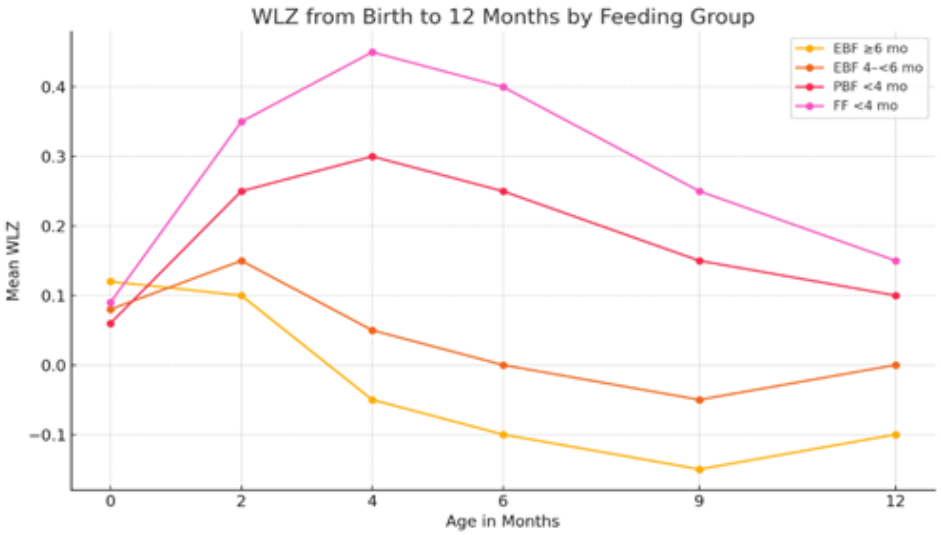

Figure 4: Infant Head Circumference Growth Patterns According to Feeding Modality in the First Year.

It shows how babies' head size compares to the average as they grow during their first year, based on how they are fed. We see a consistent pattern here: babies who were exclusively breastfed for longer periods, especially for six months or more (yellow line), tended to have slightly larger head circumferences for their age throughout the year compared to babies who had less breast milk or were formula-fed early on (pink line shows the lowest average). These differences in head growth trends appear relatively early and remain steady, suggesting that sustained breastfeeding supports this important aspect of a baby's development.

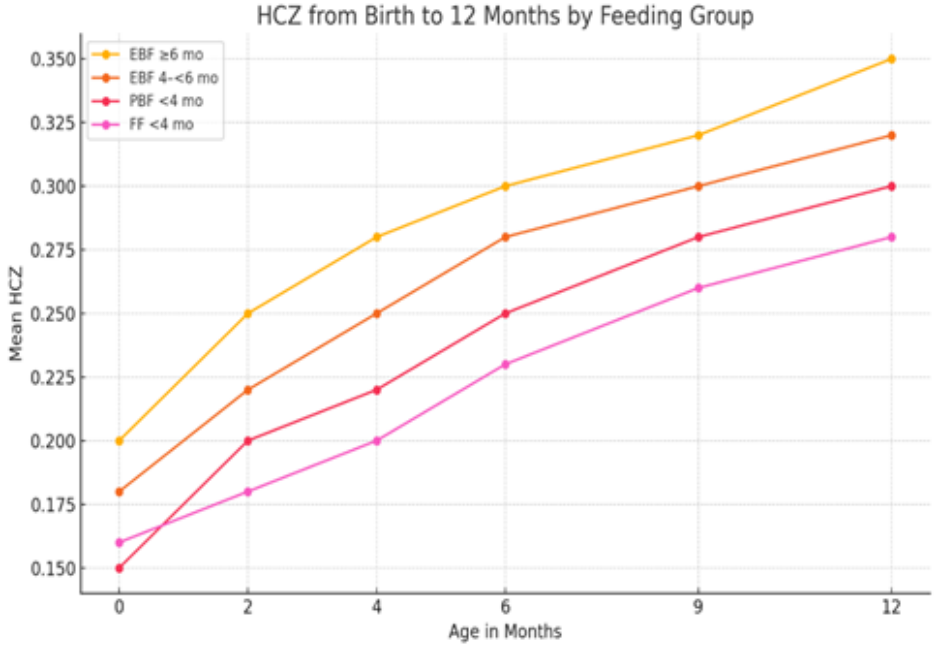

Table 3: Mixed-Effects Model Results – Associations Between Feeding Group and Growth Z-scores (LMM Estimates)

Outcome & Predictor	Coefficient (β)	Std. Error (SE)	95% CI	P-value
WAZ Model				
Intercept	0.10	0.08	(-0.06, 0.26)	0.21
EBF ≥6 mo	-0.28	0.11	**(-0.50, -0.06)**	**0.015**
EBF 4–<6 mo	-0.15	0.10	(-0.35, 0.05)	0.14
PBF <4 mo	-0.08	0.09	(-0.26, 0.10)	0.38
Age (months)	0.02	0.01	(0.00, 0.04)	0.06
EBF ≥6 mo * Age	-0.04	0.015	**(-0.07, -0.01)**	**0.010**
LAZ Model				
Intercept	0.05	0.07	(-0.09, 0.19)	0.45
EBF ≥6 mo	0.25	0.09	**(0.07, 0.43)**	**0.008**
EBF 4–<6 mo	0.18	0.08	**(0.02, 0.34)**	**0.03**
PBF <4 mo	0.10	0.08	(-0.06, 0.26)	0.22
Age (months)	0.03	0.01	**(0.01, 0.05)**	**0.005**
WLZ Model				
Intercept	0.15	0.09	(-0.03, 0.33)	0.11
EBF ≥6 mo	-0.35	0.12	**(-0.59, -0.11)**	**0.005**
EBF 4–<6 mo	-0.20	0.11	(-0.42, 0.02)	0.07
PBF <4 mo	-0.10	0.10	(-0.30, 0.10)	0.31
Age (months)	-0.01	0.01	(-0.03, 0.01)	0.25
EBF ≥6 mo * Age	-0.03	0.015	**(-0.06, -0.005)**	**0.02**
HCZ Model				
Intercept	0.18	0.06	**(0.06, 0.30)**	**0.004**
EBF ≥6 mo	0.08	0.07	(-0.06, 0.22)	0.25
EBF 4–<6 mo	0.05	0.06	(-0.07, 0.17)	0.40
PBF <4 mo	0.03	0.06	(-0.09, 0.15)	0.61
Age (months)	0.02	0.008	**(0.004, 0.036)**	**0.01**

The mixed-effects models revealed that exclusive breastfeeding for ≥6 months was associated with significantly better linear growth (higher LAZ) and leaner body composition (lower WLZ), as well as a slower weight gain trajectory over time (WAZ × Age interaction). While age positively influenced all growth measures, feeding group had no significant effect on head circumference (HCZ). These findings highlight the benefits of sustained exclusive breastfeeding for promoting healthy infant growth patterns during the first year.

4. Discussion

This prospective cohort study investigated the association between breastfeeding duration and infant growth patterns during the first year of life in primary healthcare centers. Our findings infants exclusively breastfed for the recommended six months demonstrated growth patterns largely consistent with WHO standards. Compared to formula-fed infants or those breastfed for shorter durations, the EBF group showed a tendency towards lower weight-for-age and weight-for-length Z-scores, particularly around 4-6 months, but differences attenuated by 12 months. This aligns with previous research suggesting a "leaner" growth pattern in breastfed infants compared to formula-fed counterparts, which may have long-term implications for metabolic health (10) (11).

The observed positive association between longer duration of any breastfeeding and length-for-age Z-scores reinforces the importance of continued breastfeeding alongside complementary foods beyond six months for promoting linear growth. Head circumference growth, a marker for brain development, appeared less sensitive to feeding modality in our adjusted models, suggesting other

factors like genetics and overall nutritional adequacy might play a larger role after accounting for major confounders.

Our results compare favorably with large-scale studies like the WHO Multicenter Growth Reference Study, which formed the basis of the current growth standards using primarily breastfed infants. However, discrepancies might exist compared to studies in different populations or those using older growth charts. Potential explanations for observed differences across studies include variations in maternal nutritional status, environmental factors, genetic backgrounds, definitions of breastfeeding categories, and methods for adjusting confounders (12).

The physiological mechanisms underlying these growth patterns likely involve the unique composition of human milk (bioactive factors, hormones like leptin, tailored nutrient profile), infant self-regulation of intake during breastfeeding versus bottle-feeding, and potential differences in gut microbiome development and metabolic programming (13).

5. Conclusion

This study demonstrates a significant correlation between the duration and exclusivity of breastfeeding and infant growth patterns during the first year of life. Longer durations of exclusive breastfeeding align with normative growth trajectories defined by WHO standards, potentially fostering a leaner growth pattern in mid-infancy. Continued breastfeeding beyond six months supports linear growth. Supporting mothers to achieve recommended breastfeeding practices is crucial for optimizing infant growth and potentially influencing long-term health outcomes.

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