THE USE OF PASSIVE DIETARY ASSESSMENT AMONG BREASTFEEDING MOTHERS IN GHANA

by

CAROLINE CERMINARO

(Under the Direction of ALEX KOJO ANDERSON)

ABSTRACT

Misconceptions of infant feeding cues contribute to suboptimal breastfeeding practices in developing countries. Using mixed-methods, we assessed infant feeding patterns in relation to sociodemographic characteristics of a low-income population. A passive wearable device, Automatic Ingestion Monitor (AIM) was worn by mothers for infant feeding assessment in rural and urban communities in Ghana. Maternal self-report of breastfeeding challenges, successes, daily frequency and duration was collected. AIM-captured images were manually annotated and compared to participant self-reported infant feeding patterns. The results show interesting differences between urban versus rural infant feeding practices of Ghanaian mothers. As expected, maternal-reported infant feeding characteristics differed from AIM captured images. We observed over-reporting of breastfeeding duration and frequency from maternal report. There was high participant compliance (83%) wearing the AIM device, suggesting low user burden during wear time. Future studies should explore automatic annotation of images to prevent potential errors associated with manual image annotation.

INDEX WORDS: Automatic Ingestion Monitor (AIM), Breastfeeding, Infant Feeding Assessment, Wearable Device, Mixed Feeding, Ghana

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CAROLINE CERMINARO

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CAROLINE CERMINARO

Major Professor:	Alex Anderson
Committee:	Sina Gallo
	Emma Laing

Electronic Version Approved:

Ron Walcott
Vice Provost for Graduate Education and Dean of the Graduate School
The University of Georgia
August 2021

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CHAPTER 1

INTRODUCTION

1.1 GLOBAL BREASTFEEDING TRENDS

Breastfeeding practices vary worldwide, from time of initiation to duration of exclusive breastfeeding. [1] WHO and UNICEF currently recommend that all infants receive breastmilk within 1 hour of birth to enhance breastmilk production and ensure the infant receives colostrum, or "first milk." [2] According to UNICEF's most updated Breastfeeding Scorecard report, only 74 countries met this recommendation as of 2020. [1] In regards to breastfeeding duration, WHO and UNICEF recommend that infants should be exclusively breastfed for the first 6 months of life and supplemented with appropriate complementary foods while they continue to breastfeed for at least 2 years. [3] WHO defines exclusive breastfeeding as when the infant receives only breastmilk without any complementary food or drink, including water. [4] If these recommendations are followed, exclusive breastfeeding for the first 6 months of life is reported to have a positive impact on an infant's health outcomes. [5] In general, exclusive breastfeeding rates are very low across the globe with only 19 countries reporting 60% of infants as exclusively breastfed at 0-5 months. Moreover, in the United States, only 20-40% of infants are exclusively breastfed. [1] Breastfeeding continuation rates at one year of age and beyond similarly lag behind the recommendations throughout the globe. The majority of countries where greater than 80% of infants are breastfed at 1 year and beyond are in Africa. On the contrary, some of the largest countries in the world such as China and the United States report significantly lower breastfeeding continuation rates of less than 40%. [1]

International initiatives such as the Global Breastfeeding Collective led by WHO and UNICEF aim to improve breastfeeding rates through the contributions of over 20 international agencies. This collective partnership works to increase financial support, policies, and interventions to support breastfeeding mothers. [6] For example, by 2025, the Global Breastfeeding Collective aims to increase access to breastfeeding counselling and improve the relationship between health facilities and community members. In 2030, the Collective hopes to see 70% of babies worldwide initiate breastfeeding within one hour of birth. In the United States, Healthy People 2030 has established 2 breastfeeding-related targets. The breastfeeding targets for Healthy People 2030 include increasing the proportion of infants exclusively breastfed through 6 months of age (MICH-15) and amount of infants breastfed at 1 year of age (MICH-16). [7] These Healthy People 2030 goals were established in hopes of promoting the health benefits of exclusive breastfeeding through tactics such as peer support and longer maternity leaves. [7] Despite ongoing national and international efforts, breastfeeding rates remain below target.

1.2 THE BENEFITS AND BARRIERS OF BREASTFEEDING

Human breast milk is a source of beneficial nutrients that support the cognitive development, healthy weight gain, and general health of infants. [8] [9] Mothers also benefit from the act of breastfeeding by way of protection against breast cancer, diabetes and other psychological and emotional benefits. [10] [11] Considering all the benefits of breastfeeding, it poses the question of why exclusive breastfeeding rates are still below the recommendation, particularly in developing countries. Developing countries uniquely benefit from breastfeeding due to its health, environmental and economic impacts. Breast milk is both free of cost and packaging, unlike breast milk alternatives such as formula. [12, 13] The bioavailability of

nutrients makes breast milk particularly important for infant feeding in nations where malnutrition is prevalent. [14]

Various breastfeeding barriers exist for mothers globally; however, mothers in developing countries frequently report low self-efficacy, cultural beliefs and practices discouraging exclusive breastfeeding, low community support, and maternal employment as major hindrances. [15] [16] [17] Furthermore, the perception that breastmilk production is insufficient frequently discourages mothers from exclusively breastfeeding their infants, leading to early introduction of supplemental foods. [18] A little known fact, however, is that insufficient milk production rarely occurs among women; the false perception of inadequate milk production often drives mothers away from exclusive breastfeeding. [18]

One additional mealtime challenge is correctly interpreting an infant's feeding cues, which may range from facial expressions to physical gestures. [19] Feeding cues provide a glimpse into the wants and needs of an infant. Poor maternal understanding of feeding cues has even been associated with greater weight-for-age for some infants. [19] The task of observing and understanding these cues during infant feeding assessment poses difficulty to mothers and researchers alike.

1.3 CURRENT METHODS OF INFANT FEEDING ASSESSMENT

Infant feeding assessment is typically performed through maternal recall, which is entirely memory-based. Numerous arguments exist against memory-based dietary recall methods, such as the fact that human memory is not a valid, measurable tool for data collection. [20] Maternal recall has shown to be biased, as mothers often overestimate how much and what types of foods their infant is eating. [21] Video capture has been used as an alternative to circumvent the bias of maternal recall, though this method is accompanied by shortcomings as

well. Participant behavior in front of a video camera is comparably biased, especially in a laboratory setting away from home. [22] Wearable devices that passively perform infant feeding assessment may eliminate shortcomings of current infant feeding/dietary recall methods, while posing little burden on users. Such devices may allow for detailed examination of infant feeding sessions with no reliance on memory.

Problem Statement

Current infant feeding assessment methods can be resource-intensive, requiring time, lab space, and the presence of a researcher. Though these traditional methods are frequently used in the United States and other developed countries, low- and middle-income countries cannot rely on such exhaustive tools due to a number of reasons including low literacy rates and expertise. [6] Traditional methods that require active reporting such as maternal recalls place substantial weight on the participant's memory. Further, active reporting at mealtimes requires literacy and familiarity with portion sizes. When a dietary recall is biased, the foundation of that individual's care plan is negatively affected. Inaccuracy of dietary recall through these methods prevents progress in the dietetics field and enhancement of the nutrition care process. [6]

Objective dietary assessment methods, particularly infant feeding assessment, are limited for all populations, but particularly for infants in lower-income countries. This issue is currently being addressed by utilizing wearable devices to automatically and passively capture real-time images of food consumption, which eliminates any reliance on memory. This methodology was extended for infant feeding in the current project. A questionnaire collecting caregiver self-reports was used to supplement digital imagery from the AIM device, allowing for a side-by-side comparison. Questionnaires were administered in a face-to-face interview with responses manually recorded by a research assistant, eliminating the burden of active participant reporting.

Passive dietary assessment, such as wearable image-capturing devices, decreases the possibility of self-reported errors and is also less intrusive than eating/feeding in front of a video camera or actively logging one's food choices. Objectively captured images provide a more holistic view of the mother's experiences and challenges, which range from physical to emotional. When mothers self-report their breastfeeding experiences, it is often difficult to determine the root of the problem without active observation. By collecting detailed feedback through yes/no and open-ended questions and comparing them directly to images of the experience, a deeper analysis can be made regarding how and why these challenges or successes are occurring between the mother and infant.

To the best of our knowledge, this is the first study using a passive wearable device (AIM) solely for infant feeding assessment, which works to accomplish our mission of providing a passive dietary monitoring system for individuals of all ages living in low- and middle-income countries. The main goal of this study is to test the feasibility of an objective and passive device to assess infant feeding cues and general infant feeding patterns. This research is significant because it advances our understanding of infant feeding cues and provides us with an innovative and convenient method of doing so. The use of passive, image-capturing devices for the purpose of dietary assessment has previously been conducted; however, this technique has not been used specifically for the purpose of assessing infant feeding in developing countries. [23] [24]

This study allows us to gain both visual and caregiver-reported insight regarding infant feeding patterns, ranging from physical and facial cues to duration and frequency. Our research shows the widespread application that the AIM device may provide to diverse populations. We hope to contribute to the field of dietary intake assessment by utilizing objective evaluation of infant feeding patterns for possible lactation counseling and education purposes.

REFERENCES

1. World Health Organization, U. *Increasing commitment to breastfeeding through funding and improved policies and programmes: Global breastfeeding scorecard 2019*. Nutrition Publications 2019 cited 2020 19 October.
2. UNICEF, W. *Capture the Moment- Early Initiation of Breastfeeding: The best start for every newborn*. 2018 cited 2021 January 13.
3. *Breastfeeding Report Card* Breastfeeding 2020 September 17, 2020 cited 2021 January 2; Available from: https://www.cdc.gov/breastfeeding/data/reportcard.htm.
4. *About the Collective*. Global Breastfeeding Collective cited 2021 January 3rd; Available from: https://www.globalbreastfeedingcollective.org/about-collective.
5. *Nutrition and Healthy Eating Objectives* Infants 2020 cited 2021 January 2; Available from: https://health.gov/healthypeople/objectives-and-data/browse-objectives/nutrition-and-healthy-eating.
6. *Breastfeeding*. Nutrition; Available from: https://www.who.int/nutrition/topics/exclusive_breastfeeding/en/.
7. Isaacs, E.B., et al., *Impact of breast milk on intelligence quotient, brain size, and white matter development.* Pediatric research, 2010. **67**(4): p. 357-362.
8. Buvinger, E., et al., *Observed infant food cue responsivity: Associations with maternal report of infant eating behavior, breastfeeding, and infant weight gain.* Appetite, 2017. **112**: p. 219-226.

9. *Breastfeeding Report Card*. Centers for Disease Control and Prevention 2018 August 20, 2018 cited 2020 January 5; Available from: https://www.cdc.gov/breastfeeding/data/reportcard.htm.

10. Gross, R.S., et al., *Maternal Perceptions of Infant Hunger, Satiety, and Pressuring Feeding Styles in an Urban Latina WIC Population*. 2010, ELSEVIER SCIENCE B.V. AMSTERDAM: United States. p. 29.

11. *Breastfeeding and the Use of Human Milk.* Pediatrics, 2012. **129**(3): p. e827.

12. Karlsson, J.O., et al., *The carbon footprint of breastmilk substitutes in comparison with breastfeeding.* Journal of Cleaner Production, 2019.

13. Victora, C.G., et al., *Breastfeeding in the 21st century: epidemiology, mechanisms, and lifelong effect.* The Lancet, 2016. **387**(10017): p. 475-490.

14. Kavle, J.A., et al., *Addressing barriers to exclusive breast-feeding in low- and middle-income countries: a systematic review and programmatic implications.* Public Health Nutrition, 2017. **20**(17): p. 3120-3134.

15. Tuthill, E.L., et al., *HIV infection, hunger, breastfeeding self-efficacy, and depressive symptoms are associated with exclusive breastfeeding to six months among women in western Kenya: a longitudinal observational study.* International Breastfeeding Journal, 2020. **15**(1): p. 1-9.

16. Kakute, P.N., et al., *Cultural Barriers to Exclusive Breastfeeding by Mothers in a Rural Area of Cameroon, Africa.* Journal of Midwifery & Women's Health, 2005. **50**(4): p. 324-328.

17. Li, R., et al., *Why mothers stop breastfeeding: mothers' self-reported reasons for stopping during the first year.* Pediatrics, 2008. **122 Suppl 2**: p. S69-76.

18. Ventura, A.K., S. Sheeper, and J. Levy, *Exploring Correlates of Infant Clarity of Cues During Early Feeding Interactions.* Journal of the Academy of Nutrition & Dietetics, 2019. **119**(9): p. 1452-1461.

19. Archer, E., M.L. Marlow, and C.J. Lavie, *Controversy and debate: Memory-Based Methods Paper 1: the fatal flaws of food frequency questionnaires and other memory-based dietary assessment methods.* Journal of Clinical Epidemiology, 2018. **104**: p. 113-124.

20. van Zyl, Z., et al., *The accuracy of dietary recall of infant feeding and food allergen data.* Journal of Human Nutrition and Dietetics, 2016. **29**(6): p. 777-785.

21. Hetherington, M.M., *Understanding infant eating behaviour – Lessons learned from observation.* Physiology & Behavior, 2017. **176**: p. 117-124.

22. Beltran, A., et al., *Dietary Assessment with a Wearable Camera among Children: Feasibility and Intercoder Reliability.* Journal of the Academy of Nutrition and Dietetics, 2018. **118**(11): p. 2144-2153.

23. Raber, M., et al., *Utility of eButton images for identifying food preparation behaviors and meal-related tasks in adolescents.* Nutrition journal, 2018. **17**(1): p. 32-32.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION TO BREASTFEEDING AND GLOBAL HEALTH STATUS

The act of breastfeeding is a fundamental pillar in the improvement of public health. Breastfeeding offers unique engagement between the mother and infant, allowing the mother to familiarize herself with feeding cues such as signals of hunger, readiness to feed, and satiety of the infant. [22] The mother-infant relationship during feeding serves as an insightful interaction, providing significant information about a child's needs. [10, 11] In both industrialized and developing countries, breast milk serves as a natural source of easily digestible nutrient, adapting to the evolving needs of the infant during the different stages of development in early life.

In addition to being cost effective, breastfeeding provides a number of health benefits for both the mother and baby. [25] Breast milk not only protects the infant against infectious diseases, but also promotes cognitive and sensory development. [8] Maternal benefits during breastfeeding have been widely reported by the CDC and supported through extensive review, encompassing emotional satisfaction through the release of oxytocin along with protection against maternal breast cancer, ovarian cancer, and type 2 diabetes. [26] [27] [5] Despite the array of benefits, there are also a variety of barriers ranging from physical difficulties, emotional and mental health challenges, and lack of community support that prevent mothers from breastfeeding as recommended. [10] Compared to UNICEF's 2030 collective target stated in the Global Breastfeeding Scorecard, current exclusive breastfeeding rates for babies under 6 months are lacking by 30%. [1] Eliminating this disparity will improve the health and productivity of the

global population. The following literature review will examine the relationship between breastfeeding and global health status in addition to infant feeding assessment methods and efforts being taken to innovate existing tools.

2.2 BREASTFEEDING BENEFITS FOR THE YOUNG INFANT

Exclusive breastfeeding, which occurs when an infant receives only breastmilk without other food or drink, serves as the foundation of optimal infant development. [4] [25] Although WHO and UNICEF's recommendation is to exclusively breastfeed for the first 6 months postpartum, exclusive breastfeeding for just 3 to 4 months has proven protective against an infant's risk of allergic diseases such as asthma and digestive issues such as Inflammatory Bowel Disease. [28, 29] Early initiation of breastfeeding is key for favorable health outcomes because it lowers risk of neonatal mortality and guarantees the infant receives nutrient-dense colostrum, or "first milk." [30] Further, mothers who initiate breastfeeding earlier show longer duration of breastfeeding, thus extending this period of developmental benefits. [31] Exclusive breastfeeding yields positive developmental outcomes involving the gut microbiota, cognitive development, and healthy weight gain. [32] [33] [34]

2.2.1 Breastfeeding and the Diversification of Gut Microbiota

The diversification of an infant's gut microbiota through breastfeeding serves as a major factor contributing to optimal infant development. Nutrition, specifically from early feeding practices, plays a key role in microbiota evolvement and overall health. [32] Following microbial transfer from the umbilical cord blood and amniotic fluid, a mother's breast milk is one of the initial exposures to microbes that an infant may receive. [11] Human milk oligosaccharides (HMOs), or complex sugars exclusively found in human breast milk and absent from most formulas, are thought to serve as prebiotics for infants, promoting growth of beneficial bacteria.

Accumulating evidence in the literature shows that HMOs decrease an infant's risk of bacterial, viral and parasite infections. [35] Wang et al compared the microbiota of Caucasian, formula-fed and breastfed infants through stool sample collection at 3 months of age. Researchers were able to draw an association between HMO profiles and several bacterial genera. [36]. To arrive at this conclusion, HMOs were extracted from milk samples, purified, and profiled in order to determine the relative amount of each oligosaccharide species. DNA was isolated from fecal samples collected from each infant's diaper. Associations between HMO profiles and bacterial genera were examined by partial least squares regression. [36] Overall, the authors observed that the microbiota of breastfed infants differed greatly from that of formula-fed infants in abundances of specific bacterial strains such as Streptococcus and Enterococcus. This study demonstrated the favorable relationship between human milk oligosaccharide composition and infant microbiota diversification. [36]

The microbiota diversification observed in exclusively breastfed infants is possibly related to reduced diarrhea-related gut microbiota dysbiosis and protection against common neonatal pathogens. [32] [37] Trend et al drew this conclusion through a study which collected breast milk from mothers 7 and 21 days postpartum to assess the antimicrobial activity against *Staphylococcus epidermidis*, *Staphylococcus aureus*, *Escherichia coli*, and *Streptococcus agalactiae.* They compared breastmilk antimicrobial activity to that of infant formula and formula supplemented with antimicrobial peptides. [37] Concentrations of both lactoferrin and defensins in human breast milk were found to have protective antimicrobial characteristics, leading to decreased instances of late-onset neonatal sepsis. Lactoferrin in breast milk displayed a negative correlation with E. Coli and S. aureus colony forming units. [37] Evidence from Trend

and colleagues suggests breast milk components such as lactoferrin and defensins may protect infants from infection through bacteriostatic activity against certain pathogens.

2.2.2 Breastfeeding and Infant Brain Development

Accompanying gut microbiota diversification, breastfeeding may play a favorable role in infant brain development. Research has suggested a link between breastfeeding and cognitive development, especially among preterm infants who are less neurologically mature. [33] Isaacs and colleagues explored the relationship between breastfeeding, cognition, and brain volume, finding substantial data to support their hypothesis that breast milk promotes brain growth. [8] This particular study used MRI scans of adolescent cohort members from a previous randomized trial to examine the impact of breastfeeding on neural volume. The 50 adolescents included in this follow-up study (26 M; 24 F) were born at 30 weeks GA or less, considered neurologically normal, and had a mean age of 15 years 9 months at the time of follow-up data collection. A Wechsler IQ test was given to each participant along with the MRI scan and MRI volumetric analysis. Results showed an evident relationship between early breast milk intake, IQ, and white matter development in the brain. Male participants exhibited higher cognitive levels than females. A proposed explanation for this improved cognitive development was the higher concentration of cholesterol found in breast milk compared to infant formula. [8] Cholesterol availability plays a role in intellectual performance, serving as a rate-limiting factor for brain maturation in the mice model. [38] Isaacs et al.'s findings promote the influence of breastfeeding on cognitive development, particularly in males.

A prospective, population-based cohort study by Herba and colleagues discovered results supportive of Isaacs et al. Researchers discovered larger gangliothalamic diameter, which encompasses the basal ganglia and thalamus, along with non-specific neural developmental

advantages, in exclusively breastfed babies compared with bottle-fed babies. [33] Measurements of gangliothalamic ovoid diameter of 680 babies were supplemented with maternal reports of breastfeeding habits at two months postpartum. Cranial ultrasounds of breastfed infants at 7 weeks post-natal displayed more mature neural expansion, solidifying the association between breastfeeding in the first 2 months of life and early cognitive development. [33] Interestingly, exclusive breastfeeding yielded larger head circumference and smaller ventricular volume among infants as well. Herba and colleagues showed the neural developmental advantages of early exclusive breastfeeding through this Generation R study. [33]

2.2.3 Breastfeeding and Infant Weight Gain

Healthy weight gain is another important component of infant development, thus the rate and amount of weight gain during infancy is a common area of concern for mothers and healthcare professionals alike. [25] Infants who are breastfed for any duration during infancy have a lower risk for being overweight and obese compared to formula-fed infants. [25] Lower weight gain during the neonatal period is due to lower mean calorie intake among breastfed infants. Several meta-analyses reviewing both recent and preceding research have confirmed the favorable effects of breastfeeding on weight. [39] [34] [40] A meta-analysis by Harder and colleagues discovered each month of breastfeeding to be associated with a four percent decrease in risk of becoming overweight, lasting up to a 9 month duration. The majority of the studies included in this review were cohort designs ranging in size and origin. [12] A more recent meta-analysis including 25 studies from 12 different countries drew similar conclusions. Publication dates ranged from 1997 to 2014 and included German, American, British, Australian, Chinese, Japanese, Irish, Greek, Brazilian, Dutch, Czech, and Canadian studies. Among the 25 included studies, 10 prospective cohort studies, 5 historical cohort studies, and 10 cross-sectional surveys

were assessed. Consistent findings suggested that among breastfed children, childhood obesity risk was decreased by 22% compared to non-breastfed children. [39] 17 of the chosen studies looked specifically at breastfeeding duration and obesity, presenting several common categories for duration including <3 months, 3-5 months, and greater than 7 months. Longer duration of breastfeeding, specifically for greater than 7 months, showed significant protection against childhood obesity. One limitation of this meta-analysis and similar analyses is the varying definition of "overweight" among different studies, making it difficult to specify an inclusion criteria. [34] [39] Although an inverse association has been found between breastfeeding duration and risk of being overweight, the mechanism for this protective effect is still not widely understood.

To further support the argument that breastfeeding plays a positive role in healthy weight outcomes, it should be noted that self-regulation patterns differ between breastfed and formula-fed infants. Breastfed infants develop better self-regulation and control over milk intake compared to bottle-fed infants, who show increased bottle-emptying and poor self-control during feedings. [25] Excessive weight gain in infants older than 6 months has been observed by those fed by a bottle compared to the breast, possibly due to this poor self-control. [41] Li et al examined infant-initiated bottle-emptying in relation to risk for excess weight, hypothesizing that breastfed infants will have less excess weight than bottle-fed infants >6 months postpartum. [42] Infant feeding practices were maternally-reported in a survey completed by 1,986 participants. Researchers examined the association between excess weight risk and maternal-reported feeding practices through logistic regression models. [42] Infants fed <20% breastmilk during the first 6 months of life were at least 2 times more at risk for excess weight in late infancy. Further, infants with higher bottle-emptying habits and lower self-regulation had a 69% increase in risk for

excess weight during late infancy. [42] Early development of self-regulation during breastfeeding may continue throughout adulthood, protecting against excess weight gain and improving overall health outcomes. [9]

2.3 THE UNIQUE IMPACT OF BREASTFEEDING IN DEVELOPING COUNTRIES

The importance of breastfeeding is especially relevant in low- and middle-income countries for a number of reasons. Besides the widely-known health benefits such as protection against infection, obesity, and diabetes, breastfeeding provides financial and environmental benefits as well. [14] [25] Breastfeeding aligns with Sustainable Development Goals by providing a vital source of nutrients without creating a large ecological footprint. Sustainable Development Goals are 17 objectives set by the UN in response to current, global issues. [14] Specifically, there lies a connection between breastfeeding and sustainable development goals 1, 3 and 11.

Sustainable Development Goal 3 aims to "ensure healthy lives and promote well-being for all ages." [43] The correlation between SDG 3 and breastfeeding is evident, considering the vast array of health benefits for mothers and infants alike. In 2019, notable progress was made towards this goal, including increased life expectancy and decreased maternal and child mortality; however, there is still work to be done. [43] According to Jones and colleagues, ninety percent of the world's childhood deaths occur in developing countries, which could potentially be decreased by 13% through exclusive breastfeeding for 6 months and weaning after 1 year. [44] This is the equivalent of preventing 1 million infant deaths each year through breastfeeding alone. [25]

Substantial research has solidified the impact of breastfeeding on extended lifespan. [45] A review conducted in 2015 by Sankar et al proved the importance of exclusive breastfeeding for

decreased all-cause and infection-related mortality rates in infants and children 0-23 months of age. [45] Of the 13 included studies from nations such as Africa and southeast Asia, two were secondary analyses from randomized control trials, nine were prospective cohort studies, and two were case-control. All studies assessed the impact of predominant, partial, or non-breastfeeding in the first 6 months of life as well as non-breastfeeding beyond 6 months of life. [45] Both infection-related and all-cause mortality was assessed during 0-5 months of age, 6-11 months of age, and 12-23 months of age. Infection-related mortality was due to infections such as measles, malaria, and sepsis. Among partially, predominately, and non-breastfed infants, the risk of all-cause mortality was 1.8-2.0 fold higher than exclusively breastfed infants. Further, when compared to predominately and partially breastfed infants, non-breastfed infants had a 7.2 and 3.7 fold increase in risk of infection-related mortality. [45] Suboptimal breastfeeding practices led to significantly higher risk of both all-cause and infection-related mortality. [45] These long-lasting protective effects described by Sankar et al are especially crucial in countries where undernutrition is prevalent. [14]

The impact of breastfeeding on achieving UN Sustainable Development Goals extends far past its widespread health benefits. For example, SDG 1 is to end poverty in all forms, which is supported by the act of breastfeeding; however, economic savings is a distinctive benefit of breastfeeding that fewer studies have explored. Breastfeeding is free of cost, thus promoting economic growth and additional income into the global economy. In Spain, a longitudinal two-group observational study by Santacruz-Salas and colleagues assessed clinical history of 236 healthy mother-newborn pairs throughout the first 6 months postpartum. [46] The two groups were categorized by whether the infant was exclusively breastfed for the first 6 months of life or non-exclusively breastfed using formula. Through two-part regression models, exclusive

breastfeeding was estimated to generate savings in healthcare costs over the first 6 months of an infant's life, including specialized care, primary care, and medical emergencies. [46] These findings by Santacruz-Salas et al suggest significant economic benefits from the act of exclusive breastfeeding, which have the potential to positively affect low income countries.

From an environmental standpoint, breastfeeding supports SDG11, which aims to create sustainable cities and communities, by providing a waste-free food source and decreasing the use of packaging and emission of greenhouse gases. [8] Although substantial progress of goal 11 was achieved in 2019 towards reducing urban populations living in poverty, 2 billion people globally still do not have access to a means of waste collection. [43] The proportion of waste collection from 2010 to 2018 was lowest in sub-Saharan Africa, proving their need for sustainable feeding practices such as breastfeeding. [43] In addition to excess waste, the production of animal-based food products such as breast milk substitutes contributes to greenhouse gas emissions during all stages of preparation. A recent study from Karlsson and colleagues compiled data from the UK, China, Brazil, and Vietnam, discovering the carbon footprint of breastfeeding to be 53% less than breast milk substitutes. [13] This study assessed the dairy processing, packaging, transport, bottle production, and home sterilization of bottles to illustrate regional differences in the carbon footprint of breast milk substitutes. The carbon footprint from breastfeeding in the UK, China, Brazil, and Vietnam was 40%, 53%, 43%, and 46% lower than from breast milk substitutes. [13] These findings from Karlsson et al imply that the environmental impact of breast milk substitutes is globally dominant when compared to breastfeeding.

Despite the aforementioned benefits, which prove particularly relevant in developing countries, breastfeeding prevalence varies greatly among countries of different income levels. [29] Specifically, the percentage of breastfed babies born in high-income countries is lower than

those in middle or low income countries. [29] In addition to breastfeeding prevalence, the duration of breastfeeding also varies greatly among poor and wealthy regions, with the largest gap occurring around West and Central Africa. At 2 years, 63% of the poorest families still breastfeed, compared to 26% of babies from richest families. [29] Based on a global distribution, breastfeeding at 12 months and beyond is particularly prevalent in sub-Saharan Africa, south Asia, and Latin America. [14] Although there is a higher prevalence of breastfeeding in Africa, exclusive breastfeeding rates are still unsatisfactory based on recommendations. [1] Africa would particularly benefit from an increase in exclusive breastfeeding prevalence.

2.4 BARRIERS TO BREASTFEEDING RECOMMENDATIONS

It is recommended that exclusive breastfeeding take place during the first 6 months postpartum; however, less than 60% of most African mother-infant pairs are meeting this recommendation. [47] [1] This is perhaps due to the fact that breastfeeding poses a number of emotional, environmental, and physical challenges to about 92% of new mothers, especially in developing countries. Emotional challenges such as depression and low self-efficacy play a large role in early breastfeeding cessation. Physical challenges that mothers frequently face include the infant's inability to latch, sore or cracked nipples, and perceived insufficient milk production. [48] A more multi-faceted category is environmental barriers, which include everything from social norms to cultural acceptance. Each of these categories acts as a barrier to achieving breastfeeding recommendations in low-resource settings.

2.4.1 Emotional Challenges of the Breastfeeding Mother

A mother's emotional wellbeing is a key contributor to successful breastfeeding. This is suggested by the possible association between postpartum depression and reduced mother-infant interaction, breastfeeding initiation, and duration. [49] [16] Among women in developing

countries, anywhere between 15 to 57% experience depressive symptoms such as insomnia, fatigue, and irritability. [50]

A longitudinal cohort study in Kenya examined the relationship between breastfeeding confidence and maternal depressive symptoms with exclusive breastfeeding rates. [16] Because food-insecure mothers are more likely to practice non-exclusive breastfeeding, Tuthill and colleagues also explored the role of food insecurity on initiation and duration of exclusive breastfeeding. 275 women recruited from both rural and urban clinics in Kenya were interviewed twice during pregnancy and three times postpartum. [16] Mothers reported on their breastfeeding self-efficacy and social support at the first postnatal visit. In addition, participants outlined their infant feeding practices at each visit, including whether infants were exclusively breastfed or when/if other foods were introduced. Maternal depression was assessed using the Center for Epidemiologic Studies Depression Scale and food insecurity was assessed by the Individual Food Insecurity Access Scale.

As concluded in this Kenyan study, maternal depression acts as an emotional barrier with the ability to double the likelihood of early exclusive breastfeeding cessation. [16] Interestingly, this team found that high self-efficacy minimized the adverse emotional impact of food insecurity on early exclusive breastfeeding cessation in low-income households. [16] Tuthill et al highlighted that emotional barriers ranging from depression to low self-efficacy play an intermediate role in exclusive breastfeeding duration in developing countries.

2.4.2 Environmental Challenges of the Breastfeeding Mother

The success of exclusive breastfeeding relies heavily on a conducive environment, which may involve a mother's occupation, family support, or societal expectations. One systematic review that examined breastfeeding in 25 low and middle-income countries such as Ghana,

Kenya, and Nigeria found maternal employment as a prevalent environmental barrier to successful breastfeeding. [15] This review collected both qualitative and quantitative data from studies conducted between 2000 to 2015 that explored exclusive breastfeeding barriers. 16 barriers were identified from the 48 articles included. Barriers to exclusive breastfeeding in the first 6 months of life ranged from maternal employment to perceptions of poor infant behavior based on feeding cues, perceptions of insufficient milk production, and lack of family support. [41] These diverse challenges presented by Kavle et al prove that exclusive breastfeeding cessation in developing countries is due to far more than just emotional challenges. [15]

As previously mentioned, women in developing countries have been found to initiate mixed feeding with their infant due to lack of family support and exhaustion from work, among a range of other reasons. [17] A study in Cameroon which interviewed 320 mothers about their reasons for initiating mixed feeding found the top reason to be family or community pressure. Although most participants were encouraged to exclusively breastfeed by medical providers, certain cultural beliefs hindered the practice. [17] For example, participants expressed the belief that breast milk is an incomplete food source which should be supplemented with solid foods. Further, these mothers first handedly contributed to food production on a farm, from which they believed all family members should eat. [17] From this study by Kakute et al, it is apparent that cultural beliefs and lack of community support may interfere with a mother's decision to exclusively breastfeed.

2.4.3 Physical Challenges of the Breastfeeding Mother

Lack of physical coherence between the mother and infant is another hindrance to successful exclusive breastfeeding in developing countries. Whether the barrier be perceived issues with milk production, breast and nipple problems, or misunderstanding an infant's cues

during feeding, mothers are faced with various physical challenges that may inhibit a successful breastfeeding session. A systematic review focusing on qualitative studies of young child feeding in low-income countries identified all of the aforementioned challenges as barriers to breastfeeding. [51] This comprehensive search using PubMed, Embase, and Cumulative Index to Nursing and Allied Health Literature identified studies related to young child feeding in low income countries from 2006-2016. Breastfeeding barriers were broken into four categories of infant or mother-specific factors, beliefs and perceptions, lack of support from family or healthcare professionals, and time poverty. [51] Based on the authors' reported barriers, breast and nipple problems were identified in 6 out of 14 studies with high confidence. Further, insufficient breast milk production was reported in 14 out of 23 studies with high confidence. Notably, 14 out of 15 studies in the "mothers' knowledge" category reported insufficient breastfeeding knowledge or difficulty interpreting child's feeding behavior. [51] Bazzano and colleagues illustrate the significant role that physical challenges play in early breastfeeding cessation. Interpreting an infant's physical cues during feeding is one particular challenge that warrants further research.

2.5 UNDERSTANDING INFANT FEEDING CUES

Perhaps one of the greatest, yet less explored barriers for new mothers in relation to breastfeeding is the understanding, or lack thereof, of infant feeding cues. Perceived infant health and feeding cues have ranked near the top of breastfeeding barriers in developing countries. [15] Such feeding difficulties may be more prevalent among certain mother-infant interaction styles. For example, mothers who are more controlling during meal times have resulted in infants with worse behavioral outcomes. [52] Research exploring mother-infant interaction styles in relation to infant developmental outcomes has found that some infants with controlling mothers

displayed increased behavioral issues, especially during feeding. [52] Thus, a responsive mother-infant feeding relationship with solid understanding of hunger and satiety cues may lead to longer breastfeeding duration, and improved infant behavioral outcomes.

A time period that is arguably most important for understanding feeding cues is during the first 6 months postpartum while exclusively breastfeeding. Breastfed infants typically display higher engagement and disengagement behaviors than formula fed infants. [53] Blundell et al used video recordings to explore infant communication cues during formula and breastmilk feeding. Participants included 27 infants from the United Kingdom and Israel ranging from 3-22 weeks old. Feeding cues were split into either engagement or disengagement, and each video was coded based on frequency of each cue's appearance. [53] The NCAST list of communication cues was used to identify and validate each feeding cue. Cues that are commonly recognized during breastfeeding include increased sucking and facial relaxation for hunger, and nipple detachment or turning of the head for satiety. [11] Breastfed infants displayed more active engagement behaviors and overall positive mealtime communication with the mother. [53]

Because infants have limited language and cognitive skills, it is difficult for mothers to distinguish hedonic from negative facial expressions, especially in response to foods. [54] Although studies have attempted to "decode" these cues using video recordings, image capture is potentially a superior tool for assessing feeding cues among infants in developing countries. Unlike video, images allow for the analysis of specific, pinpointed moments in time. Exploring infant feeding cues during the beginning, middle, and end of feeding may support mothers in achieving more responsive feeding strategies. Considering the lack of objective means to explore infant feeding cues in developing countries, image capture presents itself as a promising method for this discovery.

2.6 DIETARY RECALL METHODS

Dietary patterns are arguably one of the most enlightening components in assessing an individual's overall health status. A diet high in nutrient-rich foods has proven to be inversely associated with all-cause mortality. [55] Despite its importance in assessing nutritional status, accurate measurement of dietary exposures continue to be a major obstacle. A number of dietary assessment tools exist to examine eating patterns of individuals throughout the lifespan, each with unique strengths and limitations. [56]

2.6.1 Subjective Dietary Assessment

Subjective dietary recall methods that are memory-based serve as a standard form of intake assessment. Since the 1990s, self-reported dietary recall has been shown to significantly underestimate as much as 70% of actual energy intake. Women have been found more likely to underreport, as well as overweight or obese individuals. [57] De Vries et al published a study in 1994 comparing self-reported energy intake from 3-day food diaries with actual intake needed to maintain body weight for a 6-9 week span. [58] Participants included 269 free-living healthy male (n = 119) and female (n = 150) adults. Reported energy intake from food diaries was approximately 277 ± 378 kcal per day lower than actual energy requirements. Women showed greater relative bias (-12.2 ± 13.7%) than men (-8.0±13.4%) when it came to underreporting energy intake. [58] This study by de Vries et al concluded that systemic underreporting occurs with the use of self-reported food diaries; however, this method is still widely used due to lack of superior alternatives.

One other traditional method is the Food Frequency Questionnaire (FFQ), which has been used since the 1990s with updates and improvements created over time. Both energy and protein intake reported using FFQs have been found underreported at a median of 30-40%. [59]

The utility of FFQs has been widely questioned for over a decade, especially when compared to other dietary recall methods such as the 24-hour recall (24HR). A study involving 484 healthy participants from Montgomery County, Maryland aimed to determine the precision of the FFQ in comparison to a 24HR. Participants completed both an FFQ and 24HR on two occasions in addition to doubly labelled water and urine assessments. Schatzkin and colleagues found the FFQ's attenuation factor to be 0.04-0.16 compared to the 24HR's of 0.1-0.2. [59] This study concluded that the FFQ should not be recommended for assessing energy or protein intake, particularly in relation to disease. Despite ongoing updates to the questionnaire, FFQ remains a vastly subjective assessment with high recall bias. [56]

Open-ended tools such as 24-hour recalls (24HR) or food diaries place substantial responsibility on the respondent to report accurately. 24HR are often administered in an interview-style, allowing for collection of details involving specific ingredients, preparation techniques, and portion sizes. [56] Although this interview typically lasts 20-30 minutes, posing minimal burden on the respondent, the data relies solely on memory. Diet records, or food diaries, require respondents to actively log their intake at meal times. Though this method relies less on long-term memory, it requires significant motivation. Both of these open-ended methods reflect short-term intake data, preventing any major implications from being made about long-term chronic disease development. [56]

A consistent argument against these current dietary assessment tools is the subjectivity due to heavy reliance on memory. [20] Recently, experts including Archer et al have continued to invalidate such methods on the basis that human memory is not a valid data collection instrument; additionally, measuring the error in these dietary assessment methods is nearly impossible. [20] Inaccuracy of dietary recall prevents progress in establishing diet-related

recommendations and guidelines. [56] For over 60 years, data from these methods has formed the basis for diet and health-related publications, in addition to the Dietary Guidelines for Americans. [20] There are profound discrepancies over the pseudoscientific nature of memory-based reporting methods, given that there is no way to ascertain accuracy of the data.

Archer et al performed a study in 2013 testing the validity of National Health and Nutrition Examination Survey (NHANES) caloric intake data from the years 1971-2010. [60] 24-hour recall data from 28,993 men and 34,369 women aged 20-74 was used to determine the credibility of self-report. A ratio of reported energy intake to basal metabolic rate was utilized in order to determine which energy intake values were implausible. [60] The majority of respondents significantly underreported their daily caloric intake; in fact, no more than 43% of overweight and obese women reported plausible values. [60] Obese men and women displayed the greatest mean disparity values, which ranged from -716 to -856 kcal per day. During the 39-year period of NHANES data, 67.3% of women and 58.7% of men reported physiologically implausible data. Underreporting was found to be substantially more common than overreporting. [60] Given these findings from Archer et al, an ongoing disconnect clearly persists between a reporter's actual intake and their perceived, self-reported intake. For over a decade, there has been an emerging need for exploration of objective dietary assessment tools due to the ambiguous nature of current techniques.

2.6.2 Objective Dietary Assessment

Currently, there are limited methods of objective dietary assessment. The duplicate diet approach and food consumption record both involve objective data collection; however, they are significantly more exhaustive, requiring active participation from researchers. [56] The duplicate diet method is often utilized to measure exposure to environmental toxins in food and beverage.

This technique requires subjects to weigh and duplicate portions of their normal diet for chemical analysis, posing a substantial burden on subjects to collect food away from the home, in social settings, etc. [61] Additionally, it is often used in conjunction with another dietary recall method, such as a food record, to document and identify collected foods. Food consumption records are similarly exhaustive, requiring a skilled researcher to actively observe subjects' food preparation and consumption. This technique, although posing minimal burden to the subjects, is limited to household analysis. [56]

Technology-based studies have explored dietary assessment through wearable devices, capturing data via digital imagery or physical sensors. [62] One study exploring the feasibility of a wearable camera found that the combination of a conventional 1-day food diary with a wearable camera provided a more accurate estimate of dietary intake than self-report alone. This study examined the use of the wearable Microsoft SenseCam among 27 healthy, athletic adults to determine nutrient intake. Simultaneously reporting energy intake through SenseCam and 1-day food diaries allowed for comparison between two data sources. [62] Additionally, mobile apps utilizing photographic food records (PFR) have been tested for feasibility and user adherence. [63] Among a sample of 42 ethnic minority mothers in California, PFR was proven impractical over an extended period of 6 months. Participants used cell-phone based ecological momentary assessment (CEMA) to record sleep, stress, mood, and exercise in conjunction with PFR at each meal. The adherence of both PFR and CEMA decreased over time. This study similarly recommended a hybrid approach of combining different self-monitoring methods for optimal accuracy. [63]

One particular tool with automatic features is a non-invasive monitor that detects chewing and swallowing through various sensors. [64] This wearable, chewing strain sensor

allows passive assessment of dietary intake in real-time under free-living conditions. The device is attached directly under the participant's outer ear in order to detect jaw motion. Sazonov and Fontana tested the device among a small group of healthy adult subjects ranging from age 18 to 57 years old. Participants were asked to eat 4 food items while wearing the device, each with different chewing properties ranging in hardness and crunchiness. A completely passive monitoring experience was achieved through sensors placed on the wearable device. [64] While chews and swallows are unique indicators of food intake, these sensors struggle to detect liquid ingestion and food surrogates such as gum. [64] Average accuracy for this particular study by Sazonov et al was 80.95%; however, it has been estimated that 95% accuracy can be achieved through detection of chews and swallows. [64, 65] Passive dietary assessment not only decreases the possibility of self-reported error, but is also less exhaustive than actively logging one's food choices.

2.7 INFANT FEEDING ASSESSMENT

When performing dietary assessment among a younger population of infants, self-report is not feasible. Maternal or caregiver recall is the most common method of infant dietary assessment; however, it is often accompanied by recall bias. [21] Existing research suggests that caution should be taken when relying on recall, especially with mother-infant pairs. One particular study by Fisher et al recruited 157 mothers of non-Hispanic white, non-Hispanic black and Hispanic origin to complete a telephone-administered 24-h recall, which was compared to a 3-day weighed food record. When compared to the weighed food record over 3 consecutive days, caregiver recall for infant or toddler dietary intake was highly overreported. [66] The maternally-reported 24-hour recall overestimated energy intake among infants by 13% and among toddlers by 29%. The food group that showed the greatest discrepancy between recall methods was dairy;

specifically, milk was the greatest source of error. Dairy intake was overestimated 46% and 29% among infants and toddlers, respectively. Overestimation in caregiver recall for infants and toddlers is often driven by portion size estimation error. [66] Maternal recall bias reduces the reliability of this tool for infant feeding assessment in future research.

One alternative to maternal recall is video capture accompanied by behavioral coding. This observational method has been explored to reveal infant engagement and disengagement cues during mealtimes. Observational studies have successfully assessed food rejection behaviors as well as duration of eating particular foods. [22] Infant gaze captured via video has been used as a measure of hunger and satiation, showing changes in gaze behavior between the start and end of mealtimes. [67] Caton et al conducted a study which recorded twenty infants between 6-18 months old during mealtimes on two occasions, showing particular interest in infant gaze behavior. A behavioral coding scheme was developed using Noldus Observer XT video software for analysis, which revealed high levels of reliability with a 95% confidence interval from .95 to .96. Exploratory gaze behavior increased throughout the meal as infants became satiated. [67]

Coding systems such as Feeding Infants: Behavior and Facial Expression Coding System (FIBFECS) have similarly been used to quantify acceptance and rejection behaviors, ranging from nose wrinkling, turning head in disinterest, and crying. [68] FIBFECS includes 6 movements measured for avoidance behavior, such as fussing or arching back, and 7 facial expressions, such as squinting, measured for acceptance behavior. Nekitsing et al conducted a study in which thirty-six mother-infant dyads were randomly assigned into intervention or control groups and filmed while eating either a well-liked or less accepted vegetable. After coding 72 video extracts for acceptance and rejection behaviors, the authors concluded that video

coding tools can be useful in assessing dietary preferences in infants and possibly identifying strategies to promote healthy eating. [68] A limitation of video studies is the requirement of adjusting the speed and pinpointing individual frames for close observation. Additionally, participant behavior in the presence of a camera is often biased. Existing studies that utilized video found it most reliable to observe "frozen" images by slowing down the film and pausing at significant points in time. [67]

An alternative tool used to assess infant milk intake, specifically, is test weighing. This method involves weighing an infant before and after each feeding session and determining difference in body weight to approximate total milk volume consumed. Test weighing has been widely used for research purposes of breastfed infants more commonly than formula-fed infants. [69] Inaccuracies may occur when using this method due to urine or feces in the diaper or vomiting during feeding. Additional inconveniences of this method include the difficult task of accurately weighing an active infant. Further, measuring an infant directly before and after feedings is disruptive to the valuable mother-infant interaction. Infants often feed throughout the night which hinders the achievement of consistent and accurate feedings. [69] Precision of test weighing has been proven poor, with differences between weight change and actual milk intake ranging from 12.4 ml up to 30 ml. [70] Test weighing using infant weighing scales has been concluded as imprecise and not sensitive enough to detect minor changes in infant weight following a feeding session.

Current methods of infant feeding assessment ranging from maternal self-report to infant behavioral coding have been proven flawed, which implies that passively-collected, objective data should be explored. [21] [67] Objective data in the form of images is preventative against user error, impreciseness of infant weighing scales, and biased behavior during observation that

may occur in film studies. A series of images can be analyzed frame-by-frame in great detail, allowing researchers to identify particular feeding cues and what they truly mean.

2.8 CURRENT USE OF IMAGE-CAPTURING DEVICES

A variety of preliminary studies have reported on wearable devices for image-based dietary assessment. [23] [24] [71] These devices yielded promising results in studying a younger population. Beltran et al conducted a study which followed a group of thirty children in Houston, Texas wearing a multisensory camera on the chest for two full days to identify eating events and portion sizes with a passive device. Low user burden was detected among children aged 9-13, suggesting high compliance for future studies. [23] A secondary analysis of this adolescent group was performed, focusing on food preparation behaviors in the home. Food preparation behaviors, ranging from prep work to food seasoning were categorized into 7 groups and analyzed. Analyses showed the most common food preparation behavior to be browsing in the refrigerator or pantry. The device provided images which were easily identifiable, proving itself as a reliable assessment method of food-related behaviors and activities. [24]

2.8.1 Conclusion

Although technological advancements have been made in developed countries to improve accuracy of dietary recall, most require both computer and numerical literacy as well as internet connection. This leaves developing countries without these aforementioned resources at a disadvantage. To address this shortcoming, our research team is validating passive, image- and sensor- based dietary assessment devices in two developing countries, Ghana and Uganda. [71] The goal of this research is to provide an innovative method of dietary assessment for developing countries, despite the lack of technological advancements. Preliminary findings suggest the possibility of using these devices to passively and objectively assess breastfeeding and other

infant feeding practices. To the best of our knowledge, no passive assessment device has been utilized to document infant feeding patterns, specifically during breastfeeding. Given the promising results from existing studies that have utilized image-capture devices to identify dietary patterns and food preparation activities such as browsing and prepping, a wearable device could comparably provide valuable insight regarding infant feeding cues and patterns.

REFERENCES

1. World Health Organization, U. *Increasing commitment to breastfeeding through funding and improved policies and programmes: Global breastfeeding scorecard 2019*. Nutrition Publications 2019 cited 2020 19 October.
2. UNICEF, W. *Capture the Moment- Early Initiation of Breastfeeding: The best start for every newborn*. 2018 cited 2021 January 13.
3. *Breastfeeding Report Card* Breastfeeding 2020 September 17, 2020 cited 2021 January 2; Available from: https://www.cdc.gov/breastfeeding/data/reportcard.htm.
4. *Breastfeeding*. Nutrition; Available from: https://www.who.int/nutrition/topics/exclusive_breastfeeding/en/.
5. Centers for Disease Control and Prevention. *Breastfeeding: Why It Matters*. 2019 cited 2020 January 14; Available from: https://www.cdc.gov/breastfeeding/about-breastfeeding/why-it-matters.html.
6. *About the Collective*. Global Breastfeeding Collective cited 2021 January 3rd; Available from: https://www.globalbreastfeedingcollective.org/about-collective.
7. *Nutrition and Healthy Eating Objectives* Infants 2020 cited 2021 January 2; Available from: https://health.gov/healthypeople/objectives-and-data/browse-objectives/nutrition-and-healthy-eating.
8. Isaacs, E.B., et al., *Impact of breast milk on intelligence quotient, brain size, and white matter development.* Pediatric research, 2010. **67**(4): p. 357-362.

9. Buvinger, E., et al., *Observed infant food cue responsivity: Associations with maternal report of infant eating behavior, breastfeeding, and infant weight gain.* Appetite, 2017. **112**: p. 219-226.

10. *Breastfeeding Report Card*. Centers for Disease Control and Prevention 2018 August 20, 2018 cited 2020 January 5; Available from: https://www.cdc.gov/breastfeeding/data/reportcard.htm.

11. Gross, R.S., et al., *Maternal Perceptions of Infant Hunger, Satiety, and Pressuring Feeding Styles in an Urban Latina WIC Population*. 2010, ELSEVIER SCIENCE B.V. AMSTERDAM: United States. p. 29.

12. Harder, T., et al., *Duration of breastfeeding and risk of overweight: a meta-analysis.* Am J Epidemiol, 2005. **162**(5): p. 397-403.

13. Victora, C.G., et al., *Breastfeeding in the 21st century: epidemiology, mechanisms, and lifelong effect.* The Lancet, 2016. **387**(10017): p. 475-490.

14. Kavle, J.A., et al., *Addressing barriers to exclusive breast-feeding in low- and middle-income countries: a systematic review and programmatic implications.* Public Health Nutrition, 2017. **20**(17): p. 3120-3134.

15. Tuthill, E.L., et al., *HIV infection, hunger, breastfeeding self-efficacy, and depressive symptoms are associated with exclusive breastfeeding to six months among women in western Kenya: a longitudinal observational study.* International Breastfeeding Journal, 2020. **15**(1): p. 1-9.

16. Kakute, P.N., et al., *Cultural Barriers to Exclusive Breastfeeding by Mothers in a Rural Area of Cameroon, Africa.* Journal of Midwifery & Women's Health, 2005. **50**(4): p. 324-328.

17. Li, R., et al., *Why mothers stop breastfeeding: mothers' self-reported reasons for stopping during the first year.* Pediatrics, 2008. **122 Suppl 2**: p. S69-76.

18. Ventura, A.K., S. Sheeper, and J. Levy, *Exploring Correlates of Infant Clarity of Cues During Early Feeding Interactions.* Journal of the Academy of Nutrition & Dietetics, 2019. **119**(9): p. 1452-1461.

19. Archer, E., M.L. Marlow, and C.J. Lavie, *Controversy and debate: Memory-Based Methods Paper 1: the fatal flaws of food frequency questionnaires and other memory-based dietary assessment methods.* Journal of Clinical Epidemiology, 2018. **104**: p. 113-124.

20. van Zyl, Z., et al., *The accuracy of dietary recall of infant feeding and food allergen data.* Journal of Human Nutrition and Dietetics, 2016. **29**(6): p. 777-785.

21. Hetherington, M.M., *Understanding infant eating behaviour – Lessons learned from observation.* Physiology & Behavior, 2017. **176**: p. 117-124.

22. Beltran, A., et al., *Dietary Assessment with a Wearable Camera among Children: Feasibility and Intercoder Reliability.* Journal of the Academy of Nutrition and Dietetics, 2018. **118**(11): p. 2144-2153.

23. Raber, M., et al., *Utility of eButton images for identifying food preparation behaviors and meal-related tasks in adolescents.* Nutrition journal, 2018. **17**(1): p. 32-32.

24. *Breastfeeding and the Use of Human Milk.* Pediatrics, 2012. **129**(3): p. e827.

25. Chowdhury, R., et al., *Breastfeeding and maternal health outcomes: a systematic review and meta-analysis.* Acta paediatrica (Oslo, Norway : 1992), 2015. **104**(467): p. 96-113.

26. Ip, S., et al., *Breastfeeding and maternal and infant health outcomes in developed countries.* Evid Rep Technol Assess (Full Rep), 2007(153): p. 1-186.

27. Barclay, A.R., et al., *Systematic Review: The Role of Breastfeeding in the Development of Pediatric Inflammatory Bowel Disease.* The Journal of Pediatrics, 2009. **155**(3): p. 421-426.

28. UNICEF. *Breastfeeding, A Mother's Gift, for Every Child*. 2018 cited 2020 January 3; Available from: https://www.unicef.org/publications/files/UNICEF_Breastfeeding_A_Mothers_Gift_for_Every_Child.pdf.

29. Khan, J., et al., *Timing of Breastfeeding Initiation and Exclusivity of Breastfeeding During the First Month of Life: Effects on Neonatal Mortality and Morbidity-A Systematic Review and Meta-analysis.* Maternal & Child Health Journal, 2015. **19**(3): p. 468.

30. *Early initiation of breastfeeding to promote exclusive breastfeeding*. e-Library of Evidence for Nutrition Actions 2019 February 11, 2019 cited 2021 January 23; Available from: https://www.who.int/elena/titles/early_breastfeeding/en/.

31. Ho, N.T., et al., *Meta-analysis of effects of exclusive breastfeeding on infant gut microbiota across populations.* Nature communications, 2018. **9**(1): p. 4169-4169.

32. Herba, C.M., et al., *Breastfeeding and early brain development: the Generation R study.* Maternal & Child Nutrition, 2013. **9**(3): p. 332-349.

33. Harder, T., et al., *Duration of Breastfeeding and Risk of Overweight: A Meta-Analysis.* American Journal of Epidemiology, 2005. **162**(5): p. 397-403.

34. Bode, L., *Human milk oligosaccharides: Every baby needs a sugar mama.* Glycobiology, 2012. **22**(9): p. 1147-1162.

35. Wang, M., et al., *Fecal Microbiota Composition of Breast-Fed Infants Is Correlated With Human Milk Oligosaccharides Consumed.* Journal of Pediatric Gastroenterology and Nutrition, 2015. **60**(6).

36. Trend, S., et al., *Antimicrobial Protein and Peptide Concentrations and Activity in Human Breast Milk Consumed by Preterm Infants at Risk of Late-Onset Neonatal Sepsis.* PLOS ONE, 2015. **10**(2): p. e0117038.

37. Saher, G., et al., *High cholesterol level is essential for myelin membrane growth.* Nature Neuroscience, 2005. **8**(4): p. 468-475.

38. Yan, J., et al., *The association between breastfeeding and childhood obesity: a meta-analysis.* BMC Public Health, 2014. **14**: p. 1267.

39. Arenz, S., et al., *Breast-feeding and childhood obesity—a systematic review.* International Journal of Obesity, 2004. **28**(10): p. 1247-1256.

40. Li, R., S.B. Fein, and L.M. Grummer-Strawn, *Association of Breastfeeding Intensity and Bottle-Emptying Behaviors at Early Infancy With Infants' Risk for Excess Weight at Late Infancy.* Pediatrics, 2008. **122**(Supplement 2): p. S77.

41. Li, R., S.B. Fein, and L.M. Grummer-Strawn, *Association of Breastfeeding Intensity and Bottle-Emptying Behaviors at Early Infancy With Infants' Risk for Excess Weight at Late Infancy.* Pediatrics, 2008. **122**(Supplement 2): p. S77.

42. Nations, U. *Sustainable Development Goals Report*. 2019 cited 2020 January 9, 2020; Available from: https://www.un.org/sustainabledevelopment/progress-report/.

43. Jones, G., et al., *How many child deaths can we prevent this year?* The Lancet, 2003. **362**(9377): p. 65-71.

44. Sankar, M.J., et al., *Optimal breastfeeding practices and infant and child mortality: a systematic review and meta-analysis.* Acta Paediatr, 2015. **104**(467): p. 3-13.

45. Santacruz-Salas, E., et al., *The Economic Influence of Breastfeeding on the Health Cost of Newborns.* Journal of Human Lactation, 2018. **35**(2): p. 340-348.

46. Karlsson, J.O., et al., *The carbon footprint of breastmilk substitutes in comparison with breastfeeding.* Journal of Cleaner Production, 2019. **222**: p. 436-445.

47. Issaka, A.I., K.E. Agho, and A.M. Renzaho, *Prevalence of key breastfeeding indicators in 29 sub-Saharan African countries: a meta-analysis of demographic and health surveys (2010-2015).* BMJ open, 2017. **7**(10): p. e014145-e014145.

48. Feenstra, M.M., et al., *Early breastfeeding problems: A mixed method study of mothers' experiences.* Sexual & Reproductive Healthcare, 2018. **16**: p. 167-174.

49. Husain, N., F. Creed, and B. Tomenson, *Depression and social stress in Pakistan.* Psychological Medicine, 2000. **30**(2): p. 395-402.

50. Scharfe, E., *Maternal Attachment Representations and Initiation and Duration of Breastfeeding.* Journal of Human Lactation, 2012. **28**(2): p. 218-225.

51. Alessandra, N.B., et al., *Qualitative Studies of Infant and Young Child Feeding in Lower-Income Countries: A Systematic Review and Synthesis of Dietary Patterns.* Nutrients, 2017. **9**(10): p. 1140-1140.

52. Forcada-Guex, M., et al., *Early dyadic patterns of mother-infant interactions and outcomes of prematurity at 18 months*. 2006. p. E107-E114.

53. Shloim, N., et al., *Looking for cues – infant communication of hunger and satiation during milk feeding.* Appetite, 2017. **108**: p. 74-82.

54. Forestell, C.A. and J.A. Mennella, *The Relationship between Infant Facial Expressions and Food Acceptance.* Current nutrition reports, 2017. **6**(2): p. 141-147.

55. Streppel, M.T., et al., *Nutrient-rich foods, cardiovascular diseases and all-cause mortality: the Rotterdam study.* Eur J Clin Nutr, 2014. **68**(6): p. 741-7.

56. Shim, J.-S., K. Oh, and H.C. Kim, *Dietary assessment methods in epidemiologic studies.* Epidemiology and health, 2014. **36**: p. e2014009-e2014009.

57. Macdiarmid, J. and J. Blundell, *Assessing dietary intake: Who, what and why of under-reporting.* Nutrition Research Reviews, 1998. **11**(2): p. 231-253.

58. de Vries, J.H., et al., *Underestimation of energy intake by 3-d records compared with energy intake to maintain body weight in 269 nonobese adults.* The American Journal of Clinical Nutrition, 1994. **60**(6): p. 855-860.

59. Schatzkin, A., et al., *A comparison of a food frequency questionnaire with a 24-hour recall for use in an epidemiological cohort study: results from the biomarker-based Observing Protein and Energy Nutrition (OPEN) study.* International Journal of Epidemiology, 2003. **32**(6): p. 1054-1062.

60. Archer, E., G.A. Hand, and S.N. Blair, *Validity of U.S. Nutritional Surveillance: National Health and Nutrition Examination Survey Caloric Energy Intake Data, 1971–2010.* PLOS ONE, 2013. **8**(10): p. e76632.

61. Potischman, N., *Biologic and Methodologic Issues for Nutritional Biomarkers.* The Journal of Nutrition, 2003. **133**(3): p. 875S-880S.

62. Thomas, K.W., et al., *Testing duplicate diet sample collection methods for measuring personal dietary exposures to chemical contaminants.* J Expo Anal Environ Epidemiol, 1997. **7**(1): p. 17-36.

63. O'Loughlin, G., et al., *Using a Wearable Camera to Increase the Accuracy of Dietary Analysis.* American Journal of Preventive Medicine, 2013. **44**(3): p. 297-301.

64. Comulada, W.S., et al., *Adherence to self-monitoring healthy lifestyle behaviours through mobile phone-based ecological momentary assessments and photographic food records over 6 months in mostly ethnic minority mothers.* Public Health Nutrition, 2018. **21**(4): p. 679-688.

65. Sazonov, E.S. and J.M. Fontana, *A Sensor System for Automatic Detection of Food Intake Through Non-Invasive Monitoring of Chewing.* IEEE sensors journal, 2012. **12**(5): p. 1340-1348.

66. Sazonov, E.S., et al., *Toward objective monitoring of ingestive behavior in free-living population.* Obesity (Silver Spring), 2009. **17**(10): p. 1971-5.

67. Fisher, J.O., et al., *Overestimation of infant and toddler energy intake by 24-h recall compared with weighed food records.* Am J Clin Nutr, 2008. **88**(2): p. 407-15.

68. McNally, J., et al., *The eyes have it: Infant gaze as an indicator of hunger and satiation.* Appetite, 2019. **133**: p. 353-361.

69. Nekitsing, C., et al., *Application and validation of the Feeding Infants: Behaviour and Facial Expression Coding System (FIBFECS) to assess liking and wanting in infants at the time of complementary feeding.* Food Quality and Preference, 2016. **48**: p. 228-237.

70. Jobarteh, M.L., et al., *Development and Validation of an Objective, Passive Dietary Assessment Method for Estimating Food and Nutrient Intake in Households in Low- and Middle-Income Countries: A Study Protocol.* Current Developments in Nutrition, 2020. **4**(2).

CHAPTER 3

THE USE OF PASSIVE DIETARY ASSESSMENT AMONG BREASTFEEDING MOTHERS IN GHANA [1]

[1] Cerminaro, C., Sazonov, E., McCrory, M., Steiner-Asiedu, M., Bhaskar, V., Gallo, S., Laing, E., and Anderson, A. K., To be submitted to *Public Health Nutrition.*

ABSTRACT

Background: Despite significant progress, there is still poor adherence with exclusive breastfeeding recommendations in some African countries, which has significant implications for infant health. Many factors including the identification of infant feeding cues can be resolved with proper education. However, there is currently no objective method for the assessment of infant feeding. Passive, wearable sensors allow for collection of objective dietary assessment that prevents user errors due to recall and biased behavior during observation.

Objective: Examine the feasibility of using a wearable device (Automatic Ingestion Monitor [AIM]) for infant feeding assessment and compare the accuracy of caregiver-reported infant feeding patterns and experiences vs. images captured by the wearable device.

Methods: This was a cross-sectional study that used mixed-methods approach. Thirty-eight mothers of young infants aged <7 months from rural (n=18) and urban (n=20) Ghanaian communities participated in the study. Mothers wore the AIM device for a 24-hour period and feasibility was assessed by user compliance. Infant feeding practices were assessed by maternal self-report via interviewer-administered questionnaire. Images from AIM were annotated and compared to maternal self-report of breastfeeding frequency, duration and feeding cues.

Results: Out of 38 participants, 25 mothers reported exclusively breastfeeding (EBF) their infant at the time of data collection, with 13 remaining participants practicing mixed feeding. A majority of mothers were single or cohabitating (n=24, 63.2%), multiparous (n=21, 55.3%), and employed full-time (n=22, 57.9%). Exclusive breastfeeding was most commonly seen among mothers under 30 years of age (n=15, 60%) and those residing in urban communities (n=14, 70%).

There was high participant compliance (83%) wearing the AIM device, suggesting low user burden during wear time. Maternal report of infant feeding differed from images objectively captured by the AIM device. On average, mothers reported average daily breastfeeding frequency to be 11 times, compared to an average of 8 times from the AIM-observed frequency. Breastfeeding duration was similarly over reported, with a mean of 18.5 minutes and AIM-captured average duration of 10 minutes per session. Feeding cues with the greatest agreement between maternal report and observation from the AIM images included signaling readiness to feed by turning the head, nipple rejection suggesting dissatisfaction, and smiling to express satiation. Urban mothers expressed negative breastfeeding reflections more frequently, whereas all reflections from rural participants were either positive or neutral.

Conclusions and Implications: Considering the limitations of current infant feeding assessment tools due to their reliance on memory, the AIM device shows promise of being a passive and objective data collection method of accurately assessing infant feeding practices. Future studies should explore the use of automatic annotation of images by artificial intelligence to avoid potential human errors associated with manual image annotation. This study shows the feasibility of using wearable passive assessment devices for infant feeding assessment among a low- and middle-income population.

3.1 INTRODUCTION

An increase in breastfeeding prevalence has the ability to improve health and productivity of the global population. Breastfeeding allows mothers to physically connect with their infant and adapt to his or her needs. Aside from the engagement that occurs between mother-infant dyads, breastfeeding provides a plethora of health, economic, and developmental benefits to mother and baby. Health benefits for the mother include both physical and emotional advantages,

ranging from decreased diabetes risk to oxytocin release. [26] [27] [5] Infant benefits are similarly extensive, ranging from brain development to protection against gastrointestinal disorders. [28, 29] [33] The WHO and UNICEF recommends exclusive breastfeeding for 6 months without any food or water supplementation. Exclusive breastfeeding is particularly crucial in low and middle-income countries with higher prevalence of poverty and malnutrition due to its economic and health benefits. [15] Despite progress in Africa, the percentage of infants meeting these exclusive breastfeeding recommendations still remains under 20% in some African countries. [1] Further, geographic differences in feeding practices between urban and rural communities have not been determined using such innovative methods.

Multiple barriers have been reported to prevent mothers from meeting breastfeeding recommendations. [17] Perceived insufficient milk supply is one of the common reasons for discontinuation of breastfeeding in both nourished and undernourished populations. [72] Further, infant satisfaction cues are often used by mothers as the chief indication of milk supply. [72] Yet, primary glandular insufficiency, the main reason for insufficient milk supply, occurs in <5 % of all women. [73] Most early breastfeeding problems can be prevented with early latching within the first hour of life and feeding often on the earliest signs of hunger, or quickly resolved with appropriate support, including education about normal patterns and volumes of newborn feeds.

Previously published studies have attempted to unveil the difficulties of infant feeding and reasons for early cessation. However, most of the existing studies rely on maternal report with no active observation or objective assessment. [15, 17] Memory-based recall, especially in regards to dietary habits, has been widely questioned as an accurate means of data collection. [20] [57] [59] Women, including mothers of young infants, have generally been found to underreport their own energy intake and over report intake of their children. [57] [66] This bias

poses challenges to researchers attempting to study infant feeding habits and how they influence developmental and health outcomes.

One proposed alternative for accurate and objective assessment of infant feeding habits is a methodology that does not rely on maternal memory or recall. This promising option is a wearable device for image-based dietary assessment (Automatic Ingestion Monitor). [74] Images captured by a passive device overcome the issue of participant bias and provide researchers a frame-by-frame view of dietary intake sessions. This technology-based method has been explored in preliminary studies, but never for the purpose of infant feeding assessment in low-income countries. [23] [24] [71] Therefore, the purpose of this study was to evaluate the feasibility of a wearable, image-capturing device for infant feeding assessment among breastfeeding mothers in both rural and urban Ghanaian communities. This pilot feasibility study had the following aims: (1) determine the feasibility of the AIM device as assessed by participant compliance, (2) examine the relationship between caregiver-reported infant feeding patterns and images of infant feeding captured by the Automatic Ingestion Monitor (AIM) device, (3) examine the relationship between caregiver-reported breastfeeding experiences and images of infant feeding captured by the AIM device.

3.2 MATERIALS AND METHODS

3.2.1 Study Design

This cross-sectional study was conducted in Ghana, Africa using a mixed-methods approach. Data collection took place from October 2019 to January 2020. Participants were recruited by word-of-mouth by trained field research assistants during their visit to the communities. Determination of exclusive breastfeeding vs. mixed feeding was performed using the mother's report and confirmation in the AIM images. Exclusive breastfeeding was defined as

feeding the infant breastmilk without any additional food or fluids, including water. [31] Participant inclusion was solely based on whether mothers had an infant 7 months old or younger. Data was collected using both the AIM device and a face-to-face interviewer-administered questionnaire. The interviewer-administered questionnaire was used to obtain information on caregiver-reported infant feeding practices, breastfeeding experiences, and general demographic information such as occupation, level of education, and marital status, among other characteristics. For the image portion of the data, the AIM device was mounted on eyeglasses and worn by mothers during wake-time of a chosen day for image capture. Captured images were reviewed and uploaded to MatLab 2020 (Mathworks, MA) and custom-made AIM annotation software for annotation. All participants received monetary incentive of 100 GH₵ (approximately 20 US dollars). All methods and procedures were reviewed and approved by the Human Subject Institutional Review Board at the University of Georgia (appendix a). All participants provided informed consent before recruitment for study participation.

3.2.2 Development and Administration of the Infant Feeding Questionnaire

The questionnaire was developed based on existing instruments and commonly reported breastfeeding challenges discovered in the literature. [18] [48] [75] [71] Past publications that utilized infant feeding questionnaires emphasize the use of a free-response format as opposed to predefined categories and answer choices. This influenced the predominately open-ended layout of the current survey. Our review of literature showed several categories of common breastfeeding struggles. The yes/no portion in our questionnaire was based on frequently reported challenges, including an infant's difficulty sucking or overall disinterest in feeding. [18] The yes/no portion contained 13 commonly-reported breastfeeding struggles compiled from previously published studies. [18] [48] [75] Our open-ended questions highlighted some of the

more complex struggles, inquiring about overall experiences and concerns with breastfeeding. Additionally, the 18-item Baby Eating Behavior Questionnaire (BEBQ) was reviewed for potential items of interest relating to hunger and satiety. [75] The final questionnaire included the following categories: sociodemographic factors (n=12), current breastfeeding practices (n=4), open-ended breastfeeding experiences and concerns (n=7), possible breastfeeding problems (n=14), open-ended physical observations before, during, and after feeding (n=5), and anthropometric measures (n=8). (appendix b)

A trained field research assistant administered the questionnaire containing both open-ended and close-ended questions in the participants' home. Questionnaires were administered in a face-to-face interview format on the day of data collection. The open-ended, physical observation (feeding cues) questions were categorized into "before," "during," and "after" feeding in order to allow for easier identification in the captured AIM images (appendix b). The open-ended questions aimed to ascertain mother's breastfeeding self-efficacy as well as breastfeeding challenges and successes. The closed-ended, yes/no questions about breastfeeding problems served to highlight common breastfeeding issues mothers' experience. Potential problems included cracked or sore nipples, clogged milk ducts, and struggle with milk flow (appendix b). Interviewers provided clarification when needed, as well as follow-up questions to provide further context for the data collection.

3.2.3 Automatic Ingestion Monitor (AIM)

Before data collection with the AIM device, a brief training session was conducted by the field research assistant with participants (Figure 1a). The training session addressed how to properly wear the AIM device, take the device off and on, and how to charge the device if needed. The training session allowed participants to ask any initial questions about the device

and its operation before data collection commenced. The AIM device mounted on eyeglasses was worn by mothers during wake time on the day of data collection, excluding any activities where she wanted to preserve privacy (Figure 1b). Participant sleep data or nighttime feeds were not assessed for the purpose of this study. Participants with prescription eyeglasses had the AIM device attached to their eyeglasses by a research assistant for data collection. The AIM device automatically captured images every 15 seconds during wake time.

These images were later processed, uploaded to MatLab and a custom-made AIM annotation software. Images were manually annotated to determine breastfeeding duration and frequency, and feeding cues of infant feeding sessions. User compliance was determined comparing "active" to "inactive" wear by participants during wake time. "Active" or compliant use of the AIM device was defined as when the participant wore the device as prescribed during wake time. "Inactive" or non-compliant was defined as when the device was not worn by the participant during wake-time; for example, the device was placed on a table or desk (Figure 1c).

Image annotation was manually completed using MatLab 2020 and custom-made AIM annotation software. Within the MatLab 2020 software, annotation was performed using the Image Labeler Toolbox. This feature allowed a research assistant to view and manually identify breastfeeding or mixed feeding sessions within each participant's 24-hour image set. The cursor was used to outline the baby and method of feeding (either breast or food product) in color-coated boxes (Figure 2a). Breastfeeding and mixed feeding image labels were manually created and used to specify the type of feeding session being displayed. The AIM annotation software was used to assess breastfeeding duration per session, daily frequency and annotate feeding cues (Figure 2b).

3.2.4 Data Analysis

Feasibility of the device as defined by participant compliance was assessed through amount of time that the device was actively worn vs. taken off throughout the wake time. Descriptive analyses were performed using SPSS 27 (IBM, NY) and reported as frequencies and percentages for categorical variables, and means for continuous variables. A comparison was performed between the captured images and questionnaire responses in order to evaluate the accuracy of mothers' self-reported breastfeeding practices. Accuracy of maternal report was defined as the percent of agreement or discrepancy with the AIM image observations. Accuracy, or agreement between maternal self-report and observation from the captured images, was determined for frequency, duration, and feeding cues of breastfeeding. Feeding cues were grouped into 3 categories: before, during, and end of feeding session. Accuracy of maternal report was compared between rural and urban participants in order to determine geographic trends. Differences between geographic groups and exclusive vs. mixed feeding groups were examined by Chi-square or Fisher's Exact test. Criterion for statistical significance was set as $p<0.05$.

3.3 RESULTS

Thirty-eight mothers (18 rural, 20 urban) and their infants under 7 months of age participated in the study. Participants were from the following ethnic groups: 45% (n=17) Akan, 27% (n=13) Ga, 6% (n=3) Ewe, and 11% (n=4) "other" (Burkinabe, Nzema, Hausa, and Krobo). Participant age ranged from 18 to 44, with an average age of 28 years old. The majority (58%) of participants were employed full-time and working in jobs ranging from hairdresser, teacher, trader, seamstress, and food vendor. About (84%) of fathers worked full-time, with a 53% majority working blue collar jobs such as mechanic, janitor, and electrician. Among all 38

participants, the average household size was 5.8 individuals, with most urban and rural participants reporting 5 members in their household. Overall, a little over one-third (37%) of participants reported to be married, which was higher in rural communities (61%) compared to 15% in the urban communities. About 44% of the participants reported annual household income of between ₵5000-10000 (Ghanaian cedis), which was similar for both communities (Table 1). A majority (55%) of the participating mothers were multiparous who have birthed between 2 and 5 children, which was higher in the rural community (72%) compared to the urban community (40%). Infant's age ranged from 1-7 months, with an average of 2.5 months (Table 1). Overall, mothers from both rural and urban communities were highly confident in regards to breastfeeding their infant (Table 2). Mothers from urban communities intended to breastfeed their infant for approximately 4 months longer than rural participants. Mothers with higher household income and longer duration of formal schooling were more likely to exclusively breastfeed their infant. Of the 38 participants, 25 mothers reported exclusively breastfeeding (EBF) their infant at the time of data collection, with the 13 remaining participants practicing mixed feeding. Exclusive breastfeeding was more common among mothers residing in urban communities. (n=14, 70%) A greater percentage of mothers under 30 years of age practiced EBF compared to mothers over 30 (n=15, 60%). A higher number of rural participants reported mixed feeding compared to urban participants. (n=7, 39%) 71% of total participants initiated breastfeeding within the recommended time frame of 1 hour after delivery; 12 of these were from the rural communities, while 15 were from the urban communities (Table 2).

3.3.1 Participant compliance of the AIM device

User compliance while wearing the AIM device was generally high among all participants, suggesting acceptability of the device. Overall compliance among the total

a.

b.

c.

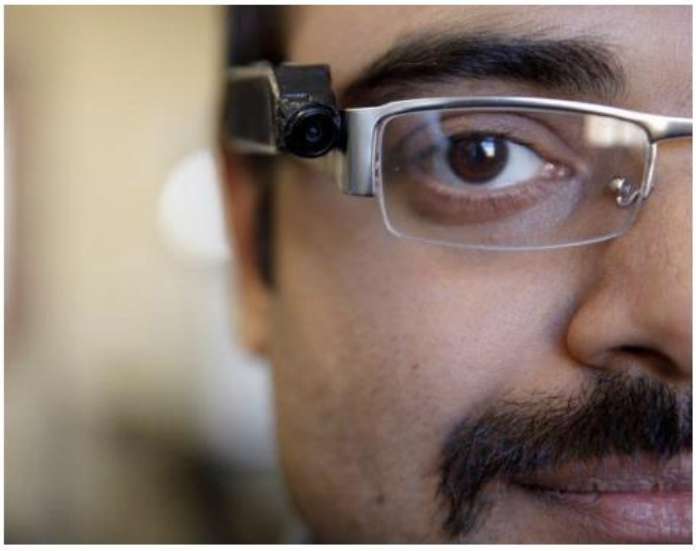
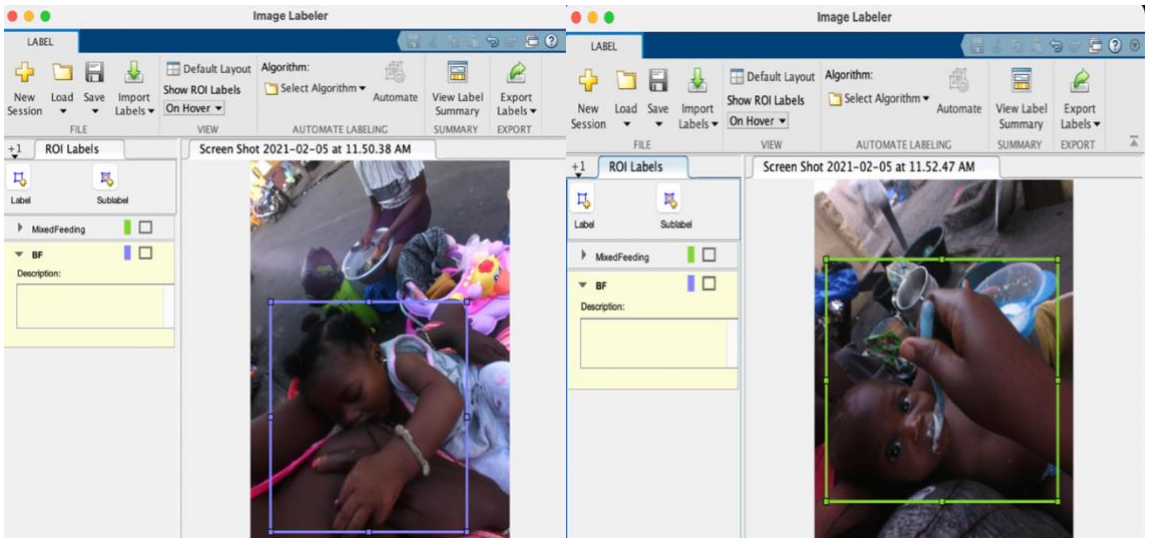


Figure 1. Automatic Ingestion Monitor

a. Detachable camera monitor
b. Eyeglasses with attached monitor
c. AIM user

a



b

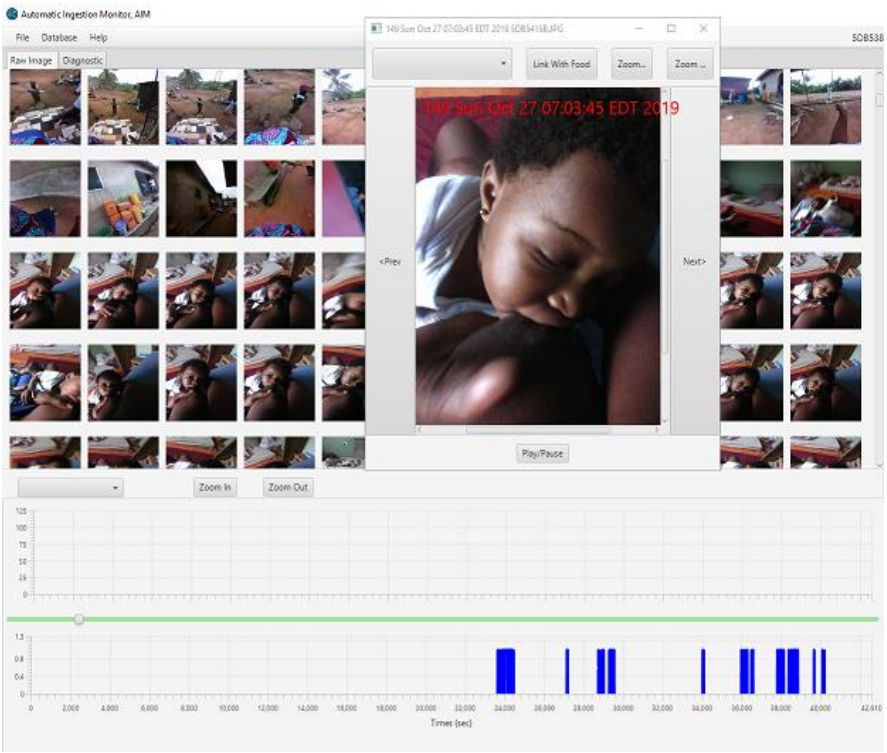


Figure 2. Infant Feeding Pattern Analysis

a. MatLab Image Labeler Toolbox

b. Custom-made Automatic Ingestion Monitor Software

Table 1. Participant Demographics (n=38)

Variables	All n (%)	Rural n (%)	Urban n (%)
Formal Education (years) (p=0.368)			
None	3 (7.9)	2 (11.1)	1 (5.0)
6-9	18 (47.4)	9 (50.0)	9 (45.0)
10-12	13 (34.2)	4 (22.2)	9 (45.0)
>12	4 (10.5)	3 (16.7)	1 (5.0)
Ethnicity (p=0.001)			
Akan	17 (44.7)	12 (66.7)	5 (25.0)
Ga	13 (34.2)	1(5.6)	12 (60.0)
Ewe	4 (10.5)	4 (22.2)	0 (0.0)
Other	4 (10.5)	1 (5.6)	3 (15.0)
Marital Status (p=0.003)			
Married	14 (36.8)	11 (61.1)	3 (15.0)
Cohabitating	24 (63.2)	7 (38.9)	17 (85.0)
Mother's Employment (p=0.619)			
Employed Full Time	22 (57.9)	9 (50.0)	13 (65.0)
Employed Part Time	4 (10.5)	2 (11.1)	2 (10.0)
Unemployed	12 (31.6)	7 (38.9)	5 (25.0)
Father's Employment (p=0.030)			
Employed Full Time	32 (84.2)	13 (72.2)	19 (95.0)
Employed Part Time	5 (13.2)	5 (27.8)	0 (0.0)
Unemployed	1 (2.6)	0 (0.0)	1 (5.0)
Parity (p=0.046)			
Primiparous	17 (44.7)	5 (27.8)	12 (60.0)
Multiparous	21 (55.3)	13 (72.2)	8 (40.0)
Yearly Household Income*(p=0.752)			
₵<5000	6 (15.8)	4 (22.2)	2 (10.0)
₵5000-10000	17 (44.7)	8 (44.4)	9 (45.0)
₵10000-₵15000	7 (18.4)	3 (16.7)	4 (20.0)
₵ 15000-20000	7 (18.4)	3 (16.7)	4 (20.0)
₵ >20000	1 (2.6)	0 (0.0)	1 (5.0)

** ₵ 1 = 0.17 USD*

Table 2. Participant Feeding Characteristics (n=38)

	Rural (mean ± SE)	Urban (mean ± SE)
BF Confidence *	8.00 ± 0.35	8.55 ± 0.39
BF Initiation after delivery (minutes)	14.78 ± 3.33	11.35 ± 2.82

Intended EBF cessation (months)	5.73 ± 0.27	9.79 ± 1.95

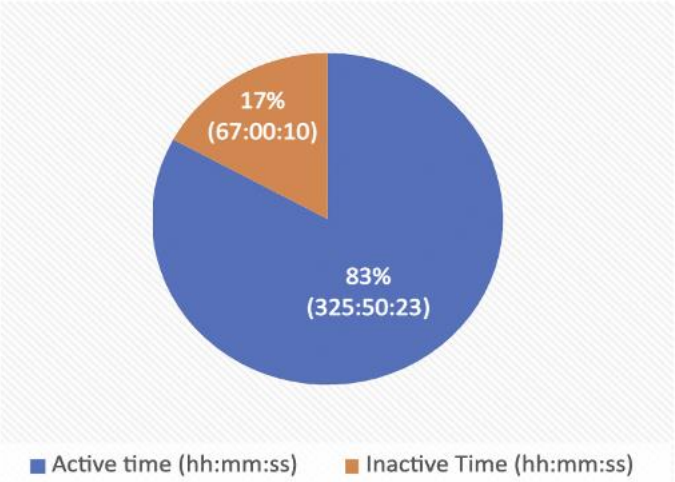
EBF=Exclusive Breastfeeding
**1-10, 10 being highest*

participants was 83%. Compliance was higher among urban (86%) compared to rural (78%) participants. Urban participants showed higher device compliance and overall active time wearing the AIM device compared to rural participants. Images from all 20 urban participants were clearer and detectable to annotate compared to images from rural participants. AIM devices worn by 2 out of the 18 rural participants did not produce detectable images for reasons unknown, therefore these participants were eliminated from the image annotation. Total "active time" of participant wear of the AIM device among urban mothers was 201 hours and 45 minutes, whereas total "active time" for rural participants was significantly lower at 124 hours and 4 minutes. Total inactive, or non-wear, time was 67 hours, with approximately 35 hours from rural and 32 hours from urban participants (Figure 3).

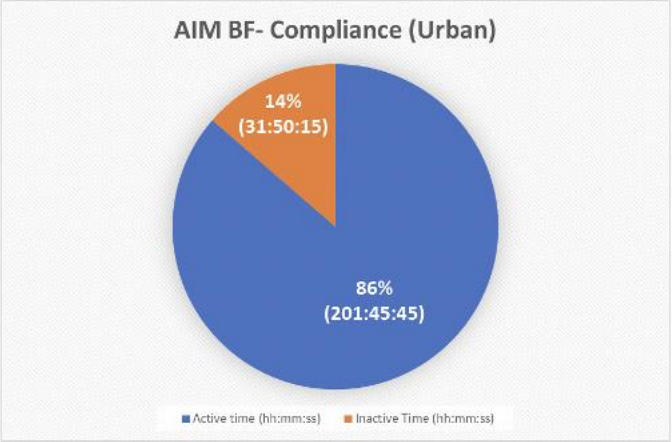
3.3.2 The relationship between caregiver-reported infant feeding patterns and AIM-captured images

In general, mothers reported a higher daily breastfeeding frequency than what was observed in the captured AIM images. Similarly, both exclusive breastfeeding (EBF) and mixed feeding mothers reported higher duration of feeding sessions than from the AIM image observations. Participants from the rural communities tended to report frequency of breastfeeding more accurately than their urban counterparts. Those who most accurately reported breastfeeding frequency were from rural communities, with MF mothers closely behind them (Table 3). Mothers mixed feeding their infants reported breastfeeding duration more accurately than their exclusive breastfeeding counterparts. About 40% of urban mothers underreported duration of their breastfeeding sessions compared to observation from the captured images.

a.



b.



c.

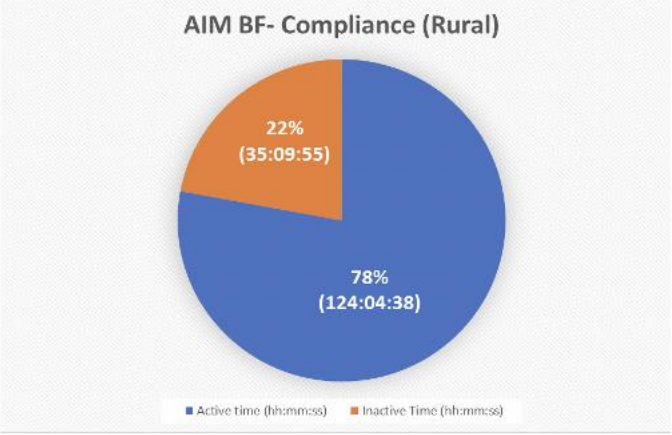


Figure 3. AIM Device Participant Compliance

a. AIM Device Total Compliance
b. AIM Device Rural Compliance
c. AIM Device Urban Compliance

Exclusively breastfeeding mothers tended to over report daily frequency (87%) and underreport duration (87.5%) of breastfeeding compared to their mixed feeding counterparts, 14.3% and 12.5%, respectively.

Maternal-reported breastfeeding frequency ranged from 3-30 times daily, whereas reported duration of breastfeeding ranged from 2-60 minutes per session. On average, mothers reported daily breastfeeding frequency to be 11 times, compared to the average AIM-observed frequency of 8 times. Breastfeeding duration was similarly over reported, with a mean of 18.5 minutes and AIM-captured average duration of 10 minutes per session. Mean duration of breastfeeding sessions for EBF mothers versus MF mothers was largely similar (EBF Mean ± SE: 10.72 ± 0.84 minutes, MF Mean ± SE: 9.67 ±1.10 minutes) (Table 3).

A majority (61%) of the total participants over reported breastfeeding duration, while only 38% over reported breastfeeding frequency. Over reporting breastfeeding duration was higher among rural participants (63.6%) compared to 36.4% of urban participants, while all underreporting duration was in the urban community. Of those who underreported breastfeeding frequency, 80% were from rural and 20% were from urban communities. Accuracy of reporting breastfeeding frequency was significantly ($p=0.041$) higher in the rural community (55.6%) compared to the urban community. (44.4%) A higher percentage (66.7%) of mothers who accurately reported breastfeeding duration were from the urban community compared to 33.3% from the rural community ($p=0.007$) (Figure 4).

Table 3. Maternal Reported vs. Researcher Observed Breastfeeding Patterns

	BF Frequency			BF Duration		
	Reported	Observed	P-value	Reported	Observed	P-value
Rural	9.28 ± 1.42	7.76 ± 0.60	0.446	25.29±2.95	10.29 ± 0.83	0.909
Urban	12.75 ± 1.27	8.45 ± 0.64	.075	12.80±2.53	10.45 ± 1.04	0.003
EBF	13.08 ±1.26	8.56 ±0.52	0.167	17.64±2.77	10.72±0.84	0.468
MF	7.31±0.84	7.25 ±0.78	0.004	20.42±3.45	9.67±1.10	0.555

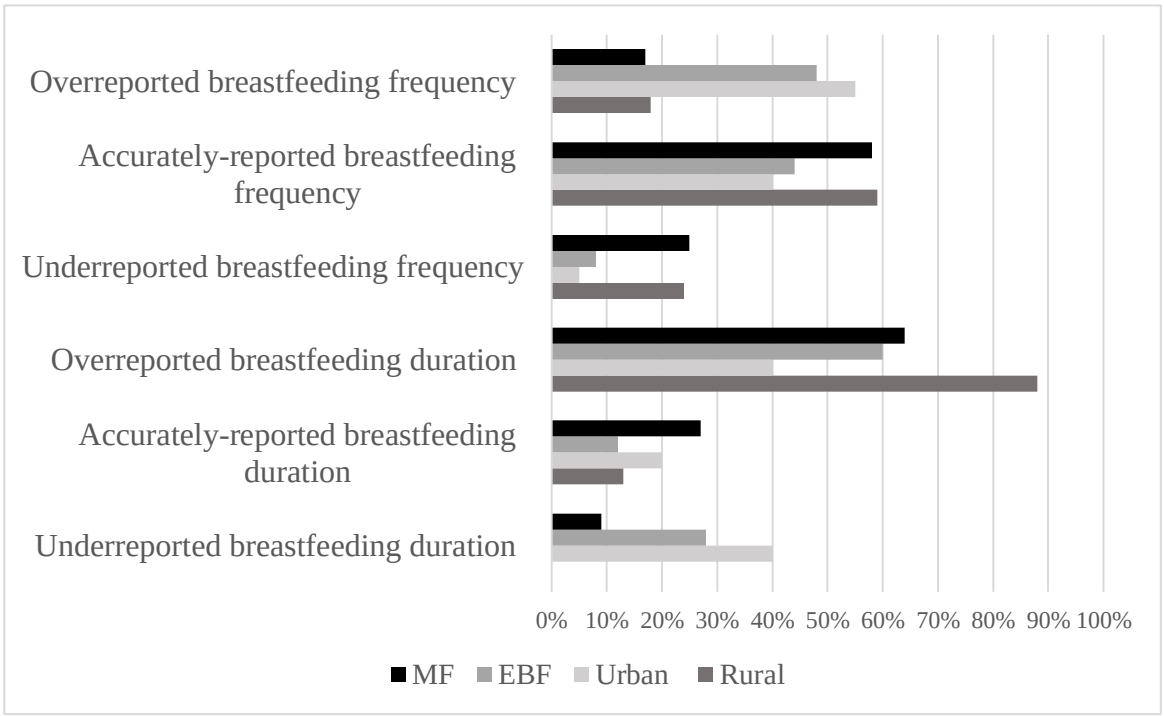


Figure 4. Accuracy of Maternal Report

3.3.3 Examining the relationship between caregiver-reported breastfeeding experiences and AIM-captured images

3.3.3a Caregiver-reported breastfeeding experiences

Caregiver-reported breastfeeding experiences were initially collected by asking mothers to share their thoughts on breastfeeding, then additionally assessed through yes/no questions (Figure 5). The majority of mothers were either neutral towards the experience or shared positive reflections. Less frequently, participants mentioned struggles or negative aspects of the breastfeeding experience. Urban mothers expressed negative breastfeeding reflections more frequently, whereas all reflections from rural participants were either positive or neutral. Mothers from urban communities were more likely to express frustrations involving the time commitment of breastfeeding and perceived insufficient milk production. Caregiver-reported breastfeeding experiences were categorized into the following common themes: "neutral, no issues" (n=12, 33%), "bond or feelings of happiness" (n=14, 39%), perceived health or financial benefits (n=5, 14%), "complained/expressed struggles." (n=5, 14%). Below are excerpts from mothers' reflections:

"It's a normal experience, nothing extraordinary"

"I feel a sense of bonding between my child and I when I breastfeed"

"I have cut down on other activities because I have to breastfeed"

Mothers from urban communities were more likely than rural to report difficulty related to infant feeding behavior, such as disinterest or struggling to swallow. Six (6) of the 13 yes/no questions involved these infant feeding habits, including distraction and feeding too often (appendix b). Among these infant-focused questions, "my baby nurses too often" was reported most frequently among all participants (Figure 5). 93% of mothers who over reported daily

breastfeeding frequency also felt their infant nursed too often. Further, 96% of exclusively breastfeeding mothers also reported their infants nursed too often. Mothers who were mixed feeding expressed less concern for these breastfeeding issues.

Physical breastfeeding issues including clogged milk ducts and struggles with milk flow were least commonly reported. Mothers who were exclusively breastfeeding at the time of data collection reported physical difficulties of the breast more frequently than those who were mixed feeding. Compared to urban mothers, rural participants experienced these issues more commonly. 6 of the 13 yes/no questions involved these physical difficulties of the breast. “I have clogged milk ducts” (n=1, 2.6%) and “my nipples are sore, cracked, or bleeding” (n=1, 2.6%) were reported by the lowest number of participants. Among all categories, the 3 most commonly reported breastfeeding struggles were “my breasts leak too much” (n=29, 76%), “my breasts are overfull/engorged” (n=28, 74%), and “my baby nurses too often” (n=32, 84%).

Urban participants were more vocal during the open-ended discussion in regards to breastfeeding struggles. 10 mothers, 9 residing in urban communities, also reported issues of breast milk production, while some described personal dietary habits and their impact on breastfeeding. Mothers reported that overeating, or eating certain foods, led to breast engorgement and/or leakage. Foods that reportedly led to breastfeeding issues include Kenkey (maize-based food usually consumed accompanied with fish or stew), teas, soups, and milk-containing foods.

“*I struggle to produce enough milk hence it is not sufficient. That is why I give NAN 1.”*

“Lack of sleep due to the insufficient milk production.”

“Because I take a lot of tea and soup, it makes my breast overfull and leak.”

“When I take a lot of mashed Kenkey, it makes my breast overfill.”

Mothers practicing mixed feeding were far less confident in the sufficiency of their milk production. In fact, most of these mothers attributed mixed feeding with cereals to lack of sufficient milk. Only 1 mother practicing mixed feeding answered "yes" to sufficient milk production, compared to 22 mothers practicing exclusive breastfeeding. Rural participants reported this issue 26% more frequently than urban participants; however, mention of supplemental cereals/formula (NAN 1) was only reported by urban mothers. NAN 1, a milk-based formula powder by Nestle, was most frequently mentioned. 15 out of 38 (40%) total participants reported that their milk production seemed insufficient, attributed to a number of reasons: infant crying (n=5, 33%), infant sleep patterns (n=2, 13%), physical difficulties (n=3, 23%), supplemental feeding (n=4, 27%), other (n=1, 7%). Infant crying was the most commonly reported explanation for perceived insufficient milk.

"Baby still cries after feeding."

"My baby cries until I give him some cereals (NAN 1)."

"She will cry until I give her NAN 1."

Aside from the aforementioned issues, 36 out of the 38 participants reported some successes experienced during breastfeeding. Infant's weight was a common trend seen among both rural and urban participants. One mother attributed the weight gain of her preterm baby solely to breast milk. Reports of infant health benefits were far more common than maternal health benefits; however, three mothers reported personal successes related to health and weight maintenance. The reported successes were categorized into the following common themes: financial outcomes (n=2, 6%), infant health outcomes (n=22, 61%), weight outcomes (n=14, 39%), maternal health outcomes (n=3, 8%) (Figure 8). Rural participants were more likely to report the financial benefits of breastfeeding, especially saving money on formulas.

"Not buying infant formula has saved me a lot of money."

"My baby is healthy which I believe is a result of the breastfeeding."

"My baby is growing fast and I'm happy about it."

"We've both been healthy."

Mothers shared a range of attitudes regarding their breastfeeding experiences; however, the majority were positive. Nearly every participant wished to acknowledge some sort of success experienced throughout breastfeeding. Mothers supplementing their breast milk with other foods seemed to do so because of perceived insufficient milk production. In general, mothers practicing mixed feeding shared more breastfeeding struggles than those exclusively breastfeeding. Mothers residing in urban areas were more elaborative on negative breastfeeding experiences, whether they involved infant feeding habits or physical difficulties of the breast. Generally, mothers seemed to enjoy breastfeeding and recognize a range of beneficial outcomes.

3.3.3b Comparing caregiver-reported experiences with AIM-captured images

Feeding cues, which were either maternal-reported or observed in AIM images, were coded and categorized using key words. The cues were grouped based on whether they occurred before, during, or at the end of the feeding session and included the following categories: expression of hunger, expression of readiness to breastfeed, enjoyment/satisfaction cues, dissatisfaction/disinterest cues, and expression of fullness/satiation. Feeding cues occurring throughout the middle to end of feeding sessions are displayed collectively as "during BF session" (Figure 7). Mothers reported a diverse range of feeding cues, involving the infants' head, hands, sounds, and facial expressions. Some maternal-reported feeding cues, such as infant sounds, could not be detected from the AIM digital images. Further, several participants

expressed that they did not closely observe cues during certain time points, which we indicated as “nothing observed” (Figure 7).

Maternal-reported cues for infant expression of hunger and dissatisfaction/disinterest showed the least discrepancy with observations from the AIM images (Figure 7). Specific cues with the highest agreement between maternal report and observation from the AIM images included signaling readiness to feed by turning the head, nipple rejection suggesting dissatisfaction, and smiling to express satiation. Infant head turning to signal breastfeeding readiness was slightly over reported by mothers compared to the AIM images. Nipple rejection by the infant to signal dissatisfaction was reported more frequently by mothers than by observation from the AIM images. Infant smiling as an expression of satiation was reported slightly more frequently by mothers than by observation from the AIM images. Cues with the lowest agreement or highest discrepancy between maternal report and observation from the AIM images included sleep as a signal of fullness, reported by 39% less mothers, and head turning to display disinterest, reported by 38% less mothers compared to the AIM images.

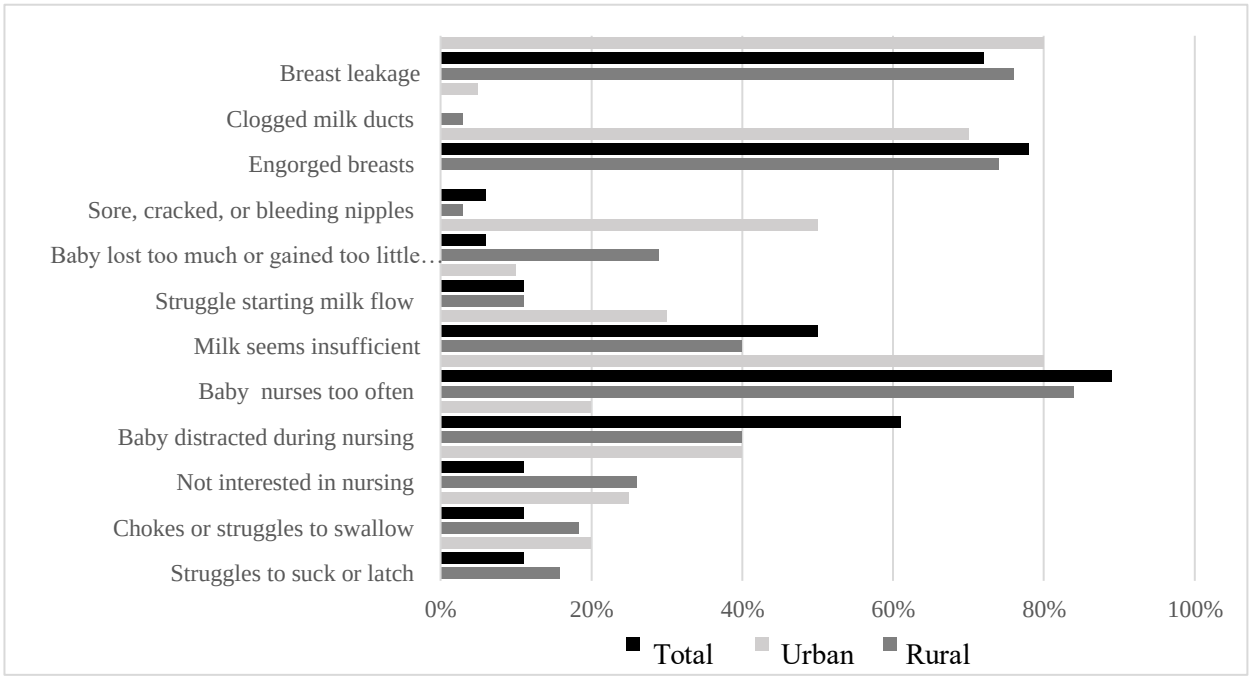
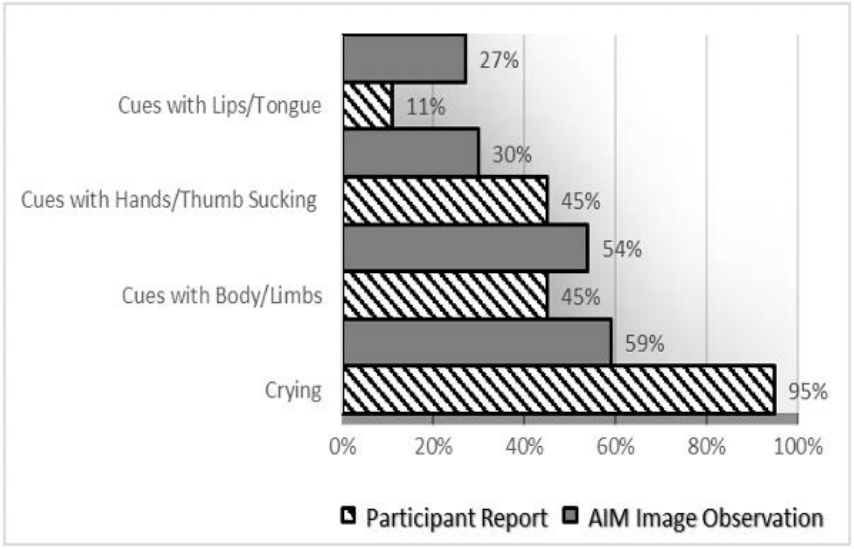


Figure 5. Maternal-Reported Breastfeeding Struggles (yes/no)

a.



b.

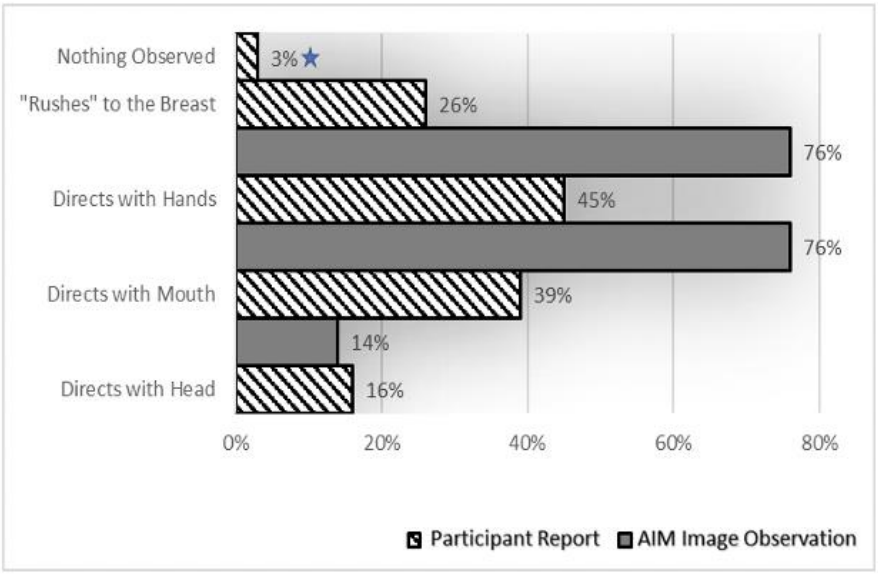


Figure 6. Maternal-reported vs. Researcher-observed infant feeding cues: Before BF Session

a. Expression of hunger
b. Expression of readiness to feed
★ *Cue undetectable with AIM device*

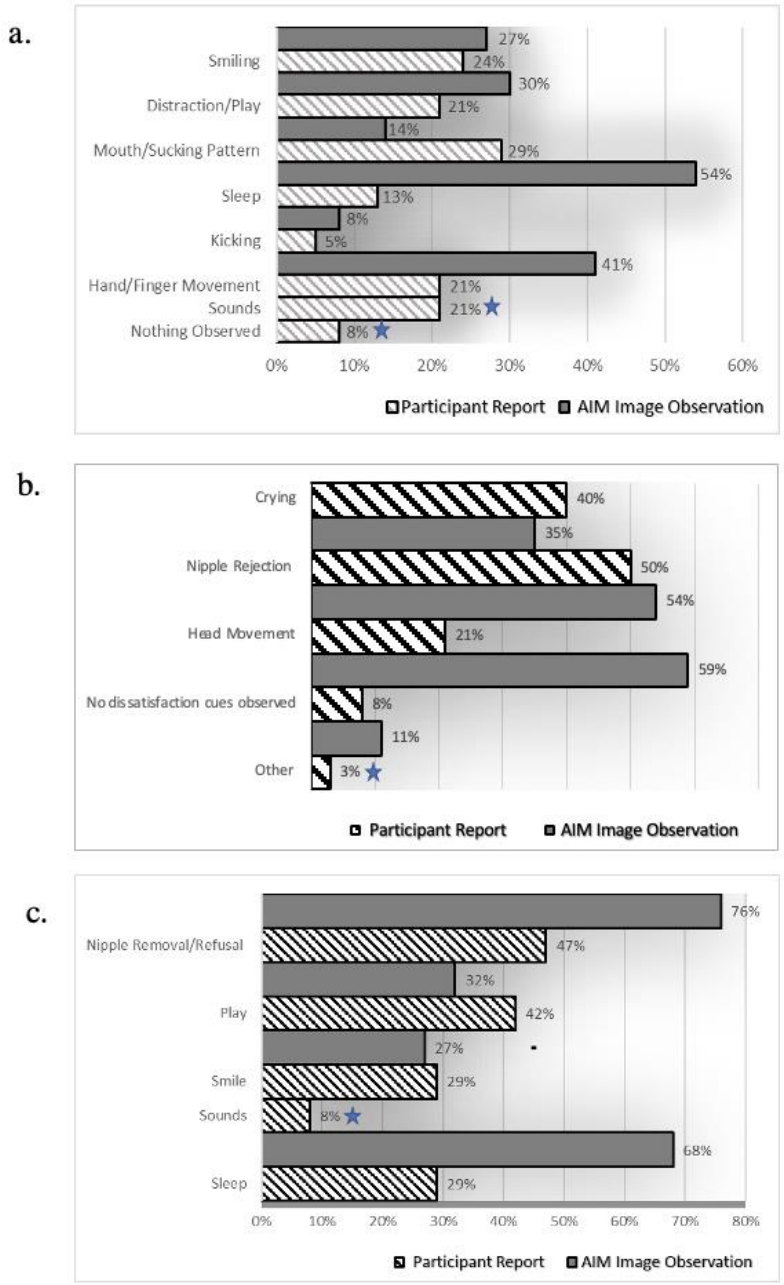


Figure 7. Maternal-reported vs. Researcher-observed infant cues: During BF session

a. Expression of enjoyment/satisfaction
b. Expression of dissatisfaction/disinterest
c. Expression of fullness/satiation
★ *Cue undetectable with AIM device*

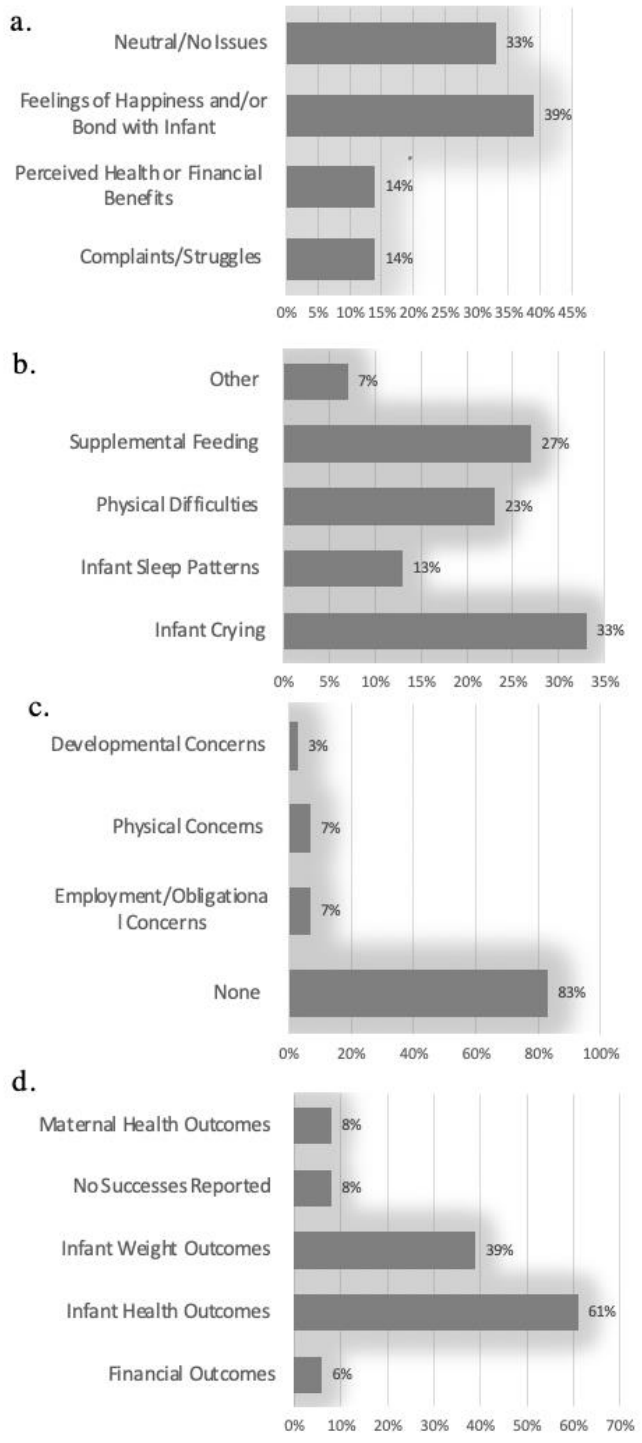


Figure 8. Maternal-Reported Breastfeeding Experiences

a. Describe your overall breastfeeding experience thus far
b. Why do you feel that your milk production is insufficient?
c. Do you have any other concerns related to breastfeeding, motherhood, etc.?
d. What successes have you experienced during breastfeeding so far?

3.4 DISCUSSION

This is the first study to use the AIM passive dietary assessment device to assess infant feeding practices among a sample of rural and urban mothers in Ghana. Through both subjective and objective forms of data, we assessed breastfeeding patterns, successes, and challenges of mothers living in Ghanaian rural and urban communities. Using participant compliance to determine the AIM device's feasibility, we found that the device was highly accepted among both urban (86%) and rural (78%) participants. In addition to device feasibility, we sought to examine the relationship between caregiver-reported infant feeding patterns and breastfeeding experiences with the images captured by the wearable device. As expected, we observed a high degree of discrepancies between maternal report and images objectively captured by the AIM device. Our qualitative data, collected in the form of maternal report, suggested interesting differences between the urban versus rural infant feeding practices of Ghanaian mothers. The digital images allowed for a side-by-side analysis with the participants' shared reflections. Although mothers shared a range of attitudes regarding their breastfeeding experiences, nearly every participant acknowledged some success experienced throughout breastfeeding.

It has been suggested that perceived infant dissatisfaction with breast milk ranks near the top of breastfeeding barriers in developing countries and beyond. [15] Mothers often desire to supplement breastmilk due to their perception that it is nutritionally inadequate or unsatiating for the infant. [17] Interestingly, this was one of the top maternal-reported breastfeeding struggles among our study participants. 15 out of 38 (40%) participants reported that their milk production seemed insufficient for the infant's needs. Further, only 1 mother practicing mixed feeding answered "yes" to sufficient milk production, compared to 22 mothers practicing exclusive breastfeeding. Infant crying was the most frequently reported reason as to why mothers felt their

milk production was insufficient. Despite the cultural and demographic differences among the current study population with many existing publications, this particular breastfeeding challenge is consistent.

Our participants' low self-efficacy surrounding sufficient milk production paralleled mothers from other cultures, socioeconomic statuses, and age groups. [18] [48] Early cessation of breastfeeding within the first 8 months postpartum has been highly associated with perceived infant dissatisfaction with breast milk and low milk supply. In addition to mothers feeling their infant nursed too often, insufficient milk production was a top reported challenge among our participants. Because all of our participants were still breastfeeding at the time of data collection, we could not draw associations between sociodemographic characteristics and breastfeeding cessation; however, younger, poorer, unmarried mothers have been associated with earlier breastfeeding cessation. [18] We observed that mothers with higher household income and longer duration of schooling were more likely to exclusively breastfeed, which may suggest later breastfeeding cessation.

Alternatively, other studies have reported mothers' desire to feed their infants homegrown/prepared food as a reason for early mixed feeding. [17] Although some of the mothers worked in food production/farming, this was not reported as a reason for early introduction of complementary foods or mixed feeding among our study participants. Reasons for mixed feeding in the current study were centered around perceived insufficient milk production and the infant appearing unsatisfied, typically signaled through crying after breastfeeding or refusing to sleep.

Lack of family and/or social support is a well-documented breastfeeding barrier to women globally. [40] Interestingly, our participants did not report this common barrier as a

challenge among our study participants. This is perhaps due to the level of social acceptance of breastfeeding in the study communities and Ghana in general. As was routinely observed in the AIM images, mothers openly breastfed in public settings, during mealtimes, and among family members without covering up as is the case in the United States and other developed countries. An interesting observation from the images was mothers gathering to breastfeed their infants in a social manner, particularly in the rural communities.

Physical challenges involving the breast morphology or condition have widely been explored in previous breastfeeding studies; however, this category of challenges was less common among our participants. [51] Neither rural nor urban participants seemed burdened by physical difficulties that accompany breastfeeding. Milk leakage, however, was repeatedly mentioned in the open-ended discussion. Many mothers attributed this issue to certain dietary habits, such as Kenkey (a maize-based food usually accompanied by stew, soup or fried fish) consumption. Another unique report noted in our open-ended responses was liquid-based foods such as soups causing breasts to overfill. Participants appeared highly observant of their dietary choices and how these may impact breastfeeding success. The perceived relationship between maternal dietary habits and milk production could not be examined in the current study due to its cross-sectional design.

To our knowledge, this is the first study to evaluate a passive, image-capturing monitor for infant feeding assessment; however, wearable cameras have been utilized previously among adults and children. [74] [23] Studies that have used wearable cameras focused on food and energy intake or portion sizes. In contrast, our study focused on observing infant feeding habits of mothers with young infants. [62] Because this is a feasibility study performing observation with a novel device, some limitations involving the AIM device's functions were to be expected.

The AIM device captures images in 15-seconds intervals, leaving brief gaps in the data collections process. The AIM device solely provides visual data in 15-second increments, thus cues could be misinterpreted without sounds and live observation. At the present time, AIM device images are currently annotated manually using observation, which is time-consuming and has been noted as a shortcoming in previous wearable device studies. [23]

The current study utilized maternal report of infant feeding practices together with digital images captured on the wearable device to yield a holistic representation of infant feeding habits in rural and urban settings in Ghana. This approach has been suggested as more insightful than each of these methods alone. By combining two data collection methods, potential gaps or inaccuracies in memory- based report can be revealed in the digital images, allowing for a higher level of accuracy and reduction of errors. Our findings show that the accuracy of maternal report for daily breastfeeding frequency was merely 55.6% among rural participants and 44.4% among urban participants compared with the frequency observed on the captured images. Notably, accuracy for maternal reported breastfeeding duration was less than 30% for all participants, regardless of their geographic location. Over report of breastfeeding duration was higher in the rural (63.6%) communities compared to 36.4% in the urban community, while all underreported duration was detected in the urban communities. One proposed explanation for mothers' over reported duration is preoccupation with other activities while breastfeeding. The AIM-captured images that reflected mothers breastfeeding while at work, supervising older siblings, and even preparing food. The inaccuracies maternal reports highlight the need for a superior means of infant feeding assessment to accurately examine the nutrition and health status of infants.

Studies that have used a wearable device for dietary intake assessment have been conducted among predominantly higher-income Caucasian participants. [23] Our study

addressed the lack of diversity among studies involving wearable devices by recruiting both rural and urban mothers in a LMIC like Ghana. Despite a number of feasibility issues that have been reported in previous wearable device studies, our participants showed high compliance with the AIM device. Total user compliance, or active time wearing the device during wake time, was 83%, suggesting our participants felt minimal burden wearing the device. Participants were instructed to remove the device during any activities where they preferred privacy, therefore some inactive time was expected. The challenging task of manually annotating images by researcher observation has been previously noted and was similarly experienced in our study. [23] The ability to automatically annotate images will go a long way to make wearable devices attractive for dietary and infant feeding assessment at the population level.

Although wearable cameras have not been used in infant feeding assessment until now, infant mealtimes have been assessed using video/film. [53] [68] [22] Both mixed feeding and breastfeeding have been observed using video in order to detect engagement and disengagement cues during the beginning, middle, and end of infant feeding sessions. The current study similarly split feeding sessions into 3 time periods of before, during, and after feeding for organizational purposes. Similar physical cues, including infant opening the mouth and reaching towards a caregiver, were observed in the current study as have been reported in previous publications. [53] One major difference between film and digital images is the detection of sounds, such as sucking, which may indicate enjoyment or hunger. We were not able to detect sounds in this study due to the use of digital images instead of video. Additionally, video recordings may capture the mother's behavior while feeding the infant, whereas participants were not visible in our images while wearing the AIM device. A researcher is often present and actively observes the feeding session in film studies; however, in the current study, participants

wore the AIM device while it passively took pictures throughout the day. The passive nature of capturing participants' surroundings every 15 seconds reduced bias in the assessment by either the participant or researcher.

Though infant behavior coding systems exist specifically for video coding, these could not be utilized to code the digital AIM images; however, many cues were adopted from these existing tools. For example, The Feeding Infants: Behavior and Facial Expression Coding System encompasses avoidance behaviors such as turning the head and acceptance behaviors such as gaping. [22] The current study observed these common feeding cues, but manually determined frequencies instead of utilizing a coding software or automatic annotation. It should also be noted that film studies typically only capture 1-2 feeding sessions to lessen the burden on participants. [68] [53] Our study collected robust wake time data that included an average of 9-11 total feeding sessions. Thus, a passive device worn for one day allows for a significantly more representative view of usual infant feeding patterns.

3.4.1 Strengths and Limitations

This study has several strengths worth discussing. Perhaps most notable, the mixed-methods approach of data collection provided us with a diverse data set that complemented each other. The high-quality AIM images provided context for the maternal self-report collected using the questionnaire. The questionnaire itself was developed based on validated questions from previous studies. [48] [18] The interviewer-administered style of our questionnaire set it apart from other, self-administered surveys and allowed for participants to ask questions and receive clarification when needed. The comparison between two data forms allowed for a more holistic and objective assessment of each participants' breastfeeding experiences.

As previously mentioned, existing publications exploring the use of passive dietary assessment devices involve participants of higher-socioeconomic status in developed countries. [23] Inclusion of mothers from both urban and rural Ghanaian communities diversified the data set and allowed us to detect trends based on geographic location. Such geographic trends included urban mothers' higher tendency to express frustrations related to breastfeeding and rural mothers' greater likelihood to mention financial benefits of breastfeeding.

Certain limitations of the current study should be noted as well. The cross-sectional design and small sample-size of this study limits the generalizability of our findings, although participants came from both rural and urban communities in Ghana. There is always a possibility of bias when collecting maternal-reported dietary recall. As reported in previous studies, mothers tend to over report daily intake of their children, while underreporting their own intake. [57] [66] Our study found that most mothers reported a higher daily breastfeeding frequency and duration than what was observed in the captured AIM images, which supports existing knowledge. Whether maternal bias is rooted in social desirability or additional reasons, it is impossible to ascertain full accuracy of maternal-reported infant feeding habits.

Although the AIM device proved to be feasible for infant feeding observation, it lacks the ability to directly measure intake. For this reason, particular maternal-reported struggles such as infant dissatisfaction with breastmilk and insufficient milk production could not be confirmed using the AIM device.

3.5 CONCLUSION

The consistency in maternal-reported breastfeeding struggles among participants in this study and previous studies suggests that these experiences are often universal. Greater education is needed to address the root of these difficulties, so mothers are better equipped to overcome

them. Novel assessment devices such as AIM allow for a more individualized, comprehensive observation of breastfeeding experiences. Our findings suggest that the AIM device data far surpasses maternal report in terms of accuracy and level of detail. Healthcare professionals who work with new mothers could potentially use this insightful data to their advantage by further personalizing their lactation counselling to fit the needs of patients. In addition to healthcare professionals, this tool has the potential to improve research and overall assessment of infant feeding habits. The superior assessment achieved using this device can shape infant feeding recommendations and increase awareness of commonly-experience breastfeeding difficulties. This study examined AIM device as a feasible and objective alternative to the traditional methods for infant feeding assessment; however, future technological advances which may eliminate the time-consuming, manual image annotation will extend the applicability of the device on an even larger scale.

REFERENCES

1. World Health Organization, U. *Increasing commitment to breastfeeding through funding and improved policies and programmes: Global breastfeeding scorecard 2019*. Nutrition Publications 2019 cited 2020 19 October.
2. UNICEF, W. *Capture the Moment- Early Initiation of Breastfeeding: The best start for every newborn*. 2018 cited 2021 January 13.
3. *Breastfeeding Report Card* Breastfeeding 2020 September 17, 2020 cited 2021 January 2; Available from: https://www.cdc.gov/breastfeeding/data/reportcard.htm.
4. *Breastfeeding*. Nutrition; Available from: https://www.who.int/nutrition/topics/exclusive_breastfeeding/en/.
5. Centers for Disease Control and Prevention. *Breastfeeding: Why It Matters*. 2019 cited 2020 January 14; Available from: https://www.cdc.gov/breastfeeding/about-breastfeeding/why-it-matters.html.
6. *About the Collective*. Global Breastfeeding Collective cited 2021 January 3rd; Available from: https://www.globalbreastfeedingcollective.org/about-collective.
7. *Nutrition and Healthy Eating Objectives* Infants 2020 cited 2021 January 2; Available from: https://health.gov/healthypeople/objectives-and-data/browse-objectives/nutrition-and-healthy-eating.
8. Isaacs, E.B., et al., *Impact of breast milk on intelligence quotient, brain size, and white matter development.* Pediatric research, 2010. **67**(4): p. 357-362.

9. Buvinger, E., et al., *Observed infant food cue responsivity: Associations with maternal report of infant eating behavior, breastfeeding, and infant weight gain.* Appetite, 2017. **112**: p. 219-226.

10. *Breastfeeding Report Card*. Centers for Disease Control and Prevention 2018 August 20, 2018 cited 2020 January 5; Available from: https://www.cdc.gov/breastfeeding/data/reportcard.htm.

11. Gross, R.S., et al., *Maternal Perceptions of Infant Hunger, Satiety, and Pressuring Feeding Styles in an Urban Latina WIC Population*. 2010, ELSEVIER SCIENCE B.V. AMSTERDAM: United States. p. 29.

12. Harder, T., et al., *Duration of breastfeeding and risk of overweight: a meta-analysis.* Am J Epidemiol, 2005. **162**(5): p. 397-403.

13. Karlsson, J.O., et al., *The carbon footprint of breastmilk substitutes in comparison with breastfeeding.* Journal of Cleaner Production, 2019. **222**: p. 436-445.

14. Victora, C.G., et al., *Breastfeeding in the 21st century: epidemiology, mechanisms, and lifelong effect.* The Lancet, 2016. **387**(10017): p. 475-490.

15. Kavle, J.A., et al., *Addressing barriers to exclusive breast-feeding in low- and middle-income countries: a systematic review and programmatic implications.* Public Health Nutrition, 2017. **20**(17): p. 3120-3134.

16. Tuthill, E.L., et al., *HIV infection, hunger, breastfeeding self-efficacy, and depressive symptoms are associated with exclusive breastfeeding to six months among women in western Kenya: a longitudinal observational study.* International Breastfeeding Journal, 2020. **15**(1): p. 1-9.

17. Kakute, P.N., et al., *Cultural Barriers to Exclusive Breastfeeding by Mothers in a Rural Area of Cameroon, Africa.* Journal of Midwifery & Women's Health, 2005. **50**(4): p. 324-328.

18. Li, R., et al., *Why mothers stop breastfeeding: mothers' self-reported reasons for stopping during the first year.* Pediatrics, 2008. **122 Suppl 2**: p. S69-76.

19. Ventura, A.K., S. Sheeper, and J. Levy, *Exploring Correlates of Infant Clarity of Cues During Early Feeding Interactions.* Journal of the Academy of Nutrition & Dietetics, 2019. **119**(9): p. 1452-1461.

20. Archer, E., M.L. Marlow, and C.J. Lavie, *Controversy and debate: Memory-Based Methods Paper 1: the fatal flaws of food frequency questionnaires and other memory-based dietary assessment methods.* Journal of Clinical Epidemiology, 2018. **104**: p. 113-124.

21. van Zyl, Z., et al., *The accuracy of dietary recall of infant feeding and food allergen data.* Journal of Human Nutrition and Dietetics, 2016. **29**(6): p. 777-785.

22. Hetherington, M.M., *Understanding infant eating behaviour – Lessons learned from observation.* Physiology & Behavior, 2017. **176**: p. 117-124.

23. Beltran, A., et al., *Dietary Assessment with a Wearable Camera among Children: Feasibility and Intercoder Reliability.* Journal of the Academy of Nutrition and Dietetics, 2018. **118**(11): p. 2144-2153.

24. Raber, M., et al., *Utility of eButton images for identifying food preparation behaviors and meal-related tasks in adolescents.* Nutrition journal, 2018. **17**(1): p. 32-32.

25. *Breastfeeding and the Use of Human Milk.* Pediatrics, 2012. **129**(3): p. e827.

26. Chowdhury, R., et al., *Breastfeeding and maternal health outcomes: a systematic review and meta-analysis.* Acta paediatrica (Oslo, Norway : 1992), 2015. **104**(467): p. 96-113.

27. Ip, S., et al., *Breastfeeding and maternal and infant health outcomes in developed countries.* Evid Rep Technol Assess (Full Rep), 2007(153): p. 1-186.

28. Barclay, A.R., et al., *Systematic Review: The Role of Breastfeeding in the Development of Pediatric Inflammatory Bowel Disease.* The Journal of Pediatrics, 2009. **155**(3): p. 421-426.

29. UNICEF. *Breastfeeding, A Mother's Gift, for Every Child*. 2018 cited 2020 January 3; Available from: https://www.unicef.org/publications/files/UNICEF_Breastfeeding_A_Mothers_Gift_for_Every_Child.pdf.

30. Khan, J., et al., *Timing of Breastfeeding Initiation and Exclusivity of Breastfeeding During the First Month of Life: Effects on Neonatal Mortality and Morbidity-A Systematic Review and Meta-analysis.* Maternal & Child Health Journal, 2015. **19**(3): p. 468.

31. *Early initiation of breastfeeding to promote exclusive breastfeeding*. e-Library of Evidence for Nutrition Actions 2019 February 11, 2019 cited 2021 January 23; Available from: https://www.who.int/elena/titles/early_breastfeeding/en/.

32. Ho, N.T., et al., *Meta-analysis of effects of exclusive breastfeeding on infant gut microbiota across populations.* Nature communications, 2018. **9**(1): p. 4169-4169.

33. Herba, C.M., et al., *Breastfeeding and early brain development: the Generation R study.* Maternal & Child Nutrition, 2013. **9**(3): p. 332-349.

34. Harder, T., et al., *Duration of Breastfeeding and Risk of Overweight: A Meta-Analysis.* American Journal of Epidemiology, 2005. **162**(5): p. 397-403.

35. Bode, L., *Human milk oligosaccharides: Every baby needs a sugar mama.* Glycobiology, 2012. **22**(9): p. 1147-1162.

36. Wang, M., et al., *Fecal Microbiota Composition of Breast-Fed Infants Is Correlated With Human Milk Oligosaccharides Consumed.* Journal of Pediatric Gastroenterology and Nutrition, 2015. **60**(6).

37. Trend, S., et al., *Antimicrobial Protein and Peptide Concentrations and Activity in Human Breast Milk Consumed by Preterm Infants at Risk of Late-Onset Neonatal Sepsis.* PLOS ONE, 2015. **10**(2): p. e0117038.

38. Saher, G., et al., *High cholesterol level is essential for myelin membrane growth.* Nature Neuroscience, 2005. **8**(4): p. 468-475.

39. Yan, J., et al., *The association between breastfeeding and childhood obesity: a meta-analysis.* BMC Public Health, 2014. **14**: p. 1267.

40. Arenz, S., et al., *Breast-feeding and childhood obesity—a systematic review.* International Journal of Obesity, 2004. **28**(10): p. 1247-1256.

41. Li, R., S.B. Fein, and L.M. Grummer-Strawn, *Association of Breastfeeding Intensity and Bottle-Emptying Behaviors at Early Infancy With Infants' Risk for Excess Weight at Late Infancy.* Pediatrics, 2008. **122**(Supplement 2): p. S77.

42. Li, R., S.B. Fein, and L.M. Grummer-Strawn, *Association of Breastfeeding Intensity and Bottle-Emptying Behaviors at Early Infancy With Infants' Risk for Excess Weight at Late Infancy.* Pediatrics, 2008. **122**(Supplement 2): p. S77.

43. Nations, U. *Sustainable Development Goals Report*. 2019 cited 2020 January 9, 2020; Available from: https://www.un.org/sustainabledevelopment/progress-report/.

44. Jones, G., et al., *How many child deaths can we prevent this year?* The Lancet, 2003. **362**(9377): p. 65-71.

45. Sankar, M.J., et al., *Optimal breastfeeding practices and infant and child mortality: a systematic review and meta-analysis.* Acta Paediatr, 2015. **104**(467): p. 3-13.

46. Santacruz-Salas, E., et al., *The Economic Influence of Breastfeeding on the Health Cost of Newborns.* Journal of Human Lactation, 2018. **35**(2): p. 340-348.

47. Issaka, A.I., K.E. Agho, and A.M. Renzaho, *Prevalence of key breastfeeding indicators in 29 sub-Saharan African countries: a meta-analysis of demographic and health surveys (2010-2015).* BMJ open, 2017. **7**(10): p. e014145-e014145.

48. Feenstra, M.M., et al., *Early breastfeeding problems: A mixed method study of mothers' experiences.* Sexual & Reproductive Healthcare, 2018. **16**: p. 167-174.

49. Scharfe, E., *Maternal Attachment Representations and Initiation and Duration of Breastfeeding.* Journal of Human Lactation, 2012. **28**(2): p. 218-225.

50. Husain, N., F. Creed, and B. Tomenson, *Depression and social stress in Pakistan.* Psychological Medicine, 2000. **30**(2): p. 395-402.

51. Alessandra, N.B., et al., *Qualitative Studies of Infant and Young Child Feeding in Lower-Income Countries: A Systematic Review and Synthesis of Dietary Patterns.* Nutrients, 2017. **9**(10): p. 1140-1140.

52. Forcada-Guex, M., et al., *Early dyadic patterns of mother-infant interactions and outcomes of prematurity at 18 months*. 2006. p. E107-E114.

53. Shloim, N., et al., *Looking for cues – infant communication of hunger and satiation during milk feeding.* Appetite, 2017. **108**: p. 74-82.

54. Forestell, C.A. and J.A. Mennella, *The Relationship between Infant Facial Expressions and Food Acceptance.* Current nutrition reports, 2017. **6**(2): p. 141-147.

55. Streppel, M.T., et al., *Nutrient-rich foods, cardiovascular diseases and all-cause mortality: the Rotterdam study.* Eur J Clin Nutr, 2014. **68**(6): p. 741-7.

56. Shim, J.-S., K. Oh, and H.C. Kim, *Dietary assessment methods in epidemiologic studies.* Epidemiology and health, 2014. **36**: p. e2014009-e2014009.

57. Macdiarmid, J. and J. Blundell, *Assessing dietary intake: Who, what and why of under-reporting.* Nutrition Research Reviews, 1998. **11**(2): p. 231-253.

58. de Vries, J.H., et al., *Underestimation of energy intake by 3-d records compared with energy intake to maintain body weight in 269 nonobese adults.* The American Journal of Clinical Nutrition, 1994. **60**(6): p. 855-860.

59. Schatzkin, A., et al., *A comparison of a food frequency questionnaire with a 24-hour recall for use in an epidemiological cohort study: results from the biomarker-based Observing Protein and Energy Nutrition (OPEN) study.* International Journal of Epidemiology, 2003. **32**(6): p. 1054-1062.

60. Archer, E., G.A. Hand, and S.N. Blair, *Validity of U.S. Nutritional Surveillance: National Health and Nutrition Examination Survey Caloric Energy Intake Data, 1971–2010.* PLOS ONE, 2013. **8**(10): p. e76632.

61. Thomas, K.W., et al., *Testing duplicate diet sample collection methods for measuring personal dietary exposures to chemical contaminants.* J Expo Anal Environ Epidemiol, 1997. **7**(1): p. 17-36.

62. O'Loughlin, G., et al., *Using a Wearable Camera to Increase the Accuracy of Dietary Analysis.* American Journal of Preventive Medicine, 2013. **44**(3): p. 297-301.

63. Comulada, W.S., et al., *Adherence to self-monitoring healthy lifestyle behaviours through mobile phone-based ecological momentary assessments and photographic food records over 6 months in mostly ethnic minority mothers.* Public Health Nutrition, 2018. **21**(4): p. 679-688.

64. Sazonov, E.S. and J.M. Fontana, *A Sensor System for Automatic Detection of Food Intake Through Non-Invasive Monitoring of Chewing.* IEEE sensors journal, 2012. **12**(5): p. 1340-1348.

65. Sazonov, E.S., et al., *Toward objective monitoring of ingestive behavior in free-living population.* Obesity (Silver Spring), 2009. **17**(10): p. 1971-5.

66. Fisher, J.O., et al., *Overestimation of infant and toddler energy intake by 24-h recall compared with weighed food records.* Am J Clin Nutr, 2008. **88**(2): p. 407-15.

67. McNally, J., et al., *The eyes have it: Infant gaze as an indicator of hunger and satiation.* Appetite, 2019. **133**: p. 353-361.

68. Nekitsing, C., et al., *Application and validation of the Feeding Infants: Behaviour and Facial Expression Coding System (FIBFECS) to assess liking and wanting in infants at the time of complementary feeding.* Food Quality and Preference, 2016. **48**: p. 228-237.

69. Scanlon, K.S., et al., *Assessment of infant feeding: the validity of measuring milk intake.* Nutr Rev, 2002. **60**(8): p. 235-51.

70. Savenije, O.E. and P.L. Brand, *Accuracy and precision of test weighing to assess milk intake in newborn infants.* Arch Dis Child Fetal Neonatal Ed, 2006. **91**(5): p. F330-2.

71. Jobarteh, M.L., et al., *Development and Validation of an Objective, Passive Dietary Assessment Method for Estimating Food and Nutrient Intake in Households in Low- and Middle-Income Countries: A Study Protocol.* Current Developments in Nutrition, 2020. **4**(2).

72. Gatti, L., *Maternal perceptions of insufficient milk supply in breastfeeding.* Journal of nursing scholarship : an official publication of Sigma Theta Tau International Honor Society of Nursing, 2008. **40**(4): p. 355-363.

73. Neifert, M.R., *PREVENTION OF BREASTFEEDING TRAGEDIES.* Pediatric Clinics of North America, 2001. **48**(2): p. 273-297.

74. Anderson, A., et al., *A Case Study of Household Food-Related Assessment Using an Innovative Passive Dietary Assessment Device in Mampong-Akuapem, Ghana (FS17-03-19).* Current Developments in Nutrition, 2019. **3**(Supplement_1).

75. Llewellyn, C.H., et al., *Development and factor structure of the Baby Eating Behaviour Questionnaire in the Gemini birth cohort.* Appetite, 2011. **57**(2): p. 388-396.

CHAPTER 4

CONCLUSIONS AND IMPLICATIONS

This study supports the feasibility of the use of an Automatic Ingestion Monitor (AIM) for infant feeding assessment and provides important insight into the diverse breastfeeding practices and experiences of rural and urban Ghanaian mothers. While there was high discrepancy determined between AIM captured images and maternal self-report, the mothers' reflections served as a valuable piece of supplementary data. Further, the high discrepancy between the two forms of data (image captured versus self-report) highlighted the unreliability of infant feeding assessment based on memory reliance. The findings of this study suggest that a passive, wearable infant feeding assessment device may be superior to memory-based methods in terms of accuracy and level of detail. Over reported maternal recall was observed among participants from both rural and urban communities, which is likely due to social desirability bias.

This study provides implications as to how and why existing infant feeding assessment methods should be improved. Currently, studying a younger population such as infants requires caregiver self-report or observation by the researcher/investigator. Memory-based tools for infant feeding assessment such as maternal recalls place substantial responsibility on the caregiver to self-report accurately. Film-based tools such as video with behavioral coding typically require active presence of a researcher and eating in a laboratory setting away from home, which introduce their own errors and biases. Finally, test-weighing is rarely precise enough to detect minor weight changes in infants after feeding sessions. Passive infant feeding assessment

methods, such as the AIM, showed a higher level of accuracy compared to maternal self-report and high user compliance from participating mothers. A transition from the use of memory-based tools to wearable, objective methods would be beneficial for assessing infant eating patterns and informing client recommendations in the future.

The qualitative data collected through maternal self-report provided useful insight that could not otherwise be obtained through the AIM device. Certain reflections involving the pleasures and struggles of breastfeeding allowed for interesting comparison between rural and urban mothers. Mothers residing in urban communities were generally more expressive of breastfeeding difficulties such as the time commitment of breastfeeding and perceived insufficient milk production. Rural participants acknowledged different breastfeeding benefits than urban mothers, such as financial savings. Generally, mothers who participated in the study enjoyed breastfeeding and acknowledged some benefits of the experience. Mothers seemed well aware that breastfeeding yielded health benefits for their infant; however, many initiated mixed feeding due to various difficulties encountered.

The objective data in the form of AIM-captured images was typically high quality and seamless to annotate. Besides a few photo sets which were blurry or difficult to discern, the AIM device proved to be an efficient and objective way to observe infant feeding without relying on maternal self-report for assessment. One major challenge of analyzing the AIM data was the volume of images captured per participant, due to the fact that images were captured in 15-second increments. This required assumption by the researcher regarding what was taking place between photos. Additionally, key feeding cues could be missed during the 15-second gap in image capture. Another major challenge was the time-consuming manual annotation process, which can hopefully be improved with some form of automatic annotation (via artificial

intelligence) in future wearable device studies. A coding software that detects infant feeding cues before, during, and after mealtimes would be an ideal addition to the current study. Further, a modification which may allow the AIM device to capture images more frequently than every 15 seconds will enhance the data analysis process. While the AIM data set was robust and included an average of 9-11 breastfeeding sessions per participant, a smaller time gap between photos would improve the annotation process even further.

Several mothers in this study noted current dietary habits and their potential impact on milk production. Future studies should expand the AIM observation to include the maternal diet in its relation to breastfeeding success. Moreover, mothers tended to report insufficient breast milk as their top struggle, which unfortunately could not be verified through AIM images. This suggests that future studies involving breastfeeding patterns should explore this issue using a wearable device or supplementary data collection methods. Further, mothers may have misconceptions about low milk supply due to the infant feeding frequently or for long durations. Efforts to diminish misconceptions and increase awareness surrounding true signs of low milk supply are warranted.

This study shows the user compliance of a novel feeding assessment device with extensive applicability. The widespread concern regarding low milk production warrants further maternal education and support. Mothers practicing mixed feeding expressed particularly low confidence for their milk production. Increasing maternal self-efficacy towards milk production and infant satiation may improve exclusive breastfeeding duration. The detailed, holistic nature of the AIM device data could potentially be used to personalize the patient care experience for new mothers receiving lactation education. Encouragingly, mothers seemed familiar with the benefits of breastfeeding including infant weight gain, immunity, and bonding. Because this

study only involved 38 mothers and was cross-sectional in nature, a more comprehensive and longitudinal study with a larger sample of mother-infant dyads is needed to confirm the validity of using the AIM device to accurately assess infant feeding practices. The high discrepancies observed in infant feeding assessment between maternal self-report and AIM images suggest that a passive device may be superior methodology for assessing infant feeding patterns and mothers' struggles during breastfeeding. The superiority of the AIM device in terms of accuracy and detail could potentially be used to improve infant feeding assessment on both a research and clinical level.

APPENDIX A

IRB APPROVAL

UNIVERSITY OF GEORGIA

Tucker Hall, Room 212
310 E. Campus Rd.
Athens, Georgia 30602
TEL 706-542-3199 | FAX 706-542-5638
IRB@uga.edu
http://research.uga.edu/hso/irb/

Human Research Protection Program

APPROVAL

December 7, 2018

Dear Alex Anderson:

On 11/7/2018, the IRB reviewed the following submission:

Type of Review:	Initial Study
Title of Study:	An Innovative Passive Dietary Monitoring System
Investigator:	Alex Anderson
IRB ID:	STUDY00006121
Funding:	BILL & MELINDA GATES FNDTN
Grant ID:	FP00011087
Review Category:	Full Board- IRB 2

Determination and findings that require documentation: Waiver of Requirement to Document Informed Consent for screening, per 21 cfr 56.109(c)(1); the committee determined that the use of the AIM Passive Dietary Monitoring System in this protocol meets the criteria for a non-significant risk device per FDA regulations; the project does not meet the FDA definition of a clinical trial.

Materials Reviewed: Recruitment Material (Screening Questionnaire, Study Info Letter), Consent Forms (Minor Assent, Study 2 Phase 1, Study 2 Phase 2, Study 3), Data Collection Instruments (Socio-demographic Survey, Dietary Recall Form, Device Daily Log, Device Manual, Food Questionnaire, In Depth Key Informant Interview Questionnaire, Sensor Burden Assessment, Follow Up Questionnaire), online submission

The IRB approved the protocol from 12/7/2018 to 11/6/2019 inclusive. Before or within 30 days of study closure, whichever is earlier, you are to submit a continuing review with required explanations. You can submit a continuing review by navigating to the active study and clicking Create Modification / CR. If continuing review approval is not granted before the expiration date of 11/6/2019 approval of this study expires on that date.

If consent will be documented, use the consent documents that were approved and stamped by the IRB. Go to the Documents tab, Final column, to download them.

Please close this study when all human subject research activities and data analysis of identifiable information is complete.

In conducting this study, you are required to follow the requirements listed in the Investigator Manual (HRP-103).

Sincerely,
Gerald Crites, MD, MEd
University of Georgia
Institutional Review Board Chairperson

APPENDIX B

INTERVIEW-ADMINISTERED BREASTFEEDING QUESTIONNAIRE

Sociodemographic Factors

How old are you? _____ years.

Mother's duration of schooling [ ] none **[ ]** 6-9 years [ ] 10-12 years[ ] >12 years

What is you ethnicity/tribe? [ ] Akan [ ] Ga [ ] Dagomba [ ] Ewe [ ] Other: _____

Marital Status [ ] Married [ ] Cohabitating [ ] Living alone

Mother's occupation [ ] Employed full time [ ] Employed part time [ ] Unemployed [ ] Other: _____

If employed, please elaborate on occupational duties/daily activities _____

_____

Father's occupation [ ] Employed full time [ ] Employed part time [ ] Unemployed [ ] Other: _____

If employed, please elaborate on occupation duties/daily activities: _____

Parity [ ] Primiparous [ ] Multiparous **(**If so, how many children?) _____

Yearly household income

[ ] <5,000 GHS [ ] 5,000-10,000 GHS [ ] 10,000-15,000 GHS **[ ]** 15,000-20,000 GHS **[ ]** >20,000 GHS

How many people (family and others) live in your household? _____

Rate your confidence for breastfeeding on a scale of 1-10 (10 being highest).

1 2 3 4 5 6 7 8 9 10

Breastfeeding

How soon after delivery did you initiate breastfeeding with your infant? _____

How are you currently feeding your infant?
[ ] Exclusive Breastfeeding [ ] Mixed-feeding (breast milk and other foods)

If exclusively breastfeeding, when do you intend to stop? _____

If mixed feeding, please elaborate on foods fed alongside breast milk and frequency of feeding.

_____

_____

Open-Ended

Describe your overall experience with breastfeeding thus far._____

_____

_____

_____

How frequently have you been breastfeeding your baby on average each day?_____

_____

On average, how long does each breastfeeding session last? _____

_____

Has your milk production been sufficient to meet your baby's needs? [ ] Yes [ ] No

If no, how do you tell that the amount of milk produced is not enough? _____

_____

Do you have any other concerns related to breastfeeding, motherhood, etc.?

_____

_____

_____

Have you experienced any of the following problems breastfeeding your baby so far? (Please check yes or no)

My baby struggles to suck or latch …….yes □ no □
My baby chokes or struggles to swallow…….yes □ no □
My baby is not interested in nursing……yes □ no □
My baby is distracted during nursing……...yes □ no □
My baby wishes to nurse too often……...yes □ no □
My milk seems insufficient for my baby's needs……yes □ no □
I struggle to get my milk flow to start……. yes □ no □
My baby has lost too much or gained too little weight……yes □ no □
My nipples are sore, cracked, bleeding ……...yes □ no □
My breasts are overfull (engorged) …….yes □ no □
I have clogged milk ducts …….. yes □ no □
My breasts leaked too much……..... yes □ no □
I have experienced no problems…….. yes □ no □

Please elaborate on the issues you have listed above. If you have experienced an issue that has not been mentioned, please discuss it below. _____

_____

_____

What successes have you experienced during breastfeeding so far? _____

_____

_____

Physical Observations: Before feeding

From your observations, how does your baby express his/her hunger to breastfeed? (please include facial expressions, limb movements, vocal expressions, etc.)

_____

_____

_____

From your observations, how does your baby express his/her readiness to breastfeed? (please include facial expressions, limb movements, vocal expressions, etc.)

_____

_____

_____

Physical Observations: During feeding

From your observations, how does your baby express enjoyment/satisfaction during a breastfeeding session?

_____

_____

_____

How does your baby express dissatisfaction/disinterest during a breastfeeding session? (please include facial expressions, limb movements, vocal expressions, etc.)

_____

_____

_____

Physical Observations: Conclusion of feeding

From your observations, how does your baby express fullness/satiation during a breastfeeding session? (please include facial expressions, limb movements, vocal expressions, etc.)

_____

_____

_____

Anthropometric Factors: Mother

Pre-gestational weight _____

Gestational weight gain _____

Current weight _____

Current height _____

Infant's gestational age at delivery _____

Type of delivery_____

Anthropometric Factors: Infant

Birth weight _____

Infant's age (months) _____