Effects of breastfeeding duration on educational attainment of children and adolescents in sub-Saharan Africa: A multisite analysis of longitudinal data

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DECLARATION OF OWN WORK

I, Shamsudeen Mohammed, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

ABSTRACT

Breastfeeding provides essential nutrients for newborn growth and development and bioactive factors for protection against childhood illnesses. In addition, some studies have linked breastfeeding to improved educational outcomes. The evidence supporting the benefit of breastfeeding on educational outcomes is largely from high-income countries, where socioeconomic status is strongly correlated with breastfeeding behaviour. It has been hypothesised that the positive effect of breastfeeding observed in high-income countries is a manifestation of socioeconomic status advantage, not the biological effect of breastfeeding. Evidence from sub-Saharan Africa, where socioeconomic status is not a strong predictor of breastfeeding, could clarify this association, but studies from sub-Saharan Africa are scarce in this debate. In this thesis, I investigated whether the duration of breastfeeding in infancy is associated with educational attainment at school age in sub-Saharan Africa.

The thesis is centred on two themes. Theme one examined the socioeconomic pattern of breastfeeding in sub-Saharan Africa based on data from six repeated cross-sectional surveys in Ghana and six longitudinal cohorts in Ethiopia, Malawi, Uganda, and Zambia. Theme two, the primary research question, investigated the association between breastfeeding duration and educational outcomes in sub-Saharan Africa through a systematic review of the existing literature on the research question and analysis of longitudinal data from cohorts in Malawi and Uganda. Educational attainment was measured as age-for-grade based on a child's expected primary school grade at each age. Key potential confounders, including paternal and maternal socioeconomic status and HIV status, were adjusted for.

The meta-analysis of the six cohorts and the pooled analysis of the data from Ghana both showed no clear socioeconomic pattern in breastfeeding. The systematic review of the association between breastfeeding and educational outcomes revealed that only two studies had investigated the association in sub-Saharan Africa before this thesis. Both studies found no conclusive evidence to support an association between breastfeeding and educational outcomes. In the analysis of longitudinal data from Uganda, I found no evidence of an association between duration of any breastfeeding and educational attainment. However, in Malawi, I found that exclusive breastfeeding for six months reduced the odds of being over-age for grade in primary school and falling behind in early school grades compared to exclusive breastfeeding for less than three months. Meta-analysis combining estimates from Malawi and those from a previous study conducted in South Africa that was identified through the systematic review also showed that exclusive breastfeeding for six months reduced the odds of repeating a grade compared to exclusive breastfeeding for less than two months.

These findings indicate that exclusive breastfeeding for two to six months may improve educational attainment, but further sub-Saharan Africa studies are needed to provide a broader understanding of the association, as the evidence is still limited. Additionally, the findings suggest that the improved educational outcomes observed among exclusively breastfed children in high-income countries may not be entirely attributable to socioeconomic confounding.

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I would also like to thank my advisors, Clara Calvert, Emily Webb, and Suzanne Filteau, for their patience and guidance throughout this journey. Their critical contributions to my initial funding proposal and consistent, insightful feedback on my research papers are deeply appreciated. I would particularly like to thank Clara for her commitment to finding time for me whenever I needed her input. Her dedication to providing timely and thoughtful advice was invaluable throughout this PhD. Emily’s expert advice on statistical decisions and analytical strategies was instrumental in refining the analysis approaches employed in this thesis.

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CHAPTER 1

Introduction

CHAPTER 1: INTRODUCTION

1.1 Background

Human breastmilk (HBM) is a complex biological fluid rich in both micronutrients and macronutrients (such as fat, protein, carbohydrates, minerals, and vitamins), as well as bioactive substances (1,2). Unlike formula, breastmilk continuously adapts its nutritive and non-nutritive components to meet the changing needs of the infant in terms of nutrition, growth and development and also to support the infant's immune function (2–4). It is, therefore, not surprising that several studies have linked optimal breastfeeding to improved child survival and health (5–8).

A systematic review and meta-analysis of observational studies and three randomised controlled trials on the short-term benefits of breastfeeding in low-, middle-, and high-income countries found that among children under five years, breastfeeding was associated with a 31% reduced risk of diarrhoea incidence and a 57% reduced risk of hospitalisation for respiratory tract infections (9). Additionally, a meta-analysis of 13 studies, including six studies from Africa, found that infants not breastfed had an eight times higher risk of dying from infectious diseases and a 14 times higher risk of all-cause mortality than those exclusively breastfed (7). Breastfeeding has also been linked with a reduced risk of non-infectious diseases, including diabetes mellitus, obesity, and hypertension (5,8). The World Health Organization and the United Nations Children's Fund encourage women to initiate breastfeeding within the first hour of birth and feed the infant only breastmilk in the first six months after birth (10,11). It is recommended that other foods and liquids be introduced only after the first six months, and breastfeeding should continue until the child's second birthday or longer.

In addition to reducing the risk of illness and death in children, studies, mostly from high-income countries, have suggested a link between breastfeeding and improved cognitive development and educational attainment. Figure 1.1 illustrates the proposed pathways for the association. Among 7855 children in the UK Millennium Cohort Study, Pereyra-Elías *et al.* (12) found that any breastfeeding was associated with higher cognitive test scores at ages 7, 11, and 14 years than not breastfeeding, even after adjusting for socioeconomic status and maternal intelligence. When the researchers investigated the effect of breastfeeding duration on educational outcomes among the children at age 16 years (13), they found that breastfeeding was associated with better educational achievements at the end of secondary education than never breastfeeding. Likewise, increased intelligence, academic achievement, memory, and motor skills at age seven were found in Australian preterm infants who were predominantly fed breastmilk in the first 28 days of life (14). In American children, Belfort et al., showed that every month of breastfeeding was associated with an increase of 0.21 points in vocabulary score at three years and an increase of 0.29 in IQ points at seven years (15). Furthermore, a meta-analysis of 17 studies, mostly from high-income countries, found a 3.4 points higher IQ score among breastfed children and adolescents (16).

While the evidence on the positive effects of breastfeeding for cognitive development and educational attainment is relatively consistent in high-income countries, it is less clear in low-and middle-income countries. In Brazil, Victora *et al.* found that children who were breastfed for 12 months or more had 0.91 more years of education than those who were breastfed for less than one month (17). Similarly, Nandi *et al.* reported 0.12 and 0.19 more years of education among children breastfed for >12 to 24 months and >24 months, respectively, compared to those breastfed for ≤12 months in India (18). However, when Horta et al., investigated the association in large birth cohorts from the Philippines, Guatemala, and India (19), they found no evidence of an association between breastfeeding and educational outcomes. Similarly, a study conducted in Turkey found no evidence of an association between breastfeeding duration and academic achievement among high school students (20). In a systematic review of 13 studies from low-income countries, only four demonstrated a positive association between breastfeeding and cognitive development (21).

In high-income countries, higher socioeconomic status and maternal education are strongly associated with optimal breastfeeding and educational attainment (5,22–24). Therefore, it has been hypothesised that the positive effects observed in studies conducted in high-income countries are likely the result of socioeconomic advantage or residual socioeconomic confounding rather than any biological effect of breastfeeding (21,25–28).

In sub-Saharan Africa, where there is some evidence that socioeconomic characteristics do not strongly predict breastfeeding behaviour (29), studies on the association between breastfeeding and educational attainment are scarce. For instance, a 2015 meta-analysis of 17 studies investigating the association between breastfeeding and intelligence did not identify any studies for inclusion from sub-Saharan Africa (30). In a 2019 systematic review on breastfed children's cognitive and educational outcomes, only one of the 73 studies identified was conducted in sub-Saharan Africa (31). As a result, the evidence for the association remains unclear in the region, and it would be naïve to generalise the findings from high-income countries to sub-Saharan Africa due to the variation in breastfeeding patterns, the influence of culture on infant feeding, and differences in childcare practices. The lack of evidence on the association from sub-Saharan Africa represents an important gap in our understanding of how breastfeeding may impact child cognitive and educational achievement across diverse contexts and populations.

Breastfeeding research in sub-Saharan Africa has predominantly focused on the health and survival benefits, with little attention given to the potential impact on educational outcomes. This study will broaden the scope of breastfeeding research in sub-Saharan Africa. Furthermore, understanding the link between breastfeeding practices and educational attainment is important for breastfeeding promotion and educational programs in sub-Saharan Africa, and knowledge of this link, if it exists, could motivate mothers to practice exclusive breastfeeding in the first six months after birth and continue to breastfeed for a longer duration. In addition, the findings of this study will advance our understanding of whether the observed association between breastfeeding and educational outcomes in high-income countries is attributable to residual socioeconomic confounding. This thesis, therefore, aimed to investigate the effects of breastfeeding duration (any breastfeeding and exclusive breastfeeding) on educational attainment among children in sub-Saharan Africa.

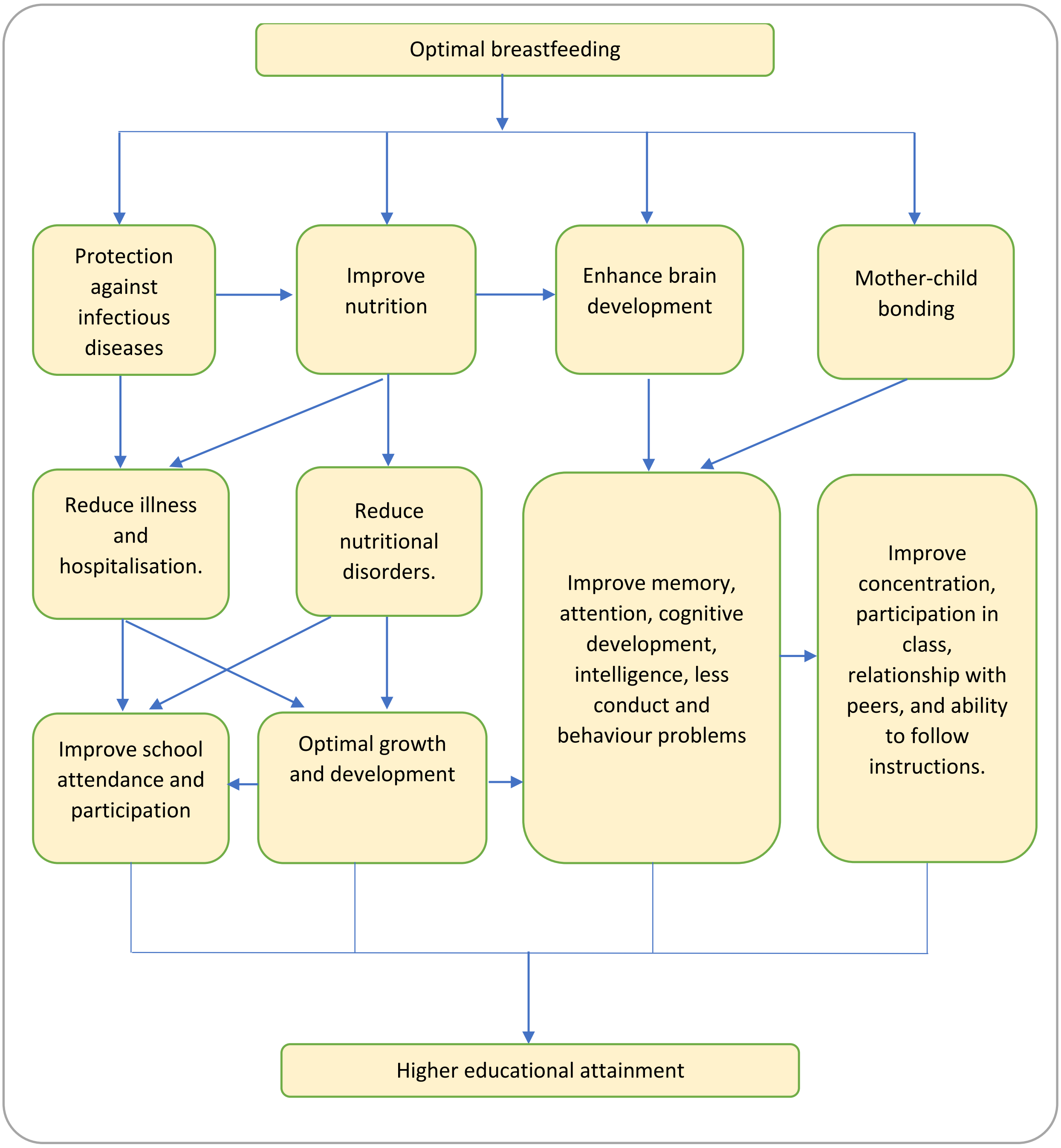

Figure 1.1 Conceptual framework illustrating the potential pathways for the association between breastfeeding and educational attainment as suggested by studies reporting better educational and cognitive outcomes among optimally breastfed children.

1.2 Aim and Objectives

The overall aim of this thesis was to assess whether longer breastfeeding duration during infancy is associated with educational attainment among children in sub-Saharan Africa.

The specific objectives of the thesis were:

1. To systematically review the current evidence on the association of breastfeeding with educational achievement and cognitive development in sub-Saharan Africa.
2. To determine the socioeconomic patterning of breastfeeding and assess factors associated with age-appropriate breastfeeding in sub-Saharan African countries.
    a. In a secondary analysis of data from nationally representative cross-sectional surveys from Ghana, 2003-2017
    b. In an individual participant data meta-analysis of six longitudinal cohorts in sub-Saharan Africa
3. To assess whether there is evidence for an association between breastfeeding duration and educational attainment in secondary analyses of existing longitudinal datasets from sub-Saharan Africa.

1.3 Thesis structure and overview

This thesis will be presented in a research paper format, incorporating published journal articles and manuscripts written in a journal format. The following provides an overview of the content of each chapter.

Chapter One (this chapter) presents a brief background to the study, exploring the benefits of breastfeeding for infant health and survival, cognitive development and educational outcomes, drawing upon prior research. It also highlights the rationale for the present study and the aim and objectives. In addition, an outline of the thesis structure is provided.

Chapter Two presents a systematic review published in the Journal of Global Health to address objective one (doi: 10.7189/jogh.12.04071). This review examines the association of breastfeeding with cognitive development and educational achievement in sub-Saharan Africa. It provides insights into the evidence on the topic prior to this PhD, the potential confounding factors, the role of the confounding factors in the association, and the analytical approaches used in earlier studies. The review also highlights the extent to which the association has been studied in sub-Saharan Africa.

Chapter Three discusses my search for longitudinal datasets in sub-Saharan Africa for this analysis and the eligibility criteria for selecting suitable data sources. I also recount the challenges and obstacles I encountered while pursuing the data sources and the suitability of acquired datasets for this thesis.

Chapter Four presents a research paper published in BMJ Open on time trends in the prevalence and determinants of age-appropriate breastfeeding among children under two years in Ghana (doi.org/10.1136/bmjopen-2021-059928). The study used pooled data from the 2003-2014 Ghana Demographic and Health Surveys (DHS) and the 2006-2017 Ghana Multiple Indicator

Cluster Surveys (MICS). The main aim was to understand how maternal and child sociodemographic characteristics, as well as obstetric and healthcare factors, influence appropriate breastfeeding from birth to age 23 months in Ghana. The findings presented in the chapter address objective 2a.

In **Chapter Five**, I present a manuscript in a journal format that focuses on the socioeconomic patterns of breastfeeding in six sub-Saharan African cohorts to address objective 2b. Given the importance of socioeconomic factors as confounders in the relationship between breastfeeding and educational attainment, the work presented in this chapter addresses whether there are socioeconomic disparities in the duration and patterns of breastfeeding in sub-Saharan Africa.

Chapter Six presents a research paper published in Scientific Reports on the effects of exclusive breastfeeding on educational attainment and longitudinal trajectories of grade progression among children in Malawi (doi.org/10.1038/s41598-023-38455-5). In this study, I examine the primary school progression of pupils in rural Malawi from ages six to thirteen, highlighting when pupils began to fall behind and the various trajectories of grade progression. I assessed whether exclusive breastfeeding duration in infancy was associated with age-for-grade attainment and trajectories of grade progression. This chapter is dedicated to addressing objective three.

In **Chapter Seven**, I present a manuscript in journal format on the association between breastfeeding and educational attainment in Uganda. I assess whether breastfeeding duration in infancy and early childhood was associated with age-for-grade attainment at school age using data from a population-based cohort study in rural Southwest Uganda. The findings presented in the chapter address objective three.

In **Chapter Eight**, I summarise the main findings and notable contributions of this thesis while acknowledging the limitations and strengths. I also provide recommendations and suggestions for future research.

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CHAPTER 2

Paper 1

The association of breastfeeding with cognitive development and educational achievement in sub-Saharan Africa: a systematic review

CHAPTER 2: PAPER 1 - THE ASSOCIATION OF BREASTFEEDING WITH COGNITIVE DEVELOPMENT AND EDUCATIONAL ACHIEVEMENT IN SUB-SAHARAN AFRICA: A SYSTEMATIC REVIEW

2.1 Introduction

To address the first objective of this thesis, this chapter systematically reviews and synthesises the empirical evidence on the association of breastfeeding with cognitive development and educational achievement in sub-Saharan Africa. The review provides a summary of the evidence on the association before this thesis, highlighting the extent to which the association has been investigated in sub-Saharan Africa. Additionally, it sheds light on the confounding factors that may influence the association in the region. I also assess the methodological quality and limitations of existing studies and suggest directions for future research. The main paper is provided in section 2.2, and supplementary materials for the paper are included in section 2.3.

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SECTION E

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Date	8th April 2024

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2.2 Published paper

Electronic supplementary material:
The online version of this article contains supplementary material.

journal of global health

PAPERS

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The association of breastfeeding with cognitive development and educational achievement in sub-Saharan Africa: A systematic review

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Background Systematic reviews and meta-analyses of studies mainly from high-income countries suggest that breastfeeding improves cognitive function and educational achievement. However, these associations may be a manifestation of who breastfeeds in these settings rather than an actual effect of breastfeeding. We investigated the association of breastfeeding with cognitive development and educational achievements in sub-Saharan Africa, where breastfeeding is the norm, and socioeconomic status is not strongly correlated with ever breastfeeding.

Methods We searched Medline, Embase, PsycINFO, Cochrane Central Register of Controlled Trials (CENTRAL), and Africa-Wide Information in January 2021 for studies that assessed the cognitive and educational benefits of breastfeeding in children and adolescents in sub-Saharan Africa. Two reviewers independently screened, extracted, and critically appraised the included studies.

Results After reviewing 5552 abstracts and 151 full-text articles, seventeen studies on cognitive development and two on educational achievements met our predefined inclusion criteria. The included studies were from ten sub-Saharan African countries and published between 2013 and 2021, with sample sizes ranging from 54 to 6573. Most of the studies (n = 14) were prospective cohort studies, but only nine collected data on breastfeeding prospectively. The studies differed in analytic approaches and cognitive and educational achievements measurements. Of the 17 studies on cognitive development, only four adjusted sufficiently for key confounders. None of these four studies found an overall association between breastfeeding and cognitive development in children or adolescents in sub-Saharan Africa. The two studies on education measured achievements based on the highest grade of school attained, 12 or more years of education, or grade repetition at age 7-11 years. Both studies adjusted for a range of sociodemographic factors and found no evidence that children exclusively breastfed or breastfed for a longer duration have a better educational outcome than sub-optimally breastfed children.

Conclusions The current evidence from sub-Saharan Africa is limited but does not corroborate previous findings that breastfeeding is associated with improved cognitive development and educational achievement.

Registration This study is registered with PROSPERO, CRD42021236009.

In 1929, Hoefer and Hardy reported a link between breastfeeding and cognitive development in their study of 7- to 13-year-olds in the United States [1], triggering a wave of studies investigating the association further. Since then, a number of systematic reviews and meta-analyses have evaluated and summarised the available evidence on the topic, with most of the reviews suggesting improved cognitive development and better educational outcomes in breastfed children [2-4]. For example, a meta-analysis commissioned by the World Health Organisation in 2007 found that breastfed children score 4.9 points higher on intelligence tests than non-breastfed children [3]. This meta-analysis was updated in 2013 [4] and again in 2015 [2], with results showing that breastfeeding was associated with 3.5 and 3.4 higher points in intelligence test scores, respectively.

There has been extensive debate on whether the association of breastfeeding with cognitive development and educational achievement is likely to be causal. It has been suggested that breastfed children have a higher cognitive function and educational achievement than non-breastfed children because of the high level of long-chain polyunsaturated fatty acids (LCPUFA) in breastmilk [5-7]. Nevertheless, in many settings, parents who breastfeed are likely to be different from parents who do not breastfeed (eg, with respect to socioeconomic status and maternal IQ) [8], and therefore any observed association with breastfeeding could be due to parental/family characteristics rather than a causal association with breastfeeding.

If breastfeeding does improve cognitive development and educational achievement, then we would expect to find evidence for this association across a range of different contexts; however, a review published in 2013 compared results from high-income and low- and middle-income countries and concluded that the 13 studies from low- and middle-income countries (LMICs) were more likely to report no effect of breastfeeding on cognitive development than the 71 studies from high-income countries [9]. Like other systematic reviews and meta-analyses exploring the association between breastfeeding and cognitive development or educational achievement [2,10], this review did not identify any studies from sub-Saharan Africa for inclusion [9].

Most of the research on breastfeeding in sub-Saharan Africa has been focused on the protective effects of breastfeeding on morbidity and mortality because of the high level of childhood infectious diseases in this region. Due to the lack of reviews on this topic focusing on sub-Saharan Africa, the cognitive and educational benefits of breastfeeding in the region are unclear. Language, childcare practices, and culture influence cognitive development, so it will be misleading to generalise reviews of studies from high-income countries to the sub-Saharan African context. We aimed to systematically review empirical evidence on the association of breastfeeding with cognitive development and educational achievement in children and adolescents in Sub-Saharan Africa.

METHODS

Protocol and registration

The protocol for the systematic review was registered with PROSPERO [11]. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guided the structure and reporting of the review [12].

Eligibility criteria

To be eligible for inclusion, studies had to meet the following criteria:

Participants

Studies were included if participants were children or adolescents aged 0-18 years in sub-Saharan Africa. Sub-Saharan Africa was defined as the 46 countries of Africa that lie south of the Sahara. For studies that investigated participants of all ages or analysed data from multiple countries, we included and extracted only the findings that met the eligibility criteria.

Exposure

Duration of breastfeeding and breastfeeding pattern appropriate to age were the exposures assessed. We excluded studies where breastfeeding information was collected five years or more after birth, as the length of recall is a potential source of bias [13]. We specified *a priori* to include studies regardless of confounder adjustment. However, for the narrative synthesis of results, we focused on studies that adjusted for maternal education or measures of socioeconomic status. Because of the strong correlation of breastfeeding with maternal education and measures of socioeconomic status, estimates from studies that do not adjust for these potential confounders can be misleading or biased.

Outcome measures

Studies had to report educational achievement or cognitive development as an outcome. Educational achievement was defined as the highest level of education attended or completed or how children and adolescents accomplished learning goals (eg, performance on a test). Cognitive development was defined as how children and adolescents think, process knowledge, solve problems, and develop skills. Included studies had to use validated age-appropriate methods to measure cognitive development. We excluded studies that solely assessed social and emotional-behavioural functioning as outcomes.

Type of study

Prospective and retrospective observational studies (cohort studies, case-control studies, and cross-sectional studies) and trials were considered for inclusion. There were no restrictions on language or publication date. Conference papers, reviews, and qualitative studies were excluded.

Data sources and search strategy

A comprehensive literature search was conducted in Medline, Embase, PsycINFO, Cochrane Central Register of Controlled Trials (CENTRAL), and Africa-Wide Information electronic databases for relevant peer-reviewed articles from the databases' inception. A search strategy was developed based on the review's four main concepts: breastfeeding, educational achievement, cognitive development, and sub-Saharan Africa. First, a brief search was conducted in each database to determine the free-text terms, keywords, and synonyms used in the thesaurus to describe the main concepts. A full search strategy was then constructed with guidance from previous reviews [2,14-17] using a combination of subject headings and a wide range of free-text terms and synonyms for the main concepts. The search was refined through an iterative process and in consultation with a specialist Librarian (see Table S1 in the **Online Supplementary Document** for the full search strategy). The database searches were conducted in January 2021. Reference lists and citations of included studies and existing reviews and meta-analyses were searched (backward and forward reference searching). The backward and forward reference searching was conducted in the Web of Science Core Collection and Google Scholar in July 2021.

Screening of studies and data extraction

Articles retrieved from the database searches were imported to Mendeley citation manager, and duplicates were removed. A second deduplication was carried out in a more sensitive system [18], the Rayyan systematic review manager [19], to ensure complete deduplication of the search results. Authors SM and CC initially screened 20% of the titles and abstracts against the eligibility criteria for relevance. SM screened the remaining titles and abstracts, and CC checked them for consistency. SM obtained and read the full text of the articles kept after the initial screening to exclude those that did not meet the predefined inclusion criteria. For studies with no full text available online, SM attempted contact with the authors. CC reviewed decisions on 25% of the full-text articles screened using the same criteria.

Data extraction was performed by SM and CC using a data extraction form developed in Microsoft Excel. The form contained fields for study setting and design, data collection methods, study population and sample size, age at recruitment and follow-up period, breastfeeding measurement, assessment of education, cognitive outcomes and covariates, and a summary of findings before and after adjustment. The extraction form was piloted on four articles, and based on the pre-test results, modifications were made to the form. We attempted to contact authors of studies for more information where necessary. Disagreements between reviewers were settled through discussions.

Critical appraisal of studies

The criteria used to judge the methodological quality of the included studies were adapted from the Joanna Briggs Institute's (JBI) critical appraisal tools for analytical cross-sectional studies [20], cohort studies [21], and randomised controlled trials (RCTs) [22]. SM conducted the quality appraisal, and CC checked a sample for consistency. The presence or absence of a criterion was denoted with "low risk of bias" or "high risk of bias", respectively, and "unclear" was used where authors did not provide sufficient information to judge a criterion.

Data synthesis

We decided, *a priori*, to conduct a meta-analysis if at least two studies were homogeneous with respect to definition, classification, or measurement of breastfeeding and cognitive development or educational achievements and used comparable analytic approaches [11]. However, after reviewing the studies, a meta-analysis was deemed inappropriate given the heterogeneity of breastfeeding classification, outcome measurements, and analytic techniques. Instead, we conducted a narrative synthesis focusing on studies that controlled for maternal education or measures of socioeconomic status and other important confounders in the design or analysis. Effect estimates and 95% confidence intervals from the included studies were extracted and presented in tables. In studies where cognitive development or educational achievement were measured as continuous variables, we showed the mean differences of these outcomes by breastfeeding groups. Odds ratios were reported for studies where the outcomes were recorded as dichotomous variables. Because the estimates were derived using different methodologies and analytic approaches, we did not pool or combine them to produce a single overall effect estimate; each study was presented separately in the tables.

Ethics approval

Ethical approval was not required for this study.

RESULTS

A flowchart of the study selection process is presented in **Figure 1**. Overall, 5546 potentially relevant articles were found in five databases. Six additional articles were identified through hand-searching. After removing duplicates (n = 1846), and screening titles and abstracts, 151 articles remained. Full texts of the 151 articles were reviewed, and 19 articles were eligible for inclusion. Of the 19 included articles, 17 were on cognitive development and two on educational achievements.

Critical appraisal of included studies

Each study was assessed for the possibility of selection bias, measurement bias, and confounding (Table S2 in the **Online Supplementary Document**). For most of the studies, the criteria for inclusion were clearly defined, and children or adolescents from the same population were compared. However, in 27% of the studies, there was a substantial loss to follow-up (over 20%), and 44% of the studies did not provide sufficient information to decide on the extent of loss to follow-up. In 21% of the studies, breastfeeding information was collected retrospectively. More than half of the studies (10/19) did not provide sufficient information to judge if breastfeeding was measured similarly in the groups. All 17 studies on cognitive development used validated tools to assess cognition. Most studies (13/19) did not adjust sufficiently for potential confounders.

Breastfeeding and cognitive development in sub-Saharan Africa

Of the 17 studies on cognitive development, 12 were prospective cohort studies [23-34], four were cross-sectional studies [35-38], and one was a cluster RCT [39] (**Table 1** and Table S3 in the **Online Supplementary Document**). These studies were published between 2013 and 2021, with the majority (88%) published in the last five years. There was high variability in sample sizes, ranging from 54 to 6573. The studies were conducted across ten sub-Saharan African countries, but most were done in South Africa [23,27,29,30,31,34,36]. Three studies were multicentred, pooling data from Uganda and Burkina Faso [39], Uganda and Malawi [24], and Ghana and Malawi [33].

Exclusive breastfeeding, duration of breastfeeding, or ever breastfed were the three main breastfeeding exposures. 17 different psychometric tools were used to measure cognitive development, with five studies using multiple tools. The most frequently used psychometric tool was the Bayley Scales of Infant and Toddler Development (BSID). Most of the studies (n = 12) only included participants younger than three years (range six months to 11 years).

11 of the cognitive development studies did not adjust for any confounders [24-29,33-37], and two studies adjusted for some confounders but not maternal education or family socioeconomic status [31,32] (Table S3 and S4 Table in the **Online Supplementary Document**). Only four studies controlled for maternal education or measures of family socioeconomic status [23,30,38,39], with one of these adjusting for maternal intelligence [23].

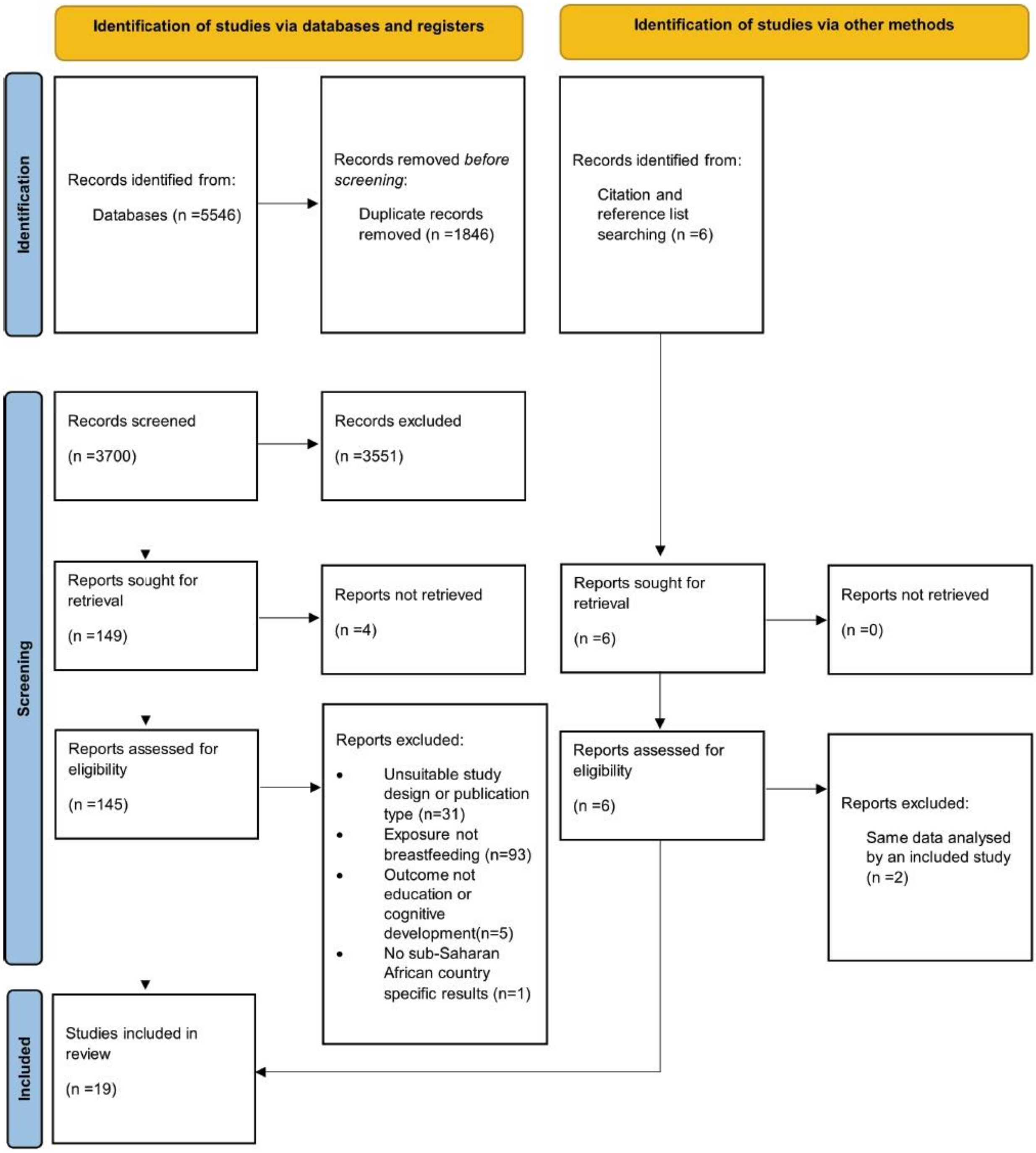

Figure 1. PRISMA flow diagram of the study selection process.

None of the four studies that adjusted for maternal education or family socioeconomic status found evidence of an association between breastfeeding and cognitive development in the overall sample (**Table 2**). Namazzi et al. assessed cognitive development in nine to 12 months olds (n = 487) using the Malawi Developmental Assessment Tool (MDAT) [38]. Exclusive breastfeeding at six months was the exposure, and adjustment was made for maternal education, maternal age, birth weight, post-neonatal complications, number of childhood illnesses and other confounders in the analysis. There was no evidence in the adjusted analysis that exclusive breastfeeding at six months improved children's cognitive development (**Table 2**). In Le Roux et al.'s study of 521 breastfed HIV-exposed uninfected and HIV-unexposed children in South Africa, the BSID-III was used to assess cognitive development in children aged 11-18 months [30]. After adjusting for maternal education,

Table 1. Characteristics and findings of studies on cognitive development and educational achievements that adjusted sufficiently for relevant confounders

No	Author(s) name, year of publication	Setting	Study design	Study dates	Aim of study	Description of study population	Measurement of breastfeeding	Breastfeeding groups compared	Assessment of cognitive and educational outcome
					A. Cognitive development				
1	Rochat et al., 2016 [23]	South Africa	Prospective cohort study	2012-2014	To investigate the association between exclusive breastfeeding, HIV exposure, and other early and current life factors and later cognitive development, executive function, and emotional behavioural development in children aged 7 to 11 y.	906 HIV-negative primary school-aged children born to HIV-positive and HIV-negative mothers enrolled in an intervention cohort study supporting them to practice exclusive breastfeeding for the first 180 d of life in a rural area of South Africa.	The total number of days in the first six months that the child received only breastmilk was collected and then divided by 30 into months, irrespective of whether the days were sequential.	Exclusive breastfeeding for 2-5 mo and 6 mo vs 0-1 mo.	At age 7-11 y, the Kaufman Assessment Battery for Children (KABC-II) was used to assess cognitive development.
2	Namazzi et al., 2019 [38]	Uganda	Cross-sectional	2017	To establish the prevalence and factors associated with neurodevelopmental disability among infants in Eastern Uganda.	487 infants born between January and March 2017 in the Iganga/Mayuge Health Demographic Surveillance Site (HDSS) in Eastern Uganda.	Unclear	Exclusive breastfeeding for six months vs non-exclusive breastfeeding	Neurodevelopment was assessed in December 2017 using the Malawi Developmental Assessment Tool (MDAT).
3	Tumwine et al., 2018 [39]	Uganda and Burkina Faso	Community-based cluster-randomised trial	2013-2015	To assess the effects of exclusive breastfeeding peer counselling in the first six months of life on cognitive abilities, social-emotional development, school performance and linear growth among 5–8 y old children in Uganda and Burkina Faso.	1083 children residing in selected clusters in rural Banfora, Southwest Burkina Faso, and from the Mbale District, Eastern Uganda.	Unclear	Exclusive breastfeeding status at 12 weeks	At 5-8 y, the Kaufman Assessment Battery for Children, second edition (KABC-II), the Test of Variables of Attention (T.O.V.A.1) and the Children's Category Test (CCT 1) were used to assess child development.
4	Le Roux et al., 2018 [30]	South Africa	Prospective birth cohort	2013-2017	To assess neurodevelopment of breastfed HIV-exposed uninfected (HEU) and breastfed HIV-unexposed children in the context of universal maternal antiretroviral therapy (ART)	521 participants, of which 215 were HEU and 306 HIV-unexposed children born to women who initiated ART in pregnancy in a peri-urban community and breastfed their children.	Information on breastfeeding duration was determined from maternal self-report of infant feeding practices at 6 weeks; 3, 6, 9 and 12 mo, with the last visit taken as the last day of breastfeeding.	Breastfeeding duration in months	At age 11–18 mo, the Bayley Scales of Infant and Toddler Development, Third Edition (BSID-III), was used to assess child development.
					B. Educational achievement				
1	Horta et al., 2013 [40]	South Africa	Prospective cohort study	1990-2009	To assess the association between early feeding practices and long-term school achievement.	2225 babies born to predominantly poor black women residing in an area of Johannesburg.	Information on infant feeding practices was collected from mothers when the cohort members were 3, 6, 12, and 24 mo old on whether they were ever breastfed, if they were still breastfeeding, and for those who had stopped, when they stopped, and when complementary foods were introduced.	Ever breastfed vs never breastfed. Breastfeeding ≤1 mo vs >1-3 mo, >3-6 mo, >6-12 mo >12-18 mo >18-24 mo >24 mo	The highest school grade attained and completion of ≥12 y of schooling.
2	Mitchell et al., 2016 [41]	South Africa	Prospective cohort study	2001-2014	To investigate early life factors associated with earliest repeated grade and explore child characteristics and parental reports of reasons for failure among early repeaters.	894 HIV-negative children born and residing in northern KwaZulu-Natal whose mothers were alive and had participated in an intervention to support exclusive breastfeeding.	Exclusive breastfeeding was estimated as the number of days a child received only breast milk and no other fluids or solids. This was divided into months.	Exclusive breastfeeding 0–1-mo vs 2-5 mo, and 6 mo	At age 7-11 y, mothers or caretakers were asked about their children's schooling history and any repeated grades.

y – year, mo – months

Table 2. Estimates of the effect of breastfeeding on cognitive development in sub-Saharan Africa from studies adjusted sufficiently for relevant confounders

ODDS RATIOS (95% CI)										
Study 1: Rochat et al., 2016 [23]*										
	Sequential		Planning		Learning		Simultaneous		Riddle	
	Unadjusted odds ratio (95% CI)	Adjusted odds ratio (95% CI)	Unadjusted odds ratio (95% CI)	Adjusted odds ratio (95% CI)	Unadjusted odds ratio (95% CI)	Adjusted odds ratio (95% CI)	Unadjusted odds ratio (95% CI)	Adjusted odds ratio (95% CI)	Unadjusted odds ratio (95% CI)	Adjusted odds ratio (95% CI)
Exclusive breastfeeding (overall sample)										
0-1 mo	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2-5 mo	1.09 (0.7 to 1.7)	1.27 (0.8 to 2.1)	0.93 (0.6 to 1.5)	0.96 (0.6 to 1.6)	0.93 (0.6 to 1.5)	1.16 (0.7 to 1.9)	1.02 (0.6 to 1.6)	1.34 (0.8 to 2.2)	0.76 (0.5 to 1.2)	1.07 (0.6 to 1.8)
6 mo	1.01 (0.7 to 1.6)	1.23 (0.8 to 2.0)	0.75 (0.5 to 1.1)	0.80 (0.5 to 1.3)	1.04 (0.7 to 1.6)	1.29 (0.8 to 2.1)	0.94 (0.6 to 1.4)	1.29 (0.8 to 2.1)	0.77 (0.5 to 1.2)	1.18 (0.7 to 1.9)
Study 2: Namazzi et al., 2019 [38]†										
	Neuro-developmental disability									
	Unadjusted odds ratio (95% CI)	Adjusted odds ratio (95% CI)	-	-	-	-	-	-	-	-
Exclusive breastfeeding for six months										
Yes	1.00	1.00	-	-	-	-	-	-	-	-
No	1.37 (0.70 to 2.67)	0.62 (0.30 to 1.27)	-	-	-	-	-	-	-	-
Mean difference (95% confidence interval)										
Study 3: Tumwine et al., 2018 [39]‡										
	General cognition		Working memory		Attention		Inhibition		Cognitive flexibility	
	Unadjusted mean difference (95% CI)	Adjusted mean difference (95% CI)	Unadjusted mean difference (95% CI)	Adjusted mean difference (95% CI)	Unadjusted mean difference (95% CI)	Adjusted mean difference (95% CI)	Unadjusted mean difference (95% CI)	Adjusted mean difference (95% CI)	Unadjusted mean difference (95% CI)	Adjusted mean difference (95% CI)
Exclusive breastfeeding promotion intervention	0.08 (-0.13 to 0.29)	-0.07 (-0.30 to 0.15)	-0.01 (-0.32 to 0.29)	-0.07 (-0.29 to 0.16)	0.12 (-0.02 to 0.26)	0.11 (-0.13 to 0.35)	0.03 (-0.17 to 0.23)	-0.05 (-0.28 to 0.19)	-0.07 (-0.21 to 0.07)	0.02 (-0.27 to 0.30)
Study 4: Le Roux et al., 2018 [30]§										
	Cognitive development		Motor development		Language development		-	-	-	-
	Unadjusted mean difference (95% CI)	Adjusted mean difference (95% CI)	Unadjusted mean difference (95% CI)	Adjusted mean difference (95% CI)	Unadjusted mean difference (95% CI)	Adjusted mean difference (95% CI)	-	-	-	-
Breastfeeding duration (months)	0.11 (-0.11 to 0.34)	0.09 (-0.13 to 0.31)	0.19 (-0.04 to 0.41)	0.15 (-0.08 to 0.37)	0.02 (-0.22 to 0.26)	0.01 (-0.24 to 0.25)	-	-	-	-

CI – confidence interval

*Adjusted for child sex, child age, mother's age at birth, maternal IQ, mother's education at birth, birthweight, birth order, mother's HIV status, residence, income provider, owning fridge, perception of wealth, crèche, HOME assessment score, maternal mental health, and parenting stress.

†Adjusted for father's occupation, maternal age, maternal education, tetanus toxoid to the mother, marital status, mother parity, ANC attendance, place of delivery, birth weight, cried at birth, post-neonatal complications, and number childhood illnesses.

‡Adjusted for socioeconomic status, electricity in-home, duration in kindergarten and cluster.

§Maternal HIV, education, alcohol use and IPV; infant gestational age at birth, and birth size.

HIV status, alcohol use and intimate partner violence (IPV), infant gestational age at birth, and birth size, the mean differences of the three subscales of BSID-III showed no evidence of improved cognitive function in those breastfed for a longer duration (**Table 2**).

In Rochat et al.'s prospective study of 906 HIV-negative primary school-aged children in South Africa [23], cognitive development was assessed at 7-11 years using the Kaufman Assessment Battery for Children (KABC-II). After controlling for the mother's education at birth, ownership of fridge, perception of wealth, maternal intelligence, and other sociodemographic confounders, there was no evidence that a longer duration of exclusive breastfeeding was associated with improved cognitive development (**Table 2**). However, there was weak evidence in the sex-stratified analysis that boys exclusively breastfed for longer were two times more likely to score above the mean for learning ability sub-scale than those breastfed for less than a month (Table S5 in the **Online Supplementary Document**). It was unclear whether the subgroup analysis was prespecified, and there was no benefit in the other four domains of development or for girls.

In Tumwine et al.'s cluster RCT of exclusive breastfeeding peer counselling in Burkina Faso and Uganda (n = 1083), cognitive development was assessed at age 5-7 using the KABC-II, Test of Variables of Attention (T.O.V.A) and the children's category test (CCT) [39]. In the intention to treat analysis, there was no evidence that being randomised to exclusive breastfeeding peer counselling was associated with improved cognitive development on any of the psychometric tools used (**Table 2**). Electricity in-home, SES, and kindergarten attendance were imbalanced at baseline and were controlled in the analysis. In a secondary analysis ignoring the randomisation, there was evidence of improved inhibition among children exclusively breastfed at 12 weeks. It was unclear whether the secondary analysis was prespecified, and there was no evidence of improved performance on the other four cognitive measures (Table S5 in the **Online Supplementary Document**).

Breastfeeding and educational achievement in sub-Saharan Africa

Two prospective cohort studies assessed the effect of breastfeeding on educational achievements in South Africa. The breastfeeding exposures and the measures of educational achievements differed in the two studies (**Table 1**).

In Horta et al.'s study of 2225 children (average age of 17.7 years) born to predominantly poor black women in Johannesburg [40], the highest grade of schooling attained and completion of 12 or more years of education were the measures of educational achievement. The exposures were ever breastfed and the duration of breastfeeding. After adjusting for socioeconomic status at birth, maternal schooling, skin colour, maternal age, smoking during pregnancy, birthweight, age at follow-up, and sex, there was no evidence that either breastfeeding indicator was associated with better grade progression or completion of schooling than never breastfeeding or breastfeeding for a month or less (**Table 3**).

Mitchell et al. re-enrolled 894 7-11-year-olds in northern KwaZulu-Natal [41]. The outcome was grade repetition at age 7-11 years and the exposure was exclusive breastfeeding in the first six months. The analysis controlled for maternal age, maternal education, residence, main income, and fridge ownership (all measured at birth) and child age, sex, birth order, birth weight, and HIV exposure. There was no evidence that a longer duration of exclusive breastfeeding was associated with favourable school progression (**Table 3**). Likewise, in sex-stratified subgroup analysis, there was no evidence of an association between exclusive breastfeeding and grade repetition in girls or boys (Table S6 in the **Online Supplementary Document**).

DISCUSSION

In this systematic review, we identified 17 studies assessing the effects of breastfeeding on cognitive development and two studies on breastfeeding and educational achievement in children and adolescents in sub-Saharan Africa. However, only four studies on cognitive development and the two studies on educational achievement adjusted sufficiently for relevant confounders. Overall, we found no evidence that breastfeeding is associated with improved cognitive development or higher educational achievement in children or adolescents in sub-Saharan Africa from the studies sufficiently adjusted for confounders. Two studies found some association with cognitive development in subgroup analysis (23,39). However, it is unclear whether these subgroup analyses were pre-specified.

In contrast to our findings, many previous systematic reviews and meta-analyses have reported an association between breastfeeding and cognitive development. A 1999 meta-analysis of 11 studies found that breastfed children scored 3.2 points higher on cognitive function tests than formula-fed children. The effect persisted

Table 3. Estimates of the effect of breastfeeding on educational achievement in sub-Saharan Africa

Study 1: Horta et al., 2013 [40]*				
	Highest grade achieved at school		Completed at least 12 y of schooling	
	Unadjusted mean difference (95% CI)	Adjusted mean difference (95% CI)	Unadjusted prevalence ratio (95% CI)	Adjusted prevalence ratio (95% CI)
Ever breastfeed				
No	0.0	0.0	1.00	1.00
Yes	0.02 (-0.26 to 0.29)	-0.08 (-0.41 to 0.25)	0.97 (0.84 to 1.13)	0.95 (0.79 to 1.14)
Duration of any breastfeeding (in months)				
≤1.00	0.0	0.0	1.00	1.00
>1-3	-0.06 (-0.32 to 0.19)	-0.23 (-0.52 to 0.05)	0.92 (0.80 to 1.05)	0.83 (0.70 to 0.98)
>3-6	-0.10 (-0.38 to 0.18)	-0.10 (-0.41 to 0.21)	0.94 (0.81 to 1.09)	0.93 (0.78 to 1.10)
>6-12	0.04 (-0.22 to 0.30)	-0.03 (-0.31 to 0.26)	0.98 (0.85 to 1.12)	0.97 (0.83 to 1.12)
>12-18	-0.02 (-0.29 to 0.25)	-0.08 (-0.37 to 0.21)	0.97 (0.84 to 1.11)	0.94 (0.80 to 1.09)
>18-24	0.16 (-0.13 to 0.45)	0.09 (-0.21 to 0.40)	1.01 (0.87 to 1.17)	1.04 (0.89 to 1.21)
>24	-0.12 (-0.37 to 0.12)	-0.02 (-0.29 to 0.24)	0.89 (0.78 to 1.02)	0.97 (0.84 to 1.12)

Study 2: Mitchell et al., 2016[41]†				
	Grade repetition			
	Unadjusted odds ratio (95% CI)	Adjusted odds ratio (95% CI)	-	-
Exclusive breastfeeding for six months (Overall sample; n=842)				
0-1 mo	1.00	1.00	-	-
2-5 mo	0.77 (0.49 to 1.22)	0.76 (0.45 to 1.28)	-	-
6 mo	0.70 (0.46 to 1.07)	0.64 (0.39 to 1.06)	-	-

mo – months

*Adjusted for socioeconomic status at birth, maternal schooling, skin colour, maternal age, smoking during pregnancy, birthweight, subject's age at follow-up, and sex.

†Adjusted for maternal age, maternal education, residence, main income, and fridge ownership (all measured at birth) and child age, child sex, birth order, birth weight, HIV exposure.

until adolescence, showing a dose-response relationship [42]. A systematic review of three studies in 2007 reported higher educational achievement in breastfed children in late adolescence and young adulthood [3]. In a 2019 review of 73 studies, the majority of the studies demonstrated a positive effect of breastfeeding on cognitive development and educational achievements [10]. Similarly, in a 2015 meta-analysis of 17 studies, Horta et al., found that breastfed children scored 3.4 points higher on intelligence tests than non-breastfed children [2].

Based on these reviews and results from a cluster randomised breastfeeding intervention trial in Belarus, Horta et al., suggested that the association is causal [2]. However, none of these reviews that reported a beneficial effect of breastfeeding on cognitive development included a study from sub-Saharan Africa. Moreover, the Belarusian cluster randomised trial only found evidence of association on two measures of verbal intelligence (vocabulary (aβ=+4.9, 95% CI=+0.4 to +9.3), similarities (aβ=+4.6, 95% CI=+0.2 to +9.0), and overall verbal IQ (aβ=+7.5, 95% CI=+0.8 to +14.3)) of the Wechsler Abbreviated Scales of Intelligence (WASI) [43]. There was no significant difference between the experimental and control groups on the other two subtests of WASI that measured performance (nonverbal) intelligence (block designs (aβ=+1.9, 95% CI=-1.7 to +5.5); matrices (aβ=+1.8, 95% CI=-1.9 to +5.5); and overall performance IQ (aβ=+2.9, 95% CI=-3.3 to +9.1)). In addition, the trial did not find evidence of a difference in intelligence on full-scale IQ of WASI (aβ=+5.9, 95% CI=-1.0 to 12.8) [43].

Researchers have suggested that the presence of arachidonic acid (ARA) and docosahexaenoic acid (DHA) in breastmilk are responsible for the improved cognitive advantage in breastfed children [44] as these two long-chain polyunsaturated fatty acids (LCPUFAs) are critical for brain development [45]. However, the results of this systematic review cast doubt on this potential causal pathway, as we would expect to see similar associations in breastfed children from diverse populations, including African children. In fact, studies have shown that breastfeeding mothers in Africa and Asia have the highest level of breastmilk DHA worldwide [46]. Furthermore, a meta-analysis of 12 RCTs to examine the efficacy of LCPUFA supplementation of infant formula on cognitive development found no evidence that LCPUFA supplementation of formula improves early cognitive function [47]. It is possible that the constituents of breastmilk are not responsible for the observed positive associations in previous reviews, but rather reflect the methodological challenges in measuring the association between breastfeeding and both cognitive functioning and education status.

Most of the individual studies included in the previous reviews were from high-income countries (HICs), where exclusive breastfeeding and longer breastfeeding duration are more common in mothers with higher education and family income [8]. As higher SES is also associated with improved cognitive development and educational achievements in these settings [48-50], it is possible that the social advantage of breastfed children confounds the beneficial effect of breastfeeding reported in these reviews and the benefits are not true of breastfeeding. Although the reviews and meta-analyses were carefully designed with strict inclusion criteria to minimise the effect of confounding, residual confounding from family socioeconomic status is still possible.

Reviews that included studies from low- and middle-income countries (LMICs), where maternal education and family socioeconomic status do not greatly influence breastfeeding [8], reported null or inconclusive results. For example, when the association between breastfeeding and educational achievement was assessed in five birth cohorts from LMICS (Brazil, India, Guatemala, the Philippines, and South Africa), investigators found no evidence of an association between breastfeeding and educational achievements [40]. A review of 84 studies in 2013 found that studies from LMICs were about two times more likely to report no cognitive benefits of breastfeeding than those from HICs. The investigators concluded that the positive effect seen in HICs was probably due to residual confounding from maternal intelligence and family socioeconomic status [9].

It is also possible that the psychometric tools used to measure cognitive development accounted for the absence of evidence of an association between breastfeeding and cognitive development in sub-Saharan Africa. Most studies in this review assessed cognitive development with psychometric tools developed and validated in HICs. Despite evidence of cross-cultural differences in developmental trajectories due to factors other than intellectual abilities [51-53], when these tools assess cognitive development in sub-Saharan Africa, children's performance is compared to the norm-referenced scores established among children in HICs [54-56]. In a study to validate the BSID-III in Malawi, investigators found that using the US-based norms misclassified the neurological development of about 25%-36% of Malawian children across the subscales of the tool [55]. Misclassification and, consequently, misleading results are likely in the studies that used these tools without adapting them to the local context. Nevertheless, the studies that used the Malawi Development Assessment Tool and Kilifi Developmental Inventory found no cognitive benefit from breastfeeding [26,28,33,38]. Future studies on cognitive development should use culturally sensitive psychometric tools or adapt and validate existing tools to the local context and, where possible, adopt standardised approaches to defining exposure, outcome, and the analysis to facilitate comparison between studies.

We found wide variation in the breastfeeding exposure indicators and psychometric tools used to assess cognitive development. Different analytic approaches precluded a meta-analysis even where studies used the same breastfeeding indicator. Of the studies on cognitive development, 11 did not adjust for any potential confounders, probably because most studies were not designed to investigate the cognitive benefits of breastfeeding. In addition, two studies that adjusted for confounders failed to adjust for some important known confounders, including maternal education and measures of SES. The studies included in the present review were conducted in only ten of the 46 sub-Saharan African countries. Both studies on educational outcomes were from South Africa, demonstrating the lack of studies on this topic.

CONCLUSIONS

The current evidence in sub-Saharan Africa does not corroborate the findings elsewhere that breastfeeding is associated with improved cognitive development and educational achievements in children and adolescents. However, this conclusion was based on a small number of studies, and the measurements of cognitive development and educational achievements and the analytic approaches used varied considerably across the studies. We echo the World Health Organisation's recommendation on breastfeeding infants from birth to age two years and beyond since there is considerable evidence elsewhere [57] that breastfeeding protects against gastrointestinal infection in children. Whether it also benefits cognitive and educational outcomes remains unclear. There is a need for high-quality research on the educational benefits of breastfeeding in sub-Saharan Africa since this has far-reaching implications for the future of children and adolescents.

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Authorship contributions: SM, LLO, MM, JRG, and CC conceptualized the systematic review, and SM drafted the protocol for registration with PROSPERO. SM designed the search strategy, conducted the searches, and retrieved articles in consultation with LLO, MM, JRG, and CC. SM and CC screened the titles, abstracts, and full text of all identified articles and performed the data extraction and risk of bias assessment. LLO, MM, JRG, and CC reviewed all drafts, supervised the database searches, and contributed to the narrative synthesis. SM wrote the first draft, and all authors critically reviewed and approved the final draft.

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Additional material

Online Supplementary Document

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2.3 Supplementary materials

Table S 1: Criteria for database searches in Medline, Embase, PsycINFO, Cochrane Central Register of Controlled Trials (CENTRAL), and Africa-Wide Information

	Medline	
	Search strategy	**Results**
1	exp breast feeding/ or exp lactation/ or exp Bottle Feeding/ or exp infant nutritional physiological phenomena/ or exp Infant Formula/ or exp Milk, Human/ or exp Lactation/ or weaning/	108568
2	(Breast* adj3 (fe* or milk)).ti,ab,kw.	43487
3	((Infant or child) adj3 (fe* or nutrition or formula or milk)).ti,ab,kw.	30289
4	(formula adj3 (fe* or milk)).ti,ab,kw.	7424
5	((Bottle or cup) adj fe*).ti,ab,kw.	2385
6	((human or artificial) adj3 (milk or lactation)).ti,ab,kw.	12122
7	1 or 2 or 3 or 4 or 5 or 6	149514
8	exp cognition/ or exp intelligence/ or exp Intelligence Tests/	280236
9	((cognit* or intell*) adj2 (develop* or outcom* or function* or process* or abilit* or tes* or quotient or perform* or capab*)).ti,ab,kw.	125099
10	8 or 9	356232
11	exp academic performance/ or exp academic success/ or exp Educational Measurement/ or exp Educational Status/	199466
12	((educat* or academic* or school* or exam* or test*) adj3 (perform* or achiev* or attain* or grade* or level* or success* or status* or outcome* or result* or mark* or score* or progress* or atten* or assess* or evalua* or measur*)).ti,ab,kw.	750027
13	11 or 12	906082
14	10 or 13	1209396
15	exp "africa south of the sahara"/	212602
16	((sub-Sahara* or east* or west* or southern or central) adj2 Africa*).ti,ab,kw.	43331
17	(((Angola* or Benin* or Botswana or Burkina Faso or Burundi* or Cameroon* or Republique du Cameroun or Cape Verde* or Cabo Verde* or Central African Republic or Republique centrafricaine or Chad* or Comoros or Congo* or Democratic Republic of the Congo or Cote d'Ivoire or Ivory Coast or Djibouti* or Eritrea* or Ethiopia* or Gabon* or Republique gabonaise or Gambia* or Ghana* or Equatorial Guinea or Guinea* or Republique de Guinee or Guinea Bissau or Republica da Guine-Bissau or Kenya* or Lesotho or Liberia* or Madagascar or Malawi* or Mali* or Mauritania* or Mauriti* or Mayotte or Mozambi* or Namibia* or Republic of the Niger or Republique du Niger or Niger* or Nigeria* or Rwanda* or Democratic Republic of Sao Tome) and Principe) or Republica Democratica de Sao Tome e Principe or Senegal* or Republique du Senegal or Seychell* or Sierra Leone* or Somalia* or South Africa* or Sudan* or Swaziland or eSwatini or Togo* or Uganda* or United Republic of Tanzania or Zambia* or Zimbabwe*).ti,ab,kw.	390069
18	15 or 16 or 17	423932
19	7 and 14 and 18	830
	Embase	
	Search strategy	**Results**

1	exp breast feeding/ or exp lactation/ or exp Bottle Feeding/ or exp infant nutritional physiological phenomena/ or exp Infant Formula/ or exp Milk, Human/ or exp Lactation/ or weaning/	170201
2	(Breast* adj3 (fe* or milk)).ti,ab,kw.	58029
3	((Infant or child) adj3 (fe* or nutrition or formula or milk)).ti,ab,kw.	45733
4	(formula adj3 (fe* or milk)).ti,ab,kw.	11515
5	((Bottle or cup) adj fe*).ti,ab,kw.	3180
6	((human or artificial) adj3 (milk or lactation)).ti,ab,kw.	17289
7	1 or 2 or 3 or 4 or 5 or 6	226710
8	exp cognition/ or exp cognitive development/ or exp cognitive function test/ or exp intelligence/ or exp intellect/ or exp intelligence quotient/ or exp psychomotor development/	2476232
9	((cognit* or intell*) adj2 (develop* or outcom* or function* or process* or abilit* or tes* or quotient or perform* or capab*)).ti,ab,kw.	218212
10	8 or 9	2528653
11	exp academic performance/ or exp academic success/ or exp Educational Measurement/ or exp Educational Status/	1606956
12	((educat* or academic* or school* or exam* or test*) adj3 (perform* or achiev* or attain* or grade* or level* or success* or status* or outcome* or result* or mark* or score* or progress* or atten* or assess* or evalua* or measur*)).ti,ab,kw.	1456018
13	11 or 12	2831819
14	10 or 13	4838250
15	exp "africa south of the sahara"/	365622
16	((sub-Saharan or east or west or southern or central) adj2 Africa*).ti,ab,kw.	64371
17	(((Angola* or Benin* or Botswana or Burkina Faso or Burundi* or Cameroon* or Republique du Cameroun or Cape Verde* or Cabo Verde* or Central African Republic or Republique centrafricaine or Chad* or Comoros or Congo* or Democratic Republic of the Congo or Cote d'Ivoire or Ivory Coast or Djibouti* or Eritrea* or Ethiopia* or Gabon* or Republique gabonaise or Gambia* or Ghana* or Equatorial Guinea or Guinea* or Republique de Guinee or Guinea Bissau or Republica da Guine-Bissau or Kenya* or Lesotho or Liberia* or Madagascar or Malawi* or Mali* or Mauritania* or Mauriti* or Mayotte or Mozambi* or Namibia* or Republic of the Niger or Republique du Niger or Niger* or Nigeria* or Rwanda* or Democratic Republic of Sao Tome) and Principe) or Republica Democratica de Sao Tome e Principe or Senegal* or Republique du Senegal or Seychell* or Sierra Leone* or Somalia* or South Africa* or Sudan* or Swaziland or eSwatini or Togo* or Uganda* or United Republic of Tanzania or Zambia* or Zimbabwe*).ti,ab,kw.	526181
18	15 or 16 or 17	647807
19	7 and 14 and 18	2644
	Pshyinfo	
	Search strategy	**Results**
1	exp breast feeding/ or exp lactation/ or exp Bottle Feeding/ or weaning/	5788
2	(Breast* adj3 (fe* or milk)).ti,ab.	3168
3	((Infant or child) adj3 (fe* or nutrition or formula or milk)).ti,ab.	8234
4	(formula adj3 (fe* or milk)).ti,ab.	536
5	((Bottle or cup) adj fe*).ti,ab.	422
6	((human or artificial) adj3 (milk or lactation)).ti,ab.	261
7	1 or 2 or 3 or 4 or 5 or 6	14815

8	exp Cognitive Development/ or exp cognition/ or exp cognitions/ or exp cognitive ability/ or exp cognitive assessment/ or exp executive function/ or exp intelligence/ or exp intelligence measures/ or exp intelligence quotient/ or exp Intellectual Development/	390464
9	((cognit* or intell*) adj2 (develop* or outcom* or functio* or process* or abilit* or tes* or achieve* or quotient or perform* or capab*)).ti,ab.	162596
10	8 or 9	471134
11	exp academic achievement/ or exp Academic Aptitude/ or exp Educational Attainment Level/ or exp educational measurement/ or exp education/	486454
12	((educat* or academic* or school* or exam* or test*) adj3 (perform* or achiev* or attain* or grad* or level* or success* or status* or outcome* or result* or mark* or score* or progress* or atten* or assess* or evalua* or measur*)).ti,ab.	418273
13	11 or 12	769568
14	10 or 13	1130189
15	((sub-Saharan or east* or west* or south* or central) adj2 Africa*).ti,ab.	20596
16	(((Angola* or Benin* or Botswana or Burkina Faso or Burundi* or Cameroon* or Republique du Cameroun or Cape Verde* or Cabo Verde* or Central African Republic or Republique centrafricaine or Chad* or Comoros or Congo* or Democratic Republic of the Congo or Cote d'Ivoire or Ivory Coast or Djibouti* or Eritrea* or Ethiopia* or Gabon* or Republique gabonaise or Gambia* or Ghana* or Equatorial Guinea or Guinea* or Republique de Guinee or Guinea Bissau or Republica da Guine-Bissau or Kenya* or Lesotho or Liberia* or Madagascar or Malawi* or Mali* or Mauritania* or Mauriti* or Mayotte or Mozambi* or Namibia* or Republic of the Niger or Republique du Niger or Niger* or Nigeria* or Rwanda* or Democratic Republic of Sao Tome) and Principe) or Republica Democratica de Sao Tome e Principe or Senegal* or Republique du Senegal or Seychell* or Sierra Leone* or Somalia* or South Africa* or Sudan* or Swaziland or eSwatini or Togo* or Uganda* or United Republic of Tanzania or Zambia* or Zimbabwe*).ti,ab.	43737
17	15 or 16	49554
18	7 and 14 and 17	90

Cochrane library

ID	**Search strategy**	**Hits**
#1	MeSH descriptor: [Breast Feeding] explode all trees	1857
#2	MeSH descriptor: [Infant Nutritional Physiological Phenomena] explode all trees	2792
#3	MeSH descriptor: [Bottle Feeding] explode all trees	218
#4	MeSH descriptor: [Weaning] explode all trees	136
#5	MeSH descriptor: [Infant Formula] explode all trees	610
#6	MeSH descriptor: [Milk, Human] explode all trees	999
#7	((Breast* or formula or bottle or cup) NEAR/3 (fe* or milk))	10763
#8	((human or artificial) NEAR/2 (milk or lactation))	3073
#9	((human or artificial) NEAR/2 (milk or lactation))	3073
#10	#1 or #2 or #3 or #4 or #5 or #6 or #7 or #8 or #9	12202
#11	MeSH descriptor: [Cognition] explode all trees	10149
#12	MeSH descriptor: [Intelligence] explode all trees	5775
#13	(cognit* or intell*) NEAR/3 (develop* or outcom* or function* or process* or abilit* or tes* or achieve* or quotient or perform* or capab*)	33011
#14	#11 or #12 or #13	43475
#15	MeSH descriptor: [Academic Performance] explode all trees	74
#16	MeSH descriptor: [Academic Success] explode all trees	48
#17	MeSH descriptor: [Education] explode all trees	32544
#18	MeSH descriptor: [Educational Measurement] explode all trees	4673

#19	MeSH descriptor: [Educational Status] explode all trees	1444
#20	((educat* or academic* or school* or exam* or test*) NEAR/3 (perform* or achiev* or attain* or grade* or level* or success* or status* or outcome* or result* or mark* or score* or progress* or atten* or assess* or evalua* or measur*))	147955
#21	#15 or #16 or #17 or #18 or #19 or #20	170168
#22	#14 or #21	198480
#23	MeSH descriptor: [Africa South of the Sahara] explode all trees	6328
#24	(*sahara* or sub-Sahara* or east* or west* or south* or central) NEAR/3 (Africa*)	10608
#25	Angola* or Benin* or Botswana or "Burkina Faso" or Burundi* or Cameroon* or "Republique du Cameroun" or "Cape Verde*" or "Cabo Verde*" or "Central African Republic" or "Republique centrafricaine" or Chad* or Comoros or Congo* or "Democratic Republic of the Congo" or "Cote d'Ivoire" or "Ivory Coast" or Djibouti* or Eritrea* or Ethiopia* or Gabon* or "Republique gabonaise" or Gambia* or Ghana* or "Equatorial Guinea" or Guinea* or "Republique de Guinee" or "Guinea Bissau" or "Republica da Guine-Bissau" or Kenya* or Lesotho or Liberia* or Madagascar or Malawi* or Mali* or Mauritania* or Mauriti* or Mayotte or Mozambi* or Namibia* or "Republic of the Niger" or "Republique du Niger" or Niger* or Nigeria* or Rwanda* or "Democratic Republic of Sao Tome and Principe" or "Republica Democratica de Sao Tome e Principe" or Senegal* or "Republique du Senegal" or Seychell* or "Sierra Leone*" or Somalia* or "South Africa*" or Sudan* or Swaziland or eSwatini or Togo* or Uganda* or "United Republic of Tanzania" or Zambia* or Zimbabwe*	22178
#26	#23 or #24 or #25	24537
#27	#10 and #22 and #26	305

Africa-Wide Information

	Search strategy	**Results**
S11	S4 AND S7 AND S10	(1,677)
S10	S8 OR S9	(2,915,364)
S9	Angola* or Benin* or Botswana or "Burkina Faso" or Burundi* or Cameroon* or "Republique du Cameroun" or "Cape Verde*" or "Cabo Verde*" or "Central African Republic" or "Republique centrafricaine" or Chad* or Comoros or Congo* or "Democratic Republic of the Congo" or "Cote d'Ivoire" or "Ivory Coast" or Djibouti* or Eritrea* or Ethiopia* or Gabon* or "Republique gabonaise" or Gambia* or Ghana* or "Equatorial Guinea" or Guinea* or "Republique de Guinee" or "Guinea Bissau" or "Republica da Guine-Bissau" or Kenya* or Lesotho or Liberia* or Madagascar or Malawi* or Mali* or Mauritania* or Mauriti* or Mayotte or Mozambi* or Namibia* or "Republic of the Niger" or "Republique du Niger" or Niger* or Nigeria* or Rwanda* or "Democratic Republic of Sao Tome and Principe" or "Republica Democratica de Sao Tome e Principe" or Senegal* or "Republique du Senegal" or Seychell* or "Sierra Leone*" or Somalia* or "South Africa*" or Sudan* or Swaziland or eSwatini or Togo* or Uganda* or "United Republic of Tanzania" or Zambia* or Zimbabwe*	(2,822,743)
S8	(sub-Sahara* or subsahara* or east* or west* or south* or central) N3 (Africa*)	(2,048,410)
S7	S5 OR S6	(107,065)
S6	((educat* or academic* or school* or exam* or test*) N3 (perform* or achiev* or attain* or grade* or level* or success* or status* or outcome* or result* or mark* or score* or progress* or atten* or assess* or evalua* or measur*))	(100,937)
S5	(cognit* or intell*) N3 (develop* or outcom* or function* or process* or abilit* or tes* or achieve* or quotient or perform* or capab*)	(8,318)
S4	S1 OR S2 OR S3	(21,059)
S3	((human or artificial) N3 (milk or lactation))	(1,302)
S2	((Infant or child) N3 (fe* or breast* or breast-fe* or nutrition or formula or milk))	(16,643)
S1	((Breast* or formula or bottle or cup) N2 (fe* or milk))	(7,237)

Table S 2: Results of risk of bias assessment of included studies

No.	Authors	Were the criteria for inclusion in the sample clearly defined?	Were the exposed and unexposed groups similar and recruited from the same population?	Was follow up complete for all participants?	Were breast feeding data collected prospectively?	Was breastfeeding measured similarly to assign people to both exposed and unexposed groups?	Were educational achievement or cognitive development measured validly or reliably?	Were family income or maternal education controlled for in the design or analysis?	Were other confounding factors controlled for in the design or analysis?
A. Cognitive development									
1	Rochat et al., 2016(1)	Yes	Yes	≤20% LTFU	Yes	Yes	Yes	Yes	Yes, see table 2
2	Namazzi et al., 2019(2)	No	Yes	Not stated	Unclear	Unclear	Yes	Yes	Yes, see table 2
3	Tumwine et al., 2018(3)	Yes	Yes	Over 20% LTFU	Yes	Unclear	Yes	Yes	Yes, see table 2
4	Le Roux et al., 2018(4)	Yes	Yes	≤20% LTFU	No	Yes	Yes	Yes	Yes, see table 2
5	Madlala et al., 2020(5)	Yes	Yes	Over 20% LTFU	Unclear	Unclear	Yes	No	Yes, see appendix p 8
6	McDonald et al., 2013(6)	Yes	Yes	Unclear	Yes	Yes	Yes	No	Yes, see appendix p 8
7	Boivin et al., 2019(7)	Yes	Yes	≤20% LTFU	Yes	Unclear	Yes	No	No
8	Ngoma et al., 2014(8)	Yes	Yes	Not stated	Yes	Unclear	Yes	No	No
9	Strehlau et al., 2020(9)	Yes	Yes	Not stated	Unclear	Unclear	Yes	No	No
10	Eales et al., 2020(10)	Yes	Yes	Not stated	No	Unclear	Yes	No	No
11	Prado et al., 2017(11)	No	Yes	Not stated	Yes	Yes	Yes	No	No
12	Donald et al., 2019(12)	Yes	Yes	Over 20% LTFU	Yes	Yes	Yes	No	No
13	Chaudhury et al., 2021(13)	Yes	Yes	≤20% LTFU	Unclear	Unclear	Yes	No	No
14	Ekholuenetale et al., 2020(14)	No	Yes	N/A	No	Yes	Yes	No	No
15	Namazzi et al., 2020(15)	Yes	Yes	≤20% LTFU	Unclear	Unclear	Yes	No	No
16	White et al., 2020(16)	Yes	Yes	Over 20% LTFU	No	Yes	Yes	No	No
17	Sirajee et al., 2021(17)	Yes	Yes	Over 20% LTFU	Unclear	Unclear	Yes	No	No
B. Educational achievements									
1	Horta et al., 2013(18)	Yes	Yes	Not stated	Yes	Yes	Unclear	Yes	Yes, see table 3
2	Mitchell et al., 2015(19)	Yes	Yes	Not stated	Yes	Yes	Yes	Yes	Yes, see table 3
Total									
		3	0	5	4	0	0	13	11
		16	19	5	9	9	18	6	8
		0	0	8	6	10	1	0	0
Legend		Low risk of bias	High risk of bias	Unclear					

LTFU: loss to follow-up

Note: studies are organised based on the order in which they appeared in Table 1 and appendix page 8 (characteristics of studies included in the review).

Table S 3: Characteristics and findings of studies on cognitive development not adjusted sufficiently for maternal education or measures of socioeconomic status

No	Author(s) name, year of publication, study setting and design.	Aim of study	Description of study Population	Measurement of breastfeeding	Breastfeeding groups compared	Assessment of cognitive and educational outcome	Summary of findings before adjustment	Covariates and confounders adjusted for	Summary of findings after adjustment
5	Madlala et al., 2020(5) **Setting:** South Africa **Study design**: Prospective cohort study **Study dates**: April 2015-May 2018	To examine the association of maternal and child factors with neurodevelopment at 12–24 months of age.	355 live singleton HEU children whose mothers initiated ART pre- or during pregnancy and were attending primary health care at Gugulethu Community Health Centre, a semi-urban area with a population predominantly made up of black African ethnic group with low socioeconomic status.	Unclear	Ever breastfed vs never breastfed. Breastfeeding <6months vs breastfeeding ≥6months (restricted to ever breastfed children)	At age 12-24 months, the Ages and Stages Questionnaire (ASQ) was used to assess neurodevelopment.	There was no evidence of association between ever breastfed and neurodevelopment. Breastfeeding for ≥6 months was associated with decreased odds of delayed neurodevelopment (specifically a measuring combining communication + problem-solving + personal-social)	Sex, size for gestational age, delivery gestational age, and weight-for-age at assessment	After adjustment, there was no evidence of association between ever breastfed and neurodevelopment. Breastfeeding for ≥6 months was no longer associated with neurodevelopment after adjustment
6	McDonald et al., 2013(6) **Setting**: Tanzania **Study design**: Prospective cohort study	To identify the maternal, socioeconomic, and child correlates of psychomotor and mental development in the first 18 months of life among Tanzanian infants born to HIV infected women.	311 children of mothers enrolled in a trial to examine the effect of multivitamin supplements on mother-to-child HIV-1 transmission and disease progression.	Information on breastfeeding practices was collected from mothers monthly for a minimum of 18 months from birth.	Duration of exclusive breastfeeding ≥3months vs <3months	At 6, 12, and 18 months of age, the Psychomotor Development Index (PDI) and Mental Development Index (MDI) of the Bayley Scales of Infant Development, 2nd edition (BSID-II)	There was no evidence of association between the duration of exclusive breastfeeding and PDI or MDI of the BSID-II.	Child age at cognitive assessment and parent study treatment regimen.	After adjustment, there was no evidence of association between duration of breastfeeding and PDI or MDI of the BSID-II.

	Study dates: unclear					were used to assess child development.			
7	Boivin et al., 2019(7) **Setting**: Uganda and Malawi **Study design**: Prospective cohort study **Study dates**: 2013-2014	To compare neurodevelopmental outcomes of antepartum and post-partum antiretroviral exposure in HIV-exposed uninfected (HEU) children with HIV-unexposed and uninfected (HUU) children aged 12, 24, 48, and 60 months.	861 children: 405 HEU children whose mothers received antiretroviral prophylaxis during pregnancy and triple antiretroviral treatment or infant nevirapine during breastfeeding and 456 HUU in Blantyre and Kampala.	Information on breastfeeding practices were collected at 12 and 24 months from primary caregivers.	Breastfeeding at 12months vs No breastfeeding at 12 months	At age 12, 24, and 48 months the Mullen Scales of Early Learning (MSEL) was administered. At 48 and 60 months, the Kaufman Assessment Battery for Children, second edition (KABC-II), was administered to assess child development.	In Uganda, breastfeeding was associated with lower MSEL cognitive score in HEU children but with higher scores in HUU children. There was no evidence of association between breastfeeding and the KABC II index in either group. In Malawi, there was no evidence of association between breastfeeding and MSEL score or KABC II index.	Not available	Not available
8	Ngoma et al., 2014(8) **Setting**: Zambia **Study design**: Cross-sectional study **Study dates**: 2011-2013	To determine whether there is a higher risk for cognitive or language delay among children exposed to ART in utero and through 1 year of breastfeeding, compared with children born to HIV-uninfected mothers	200 HEU children born to women enrolled in the Aluvia Study and living within a single district in Lusaka.	Unclear	Duration of breastfeeding in weeks	At age 15-36 months, the Capute Scales Clinical Adaptive Test/Clinical Linguistic and Auditory Milestone Scale (CAT/CLAMS) was used to assess child development.	There was no evidence of association between the duration of breastfeeding and odds of having a Capute Full-Scale Developmental Quotient (FSDQ) score less than 85.	Not available	Not available

9	Strehlau et al., 2020(9) **Setting**: South Africa **Study design**: Prospective cohort study **Study dates**: 2016-2018	To describe neurodevelopmental assessment results at 12 months of age from a cohort of HEU children from similar socioeconomic backgrounds.	70 HEU children with no congenital abnormalities or history of significant birth trauma delivered at the Rahima Moosa Mother and Child Hospital, Johannesburg.	Unclear	Exposure to breastmilk	At age 48 weeks the Bayley Scales of Infant and Toddler Development-3rd Edition (BSID-III) was used to assess child development.	There was no evidence of association between exposure to breastmilk and achieving a composite score of ≥110 using the Bayley Scales.	Not available	Not available
10	Eales et al., 2020(10) **Setting**: South Africa **Study design**: Cross-sectional study **Study dates**: Unclear	To determine the relationship between infant feeding characteristics and developmental outcomes	144 children attending a well-baby immunisation clinic in the Tshwane District, Gauteng province of South Africa.	Information on participants feeding history were collected from parent/caregiver's using a questionnaire.	unclear	At between 6-12 months, child development was assessed with the Parent's Evaluation of Developmental Status (PEDS) tools and Parent's Evaluation of Developmental Status – Developmental Milestones (PEDS-DM)	There was an association between ever breastfed, receipt of breastmilk, colostrum, and appropriate receptive language skills. Longer breastfeeding duration was associated with appropriate expressive language skills.	Not available	Not available
11	Prado et al., 2017(11) **Setting**: Ghana and Malawi **Study design**: Prospective cohort study	To identify the factors associated with 18-month language and motor development and the pathways through which these factors operate.	3083 children from two countries (Ghana and Malawi) who participated in the International Lipid-Based Nutrient Supplements (iLiNS) Project, which assigned participants to	Information on child feeding practices was collected using a (24hour and/or 7-day) dietary recall questionnaire administered to mothers/caregivers at multiple time points from age 1 to 5 months.	Exclusive Breastfeeding for the first 6 months	At age 18 months, the Kilifi Developmental Inventory (KDI) and a 100-word vocabulary checklist were used to assess motor and language development in Ghana and Malawi.	There was no evidence of association between exclusive breastfeeding and language or motor development in both Ghana and Malawi.	Not available	Not available

	Study dates: unclear		receive various doses and formulations of lipid-based nutrient supplements (LNS) or to control groups.			In Burkina Faso, the Developmental Milestones Checklist-II (DMC-II) was used.			
12	Donald et al., 2019(12) **Setting**: South Africa **Study design**: Prospective birth cohort **Study dates**: 2012-2015	To investigate the risk and protective factors of early childhood developmental outcomes and determine sex differences in the impact of such factors in a birth cohort.	734 children residing in Paarl, a low-socioeconomic community 60km away from Cape Town.	Information on infant feeding practices was collected from mothers at birth, 6, 10, and 14 weeks, and at 6 and 9 months.	Duration of exclusive breastfeeding in first 6 months	At age 24 months, the Bayley Scales of Infant and Toddler Development (Third Edition) (BSID-III) was used to assess Child development.	There was no evidence of association between exclusive breastfeeding and child development	Not available	Not available
13	Chaudhury et al., 2021(13) **Setting**: Botswana **Study design**: Prospective birth cohort **Study dates**: 2010-2012	To determine if HIV-exposed uninfected (HEU) children had worse neurodevelopmental outcomes at 24 months compared with HIV-unexposed uninfected (HUU) children.	905 children of HIV-infected and uninfected mothers residing in Gaborone and Mochudi in Botswana	Unclear	Ever breastfed vs never breastfed	At age 22-29 months, the Bayley Scales of Infant and Toddler Development, Third Edition (Bayley-III) and the Development Milestones Checklist (DMC) was used to assess child development.	There was no evidence of association between ever breastfed and child development	Not available	Not available
14	Ekholuenetal e et al., 2020(14) **Setting**: Benin **Study design**:	To examine the impact of stunting on cognitive development of children under-5 years in Benin.	6573 children born within the 5 years prior to the 2017-18 Benin Demographic and Health Survey survey was used with a sample of 6573 children included from	Information on infant breastfeeding practices was collected from mother's.	Duration of breastfeeding <12 months vs 12months or more.	Cognitive development was measured using a set of 8 items: (1) child can identify or name at least 10 letters of alphabet, (2) child can read at least four words, (3) child can identify or	There was no evidence of association between breastfeeding and cognitive development.	Not available	Not available

	Cross-sectional **Study dates**: 2017-18		BDHS—2017/ 18 survey.			name at least 10 numbers, (4) child can pick up small object with two fingers, (5) child follows simple directions, (6) child can perform task independently, (7) child gets along well with other children or adults, and (8) child does not get distracted easily.			
15	Namazzi et al., 2020(15) **Setting**: Uganda **Study design**: Prospective cohort study **Study dates**: May 2018 to May 2019	To determine the neurodevelopmental outcomes among preterm infants and identify any modifiable factors associated with neurodevelopmental disability.	398 children (187 born at term and 211 preterm) delivered at the Iganga hospital in Eastern Uganda between May and July 2018 and whose mothers were residents within a 20 km radius area of the hospital.	Unclear	Exclusive breastfeeding in first six months vs mixed feeding.	At age 6 to 8 months, the Malawi Developmental Assessment tool was used to assess neurodevelopment.	There was no evidence of association between exclusive breastfeeding and neurodevelop mental disability.	Not available	Not available
16	White et al., 2020(16) **Setting**: South Africa **Study design**: Prospective cohort study **Study dates**: 2016 to 2017	To determine the effects of HIV on growth and immune- and neurodevelopment in infants in early life	54 children (22 HIV uninfected and 32 HIV infected) whose mothers delivered at the Kalafong Provincial Tertiary Hospital in Pretoria between June and December 2016.	At 8 to 16 weeks follow-up after birth, mothers reported whether they were, or had ever, exclusively breastfed their infants. If the infants were currently receiving formula, and the age at which formula was introduced.	Exclusive breastfeeding at follow-up	At 8 to 16 weeks postpartum, the Guide for Monitoring Child Development (GMCD) was used to assess neurodevelopment.	There was no evidence of association between exclusive breastfeeding and infant neurodevelop ment.	Not available	Not available
17	Sirajee et al., 2021(17) **Setting**: Uganda	To determine the associations between prenatal and postnatal growth and subsequent	170 HIV-Exposed, Uninfected Infants delivered at the Jinja Regional Referral Hospital	Unclear	Exclusive breastfeeding at 6weeks, 12 and 18 months, and	At age 12 to 18 months, the Malawi Development Assessment Tool (12 and 18 months)	There was no evidence of association between exclusive	Not available	Not available

	Study design: Prospective cohort study **Study dates**: 2016 to 2018	neurodevelopment in Ugandan HEU infants	and Kambuga District Hospital in Uganda.		breastfed within 1 hour after birth.	and the Colour Object Association Test (18 months) were used to assess child development.	breastfeeding or breastfeeding within 1 hour, and infant neurodevelop ment.		

Table S 4: Estimates of the effect of breastfeeding on cognitive development in sub-Saharan Africa from studies not adjusted for maternal education or measures of socioeconomic status

Study 5: Madlala et al., 2020(5)*					-
	Gross + Fine motor		**Comm + ProbSolv + PerSocial**		-
	Unadjusted odds ratio (95% CI)	**Adjusted odds ratio (95% CI)**	**Unadjusted odds ratio (95% CI)**	**Adjusted odds ratio (95% CI)**	-
Breastfeeding					
Never	1.00	1.00	1.00	1.00	-
Ever	0.99 (0.46-2.14)	1.23 (0.49-3.09)	0.61 (0.25-1.49)	1.07 (0.35-3.26)	-
Breastfeeding duration					
< 6 months	1.00	-	1.00	-	-
≥ 6 months	0.72 (0.45-1.17)	-	0.50 (0.26-0.97)	-	-
Study 6: McDonald et al., 2013(6)†					
	Psychomotor Development Index (PDI)		**Mental Development Index (MDI)**		-
	Unadjusted mean difference (95% CI)	**Adjusted mean difference (95% CI)**	**Unadjusted mean difference (95% CI)**	**Adjusted mean difference (95% CI)**	-
Duration of exclusive breastfeeding (months)					
≥3	0.00	0.00	0.00	-	-
<3	2.32 (-0.54; 5.17)	1.04 (-1.50; 3.59)	1.16 (-0.92; 3.23)	-	-
Study 7: Boivin et al., 2019(7)					
	Uganda		**Malawi**		-
	MSEL composite cognitive score	**KABC mental processing index**	**MSEL composite cognitive score**	**KABC mental processing index**	-
	Mean difference (SE), p-value	**Mean difference (SE), p-value**	**Mean difference (SE), p-value**	**Mean difference (SE), p-value**	-
HIV-exposed and uninfected children (PROMISE 1077-BF)					
Breastfeeding at 12 months	- 4.38(1.54), 0.005	-2.16 (1.60), 0.18	-3.99 (2.64), 0.13	-7.39 (3.13), 0.02	-
No breastfeeding at 12 months	0.00	0.00	0.00	0.00	-
HIV-unexposed and uninfected children (controls)					
Breastfeeding at 12 months	5.96 (2.34), 0.0119	1.49 (2.76), 0.59	4.73 (9.32), 0.61	-6.82 (7.98), 0.39	-
No breastfeeding at 12 months	0.00	0.00	0.00	0.00	-
Study 8: Ngoma et al., 2014(8)					
	HIV-exposed uninfected	**Control**	**P-value**	**P-value for univariable regression**	-
	Mean (SD)	**Mean (SD)**			
Duration of breastfeeding (weeks)	50.0 (9.0)	71.6 (24.6)	<0.001	0.12	-
Study 9: Strehlau et al., 2020(9)					
No estimates reported					
Study 10: Eales et al., 2020(10)					
No estimates reported. Only p-values presented					

Study 11: Prado et al., 2017(11)					
	Ghana		**Malawi**		-
	Language	**Motor**	**Language**	**Motor**	-
	Mean difference (SE), p-value	**Mean difference (SE), p-value**	**Mean difference (SE), p-value**	**Mean difference (SE), p-value**	-
Exclusive Breastfeeding First 6 months	-0.03 (0.06), 0.65	-0.04 (0.07), 0.51	0.14 (0.23), 0.56	-0.07 (0.22), 0.74	-
Study 12: Donald et al., 2019(12)					
	Global developmental delay				-
	Total	**Girls**	**Boys**		-
	Unadjusted odds ratio (95% CI)	**Unadjusted odds ratio (95% CI)**	**Unadjusted odds ratio (95% CI)**		-
Exclusive Breastfeeding First 6 months	1.26 (0.69; 2.29)	0.89 (0.33; 2.42)	1.59 (0.74; 3.41)		-
Study 13: Chaudhury et al., 2021(13)					
	Cognitive	**Gross motor**	**Fine motor**	**Expressive language**	**Receptive language**
Ever vs never breastfed	1.48 (0.99 to 2.22)	0.98 (0.66 to 1.46)	0.94 (0.61 to 1.46)	0.74 (0.52 to 1.05)	0.97 (0.66 to 1.44)
Study 14: Ekholuenetale et al., 2020(14)					
	Optimal cognitve development	**sub-optimal cognitve development**	**P-value**	**-**	-
Duration of breastfeeding					
< 12 months	600 (62.8%)	356 (37.2%)	0.761	-	-
12 months +	512 (62.1%)	313 (37.9%)		-	-
Study 15: Namazzi et al., 2020(15)					
	Neurodevelopmental disability				
	Unadjusted odds ratio (95% CI)	**-**	**-**	**-**	**-**
Exclusive breastfeeding					
Yes	1.00	-	-	-	-
Mixed feeding	1.2 (0.63 - 2.49)	-	-	-	-
Study 16: White et al., 2020(16)					
	Neurodevelopmental outcomes				
	Unadjusted risk ratio (95% CI)	-	-	-	-
Exclusive breastfeeding at 12 weeks	1.67 (0.74, 3.77)	-	-	-	-
Exclusive breastfeeding at 12 weeks (infants exposed to food-insecure conditions)	0.41 (0.19, 0.87)	-	-	-	-
Study 17: Sirajee et al., 2021(17)					
	Below average developmental score	**Above average developmental score**	**P-value**	-	-
Breastfed within 1 hour	64 (79)	68 (76)	0.96	-	-
Exclusive breast feeding					
6 weeks	72 (89)	78 (88)	0.99	-	-
12 months	0	2 (2.2)	0.5	-	-

*Sex, size for gestational age, delivery gestational age, and weight-for-age at assessment
†Child age at cognitive assessment and parent study treatment regimen.

Table S 5: Summary of subgroup analysis on the association between breastfeeding and cognitive development in sub-Saharan Africa

Odds ratios (95% Confidence interval)

Study 1: Rochat et al., 2016(1)*

	Sequential		**Planning**		**Learning**		**Simultaneous**		**Riddle**	
	Unadjusted odds ratio (95% CI)	**Adjusted odds ratio (95% CI)**	**Unadjusted odds ratio (95% CI)**	**Adjusted odds ratio (95% CI)**	**Unadjusted odds ratio (95% CI)**	**Adjusted odds ratio (95% CI)**	**Unadjusted odds ratio (95% CI)**	**Adjusted odds ratio (95% CI)**	**Unadjusted odds ratio (95% CI)**	**Adjusted odds ratio (95% CI)**
Exclusive breastfeeding (Girls)										
0-1 months	-	1.00	-	1.00	-	1.00	-	1.00	-	1.00
2-5months	-	1.34 (0.6 - 2.8)	-	0.70 (0.3 - 1.5)	-	0.57 (0.3 - 1.2)	-	1.10 (0.5 - 2.3)	-	1.00 (0.5 - 2.2)
6 months	-	1.69 (0.8 - 3.5)	-	0.49 (0.2 - 1.0)	-	0.77 (0.4 - 1.6)	-	1.07 (0.5 - 2.2)	-	0.90 (0.4 - 2.0)
Exclusive breastfeeding (Boys)										
0-1 months	-	1.00	-	1.00	-	1.00	-	1.00	-	1.00
2-5months	-	1.24 (0.6 - 2.5)	-	1.08 (0.5 - 2.2)	-	2.07 (1.0 - 4.3)	-	1.52 (0.7 - 3.2)	-	1.12 (0.5 - 2.4)
6 months	-	0.90 (0.5 - 1.7)	-	1.13 (0.6 - 2.1)	-	1.87 (0.9 - 3.7)	-	1.59 (0.8 - 3.1)	-	1.58 (0.8 - 3.1)

Mean difference (95% Confidence interval)

Study 3: Tumwine et al., 2018(3)†

	General cognition		**Working memory**		**Attention**		**Inhibition**		**Cognitive flexibility**	
	Unadjusted mean difference (95% CI)	**Adjusted mean difference (95% CI)**	**Unadjusted mean difference (95% CI)**	**Adjusted mean difference (95% CI)**	**Unadjusted mean difference (95% CI)**	**Adjusted mean difference (95% CI)**	**Unadjusted mean difference (95% CI)**	**Adjusted mean difference (95% CI)**	**Unadjusted mean difference (95% CI)**	**Adjusted mean difference (95% CI)**
Exclusive breastfeeding at 12 weeks	0.07 (-0.11 - 0.24)	0.14 (-0.12 - 0.41)	0.04 (-0.15 - 0.23)	0.07 (-0.19 - 0.31)	0 (-0.13 - 0.13)	0.06 (-0.17 - 0.29)	0.03 (-0.15 - 0.20)	0.24 (0.02 - 0.46)	-0.02 (-0.15 - 0.09)	0.05 (-0.29 - 0.19)

* Adjusted for child sex, child age, mother's age at birth, maternal IQ, mother's education at birth, birthweight, birth order, mother's HIV status, residence, income provider, owning fridge, perception of wealth, crèche, HOME assessment score, maternal mental health, and parenting stress.

† Adjusted for socioeconomic status, electricity in-home, duration in kindergarten and cluster

Table S 6: Estimates from sex-stratified subgroup analysis of the association between breastfeeding and educational achievement in sub-Saharan Africa.

Study 2: Mitchell et al., 2015(19)*				
	Grade repetition			
	Unadjusted odds ratio (95% CI)	**Adjusted odds ratio (95% CI)**	**-**	**-**
Exclusive breastfeeding for six months (Girls; n = 429)				
0-1 month	1.00	1.00	-	-
2-5 months	0.90 (0.44; 1.82)	0.98 (0.43; 2.25)	-	-
6 months	0.75 (0.39; 1.44)	0.76 (0.33; 1.74)	-	-
Exclusive breastfeeding for six months (Boys; n = 413)				
0-1 month	1.00	1.00	-	-
2-5 months	0.76 (0.39; 1.48)	0.67 (0.33; 1.36)	-	-
6 months	0.72 (0.39; 1.32)	0.56 (0.29; 1.10)	-	-

* Adjusted for maternal age, maternal education, residence, main income, and fridge ownership (all measured at birth) and child age, child sex, birth order, birth weight, HIV exposure

2.4 References for supplementary materials

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CHAPTER 3

Identifying data sources

CHAPTER 3: IDENTIFYING DATA SOURCES

3.1 Introduction

In this chapter, I discuss the data sources for this thesis and recount my experience accessing these datasets, highlighting the challenges I encountered during the process and how I adapted the study to accommodate unexpected disruptions.

3.2 Data sources and eligibility

In sub-Saharan Africa, a common source of prospective, longitudinal data is Health and Demographic Surveillance Systems (HDSS). HDSS sites are strategically located in both rural and urban areas of low- and middle-income countries to track defined populations over time (1). The process usually starts with a census and continues with regular monitoring and data collection, at least annually, to update the information of household members.

To identify suitable data for this thesis, the list of HDSS sites in sub-Saharan Africa was obtained through a comprehensive search of the INDEPTH (International Network of Field Sites with Continuous Demographic Evaluation of Populations and Their Health in Developing Countries) website (2) and other published works about HDSS sites in Africa (1,3–5). I also searched the International Journal of Epidemiology, where most HDSS published their profiles, for the profiles of surveillance sites in SSA. The HDSS profiles identified in the journal and information gathered from the INDEPTH Data Repository and individual HDSS websites were reviewed to identify sites that collected data on infant feeding practices, including breastfeeding, age of introduction of other foods or liquids, weaning age, and the duration of any breastfeeding.

I also identified additional potential longitudinal data sources to contact through my systematic review (Chapter Two) of the association of breastfeeding with cognitive development and educational achievement in sub-Saharan Africa. Additionally, I contacted nutrition and maternal and child health researchers at the London School of Hygiene and Tropical Medicine (LSHTM) to source data for this thesis.

The following inclusion criteria were used to determine the potential data sources to approach: (1) the source has at least one measure of school grade level beyond the official school entry age for the country or an indicator of academic performance; and (2) the source has information on breastfeeding practices sufficient to determine either the duration of exclusive breastfeeding, the duration of any breastfeeding, the duration of predominant breastfeeding, or whether a child was ever breastfed.

Nineteen potentially suitable data sources were identified (Table 3.1) and approached for data access. I also explored the Demographic and Health Surveys and Multiple Indicator Cluster Surveys in sub-Saharan Africa to determine their suitability for this analysis.

Table 3.1 Potential data sources identified

	Data source	Country
1	Young Lives (YL) longitudinal study	Ethiopia
2	Performance Monitoring for Action Ethiopia (PMA-ET) Cohort 1	Ethiopia
3	Performance Monitoring and Accountability 2020 Maternal and Newborn Health (PMA-MNH) survey	Ethiopia
4	Project TOVI and EXPLORE	Benin
5	Navrongo HDSS	Ghana
6	Kintampo HDSS	Ghana
7	Dodowa HDSS	Ghana
8	African Population and Health Research Centre (APHRC) HDSS	Kenya
9	Karonga HDSS	Malawi
10	Promoting Maternal and Infant Survival Everywhere Breastfeeding (PROMISE-BF) study	Malawi and Uganda
11	Manhiça HDSS	Mozambique
12	Agincourt HDSS	South Africa
13	Africa Health Research Institute (AHRI) HDSS	South Africa
14	Farafenni HDSS	The Gambia
15	Mbita HDSS	Kenya
16	Mediational intervention for sensitising caregivers (MISC) study	Uganda
17	Kyamulibwa HDSS (General Population Cohort)	Uganda
18	Chilenje Infant Growth, Nutrition and Infection Study (CIGNIS) trial	Zambia
19	Breastfeeding and Postpartum Health (BFPH) study	Zambia

3.3 Challenges and obstacles to accessing data.

I contacted the custodians or centre directors of each data source via email to discuss the aim of the study and the data requirement. Accessing the datasets presented various challenges. While some sources provided the requested datasets within a few months, others required navigating complex processes and negotiations, resulting in delays and, in some cases, lack of access to the required data. Table 3.2 shows the duration of contact with each data source, the number of follow-ups and reminders, and the outcome of the data request.

One of the primary obstacles I encountered was unresponsiveness from certain sources despite multiple follow-up emails and reminders at reasonable intervals. For example, in October 2021, I contacted the centre director of one of the HDSS sites to request data access. After numerous reminders from November 2021 to January 2022, I was finally asked to discuss my request with the data manager. It took more follow-up emails from January to April 2022 to get a response from the data manager on the availability of the requested variables. In May 2022, I met with the data manager via Zoom to discuss my request, and he assured me that they had the data and were willing to share it for my project. However, numerous follow-up emails and reminders after the meeting to access the data went unanswered and access to the data was never granted. I faced similar issues with other HDSS sites I contacted for data.

In certain cases, data access was delayed because the research centre was unsure if they had the data I requested. In one instance, discussions began in February 2021, and the data were finally shared in April 2023 after I provided information from previous studies conducted at the centre to prove that they had collected the data and to assist the data manager in identifying the survey rounds in which the data were collected. However, at some HDSS sites, the data I requested were from studies nested in the HDSS. In one such case, my request for educational attainment data from the core HDSS was approved, but custodians of a nested breastfeeding study denied my request, citing their intention to analyse the data themselves.

For some sources, administrative procedures and complex approval processes hindered data access. In October 2021, the head of one HDSS confirmed they had the data I requested but needed the centre director's approval to share them. Despite follow-up emails from November 2021 to February 2022, the approval to share the variables I requested was still pending. In response to a follow-up in April 2022, I was informed that my request had been denied due to an ongoing review of the site's data-sharing policy. In January 2023, I attempted accessing the data again, this time through a third party, but it was unsuccessful.

The COVID-19 pandemic added to my data access challenges. I contacted most principal investigators and HDSS directors at the height of the pandemic, when many worked from home and had limited access to the information required to answer my requests and queries. Data collection was halted at most HDSS sites, and the ethics and scientific committees in charge of approving requests at some HDSS were not meeting. In the case of the Benin data, information on breastfeeding had already been collected, but COVID-19 restrictions delayed school performance data collection and prevented timely access to the data.

For some data sources, the process of data acquisition was less complex. Data from the Young Lives (YL) longitudinal study in Ethiopia, the Performance Monitoring for Action Ethiopia (PMA-ET) Cohort 1, and the Performance Monitoring and Accountability 2020 Maternal and Newborn Health (PMA-MNH) survey were publicly accessible and were downloaded after submitting a request to the data curators. Data from the Chilenje Infant Growth, Nutrition and Infection study (CIGNIS) and the Breastfeeding and Postpartum Health (BFPH) study were obtained from the principal investigator in the early months of my PhD. Data from the Karonga HDSS was obtained within four months of my request to the director.

Table 3.2 Duration of contact with data source, number of follow-up emails and reminders, and outcome of the data request

First contact	Last contact	Duration of contact	Number of follow-up emails and reminders	Outcome
08-02-2021	08-02-2021	<1 month	■	Successful
15-03-2021	15-03-2021	<1 month	●	Unsuccessful
12-08-2021	18-08-2021	<1 month	■	Successful
20-11-2021	25-11-2021	<1 month	■	Successful
21-09-2021	11-10-2021	<1 month	●●	Unsuccessful
19-10-2021	21-12-2021	1-3 months	●●	Unsuccessful
15-03-2021	20-04-2021	1-3 months	■■■	Successful
22-09-2021	30-09-2021	<1 month	●●●	Unsuccessful
20-08-2021	06-10-2021	1-3 months	■■■■	Successful
20-08-2021	06-09-2021	<1 month	■■■■	Successful
20-08-2021	06-09-2021	<1 month	■■■■	Successful
21-09-2021	24-02-2022	4-11 months	●●●●●●	Unsuccessful
29-08-2022	08-12-2022	1-3 months	●●●●●●●	Unsuccessful
11-10-2021	06-04-2022	4-11 months	●●●●●●●●	Unsuccessful
26-04-2021	12-07-2023	≥12 months	●●●●●●●●●●	Unsuccessful
18-11-2021	23-09-2022	4-11 months	●●●●●●●●●●●●	Unsuccessful
22-09-2021	24-05-2022	4-11 months	●●●●●●●●●●●●●●●●●●	Unsuccessful
11-11-2021	19-07-2022	4-11 months	●●●●●●●●●●●●●●●●●●	Unsuccessful
24-02-2021	14-04-2023	≥12 months	■■■■■■■■■■■■■■■■■■■■■■■	Successful
Duration of contact	<1 month	1-3 months	4-11 months	≥12 months
Follow-ups	Successful outcome (■)		Unsuccessful outcome (●)	

3.4 Suitability of acquired datasets.

Of the nineteen data sources I contacted, nine (Young Lives, Kyamulibwa HDSS, Karonga HDSS, CIGNIS, BFPH, Farafenni HDSS, APHRC, PMA-ET, and PMA-MNH) granted access to their data. A flowchart illustrating the journey to accessing these datasets is shown in Figure 3.1. However, not all of the datasets I obtained were suitable for investigating all three specific objectives of this thesis.

Of the three datasets I received from APHRC, one had breastfeeding information but lacked data on education, while the other had schooling achievement data but no breastfeeding information. I attempted to link these two datasets, but it was unsuccessful because the participants in each dataset were different, even though both were provided from the same HDSS site. The third dataset had data on migration in the HDSS but no data relevant to my analysis. The three datasets also lacked information on maternal and family socioeconomic indicators.

The Young Lives study had information on education but lacked sufficient breastfeeding information. The study enrolled 6–17-month-olds and only collected data on breastfeeding duration in the first round of the survey. However, because 93.4% of the participants were still breastfeeding in the first round, determining when most of the children stopped breastfeeding was impossible, and information to determine exclusive breastfeeding was not collected.

Similarly, the Farafenni HDSS data only had information to determine the duration of breastfeeding for 870 children, with most breastfed for either one (n=470) or two (n=384) years. However, only 182 children had both breastfeeding duration and educational attainment data, with little variation in breastfeeding. Also, the information on educational attainment was mostly limited to early primary school. Despite discussing the issue with the data manager, no additional information was available.

In the BFPH study in Zambia, exclusive breastfeeding data were available for 374 children, but only 64 children successfully followed at ages 9 to 12 had data on education. The CIGNIS study in Zambia also had limited educational data, despite suitable data on breastfeeding duration. The information on children's grade level was available only up to grade five, with 90.2% in grades one to three and two (0.6%) children in grade five. Only one child was over-age for their grade based on UNESCO's (6) classification. I considered pooling the BFPH and CIGNIS data since both were conducted in Chilenje, Zambia, but this was hindered by the fact that BFPH only collected data on exclusive breastfeeding in the first four months after birth, while CIGNIS collected information on only the duration of breastfeeding. Also, because nearly all the children in BFPH and CIGNIS were breastfed, it was not feasible to analyse the effect of ever breastfeeding on educational attainment. These datasets, therefore, contributed to the analyses related to objective two but were unsuitable to investigate objective three of this thesis.

The data from the Karonga HDSS and Kyamulibwa HDSS (General Population Cohort) had suitable information on breastfeeding and educational attainment. They contributed to analyses related to both objectives two and three.

I examined the Demographic and Health Surveys (DHS) and Multiple Indicator Cluster Surveys (MICS) in sub-Saharan African countries for their suitability for investigating the association between breastfeeding and educational outcomes. I found that while the surveys collect data on educational outcomes for school-going children, information on breastfeeding for these children is not collected. Breastfeeding information in the surveys is only available for children younger than two years. Although some countries collect data on early childhood development for children under five years old in sub-Saharan Africa, this primarily pertains to those aged four to five years, for whom breastfeeding information is not included in the surveys.

Data from the 2003-2014 Ghana DHS and the 2006-2017 Ghana MICS were analysed to understand the socioeconomic and demographic determinants of age-appropriate breastfeeding in Ghana. This analysis was conducted in anticipation of obtaining longitudinal data from at least one of the three research centres I contacted in Ghana.

Datasets with suitable data only on breastfeeding were analysed to understand the socioeconomic patterning of breastfeeding (objective Two), while datasets with suitable data on breastfeeding and education were used to investigate the association between breastfeeding and educational attainment (objective Three).

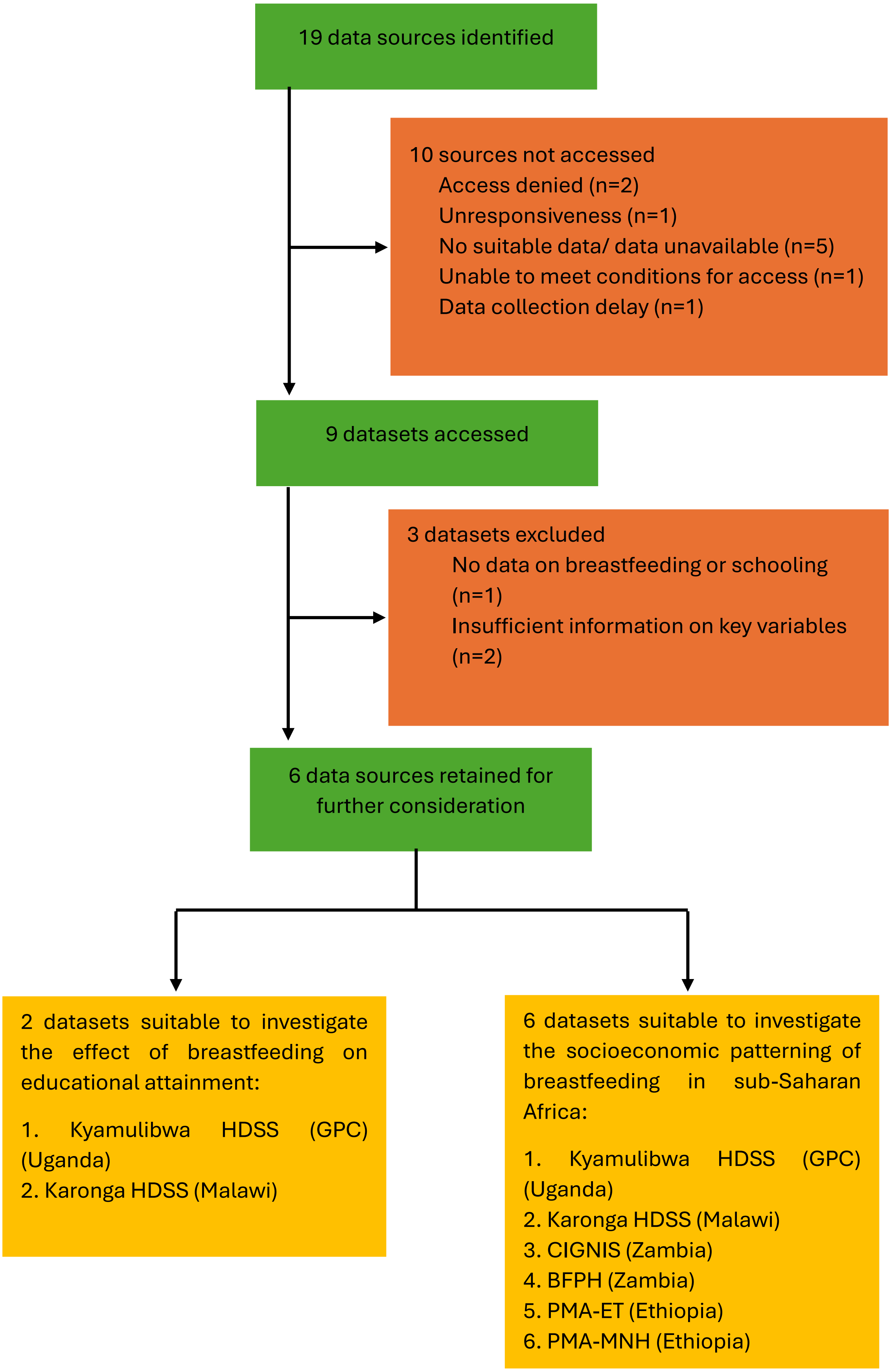

Figure 3.1 Flow chart of access to data sources and data suitability

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CHAPTER 4

Paper 2

Time trends in the prevalence and determinants of age-appropriate breastfeeding among children aged 0-23 months in Ghana: a pooled analysis of population-based surveys, 2003 to 2017

CHAPTER 4: PAPER 2 - TIME TRENDS IN THE PREVALENCE AND DETERMINANTS OF AGE-APPROPRIATE BREASTFEEDING AMONG CHILDREN AGED 0-23 MONTHS IN GHANA: A POOLED ANALYSIS OF POPULATION-BASED SURVEYS, 2003 TO 2017

4.1 Introduction

This chapter uses data from the 2003 to 2014 Ghana Demographic and Health Surveys (DHS) and the 2006 to 2017 Ghana Multiple Indicator Cluster Surveys (MICS) to investigate objective 2a. The analysis had a twofold purpose: firstly, to understand how paternal and maternal sociodemographic characteristics, child characteristics, obstetric factors, and healthcare factors influence appropriate breastfeeding practices among children ages 0-5 months (exclusive breastfeeding), 6-11 months, and 12-23 months. Secondly, the insights from this analysis were intended to inform and shape modelling strategies and frameworks on the association between breastfeeding and educational outcomes in Ghana or similar contexts. Unfortunately, none of the data sources I approached in Ghana approved my request to share their data. The main paper is presented in section 4.2 and supplementary materials for the paper are included in section 4.3.

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Thesis Title	Effects of breastfeeding duration on educational attainment of children and adolescents in sub-Saharan Africa: A multisite analysis of longitudinal data		
Primary Supervisor	Laura Oakley		

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For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	I requested the data from the Demographic and Health Survey program and UNICEF's Multiple Indicator Cluster Surveys, conducted the data management, planned the data analysis, and conducted the data analysis. I conducted the literature search for the study and prepared the manuscript for submission to the journal. My supervisors provided critical input on interpreting, discussing, and presenting the results.

SECTION E

Student Signature	
Date	8th April 2024

Supervisor Signature	
Date	9th April 2024

4.2 Published paper

Open access Original research

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Time trends in the prevalence and determinants of age-appropriate breast feeding among children aged 0–23 months in Ghana: a pooled analysis of population-based surveys, 2003–2017

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ABSTRACT

Objective We assessed the sociodemographic and maternal–child characteristics associated with age-appropriate breast feeding among children aged 0–23 months in Ghana.

Methods We pooled data on 12 743 children aged 0–23 months from three Demographic and Health Surveys (2003, 2008 and 2014) and three Multiple Indicator Cluster Surveys (2006, 2011 and 2017–2018). The outcome was age-appropriate breast feeding from birth to 23 months, with age-appropriate breast feeding defined as exclusive breast feeding at 0–5 months (ie, at less than 6 months) and breastfeeding alongside appropriate complementary feeding at 6–23 months. Potential determinants were maternal–child sociodemographic, obstetric and healthcare factors. Logistic regression was used to determine the factors associated with age-appropriate breast feeding. We accounted for the complex sampling design of the cross-sectional surveys in the analysis.

Results Most children aged 0–3 months were exclusively breastfed. Among children aged 4–5 months, the most common feeding pattern was breastfeeding alongside water and/or solid foods. Exclusive breastfeeding prevalence in children less than 6 months peaked in 2008 at 62.8% and declined to 42.9% in 2017. For 6–11 month olds, the percentage experiencing age-appropriate breast feeding has been stable over the last four surveys, ranging from 79.3% in 2008 to 81.1% in 2017. Age-appropriate breast feeding in 12–23 month olds declined from 77.8% in 2003 to 61.2% in 2017. Rural residence, younger age, non-facility births and multiple births were associated with decreased odds of exclusively breast feeding. For 6–11 month olds, age-appropriate breast feeding was less likely if the woman did not receive postnatal care. Younger age, being unmarried, high income, wanting a child later and earlier birth order were associated with decreased odds of age-appropriate breast feeding in 12–23 month olds.

Conclusion Ghanaian children are now less likely to be exclusively breastfed than they were a decade ago. To succeed, breastfeeding promotion programmes should adopt approaches that address the predictors of suboptimal breast feeding at each age, as identified in this study.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ This study used a series of large nationally representative samples of woman–child dyads from rural and urban areas of Ghana.
- ⇒ Information was available on a wide range of sociodemographic and maternal–child characteristics.
- ⇒ WHO recommended definitions and cut-offs were used to categorise the age-appropriate breastfeeding indicators.
- ⇒ The study's main limitation is the reliance on maternal recall of breastfeeding practices to measure age-appropriate breast feeding.

BACKGROUND

Exclusive breast feeding for the first 6 months of life and continued breast feeding with appropriate complementary foods from 6 months to at least 2 years is recommended by the WHO and UNICEF as the best approach to feeding infants aged 0–23 months.[1 2] Breast feeding, particularly exclusive breast feeding for the first 6 months, confers several benefits for the infant.[3] For instance, breastmilk contains antibodies and immune cells that confer passive immunity on the suckling infant and play a critical role in the immune tolerance of the infant in early life.[4 5] Despite the proven benefits of breast feeding, women in Ghana have reported introducing other foods and stopping breast feeding earlier than recommended.[6]

Historically, Ghana's exclusive breastfeeding rate has been low (2.2% in 1988, 7.4% in 1993, 31.5% in 1998),[7] though it increased to a peak of 63% in 2008.[8] Recent reports from the 2017–2018 Ghana Multiple Indicator Cluster Survey (MICS) showed that the rate has since declined to 42%.[9] The trend over the last decade demonstrates that unless effective efforts are taken to reverse the downward trend in the exclusive breastfeeding rate, Ghana is on track to miss the WHO's 2025 target of exclusively breast feeding 50% of newborns during their first 6 months of life.[10]

A range of factors, including sociodemographic (maternal education, maternal age, urban–rural residence, marital status, maternal employment and income level) and obstetric characteristics (mode of delivery, place of delivery, parity, antenatal visits, postnatal care and preterm birth) of mothers and their immediate family influence breastfeeding decisions and practices in Africa and other low-income settings.[11–15] However, the range of determinants and the magnitude of the effect vary both between countries and within countries between different regions. For instance, in Ghana, no association was found between maternal education and exclusive breast feeding in a population-based study in 2013.[16] However, women with tertiary education were less likely than those with no education to practice exclusive breast feeding in a study in child welfare clinics in 2018.[17] Adolescent women were less likely than older women to practise exclusive breast feeding in studies in 2018 and 2020,[17 18] though no evidence of association was found with age in a study in 2013.[16]

Understanding the factors that hinder age-appropriate breast feeding could help inform the design of interventions to improve the number of age-appropriately breastfed children and reverse the current declines in the duration of breast feeding in Ghana. Using data from six nationally representative population-based surveys, we investigated the sociodemographic and maternal obstetric factors and child characteristics associated with age-appropriate breast feeding among Ghanaian children aged 0–23 months.

METHODS

Data sources

Our study is a secondary analysis of data from the Demographic and Health Survey (DHS) and the Multiple Indicator Cluster Survey (MICS). The three rounds of DHS data included in this analysis were collected in 2003, 2008 and 2014 while the MICS data were collected in 2006, 2011 and 2017–2018. Both DHS and MICS are nationally representative, repeated cross-sectional, population-based household surveys that use a comparable methodology to collect, analyse and disseminate information on population health and demographic trends of women, children and men of selected households using a multistage stratified cluster sampling approach. For the surveys analysed in this study, Ghana's former 10 administrative regions were stratified into urban and rural areas and further divided into clusters (enumeration areas) using the probability proportional to size method based on the number of households. Households in each cluster were listed, and systematic methods were used to select a fixed number of households from each cluster for interviews. Both DHS and MICS oversampled rural enumeration areas in Ghana's middle and northern regions.

MICS and DHS work closely together and use interagency processes to ensure that survey instruments are as comparable as possible.[19] In addition, both surveys were carried out by the Ghana Statistical Services, in collaboration with other public institutions and ministries, using the same sampling frame, similar procedures and processes, permitting the pooling of data across the surveys. A detailed description of the sample design, questionnaires used, and methodology of the surveys is published elsewhere.[9 20–24]

Study population

This study included only children born in the 2 years before the survey who were alive and living with their mothers at the time of the survey. Only the last-born child was included in the analysis for women who delivered more than one child in the 2 years preceding the survey. Children older than 23 months were excluded.

Definitions of indicators

Outcome variable

In both DHS and MICS, women were asked about their children's feeding practices 24 hours preceding the interview. Women were asked if they ever breastfed the child, were still breastfeeding the child, how long after birth they first put the child to the breast and if the child was given anything to drink other than breastmilk in the first 3 days after delivery. In addition, the surveys asked women about (1) other types of milk (powder/tinned milk, formula or fresh milk), (2) plain water, (3) non-milk liquids (juice drinks, tea, flour water (zomkom) or coffee) and (4) solid, semisolid or soft foods the child had the day or night before the interview. This information was used together with the child's current age to estimate the child's current breastfeeding status.

For the analysis reported here, the outcome of interest was age-appropriate breast feeding, defined as the feeding of infants 0–5 months (ie, less than 6 months old) with only breastmilk and no other liquids or solids except for oral rehydration salt, drops and syrups (vitamins, mineral supplements or medicines) in the 24 hours preceding the interview; and the feeding of children aged 6–23 months with breastmilk as well as solid, semisolid or soft foods in the 24 hours preceding the interview. These indicators are recommended for use with a cross-sectional sample by the WHO.[25]

Potential determinants

We examined three groups of explanatory variables for the determinants of age-appropriate breast feeding. The variables were chosen after a careful evaluation of relevant studies, including systematic reviews.[26–29]

Maternal sociodemographic factors

The maternal sociodemographic factors assessed for association with age-appropriate breast feeding were age, marital status, place of residence (urban vs rural),

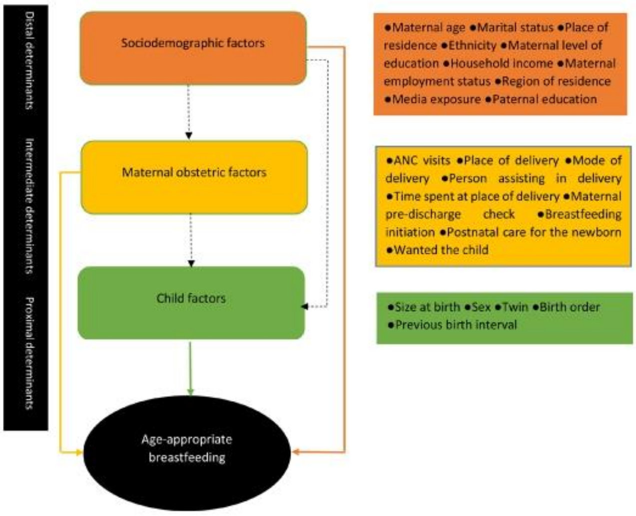

Figure 1 Conceptual framework of the determinants of age-appropriate breast feeding based on the hierarchical approach proposed by Victora *et al*.[32] ANC, antenatal care.

ethnicity, level of education, household income, employment, region, media exposure and paternal education. Media exposure was unavailable for MICS 2006, and employment was only available in the three DHSs.

Maternal obstetric and healthcare factors

The maternal obstetric and healthcare factors assessed were the number of antenatal visits, place of delivery, mode of delivery, person assisting in delivery, time spent at place of delivery, maternal pre-discharge check (this was asked to women who delivered in a health facility), breastfeeding initiation, postnatal care and wantedness of the child (wanted then, wanted later and wanted no more). For the 2003 DHS and 2006 MICS, data on 'postnatal care for the newborn' were not collected. 'Time spent at place of delivery' and 'maternal pre-discharge check' were unavailable for MICS 2006.

Child characteristics

The child characteristics assessed were sex, multiple births, maternal report of child size at birth, birth order and previous birth interval.

Conceptual framework

To guide the analysis, we developed a conceptual framework. The UNICEF conceptual framework on child undernutrition[30 31] was considered, but Victora *et al*,[32] hierarchical framework was better suited to the study's objectives since evidence suggests that breastfeeding determinants are hierarchical,[26–28] extending from distal to proximate determinants. Furthermore, the hierarchical framework structure allows for the systematic adjustment for any distal influence on proximal determinants while avoiding mediating factor adjustment. On the other hand, the UNICEF framework is cyclical, making it unsuitable for guiding the analysis and interpretation of our study. As a result, the hierarchical conceptual framework was used to clarify the relationship among the explanatory factors, their relationship with the outcome of interest and to demonstrate how the hierarchical interrelationships between the factors were controlled in the analysis (figure 1).

Data analysis

Stata V.16 (Stata Corp) was used. The six surveys were pooled to improve power and examine any time trends. Clustering, stratification and survey weight variables from the DHS and MICS were applied.[8 9 22 33–35] As per DHS guidelines, we de-normalised the weights to account for pooling the data from separate surveys.[36]

As age-appropriate breast feeding varies depending on the child's age, we analysed the data in three groups according to the child's age at the time of the survey: 0–5 months, 6–11 months and 12–23 months. Anything other than exclusive breast feeding is classified as inappropriate in the youngest group. Inappropriate breast feeding in the older age groups can result from the delayed introduction of semisolid and solid foods or stopping breast feeding too early, the latter of which is more common with increasing age.

Multivariable logistic regression was used to examine the independent association of the potential determinants with exclusive breast feeding 0–5 months and age-appropriate breast feeding at 6–11 and 12–23 months. All potential determinants were included in the multivariable model at each level, but only determinants associated with the outcomes at $p<0.10$ were retained as confounders for the more proximate levels. In line with the hierarchical approach, sociodemographic factors were first introduced into the multivariable model and factors associated with the outcome were retained in a core model. Then, maternal obstetric factors were added one at a time to the retained sociodemographic factors (sociodemographic factors+maternal obstetric factors), and we kept maternal obstetric factors that showed evidence of association with the outcomes in the adjusted model. Finally, child factors were added one at a time to the retained sociodemographic and maternal obstetric factors (sociodemographic factors+maternal obstetric factors+child factors), and we retained only child factors that were independently associated with the outcomes.

The main multivariable model omitted potential determinants that were not available in all the surveys. Estimates for the omitted variables were produced from a separate model using the hierarchical modelling approach described. We adjusted all of the models for the years in which the surveys were conducted and separately examined the association between survey year and odds of age-appropriate breast feeding, having adjusted for the sociodemographic, maternal and child factors associated with age-appropriate breast feeding.

Sensitivity analyses were conducted using the same analytical approach to explore the major types of age-inappropriate breast feeding. In children aged 6–11 months, we examined the introduction of solid food by

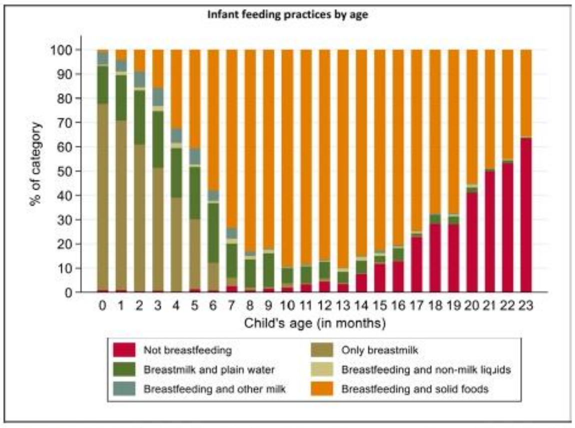

Figure 2 Distribution of infant feeding practices by child's age.

excluding the (few) children who were not breastfed. The second analysis examined continued breast feeding in children aged 12–23 months by excluding the (few) children who did not receive solid food.

Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research

RESULTS

Trends in prevalence of age-appropriate breast feeding, 2003–2017

All the surveys had response rates higher than 90%, and we included a total of 12 743 (unweighted) children aged 0–23 months in the analysis (online supplemental material table 1), with 3329 children aged 0–5 months, 3241 aged 6–11 months and 6173 aged 12–23 months. Overall, the pooled data showed that 51.6% of infants aged 0-5 months were exclusively breastfed, and 77.9% and 69.4% of women reported feeding infants breastmilk as well as solid, semisolid or soft foods at ages 6–11 months and 12–23 months, respectively. Figure 2 indicates that while some infants aged less than 1 month were given water (15.7%) or other forms of milk (5.1%) alongside breastmilk, the majority of infants aged 0–3 months were exclusively breastfed. Beyond age 3 months, most children were given solid foods or water, alongside breast feeding. The percentage of children receiving breastmilk and solid food increased until it peaked at 10–13 months. Cessation of breast feeding gradually increased from the first month after birth, and more than half of the children aged 22 months were not fed any breastmilk.

As illustrated in figure 3A, all surveys showed a similar pattern in age-appropriate breast feeding from birth to 23 months. After the initial high rate of exclusive breast feeding at birth in all the surveys, there was a rapid decline in exclusive breast feeding to age 5 months. The percentage of children age-appropriately breastfed (breast feeding with solid foods) gradually increased after this until around 12 months, after which it steadily declined.

The prevalence of exclusive breast feeding in children younger than 6 months peaked in 2008 and then declined (figure 3B). In the 6–11 month age group, the prevalence of age-appropriate breast feeding rose initially and has remained steady throughout the last four surveys, whereas the prevalence of age-appropriate breast feeding in children aged 12–23 months has declined.

Determinants of age-appropriate breast feeding in children aged 0–23 months

Table 1 summarises the factors associated with exclusive breast feeding in children aged 0–5 months, with the results for all potential determinants provided in online supplemental material 2 (online supplemental material tables 2–4). Maternal age, place of residence, ethnicity, region, place of delivery and multiple births were the factors associated with exclusive breast feeding in children

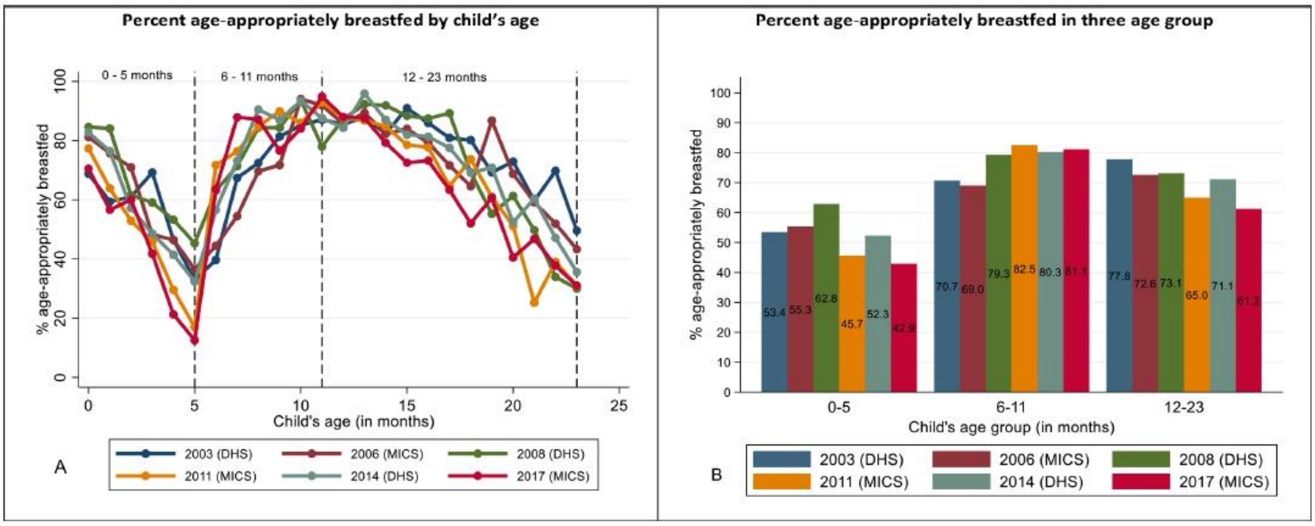

Figure 3 Percent age-appropriately breastfed by (A) child's age (in months) and (B) by child's age group. DHS, Demographic and Health Survey; MICS, Multiple Indicator Cluster Survey.

Table 1 Summary of pooled unadjusted and adjusted estimates of the factors associated with exclusive breast feeding in children aged 0–5 months in Ghana, 2003–2017

	Number exclusively breastfed*	% exclusively breastfed†	Unadjusted OR (95% CI)	Wald test P value	Adjusted OR (95% CI)	Adjusted Wald test P value
Sociodemographic factors						
Maternal age (in years)‡						
<20	123	40.6	0.62 (0.46 to 0.84)	0.006	0.62 (0.45 to 0.85)	0.01
20–34	1264	52.5	1.00		1.00	
35–49	429	53.2	1.03 (0.82 to 1.29)		1.01 (0.80 to 1.28)	
Place of residence‡						
Urban	608	54.8	1.24 (1.02 to 1.50)	0.03	1.54 (1.25 to 1.91)	<0.001
Rural	1220	49.5	1.00		1.00	
Ethnicity‡						
Akan	446	41.7	0.48 (0.38 to 0.61)	<0.001	0.69 (0.47 to 1.00)	0.001
Ga/dangme	87	45.6	0.56 (0.38 to 0.84)		0.76 (0.45 to 1.27)	
Ewe	215	63.2	1.15 (0.83 to 1.60)		1.49 (0.93 to 2.39)	
Mole-dagomba	622	59.9	1.00		1.00	
Grusi	106	60.1	1.01 (0.57 to 1.77)		1.02 (0.59 to 1.76)	
Gurma	137	64.0	1.19 (0.78 to 1.82)		1.46 (0.91 to 2.32)	
Other	214	60.2	1.01 (0.72 to 1.42)		1.22 (0.82 to 1.81)	
Region (ordered by poverty levels)‡						
Upper West region	281	72.7	1.69 (1.10 to 2.61)	<0.001	2.02 (1.26 to 3.25)	
Northern region	344	61.1	1.00		1.00	
Upper East region	238	68.9	1.41 (0.98 to 2.03)		1.61 (1.08 to 2.40)	
Volta region	152	61.4	1.01 (0.69 to 1.49)		0.86 (0.52 to 1.42)	
Brong Ahafo region	166	61.7	1.03 (0.70 to 1.50)		1.30 (0.83 to 2.05)	
Western region	112	38.7	0.40 (0.28 to 0.57)		0.59 (0.38 to 0.91)	<0.001
Central region	127	42.2	0.46 (0.33 to 0.65)		0.69 (0.44 to 1.09)	
Eastern region	130	51.6	0.68 (0.47 to 0.97)		0.92 (0.58 to 1.45)	
Ashanti region	140	39.1	0.41 (0.29 to 0.57)		0.57 (0.37 to 0.89)	
Greater Accra region	138	52.2	0.70 (0.48 to 1.02)		0.72 (0.44 to 1.17)	
Maternal/healthcare factors						
Place of delivery§						
Elsewhere	660	48.9	0.84 (0.70 to 1.01)	0.06	0.68 (0.54 to 0.84)	0.001
Health facility	1149	53.3	1.00		1.00	
Child factors						
Multiple birth¶						
Yes	40	41.7	0.68 (0.36 to 1.28)	0.24	0.56 (0.31 to 1.02)	0.06
No	1544	51.2	1.00		1.00	

Region is ordered based on the 2017 regional poverty incidence from poorest to least poor.[42]
*Unweighted count.
†Weighted percentage.
‡Adjusted for maternal age, marital status, place of residence, ethnicity, maternal educational level, household income, region, father's education and survey year (number of unweighted observations=3306).
§Adjusted for maternal age, place of residence, ethnicity, region, survey year, number of antenatal visits, place of delivery, person assisting in delivery, breastfeeding initiation and wanted last child (number of unweighted observations=3290).
¶Adjusted for maternal age, place of residence, ethnicity, region, survey year, place of delivery, sex of child, birth order, child size at birth, multiple births and previous birth interval (number of unweighted observations=2651).

younger than 6months. Adolescent women were less likely to exclusively breastfeed than older women, and those in urban areas were more likely to breastfeed exclusively than those in rural areas. Births outside healthcare facilities were associated with lower odds of exclusive breast feeding than births in healthcare facilities. Women who had multiple births were less likely to breastfeed exclusively than those with singleton births. The odds of exclusive breast feeding in the first 6months after birth varied by ethnicity and region.

A summary of the determinants of age-appropriate breast feeding at 6–11 months is presented in table 2, with the crude and adjusted estimates for all potential determinants provided in online supplemental material 2 (online supplemental material tables 5–7). Postnatal care, ethnicity and region were the factors associated with age-appropriate breast feeding at 6–11 months. Women who did not receive postnatal care were less likely to age-appropriately breastfeed at 6–11 months compared with those who received postnatal care. The odds of age-appropriate breast feeding at 6–11 months varied by ethnicity and region. In a sensitivity analysis that included only children who were still breast feeding at age 6–11 months (online supplemental material tables 11–13), the determinants were slightly different for the introduction of solid foods. Women were more likely to introduce solid foods to twins or higher-order multiples at 6–11 months compared with single-born infants. A higher paternal educational level was associated with increased odds of solid food introduction at 6–11 months compared with no paternal education. Postnatal care was not associated with the introduction of solid food at 6–11 months.

The determinants of age-appropriate breast feeding at 12–23 months are summarised in table 3, with crude and adjusted estimates for all potential determinants presented in online supplemental material 2 (online supplemental material tables 8–10). Maternal age, marital status, ethnicity, region, household income, wantedness of the child and birth order were associated with age-appropriate breast feeding at 12–23 months. Older women were more likely than women aged 20–34 years to appropriately breastfeed children aged 12–23 months, and unmarried women were less likely to appropriately breastfeed children aged 12–23 months than married women. There were regional and ethnic variations in the odds of age-appropriate breast feeding. Women in high-income households were less likely than women in low-income households to appropriately breastfeed children aged 12–23 months. Women who wanted a child later or not at all were less likely to appropriately breastfeed children aged 12–23 months than women who reported they had wanted a child. Lower-order births were less likely to be appropriately breastfed at age 12–23 months than higher-order births. In a sensitivity analysis that included only children receiving solid foods at 12–23 months (online supplemental material tables 14–16), the determinants of continued breast feeding at 12–23 months were slightly different. Non-facility delivery was associated with higher odds of continued breast feeding than facility deliveries, and women in urban areas were less likely than women in rural areas to continue breast feeding at 12–23 months. The CI for wantedness of a child was slightly wider and not associated with continued breast feeding.

Trends in the odds of age-appropriate breast feeding from 2003–2017

After adjusting for the sociodemographic, maternal and child factors associated with age-appropriate breast feeding, the odds of age-appropriate breast feeding decreased over time for children younger than 6months and those aged 12–23 months (figure 4). In the 6–11month age group, the odds of age-appropriate breast feeding were lower in the first two surveys and then stable.

DISCUSSION

We found that some women gave water and other forms of milk to children during the first month after birth, and among those aged 4months, half of the children were receiving solid foods and water. The trends over time in the prevalence of age-appropriate breast feeding varied by child's age group. Exclusive breast feeding of children under 6months increased from 53.4% in 2003 to a peak of 62.8% in 2008 before falling to 42.9% in 2017. Age-appropriate breast feeding for children aged 6–11 months rose over time and then remained steady, whereas it gradually decreased for children aged 12–23 months. Our findings showed that the factors influencing age-appropriate breast feeding in children under 2years also varied with age. Younger women were less likely to appropriately breastfeed at 0–5 months and 12–23 months. Non-facility delivery and twins or higher-order multiple births were associated with lower odds of appropriate breast feeding at 0–5 months, with no evidence of association in the other age groups. Postnatal care was only a determinant in the 6–11 months group, with non-attendance associated with lower odds of appropriate breast feeding. Maternal marital status, household income, wantedness of the child and the child's birth order were only determinants in the 12–23 months group, where unmarried women, women in high-income households, women who wanted a child later or not at all and earlier birth order were associated with lower odds of appropriate breast feeding. Across the three age groups, appropriate breast feeding varied by ethnicity and region.

In agreement with our finding, several previous studies have reported lower odds of exclusive breast feeding in adolescents.[17 18 37] Prior studies in Ghana have revealed that adolescents introduce complementary feeding earlier than recommended to avoid undesired breast changes or public breast feeding.[38 39] Moreover, young women may be more likely to lack the confidence to breastfeed effectively and are more likely to introduce other foods to compensate for perceived breastmilk insufficiency.[39–41] Perceived insufficient breastmilk may also explain why

Table 2 Summary of pooled unadjusted and adjusted estimates of the factors associated with age-appropriate breast feeding in children aged 6–11 months in Ghana, 2003–2017

	Number age-appropriately breastfed*	% age-appropriately breastfed†	Unadjusted OR (95% CI)	Wald test P value	Adjusted OR (95% CI)	Adjusted Wald test P value
Sociodemographic factors						
Ethnicity‡						
Akan	874	82.4	2.26 (1.69 to 3.02)	<0.001	1.30 (0.86 to 1.98)	0.06
Ga/dangme	163	87.7	3.44 (2.03 to 5.85)		2.17 (1.16 to 4.07)	
Ewe	299	83.5	2.45 (1.66 to 3.60)		1.80 (1.06 to 3.06)	
Mole-dagomba	667	67.5	1.00		1.00	
Grusi	110	81.1	2.07 (1.09 to 3.92)		1.55 (0.83 to 2.91)	
Gurma	130	68.5	1.05 (0.68 to 1.62)		1.17 (0.74 to 1.85)	
Other	225	65.7	0.92 (0.65 to 1.31)		0.91 (0.63 to 1.32)	
Region (ordered by poverty levels)‡						
Upper West region	259	69.9	1.65 (1.13 to 2.42)		1.69 (1.14 to 2.49)	
Northern region	364	58.5	1.00		1.00	
Upper East region	220	69.3	1.61 (1.07 to 2.40)		1.50 (0.98 to 2.31)	
Volta region	202	77.1	2.39 (1.57 to 3.63)		1.62 (0.95 to 2.75)	
Brong Ahafo region	206	75.3	2.17 (1.45 to 3.22)		1.76 (1.09 to 2.85)	
Western region	233	83.5	3.60 (2.29 to 5.67)	<0.001	2.71 (1.61 to 4.55)	<0.001
Central region	271	80.6	2.96 (1.87 to 4.67)		2.18 (1.25 to 3.80)	
Eastern region	239	86.6	4.61 (3.00 to 7.07)		3.22 (1.93 to 5.36)	
Ashanti region	284	86.1	4.40 (2.97 to 6.51)		3.49 (2.18 to 5.58)	
Greater Accra region	194	80.2	2.87 (1.81 to 4.56)		1.90 (1.13 to 3.20)	
Maternal/healthcare factors						
Postnatal care for the newborn§						
Yes	877	82.5	1.00	0.40	1.00	0.09
No	580	80.4	0.87 (0.64 to 1.20)		0.74 (0.53 to 1.04)	

Region is ordered based on the 2017 regional poverty incidence from poorest to least poor.[42]
*Unweighted count.
†Weighted percentage.
‡Adjusted for maternal age, marital status, place of residence, ethnicity, maternal educational level, household income, region, father's education and survey year (number of unweighted observations=3210).
§Adjusted for ethnicity, region, survey year, number of antenatal visits, place of delivery, person assisting in delivery, breastfeeding initiation, wanted last child, maternal pre-discharge check, caesarean delivery, time spent at place of delivery and Postnatal care for the newborn (number of unweighted observations=1715).

Table 3 Summary of pooled unadjusted and adjusted estimates of the factors associated with age-appropriate breast feeding in children aged 12–23 months in Ghana, 2003–2017

	Number age-appropriately breastfed*	% age-appropriately breastfed†	Unadjusted OR (95% CI)	Wald test P value	Adjusted OR (95% CI)	Adjusted Wald test P value
Sociodemographic factors						
Maternal age (in years)‡						
<20	210	69.5	1.05 (0.74 to 1.48)	0.01	1.21 (0.83 to 1.77)	0.04
20–34	2928	68.5	1.00		1.00	
35–49	1278	74.1	1.31 (1.10 to 1.57)		1.26 (1.04 to 1.52)	
Maternal marital status‡						
Not married	449	60.6	0.56 (0.46 to 0.69)	<0.001	0.67 (0.53 to 0.84)	0.003
married	3265	73.2	1.00		1.00	
Living with partner	702	65.5	0.69 (0.57 to 0.84)		0.91 (0.74 to 1.11)	
Ethnicity‡						
Akan	1252	60.8	0.31 (0.25 to 0.39)	<0.001	0.54 (0.38 to 0.75)	0.001
Ga/dangme	197	61.9	0.33 (0.24 to 0.46)		0.74 (0.47 to 1.15)	
Ewe	431	69.1	0.45 (0.35 to 0.59)		0.60 (0.40 to 0.90)	
Mole-dagomba	1473	83.2	1.00		1.00	
Grusi	223	79.8	0.80 (0.46 to 1.40)		0.92 (0.53 to 1.62)	
Gurma	384	80.8	0.85 (0.60 to 1.22)		0.75 (0.50 to 1.12)	
Other	493	79.5	0.78 (0.57 to 1.08)		0.95 (0.65 to 1.40)	
Household income‡						
Low income	2794	77.6	1.00	<0.001	1.00	<0.001
Middle income	691	70.2	0.68 (0.55 to 0.84)		0.95 (0.76 to 1.19)	
High income	970	58.7	0.41 (0.35 to 0.49)		0.61 (0.50 to 0.75)	
Region (ordered by poverty levels)‡						
Upper West region	559	86.9	0.98 (0.69 to 1.40)		0.83 (0.56 to 1.25)	
Northern region	965	87.1	1.00		1.00	
Upper East region	496	85.0	0.84 (0.60 to 1.19)		0.77 (0.52 to 1.14)	
Volta region	353	79.9	0.59 (0.40 to 0.85)		0.90 (0.57 to 1.42)	
Brong Ahafo region	399	73.4	0.41 (0.29 to 0.57)		0.65 (0.44 to 0.96)	
Western region	320	65.9	0.29 (0.21 to 0.40)	<0.001	0.53 (0.35 to 0.81)	<0.001
Central region	361	62.7	0.25 (0.19 to 0.33)		0.48 (0.33 to 0.72)	
Eastern region	306	60.7	0.23 (0.17 to 0.31)		0.41 (0.27 to 0.60)	

Continued

Table 3 Continued

	Number age-appropriately breastfed*	% age-appropriately breastfed†	Unadjusted OR (95% CI)	Wald test P value	Adjusted OR (95% CI)	Adjusted Wald test P value
Ashanti region	428	63.8	0.26 (0.19 to 0.36)		0.49 (0.33 to 0.71)	
Greater Accra region	268	55.5	0.18 (0.14 to 0.25)		0.38 (0.25 to 0.58)	
Maternal/healthcare factors						
Wanted last child§						
Wanted then	2767	73.1	1.00		1.00	0.09
Wanted later	1205	66.5	0.73 (0.62 to 0.86)	0.001	0.83 (0.69 to 1.00)	
Wanted no more	393	68.2	0.79 (0.61 to 1.01)		0.81 (0.61 to 1.07)	
Child factors						
Birth order¶						
1	738	62.2	0.53 (0.43 to 0.65)	<0.001	0.65 (0.50 to 0.86)	0.009
2–3	1365	67.8	0.68 (0.56 to 0.82)		0.78 (0.62 to 0.98)	
4+	1768	75.6	1.00		1.00	

Region is ordered based on the 2017 regional poverty incidence from poorest to least poor.[42]
*Unweighted count.
†Weighted percentage.
‡Adjusted for maternal age, marital status, place of residence, ethnicity, maternal educational level, household income, region, paternal education and survey year (number of unweighted observations=6057).
§Adjusted for maternal age, marital status, ethnicity, household income, region, survey year, number of antenatal visits, place of delivery, person assisting in delivery, breastfeeding initiation and wanted last child (number of unweighted observations=5867).
¶Adjusted for maternal age, place of residence, ethnicity, region, survey year, place of delivery, sex of child, birth order, child size at birth, multiple births and previous birth interval (number of unweighted observations=5260).

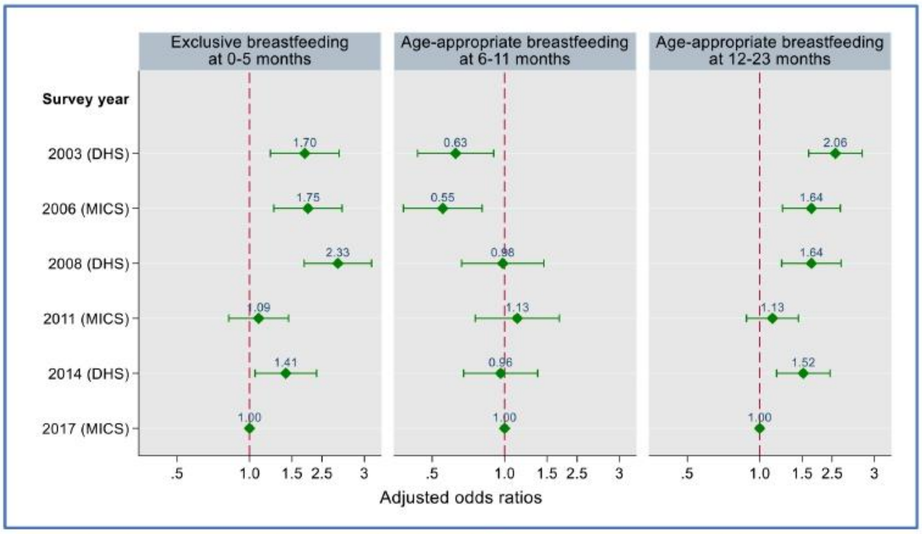

Figure 4 Trends in the odds of age-appropriate breast feeding in Ghana by survey year (adjusted for maternal age, marital status, place of residence, ethnicity, maternal educational level, household income, region, paternal education, media exposure and maternal employment). The reference category is 2017 MICS. DHS, Demographic and Health Survey; MICS. MICS, Multiple Indicator Cluster Survey.

women with multiple births were less likely to breastfeed exclusively. This could also be the consequence of the higher demand of care that comes with multiple births, compelling women to introduce other foods in the first 6 months without adequate support.

Ethnicity and region of residence were associated with exclusive breast feeding in the first 6 months after birth and age-appropriate breast feeding at 6–11 and 12–23 months. The variations in the odds of exclusive breast feeding across ethnic groups and administrative regions highlight the influence of traditional and cultural practices and regional socioeconomic disparities on breast feeding infants and young children. For instance, women in Ghana's poorest regions were more likely to practice exclusive breast feeding than those in other regions. However, it is possible that because of the higher poverty level in these regions,[42] women cannot afford infant formula, increasing their reliance on breastmilk.[38 41] Women from the Volta region, one of the country's poorest regions, were less likely to breastfeed exclusively, though the results suggested that women of the region's predominant ethnic group were more likely to breastfeed exclusively. There was only a slight variation in age-appropriate breast feeding among the regions and ethnic groups in the older age groups. It is possible that women with higher income levels were less likely to appropriately breastfeed children aged 12–23 months because they can afford complementary foods and the need for them to terminate breast feeding to return to work. Additionally, in many Ghanaian cultures, childbirth out of wedlock is frowned on,[43] and unmarried women may not receive adequate support from their families compared with those in a union. The lack of support may explain why unmarried women were less likely to appropriately breastfeed children 12–23 months than married women in our study. Even at healthcare centres, unmarried pregnant women are sometimes mistreated,[44] denying them the opportunity to learn appropriate feeding practices during antenatal and postnatal visits.

In contrast to our results, Ganle *et al*[45] found that women in rural areas were more likely to breastfeed exclusively than those in urban areas. The discrepancy between Ganle *et al*'s findings and ours could be attributed to their study's smaller sample size (n=322) and the fact that their study sample was not nationally representative. Urban women are more likely to give birth in a hospital under the supervision of trained professionals, which exposes them to expert guidance and education on exclusive breast feeding, and this may explain why, in this study, women who delivered in a health facility were more likely to breastfeed exclusively than those who delivered elsewhere. Additionally, women who deliver in healthcare facilities are likely to have used other healthcare services such as postnatal care. Indeed, our results showed that women who received postnatal care were more likely to appropriately breastfeed children aged 6–11 months than those who did not.

It is not surprising that women who wanted a child when they got pregnant were more likely to appropriately breastfeed children aged 12–23 months than those whose child was less wanted. It is reasonable to assume that women who want a child are highly likely to plan their pregnancy, seek antenatal care services, deliver in a healthcare facility, attend postnatal care and adopt other health-promoting activities, including a positive attitude towards breast feeding.

Given the vital importance of exclusive breast feeding in the early months of a child's life, it is worrying that women introduce complementary foods earlier than recommended. Efforts should be made to scale up exclusive breast feeding beyond the first 3 months after birth. For instance, adolescents and women in rural areas should be educated on the benefits of exclusive breast feeding to the child and the woman and efforts made to address any misperceptions about the practice. Any prejudice towards unmarried women needs to be addressed. Support from family and healthcare professionals could help unmarried women to appropriately breastfeed their children.

An important strength of this study is the use of a nationally representative sample of woman–child dyad from rural and urban areas of Ghana and the fact that we considered a wide range of potential determinants, adjusted for potential confounders and had a large sample size, making our findings generalisable to infants and young children under 2 years and relevant to policies on breast feeding. Also, using a hierarchical approach to the data analysis ensured the potential confounders were systematically controlled to prevent adjusting for factors on the causal pathway. The study's main limitation is the reliance on maternal recall of breastfeeding practices to measure age-appropriate breast feeding. Notably, social desirability bias has the potential to distort the associations. Women may have reported breastfeeding practices and healthcare behaviours in a manner considered acceptable or desirable. In addition, there was a slight difference in persons responding to breastfeeding questions between the surveys as the 2006 and 2011 MICSs collected information from caregivers where biological mothers were unavailable. The categorisation or regrouping of explanatory variables may have resulted in residual confounding in the adjusted analysis. The three age-appropriate breastfeeding indicators presented in this study were estimated using a cross-section of children in a given age range, as recommended by the WHO.[46] They should not be interpreted as representing the proportion of newborns who were breastfed until the upper age limits of the age-appropriate breastfeeding categories.

CONCLUSION

Our results show that in the first 3 month after birth, many women introduced other foods and liquids to children and among infants aged 4 months, more than half are no longer exclusively breastfed. However, some women delayed the introduction of solid foods. Termination of breast feeding before the recommended 2 years was common after the seventh month after birth. Exclusive breast feeding in the first 6 months and appropriate breast feeding of children 12–23 months have decreased over time. There has been no substantial change in the appropriate breast feeding of children 6–11 months in recent surveys. Our findings revealed that the determinants of age-appropriate breast feeding in Ghana are multifaceted and age-dependent. Maternal sociodemographic factors had a greater influence on age-appropriate breast feeding than obstetric or healthcare factors. Breastfeeding interventions in Ghana have been known to focus on exclusive breast feeding[47]; we recommend the extension of breastfeeding interventions throughout the first 2 years after birth, focusing on the higher-risk groups identified in this study.

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4.3 Supplementary materials

Supplementary Table 1: Characteristics of data sources included in the analysis, 2003-2017

Survey type	Date of fieldwork	Number of households interviewed	Household response rate	Number of children under two years	Unweighted number of children under two years included in the analysis	Weighted number of children under two years included in the analysis
DHS	July-October, 2003	6,251	98.7%	1575	1440	1339
MICS	August-October, 2006	5,939	94.8%	1427	1427	1421
DHS	September-November, 2008	11,778	98.9%	1281	1175	1134
MICS	September-December, 2011	11,925	99.6%	2963	2963	2995
DHS	September-December, 2014	11,835	98.5%	2415	2262	2202
MICS	October, 2017-January, 2017	12,886	99.40%	3476	3476	3395
Total				**13137**	**12743**	**12486**

Supplementary Table 2: Pooled unadjusted and adjusted estimates of the association between sociodemographic factors and exclusive breastfeeding in children aged 0-5 months in Ghana, 2003-2017.

Maternal sociodemographic factors	Number exclusively breastfed*	% exclusively breastfed[a]	Unadjusted odds ratio (95% CI)	Wald test P-value	Adjusted odds ratio (95% CI)	Adjusted Wald test P-value
Maternal age (in years) [b]						
<20	123	40.6	0.62 (0.46-0.84)	0.006	0.62 (0.45-0.85)	0.01
20-34	1264	52.5	1.00		1.00	
35-49	429	53.2	1.03 (0.82-1.29)		1.01 (0.80-1.28)	
Maternal marital status [b]						
Not married	145	38.4	0.51 (0.38-0.70)	<0.001	0.73 (0.51-1.03)	0.17
married	1359	54.8	1.00		1.00	
Living with partner	312	48.7	0.78 (0.62-0.98)		1.02 (0.79-1.32)	
Place of residence[b]						
Urban	608	54.8	1.24 (1.02-1.50)	0.03	1.54 (1.25-1.91)	<0.001
Rural	1220	49.5	1.00		1.00	
Ethnicity[b]						
Akan	446	41.7	0.48 (0.38-0.61)	<0.001	0.69 (0.47-1.00)	0.001
Ga/dangme	87	45.6	0.56 (0.38-0.84)		0.76 (0.45-1.27)	
Ewe	215	63.2	1.15 (0.83-1.60)		1.49 (0.93-2.39)	
Mole-dagomba	622	59.9	1.00		1.00	
Grusi	106	60.1	1.01 (0.57-1.77)		1.02 (0.59-1.76)	
Gurma	137	64.0	1.19 (0.78-1.82)		1.46 (0.91-2.32)	
Other	214	60.2	1.01 (0.72-1.42)		1.22 (0.82-1.81)	
Maternal level of education[b]						
No education	750	56.5	1.00	0.001	1.00	0.19
Primary	640	45.9	0.65 (0.53-0.81)		1.05 (0.81-1.37)	
Secondary	368	54.8	0.93 (0.73-1.19)		1.37 (1.00-1.87)	
Higher	66	54.7	0.93 (0.54-1.60)		1.35 (0.75-2.43)	
Household income[b]						
Low income	1056	51.7	1.00	0.76	1.00	0.15
Middle income	298	50.0	0.93 (0.73-1.19)		1.23 (0.93-1.63)	
High income	474	52.5	1.03 (0.84-1.27)		1.33 (0.98-1.79)	
Maternal employment						
Yes	540	55.8	1.00	0.51	1.00	0.15
No	190	58.4	1.11 (0.81-1.52)		1.29 (0.91-1.84)	
Region (ordered by poverty levels) [b]						
Upper West region	281	72.7	1.69 (1.10-2.61)	<0.001	2.02 (1.26-3.25)	<0.001
Northern region	344	61.1	1.00		1.00	
Upper East region	238	68.9	1.41 (0.98-2.03)		1.61 (1.08-2.40)	
Volta region	152	61.4	1.01 (0.69-1.49)		0.86 (0.52-1.42)	
Brong Ahafo region	166	61.7	1.03 (0.70-1.50)		1.30 (0.83-2.05)	
Western region	112	38.7	0.40 (0.28-0.57)		0.59 (0.38-0.91)	
Central region	127	42.2	0.46 (0.33-0.65)		0.69 (0.44-1.09)	
Eastern region	130	51.6	0.68 (0.47-0.97)		0.92 (0.58-1.45)	

Ashanti region	140	39.1	0.41 (0.29-0.57)		0.57 (0.37-0.89)	
Greater Accra region	138	52.2	0.70 (0.48-1.02)		0.72 (0.44-1.17)	
Maternal frequency of media exposure[d]						
Not at all	538	48.4	0.85 (0.68-1.06)	0.28	0.82 (0.62-1.09)	0.35
Less than once a week	201	49.1	0.87 (0.67-1.15)		0.88 (0.66-1.18)	
At least once a week	856	52.5	1.00		1.00	
Paternal education[b]						
No education	592	57.7	1.00	0.002	1.00	0.20
Primary	368	47.7	0.67 (0.52-0.86)		1.04 (0.76-1.41)	
Secondary	389	56.3	0.94 (0.74-1.21)		1.32 (0.96-1.83)	
Higher	166	45.4	0.61 (0.43-0.86)		0.92 (0.62-1.36)	
Survey years[b]						
2003	185	53.4	1.53 (1.12-2.09)	<0.001	1.47 (1.07-2.02)	<0.001
2006	223	55.3	1.65 (1.20-2.26)		1.54 (1.12-2.13)	
2008	205	62.8	2.25 (1.65-3.05)		2.16 (1.57-2.96)	
2011	420	45.7	1.12 (0.84-1.48)		1.05 (0.79-1.39)	
2014	341	52.3	1.46 (1.11-1.92)		1.36 (1.02-1.81)	
2018	454	42.9	1.00		1.00	

*Unweighted count

[a] Weighted percentage

[b] Adjusted for Maternal age, marital status, place of residence, ethnicity, maternal educational level, household income, region, Paternal education, and survey year (number of unweighted observations= 3,306).

[c] Adjusted for Maternal age, marital status, place of residence, ethnicity, maternal educational level, household income, region, Paternal education, survey year, maternal employment, and Maternal frequency of media exposure (number of unweighted observations= 1,261)

[d] Adjusted for Maternal age, marital status, place of residence, ethnicity, maternal educational level, household income, region, Paternal education, survey year, and Maternal frequency of media exposure (number of unweighted observations= 2,027)

Region is ordered based on the 2017 regional poverty incidence(36)

Supplementary Table 3: Pooled unadjusted and adjusted estimates of the association between maternal obstetric and healthcare factors and exclusive breastfeeding in children aged 0-5 months in Ghana, 2003-2017.

Maternal obstetric factors	Number exclusively breastfed*	% exclusively breastfed[a]	Unadjusted odds ratio (95% CI)	Wald test P-value	Adjusted odds ratio (95% CI)	Adjusted Wald test P-value
Number of antenatal visits[b]						
None	62	44.7	0.71 (0.47-1.07)	0.33	0.69 (0.43-1.11)	0.48
1-3 visits	298	49.8	0.87 (0.68-1.11)		0.90 (0.69-1.17)	
4-7 visits	1001	53.3	1.00		1.00	
8+ visits	431	51.0	0.91 (0.73-1.14)		0.96 (0.76-1.21)	
Place of delivery[b]						
Elsewhere	660	48.9	0.84 (0.70-1.01)	0.06	0.68 (0.54-0.84)	0.001
Health facility	1149	53.3	1.00		1.00	
Person assisting in delivery[b]						
Doctor	187	52.5	0.98 (0.72-1.34)	0.19	1.00 (0.72-1.37)	0.98
Nurse/Midwife	979	53.0	1.00		1.00	
Traditional birth attendant (TBA)	327	46.9	0.78 (0.62-0.98)		0.99 (0.53-1.85)	
Other	316	52.7	0.99 (0.77-1.28)		1.06 (0.56-1.99)	
Maternal pre-discharge check[d]						
Yes	931	47.9	1.00	0.14	1.00	0.73
No	214	53.2	1.24 (0.93-1.64)		0.94 (0.66-1.34)	
Breastfeeding initiation[b]						
Within first hour	885	53.5	1.15 (0.96-1.37)	0.13	1.11 (0.92-1.35)	0.28
After first hour	898	50.0	1.00		1.00	
Postnatal care for the newborn[e]						
Yes	563	48.7	1.00	0.98	1.00	0.37
No	460	48.6	1.00 (0.78-1.28)		1.13 (0.87-1.47)	
Wanted last child[b]						
Wanted then	1153	53.5	1.00	0.09	1.00	0.49
Wanted later	491	47.8	0.80 (0.65-0.98)		0.99 (0.79-1.24)	
Wanted no more	165	53.6	1.00 (0.74-1.35)		1.22 (0.87-1.70)	
Time spent at place of delivery[e]						
Less than a day	409	50.0	0.93 (0.71-1.22)	0.84	1.01 (0.75-1.36)	0.98
Less than a week	513	51.8	1.00		1.00	
A week or more	45	52.3	1.02 (0.58-1.80)		1.05 (0.59-1.87)	
Caesarean delivery[c]						
Yes	132	46.9	0.79 (0.56-1.11)	0.17	0.86 (0.60-1.23)	0.40
No	1207	52.8	1.00		1.00	

*Unweighted count

[a] Weighted percentage

[b] Adjusted for Maternal age, place of residence, ethnicity, region, survey year, number of antenatal visits, place of delivery, person assisting in delivery, breastfeeding initiation, and wanted last child (number of unweighted observations= 3,290)

[c] Adjusted for Maternal age, place of residence, ethnicity, region, survey year, number of antenatal visits, place of delivery, person assisting in delivery, breastfeeding initiation, wanted last child, and caesarean delivery (number of unweighted observations= 2,420)

[c] Adjusted for Maternal age, place of residence, ethnicity, region, survey year, number of antenatal visits, place of delivery, person assisting in delivery, breastfeeding initiation, wanted last child, Maternal pre-discharge check, and caesarean delivery (number of unweighted observations= 2,131)
[d] Adjusted for Maternal age, place of residence, ethnicity, region, survey year, number of antenatal visits, place of delivery, person assisting in delivery, breastfeeding initiation, wanted last child, Maternal pre-discharge check, caesarean delivery, time spent at place of delivery, and Postnatal care for the newborn (number of unweighted observations= 1,755)

Supplementary Table 4: Pooled unadjusted and adjusted estimates of the association between child factors and exclusive breastfeeding in children aged 0-5 months in Ghana, 2003-2017

Infant characteristics	Number age-exclusively breastfed*	% exclusively breastfed[a]	Unadjusted odds ratio (95% CI)	Wald test P-value	Adjusted odds ratio (95% CI)	Adjusted Wald test P-value
Sex of child[b]						
Male	957	52.4	1.00	0.46	1.00	0.81
Female	871	50.8	0.94 (0.79-1.11)		0.98 (0.82-1.17)	
Birth order[c]						
1	315	46.7	0.77 (0.60-1.00)	0.14	0.77 (0.55-1.07)	0.27
2-3	585	50.9	0.91 (0.73-1.14)		0.85 (0.65-1.10)	
4+	684	53.2	1.00		1.00	
Child size at birth[b]						
Large	814	51.0	1.00	0.30	1.00	0.23
Average	719	53.8	1.12 (0.92-1.36)		1.17 (0.95-1.43)	
Small	268	48.9	0.92 (0.71-1.19)		0.96 (0.73-1.26)	
Multiple birth[c]						
Yes	40	41.7	0.68 (0.36-1.28)	0.24	0.56 (0.31-1.02)	0.06
No	1544	51.2	1.00		1.00	
Previous birth interval[c]						
<2 years	303	45.3	0.80 (0.61-1.04)	0.07	1.07 (0.79-1.45)	0.79
2-3 years	697	51.0	1.00		1.00	
4+ years	447	53.7	1.12 (0.88-1.42)		1.09 (0.84-1.41)	

*Unweighted count
[a] Weighted percentage
[b] Adjusted for Maternal age, place of residence, ethnicity, region, survey year, place of delivery, sex of child, and size of child at birth (number of unweighted observations= 3,272).
[c] Adjusted for Maternal age, place of residence, ethnicity, region, survey year, place of delivery, and all the variables in the table (number of unweighted observations= 2,651)

Supplementary Table 5: Pooled unadjusted and adjusted estimates of the association between sociodemographic factors and age-appropriate breastfeeding in children aged 6-11 months in Ghana, 2003-2017.

Maternal sociodemographic factors	Number age-appropriately breastfed*	% age-appropriately breastfed[a]	Unadjusted odds ratio (95% CI)	Wald test P-value	Adjusted odds ratio (95% CI)	Adjusted Wald test P-value
Maternal age (in years) [b]						
<20	178	77.8	0.97 (0.64-1.48)		0.88 (0.57-1.34)	
20-34	1669	78.3	1.00	0.72	1.00	0.83
35-49	608	76.5	0.90 (0.70-1.16)		1.00 (0.77-1.30)	
Maternal marital status [b]						
Not married	297	83.2	1.66 (1.15-2.39)		1.21 (0.82-1.80)	
married	1677	74.9	1.00	<0.001	1.00	0.23
Living with partner	481	84.7	1.86 (1.39-2.50)		1.29 (0.94-1.77)	
Place of residence[b]						
Urban	838	80.9	1.34 (1.05-1.70)	0.02	1.07 (0.83-1.40)	0.59
Rural	1634	76.0	1.00		1.00	
Ethnicity[b]						
Akan	874	82.4	2.26 (1.69-3.02)		1.30 (0.86-1.98)	
Ga/dangme	163	87.7	3.44 (2.03-5.85)		2.17 (1.16-4.07)	
Ewe	299	83.5	2.45 (1.66-3.60)		1.80 (1.06-3.06)	
Mole-dagomba	667	67.5	1.00	<0.001	1.00	0.06
Grusi	110	81.1	2.07 (1.09-3.92)		1.55 (0.83-2.91)	
Gurma	130	68.5	1.05 (0.68-1.62)		1.17 (0.74-1.85)	
Other	225	65.7	0.92 (0.65-1.31)		0.91 (0.63-1.32)	
Maternal level of education[b]						
No education	906	68.7	0.55 (0.43-0.70)		0.95 (0.70-1.30)	
Primary	926	80.0	1.00	<0.001	1.00	0.19
Secondary	534	84.6	1.37 (1.02-1.85)		1.34 (0.99-1.82)	
Higher	94	83.8	1.30 (0.54-3.12)		1.25 (0.52-3.01)	
Household income[b]						
Low income	1337	73.0	1.00		1.00	
Middle income	418	83.2	1.83 (1.36-2.46)	<0.001	1.32 (0.96-1.83)	0.23
High income	717	81.4	1.61 (1.26-2.08)		1.10 (0.82-1.46)	
Maternal employment[c]						
Yes	782	77.4	1.00	0.97	1.00	0.98
No	177	77.3	0.99 (0.67-1.46)		1.00 (0.66-1.53)	
Region (ordered by poverty levels) [b]						
Upper West region	259	69.9	1.65 (1.13-2.42)		1.69 (1.14-2.49)	
Northern region	364	58.5	1.00		1.00	
Upper East region	220	69.3	1.61 (1.07-2.40)		1.50 (0.98-2.31)	
Volta region	202	77.1	2.39 (1.57-3.63)		1.62 (0.95-2.75)	
Brong Ahafo region	206	75.3	2.17 (1.45-3.22)		1.76 (1.09-2.85)	
Western region	233	83.5	3.60 (2.29-5.67)	<0.001	2.71 (1.61-4.55)	<0.001
Central region	271	80.6	2.96 (1.87-4.67)		2.18 (1.25-3.80)	
Eastern region	239	86.6	4.61 (3.00-7.07)		3.22 (1.93-5.36)	

Ashanti region	284	86.1	4.40 (2.97-6.51)		3.49 (2.18-5.58)	
Greater Accra region	194	80.2	2.87 (1.81-4.56)		1.90 (1.13-3.20)	
Maternal frequency of media exposure[d]						
Not at all	674	75.4	0.72 (0.57-0.92)		0.77 (0.57-1.04)	
Less than once a week	305	79.0	0.89 (0.61-1.28)	0.04	0.93 (0.64-1.37)	0.24
At least once a week	1262	80.9	1.00		1.00	
Paternal education[b]						
No education	663	67.2	1.00		1.00	
Primary	562	81.1	2.10 (1.54-2.85)	<0.001	1.19 (0.81-1.74)	0.41
Secondary	528	79.7	1.92 (1.42-2.61)		0.91 (0.63-1.33)	
Higher	257	85.4	2.86 (1.87-4.38)		1.35 (0.84-2.19)	
Survey years[b]						
2003	271	70.7	0.56 (0.39-0.80)		0.63 (0.43-0.90)	
2006	218	69.0	0.52 (0.35-0.75)		0.55 (0.38-0.81)	
2008	245	79.3	0.89 (0.59-1.33)	<0.001	0.98 (0.66-1.46)	0.001
2011	553	82.5	1.09 (0.73-1.64)		1.13 (0.75-1.69)	
2014	445	80.3	0.94 (0.65-1.37)		0.96 (0.68-1.37)	
2018	740	81.1	1.00		1.00	

*Unweighted count

[a] Weighted percentage

[b] Adjusted for Maternal age, marital status, place of residence, ethnicity, maternal educational level, household income, region, Paternal education, and survey year (number of unweighted observations= 3,210).

[c] Adjusted for Maternal age, marital status, place of residence, ethnicity, maternal educational level, household income, region, Paternal education, survey year, maternal employment, and Maternal frequency of media exposure (number of unweighted observations= 1,286)

[d] Adjusted for Maternal age, marital status, place of residence, ethnicity, maternal educational level, household income, region, Paternal education, survey year, and Maternal frequency of media exposure (number of unweighted observations= 2,890)

Region is ordered based on the 2017 regional poverty incidence(36)

Supplementary Table 6: Pooled unadjusted and adjusted estimates of the association between maternal obstetric and healthcare factors and age-appropriate breastfeeding in children aged 6-11 months in Ghana, 2003-2017.

Maternal obstetric factors	Number age-appropriately breastfed*	% age-appropriately breastfed[a]	Unadjusted odds ratio (95% CI)	Wald test P-value	Adjusted odds ratio (95% CI)	Adjusted Wald test P-value
Number of antenatal visits[b]						
None	83	74.1	0.83 (0.51-1.36)	0.002	1.12 (0.66-1.92)	0.17
1-3 visits	354	72.2	0.76 (0.57-1.00)		0.77 (0.57-1.05)	
4-7 visits	1363	77.5	1.00		1.00	
8+ visits	629	82.6	1.38 (1.06-1.80)		1.14 (0.86-1.52)	
Place of delivery[b]						
Elsewhere	870	73.1	0.65 (0.52-0.81)	<0.001	0.99 (0.78-1.27)	0.96
Health facility	1581	80.7	1.00		1.00	
Person assisting in delivery[b]						
Doctor	278	87.3	1.83 (1.12-3.00)	0.001	1.60 (0.98-2.59)	0.29
Nurse/Midwife	1330	79.0	1.00		1.00	
Traditional birth attendant (TBA)	450	72.7	0.71 (0.54-0.92)		1.02 (0.76-1.38)	
Other	393	73.5	0.74 (0.54-1.00)		1.09 (0.79-1.50)	
Maternal pre-discharge check[d]						
Yes	1358	81.4	1.00	0.02	1.00	0.82
No	279	74.7	0.68 (0.48-0.95)		1.05 (0.71-1.55)	
Breastfeeding initiation[b]						
Within first hour	1213	79.5	1.18 (0.94-1.47)	0.15	1.15 (0.92-1.45)	0.22
After first hour	1202	76.8	1.00		1.00	
Postnatal care for the newborn[e]						
Yes	877	82.5	1.00	0.40	1.00	0.09
No	580	80.4	0.87 (0.64-1.20)		0.74 (0.53-1.04)	
Wanted last child[b]						
Wanted then	1383	76.7	1.00	0.19	1.00	0.85
Wanted later	796	78.7	1.12 (0.89-1.41)		0.94 (0.74-1.20)	
Wanted no more	269	82.1	1.40 (0.95-2.05)		1.04 (0.69-1.56)	
Time spent at place of delivery[e]						
Less than a day	530	80.7	0.83 (0.59-1.17)	0.25	0.86 (0.60-1.21)	0.34
Less than a week	766	83.4	1.00		1.00	
A week or more	86	88.4	1.53 (0.69-3.37)		1.52 (0.66-3.51)	
Caesarean delivery[c]						
Yes	237	85.9	1.64 (0.97-2.79)	0.07	1.25 (0.76-2.08)	0.38
No	1632	78.8	1.00		1.00	

*Unweighted count

[a] Weighted percentage

[b] Adjusted for ethnicity, region, survey year, number of antenatal visits, place of delivery, person assisting in delivery, breastfeeding initiation, and wanted last child (number of unweighted observations= 3,176)

[c] Adjusted for ethnicity, region, survey year, number of antenatal visits, place of delivery, person assisting in delivery, breastfeeding initiation, wanted last child, and caesarean delivery (number of unweighted observations= 2,402)

[d] Adjusted for ethnicity, region, survey year, number of antenatal visits, place of delivery, person assisting in delivery, breastfeeding initiation, wanted last child, Maternal pre-discharge check, and caesarean delivery (number of unweighted observations= 2,096)

[e] Adjusted for ethnicity, region, survey year, number of antenatal visits, place of delivery, person assisting in delivery, breastfeeding initiation, wanted last child, Maternal pre-discharge check, caesarean delivery, time spent at place of delivery, and Postnatal care for the newborn (number of unweighted observations= 1,715)

Supplementary Table 7: Pooled unadjusted and adjusted estimates of the association between child factors and age-appropriate breastfeeding at 6-11 months in Ghana, 2003-2017

Infant characteristics	Number age-appropriately breastfed*	% age-appropriately breastfed[a]	Unadjusted odds ratio (95% CI)	Wald test P-value	Adjusted odds ratio (95% CI)	Adjusted Wald test P-value
Sex of child[b]						
Male	1224	77.2	0.93 (0.75-1.14)	0.47	0.90 (0.72-1.11)	0.32
Female	1248	78.5	1.00		1.00	
Birth order[c]						
1	482	82.3	1.31 (0.94-1.83)		1.16 (0.82-1.63)	
2-3	821	79.5	1.10 (0.84-1.43)	0.27	0.99 (0.75-1.31)	0.67
4+	927	78.0	1.00		1.00	
Child size at birth[b]						
Large	1136	77.3	1.00		1.00	
Average	937	78.8	1.09 (0.88-1.37)	0.71	1.12 (0.88-1.41)	0.64
Small	366	78.5	1.08 (0.77-1.52)		1.07 (0.75-1.54)	
Multiple birth[c]						
Yes	84	84.6	1.43 (0.66-3.09)	0.37	1.66 (0.77-3.55)	0.19
No	2146	79.3	1.00		1.00	
Previous birth interval[c]						
<2 years	493	85.7	1.83 (1.25-2.70)		1.40 (0.95-2.08)	
2-3 years	920	76.6	1.00	0.008	1.00	0.24
4+ years	608	79.6	1.19 (0.90-1.58)		1.10 (0.82-1.48)	

*Unweighted count

[a] Weighted percentage

[b] Adjusted for Maternal age, place of residence, ethnicity, region, survey year, place of delivery, sex of child, and size of child at birth (number of unweighted observations= 3,188).

[c] Adjusted for Maternal age, place of residence, ethnicity, region, survey year, place of delivery, and all the variables in the table (number of unweighted observations= 2,600)

Supplementary Table 8: Pooled unadjusted and adjusted estimates of the association between sociodemographic factors and age-appropriate breastfeeding in children aged 12-23 months in Ghana, 2003-2017.

Maternal sociodemographic factors	Number age-appropriately breastfed*	% age-appropriately breastfed[a]	Unadjusted odds ratio (95% CI)	Wald test P-value	Adjusted odds ratio (95% CI)	Adjusted Wald test P-value
Maternal age (in years) [b]						
<20	210	69.5	1.05 (0.74-1.48)		1.21 (0.83-1.77)	
20-34	2928	68.5	1.00	0.01	1.00	0.04
35-49	1278	74.1	1.31 (1.10-1.57)		1.26 (1.04-1.52)	
Maternal marital status [b]						
Not married	449	60.6	0.56 (0.46-0.69)		0.67 (0.53-0.84)	
married	3265	73.2	1.00	<0.001	1.00	0.003
Living with partner	702	65.5	0.69 (0.57-0.84)		0.91 (0.74-1.11)	
Place of residence[b]						
Urban	1283	61.2	0.53 (0.46-0.62)	<0.001	0.86 (0.70-1.05)	0.14
Rural	3172	74.9	1.00		1.00	
Ethnicity[b]						
Akan	1252	60.8	0.31 (0.25-0.39)		0.54 (0.38-0.75)	
Ga/dangme	197	61.9	0.33 (0.24-0.46)		0.74 (0.47-1.15)	
Ewe	431	69.1	0.45 (0.35-0.59)		0.60 (0.40-0.90)	
Mole-dagomba	1473	83.2	1.00	<0.001	1.00	0.001
Grusi	223	79.8	0.80 (0.46-1.40)		0.92 (0.53-1.62)	
Gurma	384	80.8	0.85 (0.60-1.22)		0.75 (0.50-1.12)	
Other	493	79.5	0.78 (0.57-1.08)		0.95 (0.65-1.40)	
Maternal level of education[b]						
No education	1966	80.6	1.00		1.00	
Primary	1549	64.8	0.44 (0.37-0.53)	<0.001	0.94 (0.76-1.18)	0.57
Secondary	827	66.9	0.49 (0.40-0.59)		1.08 (0.83-1.40)	
Higher	82	54.7	0.29 (0.18-0.47)		0.84 (0.49-1.43)	
Household income[b]						
Low income	2794	77.6	1.00		1.00	
Middle income	691	70.2	0.68 (0.55-0.84)	<0.001	0.95 (0.76-1.19)	<0.001
High income	970	58.7	0.41 (0.35-0.49)		0.61 (0.50-0.75)	
Maternal employment[c]						
Yes	1509	74.4	1.00	0.07	1.00	0.41
No	256	69.2	0.77 (0.58-1.02)		0.87 (0.63-1.21)	
Region (ordered by poverty levels) [b]						
Upper West region	559	86.9	0.98 (0.69-1.40)		0.83 (0.56-1.25)	
Northern region	965	87.1	1.00		1.00	
Upper East region	496	85.0	0.84 (0.60-1.19)		0.77 (0.52-1.14)	
Volta region	353	79.9	0.59 (0.40-0.85)		0.90 (0.57-1.42)	
Brong Ahafo region	399	73.4	0.41 (0.29-0.57)		0.65 (0.44-0.96)	
Western region	320	65.9	0.29 (0.21-0.40)	<0.001	0.53 (0.35-0.81)	<0.001
Central region	361	62.7	0.25 (0.19-0.33)		0.48 (0.33-0.72)	
Eastern region	306	60.7	0.23 (0.17-0.31)		0.41 (0.27-0.60)	
Ashanti region	428	63.8	0.26 (0.19-0.36)		0.49 (0.33-0.71)	

Greater Accra region	268	55.5	0.18 (0.14-0.25)		0.38 (0.25-0.58)	
Maternal frequency of media exposure[d]						
Not at all	1386	72.1	1.24 (1.02-1.51)		0.95 (0.73-1.23)	
Less than once a week	531	71.8	1.22 (0.97-1.54)	0.05	1.13 (0.87-1.46)	0.47
At least once a week	1975	67.5	1.00		1.00	
Paternal education[b]						
No education	1594	81.9	1.00		1.00	
Primary	956	69.0	0.49 (0.39-0.62)	<0.001	1.01 (0.77-1.31)	0.61
Secondary	870	67.0	0.45 (0.36-0.56)		0.85 (0.64-1.13)	
Higher	387	61.5	0.35 (0.27-0.46)		0.90 (0.65-1.24)	
Survey years[b]						
2003	555	77.8	1.89 (1.47-2.42)		1.83 (1.41-2.37)	
2006	534	72.6	1.43 (1.09-1.86)		1.45 (1.10-1.92)	
2008	418	73.1	1.46 (1.12-1.91)	<0.001	1.45 (1.09-1.92)	<0.001
2011	1094	65.0	1.00		1.00	
2014	794	71.1	1.33 (1.04-1.68)		1.34 (1.04-1.73)	
2018	1060	61.2	0.85 (0.67-1.08)		0.88 (0.69-1.13)	

*Unweighted count

[a] Weighted percentage

[b] Adjusted for Maternal age, marital status, place of residence, ethnicity, maternal educational level, household income, region, Paternal education, and survey year (number of unweighted observations= 6,057).

[c] Adjusted for Maternal age, marital status, place of residence, ethnicity, maternal educational level, household income, region, Paternal education, survey year, maternal employment, and Maternal frequency of media exposure (number of unweighted observations= 2,321)

[d] Adjusted for Maternal age, marital status, place of residence, ethnicity, maternal educational level, household income, region, Paternal education, survey year, and Maternal frequency of media exposure (number of unweighted observations= 5,372)

Region is ordered based on the 2017 regional poverty incidence(36)

Supplementary Table 9: Pooled unadjusted and adjusted estimates of the association between maternal obstetric and healthcare factors and age-appropriate breastfeeding at 12-23 months in Ghana, 2003-2017.

Maternal obstetric factors	Number age-appropriately breastfed*	% age-appropriately breastfed[a]	Unadjusted odds ratio (95% CI)	Wald test P-value	Adjusted odds ratio (95% CI)	Adjusted Wald test P-value
Number of antenatal visits[b]						
None	177	72.3	1.00 (0.68-1.46)	<0.001	0.72 (0.47-1.09)	0.20
1-3 visits	644	76.3	1.23 (0.97-1.57)		1.01 (0.78-1.31)	
4-7 visits	2525	72.3	1.00		1.00	
8+ visits	965	63.4	0.66 (0.56-0.79)		0.86 (0.71-1.04)	
Place of delivery[b]						
Elsewhere	1906	77.4	1.73 (1.46-2.04	<0.001	1.14 (0.94-1.38)	0.18
Health facility	2463	66.5	1.00		1.00	
Person assisting in delivery[b]						
Doctor	357	59.8	0.69 (0.53-0.89)	<0.001	0.88 (0.67-1.15)	0.59
Nurse/Midwife	2177	68.4	1.00		1.00	
Traditional birth attendant (TBA)	945	75.6	1.44 (1.17-1.76)		1.04 (0.83-1.31)	
Other	891	79.1	1.75 (1.39-2.21)		1.11 (0.86-1.43)	
Maternal pre-discharge check[d]						
Yes	2115	68.0	1.00		1.00	0.71
No	511	80.0	1.88 (1.39-2.54)		1.06 (0.77-1.48)	
Breastfeeding initiation[b]						
Within first hour	2181	70.2	1.00	0.52	1.00	0.59
After first hour	2133	71.2	1.05 (0.90-1.22)		1.05 (0.89-1.23)	
Postnatal care for the newborn[e]						
Yes	1394	69.7	1.00	0.27	1.00	0.78
No	895	67.2	0.89 (0.73-1.09)		1.03 (0.83-1.28)	
Wanted last child[b]						
Wanted then	2767	73.1	1.00	0.001	1.00	0.09
Wanted later	1205	66.5	0.73 (0.62-0.86)		0.83 (0.69-1.00)	
Wanted no more	393	68.2	0.79 (0.61-1.01)		0.81 (0.61-1.07)	
Time spent at place of delivery[e]						
Less than a day	840	66.9	1.17 (0.94-1.46)	0.18	1.13 (0.90-1.42)	0.19
Less than a week	1071	63.4	1.00		1.00	
A week or more	120	71.4	1.44 (0.89-2.34)		1.54 (0.92-2.59)	
Caesarean delivery[c]						
Yes	272	63.1	0.70 (0.53-0.93)	0.02	0.97 (0.72-1.31)	0.84
No	2776	70.9	1.00		1.00	

*Unweighted count

[a] Weighted percentage

[b] Adjusted for Maternal age, marital status, ethnicity, household income, region, survey year, number of antenatal visits, place of delivery, person assisting in delivery, breastfeeding initiation, and wanted last child (number of unweighted observations= 5,867)

[c] Adjusted for Maternal age, marital status, ethnicity, household income, region, survey year, number of antenatal visits, place of delivery, person assisting in delivery, breastfeeding initiation, wanted last child, and caesarean delivery (number of unweighted observations= 4,247)

[d] Adjusted for Maternal age, marital status, ethnicity, household income, region, survey year, number of antenatal visits, place of delivery, person assisting in delivery, breastfeeding initiation, wanted last child, Maternal pre-discharge check, and caesarean delivery (number of unweighted observations= 3,663)
[e] Adjusted for ethnicity, region, survey year, number of antenatal visits, place of delivery, person assisting in delivery, breastfeeding initiation, wanted last child, Maternal pre-discharge check, caesarean delivery, time spent at place of delivery, and Postnatal care for the newborn (number of unweighted observations= 2,990)

Supplementary Table 10: Pooled unadjusted and adjusted estimates of the association between child factors and age-appropriate breastfeeding at 12-23 months in Ghana, 2003-2017.

Infant characteristics	Number age-appropriately breastfed*	% age-appropriately breastfed[a]	Unadjusted odds ratio (95% CI)	Wald test P-value	Adjusted odds ratio (95% CI)	Adjusted Wald test P-value
Sex of child[b]						
Male	2255	68.7	1.00	0.41	1.00	0.24
Female	2200	70.0	1.06 (0.92-1.22)		1.09 (0.94-1.27)	
Birth order[c]						
1	738	62.2	0.53 (0.43-0.65)		0.65 (0.50-0.86)	
2-3	1365	67.8	0.68 (0.56-0.82)	<0.001	0.78 (0.62-0.98)	0.009
4+	1768	75.6	1.00		1.00	
Child size at birth[b]						
Large	2015	69.9	1.00		1.00	
Average	1650	70.7	1.04 (0.88-1.23)	0.69	1.04 (0.87-1.24)	0.71
Small	679	71.7	1.09 (0.89-1.35)		1.10 (0.88-1.37)	
Multiple birth[c]						
Yes	131	70.3	1.03 (0.60-1.79)	0.91	0.99 (0.55-1.78)	0.97
No	3739	69.6	1.00		1.00	
Previous birth interval[c]						
<2 years	715	61.3	0.59 (0.48-0.73)		0.91 (0.68-1.21)	
2-3 years	1723	72.8	1.00	<0.001	1.00	0.49
4+ years	1071	72.0	0.96 (0.78-1.18)		1.08 (0.87-1.35)	

*Unweighted count
[a] Weighted percentage
[b] Adjusted for Maternal age, marital status, ethnicity, household income, region, survey year, wanted last child, sex of child, and size of child at birth (number of unweighted observations= 5,920).
[c] Adjusted for Maternal age, place of residence, ethnicity, region, survey year, place of delivery, and all the variables in the table (number of unweighted observations= 5,260)

Supplementary Table 11: Sensitivity analysis of pooled unadjusted and adjusted estimates of the sociodemographic factors associated with introduction of solid foods among breastfed children aged 6-11 months in Ghana, 2003-2017.

Maternal sociodemographic factors	Number fed solid foods	% fed solid foods	Unadjusted odds ratio (95% CI)	Wald test P-value	Adjusted odds ratio (95% CI)	Adjusted Wald test P-value
Maternal age (in years) [b]						
<20	178	81.3	0.90 (0.57-1.44)	0.57	0.86 (0.46-1.63)	0.76
20-34	1669	82.8	1.00		1.00	
35-49	608	80.7	0.87 (0.66-1.14)		1.09 (0.81-1.47)	
Maternal marital status [b]						
Not married	297	87.3	1.74 (1.16-2.61)	<0.001	2.19 (0.95-5.08)	0.13
married	1677	79.8	1.00		1.00	
Living with partner	481	87.3	1.75 (1.27-2.41)		1.21 (0.83-1.77)	
Place of residence[b]						
Urban	838	86.2	1.57 (1.19-2.06)	0.001	1.02 (0.73-1.42)	0.89
Rural	1634	79.9	1.00		1.00	
Ethnicity[b]						
Akan	874	86.7	2.51 (1.83-3.42)	<0.001	1.45 (0.88-2.40)	0.03
Ga/dangme	163	93.3	5.34 (2.68-10.67)		3.47 (1.25-9.66)	
Ewe	299	88.0	2.82 (1.82-4.37)		2.07 (1.02-4.20)	
Mole-dagomba	667	72.3	1.00		1.00	
Grusi	110	84.3	2.06 (1.07-3.96)		1.51 (0.69-3.28)	
Gurma	130	74.2	1.10 (0.70-1.73)		1.13 (0.70-1.82)	
Other	225	68.8	0.85 (0.59-1.22)		0.84 (0.56-1.26)	
Maternal level of education[b]						
No education	906	73.3	0.53 (0.41-0.68)	<0.001	1.08 (0.74-1.57)	0.69
Primary	926	83.9	1.00		1.00	
Secondary	534	88.8	1.53 (1.10-2.13)		1.28 (0.86-1.90)	
Higher	94	90.2	1.77 (0.46-6.73)		1.00 (0.24-4.13)	
Household income[b]						
Low income	1337	76.7	1.00	<0.001	1.00	0.48
Middle income	418	85.6	1.81 (1.31-2.51)		1.26 (0.84-1.89)	
High income	717	87.8	2.19 (1.62-2.97)		1.15 (0.80-1.64)	
Maternal employment[c]						
Yes	782	82.3	1.00	0.98	1.00	0.98
No	177	82.4	1.01 (0.67-1.52)		0.93 (0.55-1.58)	
Region (ordered by poverty levels) [b]						
Upper West region	259	72.8	1.82 (1.17-2.83)	<0.001	1.89 (1.19-3.00)	<0.001
Northern region	364	63.2	1.00		1.00	
Upper East region	220	75.2	1.77 (1.17-2.67)		1.78 (1.12-2.84)	
Volta region	202	80.9	2.47 (1.56-3.90)		1.66 (0.86-3.21)	
Brong Ahafo region	206	78.3	2.10 (1.36-3.24)		1.59 (0.88-2.87)	
Western region	233	88.5	4.46 (2.75-7.24)		2.54 (1.38-4.67)	
Central region	271	85.0	3.29 (2.02-5.35)		1.69 (0.86-3.32)	
Eastern region	239	89.4	4.92 (3.03-7.99)		2.62 (1.39-4.96)	
Ashanti region	284	88.2	4.37 (2.90-6.58)		3.23 (1.83-5.71)	

Greater Accra region	194	88.9	4.68 (2.49-8.82)		3.27 (1.37-7.78)	
Maternal frequency of media exposure[d]						
Not at all	674	79.4	0.66 (0.51-0.87)		0.81 (0.56-1.16)	
Less than once a week	305	83.1	0.84 (0.55-1.30)	0.01	0.90 (0.55-1.47)	0.49
At least once a week	1262	85.3	1.00		1.00	
Paternal education[b]						
No education	663	70.6	1.00		1.00	
Primary	562	84.2	2.21 (1.60-3.06)	<0.001	1.22 (0.82-1.80)	0.07
Secondary	528	85.6	2.49 (1.76-3.52)		1.09 (0.72-1.66)	
Higher	257	91.3	4.36 (2.66-7.16)		2.13 (1.22-3.72)	
Survey years[b]						
2003	271	76.9	0.56 (0.38-0.83)		0.62 (0.38-1.01)	
2006	218	73.7	0.47 (0.32-0.72)		0.42 (0.25-0.70)	
2008	245	84.5	0.92 (0.60-1.42)	<0.001	0.97 (0.58-1.63)	0.007
2011	553	85.3	0.98 (0.63-1.54)		0.82 (0.50-1.34)	
2014	445	84.0	0.89 (0.59-1.33)		0.85 (0.53-1.37)	
2018	740	85.5	1.00		1.00	

*Unweighted count

[a] Weighted percentage

[b] Adjusted for Maternal age, marital status, place of residence, ethnicity, maternal educational level, household income, region, Paternal education, and survey year (number of unweighted observations= 2,505).

[c] Adjusted for Maternal age, marital status, place of residence, ethnicity, maternal educational level, household income, region, Paternal education, survey year, Maternal employment, and Maternal frequency of media exposure (number of unweighted observations= 1,081)

[d] Adjusted for Maternal age, marital status, place of residence, ethnicity, maternal educational level, household income, region, Paternal education, survey year, and Maternal frequency of media exposure (number of unweighted observations= 2,287)

Region is ordered based on the 2017 regional poverty incidence(36)

Supplementary Table 12: Sensitivity analysis of pooled unadjusted and adjusted estimates of the maternal obstetric and healthcare factors associated with introduction of solid foods among breastfed children aged 6-11 months in Ghana, 2003-2017.

Maternal sociodemographic factors	Number fed solid foods	% fed solid foods	Unadjusted odds ratio (95% CI)	Wald test P-value	Adjusted odds ratio (95% CI)	Adjusted Wald test P-value
Number of antenatal visits[b]						
None	83	78.8	0.86 (0.51-1.45)	<0.001	1.24 (0.68-2.27)	0.15
1-3 visits	354	76.1	0.74 (0.54-1.00)		0.82 (0.57-1.18)	
4-7 visits	1363	81.2	1.00		1.00	
8+ visits	629	87.8	1.66 (1.22-2.25)		1.35 (0.94-1.95)	
Place of delivery[b]						
Elsewhere	870	76.5	0.56 (0.44-0.71)	<0.001	0.95 (0.71-1.27)	0.73
Health facility	1581	85.3	1.00		1.00	
Person assisting in delivery[b]						
Doctor	278	91.7	2.13 (1.10-4.13)	<0.001	1.62 (0.81-3.26)	0.46
Nurse/Midwife	1330	83.8	1.00		1.00	
Traditional birth attendant (TBA)	450	75.9	0.61 (0.45-0.81)		0.94 (0.67-1.33)	
Other	393	76.8	0.64 (0.46-0.89)		1.12 (0.76-1.65)	
Maternal pre-discharge check[d]						
Yes	1358	84.7	1.00	0.05	1.00	0.22
No	279	79.5	0.70 (0.49-1.00)		1.32 (0.84-2.07)	
Breastfeeding initiation[b]						
Within first hour	1213	83.3	1.16 (0.90-1.50)	0.25	1.19 (0.90-1.57)	0.23
After first hour	1202	81.1	1.00		1.00	
Postnatal care for the newborn[e]						
Yes	877	85.4	1.00	0.63	1.00	0.22
No	580	84.2	0.92 (0.64-1.31)		0.78 (0.52-1.17)	
Wanted last child[b]						
Wanted then	1383	81.5	1.00	0.58	1.00	0.89
Wanted later	796	82.5	1.07 (0.83-1.39)		0.93 (0.69-1.25)	
Wanted no more	269	84.4	1.23 (0.82-1.86)		0.96 (0.58-1.58)	
Time spent at place of delivery[e]						
Less than a day	530	83.8	0.71 (0.48-1.05)	0.12	0.76 (0.49-1.19)	0.32
Less than a week	766	88.0	1.00		1.00	
A week or more	86	91.5	1.46 (0.58-3.68)		1.36 (0.48-3.84)	
Caesarean delivery[c]						
Yes	237	89.5	1.75 (0.91-3.36)	0.09	1.20 (0.63-2.27)	0.58
No	1632	83.1	1.00		1.00	

*Unweighted count

[a] Weighted percentage

[b] Adjusted for ethnicity, region, survey year, number of antenatal visits, place of delivery, person assisting in delivery, breastfeeding initiation, and wanted last child (number of unweighted observations= 2,469)

[c] Adjusted for ethnicity, region, survey year, number of antenatal visits, place of delivery, person assisting in delivery, breastfeeding initiation, wanted last child, and caesarean delivery (number of unweighted observations= 1,884)

[d] Adjusted for ethnicity, region, survey year, number of antenatal visits, place of delivery, person assisting in delivery, breastfeeding initiation, wanted last child, Maternal pre-discharge check, and caesarean delivery (number of unweighted observations= 1,634)

[e] Adjusted for ethnicity, region, survey year, number of antenatal visits, place of delivery, person assisting in delivery, breastfeeding initiation, wanted last child, Maternal pre-discharge check, caesarean delivery, time spent at place of delivery, and Postnatal care for the newborn (number of unweighted observations= 1,305)

Supplementary Table 13: Sensitivity analysis of pooled unadjusted and adjusted estimates of the child factors associated with introduction of solid foods among breastfed children aged 6-11 months in Ghana, 2003-2017.

Maternal sociodemographic factors	Number fed solid foods	% fed solid foods	Unadjusted odds ratio (95% CI)	Wald test P-value	Adjusted odds ratio (95% CI)	Adjusted Wald test P-value
Sex of child[b]						
Male	1224	82.0	0.95 (0.76-1.20)	0.68	0.92 (0.70-1.19)	0.51
Female	1248	82.7	1.00		1.00	
Birth order[c]						
1	482	86.6	1.47 (0.99-2.19)		1.10 (0.66-1.85)	
2-3	821	83.9	1.19 (0.89-1.59)	0.13	1.02 (0.74-1.41)	0.93
4+	927	81.4	1.00		1.00	
Child size at birth[b]						
Large	1136	81.7	1.00		1.00	
Average	937	82.4	1.05 (0.82-1.35)	0.77	1.09 (0.82-1.44)	0.85
Small	366	83.7	1.15 (0.77-1.72)		1.02 (0.63-1.65)	
Multiple birth[c]						
Yes	84	92.3	2.42 (1.07-5.49)	0.03	6.89 (2.36-20.15)	<0.001
No	2146	83.2	1.00		1.00	
Previous birth interval[c]						
<2 years	493	88.5	1.72 (1.09-2.69)		1.12 (0.67-1.89)	
2-3 years	920	81.7	1.00	0.06	1.00	0.79
4+ years	608	82.4	1.05 (0.77-1.43)		0.93 (0.66-1.31)	

*Unweighted count

[a] Weighted percentage

[b] Adjusted for Maternal age, place of residence, ethnicity, region, survey year, place of delivery, sex of child, and size of child at birth (number of unweighted observations= 2,505).

[c] Adjusted for Maternal age, place of residence, ethnicity, region, survey year, place of delivery, and all the variables in the table (number of unweighted observations= 2,277)

Supplementary Table 14: Sensitivity analysis of pooled unadjusted and adjusted estimates of the sociodemographic factors associated with continued breastfeeding among children receiving solid foods at age 12-23 months in Ghana, 2003-2017.

Maternal sociodemographic factors	Number still breastfeeding*	% still breastfeeding[a]	Unadjusted odds ratio (95% CI)	Wald test P-value	Adjusted odds ratio (95% CI)	Adjusted Wald test P-value
Maternal age (in years) [b]						
<20	210	72.6	1.02 (0.71-1.48)	0.006	1.14 (0.75-1.74)	0.06
20-34	2928	72.1	1.00		1.00	
35-49	1278	78.0	1.37 (1.13-1.66)		1.29 (1.04-1.59)	
Maternal marital status [b]						
Not married	449	63.6	0.51 (0.41-0.63)	<0.001	0.63 (0.49-0.81)	0.001
married	3265	77.4	1.00		1.00	
Living with partner	702	67.9	0.62 (0.51-0.76)		0.84 (0.67-1.05)	
Place of residence[b]						
Urban	1283	63.4	0.44 (0.38-0.52)	<0.001	0.79 (0.63-0.99)	0.04
Rural	3172	79.6	1.00		1.00	
Ethnicity[b]						
Akan	1252	63.4	0.21 (0.17-0.28)	<0.001	0.43 (0.30-0.64)	<0.001
Ga/dangme	197	63.2	0.21 (0.15-0.30)		0.57 (0.35-0.94)	
Ewe	431	72.6	0.33 (0.24-0.45)		0.50 (0.31-0.79)	
Mole-dagomba	1473	89.0	1.00		1.00	
Grusi	223	88.7	0.97 (0.44-2.17)		1.20 (0.53-2.69)	
Gurma	384	86.8	0.81 (0.52-1.26)		0.59 (0.36-0.99)	
Other	493	84.3	0.66 (0.45-0.97)		0.87 (0.55-1.38)	
Maternal level of education[b]						
No education	1966	86.2	1.00	<0.001	1.00	0.59
Primary	1549	68.2	0.34 (0.28-0.42)		0.90 (0.70-1.16)	
Secondary	827	69.3	0.36 (0.29-0.45)		0.99 (0.74-1.32)	
Higher	82	55.3	0.20 (0.12-0.32)		0.74 (0.43-1.29)	
Household income[b]						
Low income	2794	83.0	1.00	<0.001	1.00	<0.001
Middle income	691	74.1	0.58 (0.47-0.73)		0.91 (0.71-1.17)	
High income	970	60.4	0.31 (0.26-0.38)		0.55 (0.42-0.72)	
Maternal employment[c]						
Yes	1509	73.2	1.00	0.08	1.00	0.71
No	256	78.3	0.76 (0.56-1.04)		0.93 (0.66-1.33)	
Region (ordered by poverty levels) [b]						
Upper West region	559	93.3	0.92 (0.57-1.50)	<0.001	0.67 (0.39-1.14)	<0.001
Northern region	965	93.8	1.00		1.00	
Upper East region	496	90.6	0.64 (0.40-1.01)		0.52 (0.32-0.87)	
Volta region	353	84.0	0.35 (0.22-0.55)		0.60 (0.35-1.03)	
Brong Ahafo region	399	77.9	0.23 (0.15-0.36)		0.43 (0.26-0.71)	
Western region	320	68.8	0.15 (0.10-0.22)		0.32 (0.20-0.52)	
Central region	361	64.3	0.12 (0.08-0.17)		0.27 (0.17-0.43)	
Eastern region	306	63.5	0.12 (0.08-0.17)		0.24 (0.15-0.39)	
Ashanti region	428	67.9	0.14 (0.09-0.21)		0.32 (0.20-0.52)	

Greater Accra region	268	57.0	0.09 (0.06-0.13)		0.25 (0.15-0.41)	
Maternal frequency of media exposure[d]						
Not at all	1386	76.6	1.35 (1.09-1.67)		0.98 (0.72-1.32)	
Less than once a week	531	74.6	1.21 (0.95-1.55)	0.02	1.07 (0.81-1.43)	0.83
At least once a week	1975	70.9	1.00		1.00	
Paternal education[b]						
No education	1594	88.3	1.00		1.00	
Primary	956	72.2	0.34 (0.26-0.45)	<0.001	0.89 (0.65-1.23)	0.31
Secondary	870	70.2	0.31 (0.24-0.41)		0.73 (0.52-1.04)	
Higher	387	62.7	0.22 (0.16-0.30)		0.75 (0.51-1.10)	
Survey years[b]						
2003	555	83.6	2.45 (1.83-3.27)		2.42 (1.79-3.29)	
2006	534	76.8	1.59 (1.20-2.12)		1.61 (1.18-2.18)	
2008	418	75.7	1.49 (1.13-1.97)		1.48 (1.09-2.00)	
2011	1094	67.5	1.00	<0.001	1.00	<0.001
2014	794	74.8	1.43 (1.10-1.85)		1.51 (1.14-2.00)	
2018	1060	64.9	0.89 (0.69-1.14)		0.94 (0.72-1.23)	

*Unweighted count

[a] Weighted percentage

[b] Adjusted for Maternal age, marital status, place of residence, ethnicity, maternal educational level, household income, region, Paternal education, and survey year (number of unweighted observations= 5,725).

[c] Adjusted for Maternal age, marital status, place of residence, ethnicity, maternal educational level, household income, region, Paternal education, survey year, Maternal employment, and Maternal frequency of media exposure (number of unweighted observations= 2,192)

[d] Adjusted for Maternal age, marital status, place of residence, ethnicity, maternal educational level, household income, region, Paternal education, survey year, and Maternal frequency of media exposure (number of unweighted observations= 5,083)

Region is ordered based on the 2017 regional poverty incidence(36)

Supplementary Table 15: Sensitivity analysis of pooled unadjusted and adjusted estimates of the maternal obstetric and healthcare factors associated with continued breastfeeding among children receiving solid foods at age 12-23 months in Ghana, 2003-2018.

Maternal sociodemographic factors	Number still breastfeeding*	% still breastfeeding[a]	Unadjusted odds ratio (95% CI)	Wald test P-value	Adjusted odds ratio (95% CI)	Adjusted Wald test P-value
Number of antenatal visits[b]						
None	177	80.0	1.29 (0.83-2.00)	<0.001	0.72 (0.43-1.22)	0.53
1-3 visits	644	81.6	1.42 (1.08-1.87)		1.02 (0.76-1.37)	
4-7 visits	2525	75.7	1.00		1.00	
8+ visits	965	66.6	0.64 (0.53-0.77)		0.92 (0.75-1.12)	
Place of delivery[b]						
Elsewhere	1906	83.3	2.22 (1.84-2.69)	<0.001	1.32 (1.05-1.65)	0.02
Health facility	2463	69.1	1.00		1.00	
Person assisting in delivery[b]						
Doctor	357	61.7	0.65 (0.50-0.85)	<0.001	0.88 (0.66-1.17)	0.79
Nurse/Midwife	2177	71.1	1.00		1.00	
Traditional birth attendant (TBA)	945	82.2	1.88 (1.48-2.37)		0.87 (0.47-1.60)	
Other	891	84.5	2.21 (1.68-2.90)		0.89 (0.47-1.70)	
Maternal pre-discharge check[d]						
Yes	2115	71.0	1.00	<0.001	1.00	0.66
No	511	86.0	2.50 (1.73-3.60)		1.10 (0.73-1.65)	
Breastfeeding initiation[b]						
Within first hour	2181	73.9	1.00	0.48	1.00	0.71
After first hour	2133	75.0	1.06 (0.90-1.25)		1.03 (0.87-1.24)	
Postnatal care for the newborn[e]						
Yes	1394	72.4	1.00	0.50	1.00	0.31
No	895	70.8	0.93 (0.75-1.15)		1.13 (0.89-1.43)	
Wanted last child[b]						
Wanted then	2767	76.6	1.00	0.001	1.00	0.37
Wanted later	1205	70.3	0.72 (0.60-0.86)		0.88 (0.72-1.08)	
Wanted no more	393	72.3	0.80 (0.61-1.04)		0.85 (0.63-1.16)	
Time spent at place of delivery[e]						
Less than a day	840	70.3	1.26 (1.00-1.58)	0.08	1.20 (0.94-1.53)	0.15
Less than a week	1071	65.2	1.00		1.00	
A week or more	120	72.7	1.42 (0.86-2.33)		1.53 (0.89-2.60)	
Caesarean delivery[c]						
Yes	272	74.3	0.64 (0.48-0.86)	0.003	0.98 (0.71-1.34)	0.89
No	2776	65.0	1.00		1.00	

*Unweighted count

[a] Weighted percentage

[b] Adjusted for Maternal age, marital status, ethnicity, household income, region, survey year, number of antenatal visits, place of delivery, person assisting in delivery, breastfeeding initiation, and wanted last child (number of unweighted observations= 5,619)

[c] Adjusted for Maternal age, marital status, ethnicity, household income, region, survey year, number of antenatal visits, place of delivery, person assisting in delivery, breastfeeding initiation, wanted last child, and caesarean delivery (number of unweighted observations= 4,032)

[d] Adjusted for Maternal age, marital status, ethnicity, household income, region, survey year, number of antenatal visits, place of delivery, person assisting in delivery, breastfeeding initiation, wanted last child, Maternal pre-discharge check, and caesarean delivery (number of unweighted observations= 3,473)
[e] Adjusted for ethnicity, region, survey year, number of antenatal visits, place of delivery, person assisting in delivery, breastfeeding initiation, wanted last child, Maternal pre-discharge check, caesarean delivery, time spent at place of delivery, and Postnatal care for the newborn (number of unweighted observations= 2,858)

Supplementary Table 16: Sensitivity analysis of pooled unadjusted and adjusted estimates of the child factors associated with continued breastfeeding among children receiving solid foods at age 12-23 months in Ghana, 2003-2018.

Maternal sociodemographic factors	Number still breastfeeding*	% still breastfeeding[a]	Unadjusted odds ratio (95% CI)	Wald test P-value	Adjusted odds ratio (95% CI)	Adjusted Wald test P-value
Sex of child[b]						
Male	2255	72.2	1.00	0.28	1.00	0.13
Female	2200	73.8	1.09 (0.93-1.27)		1.14 (0.96-1.35)	
Birth order[c]						
1	738	64.4	0.45 (0.36-0.56)		0.65 (0.48-0.87)	
2-3	1365	71.6	0.63 (0.51-0.77)	<0.001	0.81 (0.63-1.04)	0.02
4+	1768	80.1	1.00		1.00	
Child size at birth[b]						
Large	2015	73.6	1.00		1.00	
Average	1650	74.0	1.02 (0.85-1.23)	0.44	1.04 (0.85-1.26)	0.44
Small	679	76.4	1.16 (0.92-1.47)		1.18 (0.92-1.52)	
Multiple birth[c]						
Yes	131	70.4	0.86 (0.50-1.50)	0.61	0.81 (0.44-1.49)	0.49
No	3739	73.3	1.00		1.00	
Previous birth interval[c]						
<2 years	715	64.1	0.51 (0.41-0.64)		0.84 (0.61-1.15)	
2-3 years	1723	77.6	1.00	<0.001	1.00	0.44
4+ years	1071	75.2	0.87 (0.70-1.09)		1.03 (0.80-1.31)	

*Unweighted count
[a] Weighted percentage
[b] Adjusted for Maternal age, marital status, ethnicity, household income, region, survey year, wanted last child, sex of child, and size of child at birth (number of unweighted observations= 5,619).
[c] Adjusted for Maternal age, place of residence, ethnicity, region, survey year, place of delivery, and all the variables in the table (number of unweighted observations= 4,973)

CHAPTER 5

Paper 3

Socioeconomic pattern of breastfeeding in sub-Saharan Africa: A multi-site analysis of longitudinal data

CHAPTER 5: PAPER 3 - SOCIOECONOMIC PATTERN OF BREASTFEEDING IN SUB-SAHARAN AFRICA: A MULTI-SITE ANALYSIS OF LONGITUDINAL DATA

5.1 Introduction

This chapter focuses on objective 2b using data from six longitudinal cohorts in Ethiopia, Malawi, Uganda, and Zambia. Given the well-established confounding effect of socioeconomic factors in the association between breastfeeding and educational attainment in high-income countries, the primary aim of this chapter is to investigate whether there exist socioeconomic disparities and patterns in ever breastfeeding, breastfeeding initiation, exclusive breastfeeding, and duration of any breastfeeding across different socioeconomic strata in the sub-Saharan cohorts. An essential aspect of this analysis lies in its broader applicability. The insights gained from this investigation will enhance our understanding of breastfeeding practices in SSA and lay the groundwork for refining modelling strategies and methodological approaches to study the association between breastfeeding and educational outcomes.

RESEARCH PAPER COVER SHEET

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For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	I requested the data from the data sources, conducted the data management, planned the data analysis, and conducted the data analysis with guidance from my supervisors. I conducted the literature search for the study and prepared the manuscript. My supervisors provided critical input on interpreting, discussing, and presenting the results.

SECTION E

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5.2 Abstract

Background

Breastfeeding rates in sub-Saharan Africa (SSA) are declining, and at the current rate, only four African countries will meet the World Health Organization's 2030 exclusive breastfeeding target. This study examined the association between maternal socioeconomic status (SES) and breastfeeding practices in SSA.

Methods

Six cohorts in Ethiopia, Malawi, Uganda, and Zambia, with 11863 participants, were analysed. Data for the cohorts were collected between 2000 and 2021, covering births from 2000 to 2019. SES exposures were maternal education and household income. Breastfeeding outcomes included ever breastfed, early initiation of breastfeeding (Ethiopia only), exclusive breastfeeding for ≥4 months or ≥6 months, and continued breastfeeding for ≥1 year. Risk ratios from multivariable Poisson regression models for individual cohorts were pooled in a random-effects meta-analysis to assess the effects of SES on breastfeeding, adjusting for confounders.

Results

The meta-analysis found no evidence of a difference in ever breastfeeding between mothers with secondary or tertiary education and those with primary/no education. Mothers with secondary education (adjusted Risk Ratio [aRR]=1.11, 95% Confidence Interval [CI]=1.01–1.21) and those from middle-wealth households (aRR=1.12, 95%CI=1.01–1.24) were more likely to initiate breastfeeding early than those with low SES (primary/no education or low household wealth), but there was no evidence of association in the tertiary education and higher-wealth groups compared to the low SES group. Estimates for the association between maternal education and exclusive breastfeeding for ≥4 months and ≥6 months varied across cohorts, with no evidence of association in most cohorts. Overall, household wealth was not associated with exclusive breastfeeding for ≥4 months or ≥6 months. The meta-analysis showed no evidence of association between household wealth and breastfeeding for ≥1 year, but mothers with tertiary education were less likely (aRR=0.93, 95%CI=0.88–0.99) to breastfeed for ≥1 year than those with primary or no education.

Conclusion

In these six SSA cohorts, we observed no clear socioeconomic pattern in breastfeeding, contrasting with patterns observed in high-income countries. Healthcare providers should continue to actively promote breastfeeding in sub-Saharan Africa, with policies and interventions inclusive of women from all socioeconomic backgrounds.

5.3 Background

Sub-Saharan Africa (SSA) continues to face substantial challenges in infant and young child nutrition, including a continued decline in breastfeeding rates among children under two years between 2000 and 2019 (1), despite the progress in feeding practices since the adoption of the Innocenti Declaration in 1990 to reverse declining breastfeeding rates (2). At the current rate of decline, projections indicate that only four African countries will meet the World Health Organization's target of achieving a 70% prevalence of exclusive breastfeeding in the first six months after birth by 2030 (3). Increased exclusive breastfeeding rates to meet the WHO 2030 targets (4) could prevent nearly 200,000 under-5 deaths in low and middle-income countries (LMICs) between 2020 and 2030 (5).

Breastfeeding in SSA is influenced by multiple factors, including social and cultural norms, access to healthcare, maternal and infant characteristics, and community and family support for breastfeeding (6–11). Socioeconomic factors such as income, education, and occupation, which influence access to resources, healthcare services, and educational resource utilisation, could also impact breastfeeding. In high-income countries, there is strong, consistent evidence that women with higher education and income are more likely to breastfeed, and for a longer duration, than women with lower education and income (12–15). However, it remains unclear if there is an association between socioeconomic status and breastfeeding in LMIC settings.

Recent analyses show mixed findings on the association between socioeconomic status and breastfeeding practices in LMICs. In two analyses of cross-sectional data from the 2010 to 2018 Demographic and Health Surveys (DHS) for over 85 LMICs, children from the poorest families had higher exclusive and continued breastfeeding rates than those from the richest families (16,17). However, a study of 2015 to 2019 DHS data from 16 SSA countries found no differences in exclusive breastfeeding by maternal education or income status (18). While that study also found no differences in breastfeeding initiation by maternal education or income (18), another study using DHS data for 32 SSA countries from 2010 to 2020 found that higher education and income levels were associated with higher odds of breastfeeding initiation (8).

A clearer understanding of the socioeconomic patterns of breastfeeding can inform policies and targeted interventions for women of different socioeconomic backgrounds. Also, researchers investigating the broader impact of breastfeeding on education, cognitive development, and childhood health can benefit from understanding the often complex interplay between socioeconomic status and breastfeeding behaviour in different settings. Previous studies have been from cross-sectional surveys, with notable limitations (19,20) and inconsistent findings. For instance, the DHS often collects data on exclusive breastfeeding by assessing the current status of mothers using the 24-hour recall method. This method has been found to overestimate breastfeeding rates and may lead to misleading conclusions when compared to the 'exclusive breastfeeding since birth' approach, which is commonly employed to collect breastfeeding data in prospective studies (20,21). In this study, we investigated the socioeconomic patterns of breastfeeding in SSA using data from six prospective longitudinal birth cohorts.

5.4 Methods

Data for this analysis came from six prospective, longitudinal cohort studies conducted in four sub-Saharan African (SSA) countries: the Performance Monitoring for Action Ethiopia Cohort 1 (PMA-Cohort1-Ethiopia) (22); the Performance Monitoring and Accountability 2020 Maternal and Newborn Health Survey in Ethiopia (PMA-MNH-Ethiopia) (23); the Karonga Health and Demographic Surveillance System site in Malawi (Karonga-HDSS-Malawi) (24); the General Population Cohort from the Kyamulibwa Health and Demographic Surveillance System in rural Southwestern Uganda (GPC-Uganda) (25); the Chilenje Infant Growth, Nutrition, and Infection Study in Zambia (CIGNIS-Zambia) (26); and the Breastfeeding and Postpartum Health study in Zambia (BFPH-Zambia) (27,28).

The Ethiopia cohorts (PMA-Cohort1-Ethiopia and PMA-MNH-Ethiopia) recruited participants using a multistage sampling approach to collect data on various reproductive, maternal, and newborn health (RMNH) indicators. Karonga-HDSS-Malawi and GPC-Uganda undertake continuous demographic surveillance in geographically defined populations to collect information on vital events, household members characteristics, and various determinants of health. Participants for CIGNIS-Zambia and BFPH-Zambia were recruited from clinics. CIGNIS-Zambia was a randomised, double-blind, controlled trial to assess the impact of two locally made complementary foods on stunting (26). BFPH-Zambia was a prospective cohort study to investigate the risk for subclinical mastitis, breast milk HIV viral load, and postpartum morbidity among lactating women (27,28). Children in the cohorts were born in 2000 or later. A description of each cohort is presented in Supplementary Table 5.1, with detailed descriptions published elsewhere (23–26,28–30).

Breastfeeding

Breastfeeding information was collected at multiple time points in each cohort. Supplementary Table 5.1 shows the specific breastfeeding-related information collected in each cohort. In general, mothers were asked about breastfeeding practices in the 24 hours preceding the interview at each round or visit, including whether the child was ever breastfed, when the mother began breastfeeding (in hours) after delivery, the child's current breastfeeding status, and the child's age when breastfeeding stopped. Mothers were also asked about the number of months the child was fed only breastmilk before other foods and liquids were introduced. Not all these indicators were available for all cohorts. Table 5.1 presents the breastfeeding indicators available for each cohort analysed.

Table 5.1 Definitions of breastfeeding indicators

Breastfeeding indicator	Definition	Groups compared	Cohorts
Ever breastfed	Proportion of children who were ever fed breastmilk.	Ever breastfed vs Never breastfed	1. PMA-Cohort1-Ethiopia 2. PMA-MNH-Ethiopia 3. Karonga-HDSS-Malawi 4. GPC-Uganda 5. CIGNIS-Zambia 6. BFPH-Zambia
Early initiation of Breastfeeding	Proportion of children who were put to the breast within one hour of birth.	Initiate breastfeeding ≤1 hour after birth vs >1 hour after birth	1. PMA-Cohort1-Ethiopia 2. PMA-MNH-Ethiopia
Exclusive breastfeeding for ≥4 months	Proportion of infants who were fed only breastmilk and no other liquids or solids except for oral rehydration salt, drops, and syrups (vitamins, mineral supplements, or medicines) for at least four months after birth.	Exclusive breastfeeding for ≥4 months vs introduced other liquids or solids for feeding before 4 months	1. PMA-Cohort1-Ethiopia 2. Karonga-HDSS-Malawi 3. GPC-Uganda 4. BFPH-Zambia
Exclusive breastfeeding for ≥ 6 months	Proportion of infants who were fed only breastmilk and no other liquids or solids except for oral rehydration salt, drops, and syrups (vitamins, mineral supplements, or medicines) for at least six months after birth.	Exclusive breastfeeding for ≥ 6 months vs introduced other liquids or solids for feeding before 6 months	1. PMA-Cohort1-Ethiopia 2. Karonga-HDSS-Malawi 3. GPC-Uganda
Continued breastfeeding for ≥ 1 year	Proportion of children who were fed breastmilk for at least one year after birth.	Continued breastfeeding for ≥ 1 year vs did not breastfeed at one year or beyond	1. PMA-Cohort1-Ethiopia 2. Karonga-HDSS-Malawi 3. GPC-Uganda 4. CIGNIS-Zambia

Measures of socioeconomic status

The measures of socioeconomic status were maternal education and asset-based household wealth. Data for these measures were collected around the time of the child's birth. Information on maternal education was from the mothers' responses to the question on their highest level of education. In general, household wealth was estimated in each cohort based on principal component analysis of a range of household assets, dwelling building materials, access to utilities, and livestock ownership, depending on what was available. Each household was assigned a score, which was then divided into quantiles based on the distribution of the score from lowest to highest household wealth. Detailed descriptions of the items included in the calculation of each cohort's wealth index are published elsewhere(23,35–38).

Data analysis

The prevalence of the breastfeeding indicators available for each cohort was calculated and summarised across participant characteristics. We classified maternal education into three categories (data from Karonga-HDSS-Malawi, CIGNIS-Zambia, and BFPH-Zambia were originally grouped in these categories): none/primary, secondary, and tertiary. Similarly, household wealth was classified into three categories: low, middle, and high.

A two-stage individual participants data (IPD) meta-analysis (39) was used to determine the association between measures of socioeconomic status and breastfeeding outcomes, with low socioeconomic status (none/primary education or low household wealth) as the reference group.

In the first stage, univariable and multivariable Poisson regression models with robust error variance (40–42) were constructed separately for each cohort and used to estimate risk ratios with corresponding 95% confidence intervals (CIs). The multivariable models were performed as a complete case analysis adjusting for potential confounders available for each cohort, including maternal age, maternal HIV status, marital status, place of residence, and parity or birth order. Analysis for the indicators “ever breastfed” for the Karonga HDSS, GPC-Uganda, PMA-MNH-Ethiopia, and BFPH-Zambia and “continued breastfeeding” for Karonga HDSS were excluded from the regression analysis because almost every mother in these cohorts breastfed or continued breastfeeding for at least one year. In the regression models for the two Ethiopian cohorts, we used Stata's survey commands to account for the multistage sampling design.

In the second stage, the study-specific adjusted risk ratios were pooled in a random-effects meta-analysis to give overall estimates of the association of each maternal educational level and household wealth level with breastfeeding. Forest plots were used to display the meta-analysis results. Between-cohort variance was assessed using the tau-squared (τ^2) test (43,44), and the percentage of variability in the cohort-specific estimates attributable to true heterogeneity, not sampling error, was evaluated with Higgins and Thompson's I^2 statistic (45). Given that some heterogeneity is expected when combining estimates across different studies, I^2 values of 25%, 50%, and 75% were considered low, moderate, and high heterogeneity, respectively (46,47). The P-value from Cochran’s Q statistic test was further used to assess for statistical evidence of heterogeneity (44). Because the number of studies in a meta-analysis and the precision of estimates can influence these heterogeneity measures (44,45,48–50), we also visually inspected the direction and magnitude of effect estimates to determine heterogeneity across the cohorts. All pooled estimates are presented in forest plots, but pooled estimates are only interpreted where there was no strong evidence of heterogeneity.

Considering the extensive breastfeeding education efforts targeting mothers with HIV and the fact that breastfeeding recommendations differ for mothers living with HIV, particularly during the periods most of the cohorts collected data, sensitivity analysis was conducted to evaluate the robustness of the results to any potential influence from this group. In the sensitivity analysis, we repeated all the analyses excluding mothers known to be living with HIV for the four cohorts with HIV data available (Karonga-HDSS-Malawi, GPC-Uganda, BFPH-Zambia, and CIGNIS-Zambia).

Ethical consideration

All the cohort studies included in this analysis received ethical approval from ethics review committees of their respective countries and informed voluntary consent from participants (23–26,28–30). The London School of Hygiene and Tropical Medicine ethics committee approved the present analysis.

5.5 Results

The study sample consisted of 11863 participants from six cohorts across four SSA countries (Ethiopia, Malawi, Uganda, and Zambia), with sample sizes ranging from 315 in the PMA-MNH-Ethiopia cohort to 6861 in the GPC-Uganda cohort (Table 5.2). The majority of mothers were aged 20-29, married, had primary education or less, lived in low-wealth households, and were known to be HIV-negative (for the four cohorts with HIV data available) (Table 5.3 and Supplementary Table 5.2).

Prevalence of breastfeeding

The prevalence of the breastfeeding indicators in each cohort is shown in Table 5.2. Nearly all the mothers breastfed their babies, with the lowest prevalence (93.7%) in the CIGNIS-Zambia cohort (particularly among mothers living with HIV (Supplementary Table 5.2)). Both Ethiopian cohorts with early initiation data had two-thirds of mothers breastfeeding within an hour of birth. Exclusive breastfeeding for at least four months was lowest in BFPH-Zambia (34.2%) and highest in PMA-Cohort1-Ethiopia (94.2%). Exclusive breastfeeding for six months or longer was 40.2% in Karonga-HDSS-Malawi, 55.8% in GPC-Uganda, and 67.9% in PMA-Cohort1-Ethiopia. Most women breastfed for at least a year, with prevalence ranging from 65.4% in CIGNIS-Zambia to 99.2% in Karonga-HDSS-Malawi.

Table 5.2 Prevalence of breastfeeding in six sub-Saharan African birth cohorts

Country	**Ethiopia**	**Ethiopia**	**Malawi**	**Uganda**	**Zambia**	**Zambia**
Cohort acronym	**PMA-Cohort1-Ethiopia**	**PMA-MNH-Ethiopia**	**Karonga-HDSS-Malawi**	**GPC-Uganda**	**CIGNIS-Zambia**	**BFPH-Zambia**
Dates of data collection*	**2019 - 2021**	**2016 - 2017**	**2002 - 2005**	**2000 - 2011**	**2005 - 2009**	**2001 - 2003**
Year of birth	**2019**	**2016**	**2002 - 2004**	**2000 - 2011**	**2005**	**2001**
Sample size	**2038**	**315**	**1464**	**6861**	**811**	**374**
	n (%)	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**
Ever Breastfed						
No	36 (1.8)	0 (0.0)	6 (0.4)	50 (0.7)	51 (6.3)	0 (0.0)
Yes	2002 (98.2)	315 (100.0)	1458 (99.6)	6811 (99.3)	760 (93.7)	374 (100.0)
Early initiation of breastfeeding						
After 1 hour	660 (32.6)	116 (36.9)	-	-	-	-
Within 1 hour	1364 (67.4)	199 (63.1)	-	-	-	-
Exclusive breastfeeding for four months						
<4 months	106 (5.8)	-	432 (29.6)	1619 (27.8)	-	246 (65.8)
≥4 months	1711 (94.2)	-	1026 (70.4)	4204 (72.2)	-	128 (34.2)
Exclusive breastfeeding for six months						
<6 months	584 (32.1)	-	872 (59.8)	2571 (44.2)	-	-
≥6 months	1234 (67.9)	-	586 (40.2)	3252 (55.8)	-	-
Continued breastfeeding						
<1 year	52 (2.6)	-	11 (0.8)	1418 (31.7)	263 (34.6)	-
≥1 year	1968 (97.4)	-	1405 (99.2)	3052 (68.3)	497 (65.4)	-

*The period during which the data analysed in this study were collected.

Table 5.3 Distribution of the breastfeeding indicators by maternal socioeconomic status for each cohort

	Total	Ever breastfed	Breastfeeding initiation within 1 hour after birth	Exclusive breastfeeding ≥4 months	Exclusive breastfeeding ≥6 months	Continued breastfeeding ≥1 year
PMA-Cohort1-Ethiopia						
Maternal education						
None/primary	1708 (81.5)	1632 (98.1)	1103 (66.6)	1374 (93.9)	997 (68.2)	1612 (98.3)
Secondary	302 (14.4)	286 (99.0)	210 (73.6)	256 (94.4)	188 (69.4)	281 (94.8)
Higher	86 (4.1)	84 (98.8)	51 (62.4)	81 (97.5)	49 (58.3)	75 (89.2)
Household wealth level						
Low	852 (40.7)	808 (97.2)	537 (64.6)	683 (93.7)	501 (68.8)	799 (98.9)
Middle	420 (20.0)	400 (97.9)	284 (69.1)	331 (93.3)	240 (67.6)	396 (98.7)
High	824 (39.3)	794 (99.5)	544 (69.5)	697 (95.1)	492 (67.1)	773 (95.4)
PMA-MNH - Ethiopia						
Maternal education						
None/primary	289 (89.2)	-	176 (62.7)	-	-	-
Secondary	32 (9.7)	-	20 (64.7)	-	-	-
Higher	4 (1.1)	-	3 (76.4)	-	-	-
Household wealth level						
Low	123 (37.4)	-	69 (58.0)	-	-	-
Middle	110 (33.5)	-	74 (71.2)	-	-	-
High	96 (29.1)	-	55 (60.4)	-	-	-
Karonga - HDSS – Malawi						
Maternal education						
None/primary	1096 (78.8)	1090 (99.6)	-	744 (68.3)	421 (38.6)	1050 (99.5)
Secondary	295 (21.2)	293 (99.3)	-	222 (75.8)	127 (43.3)	286 (99.0)
Household wealth						
Low	356 (35.1)	353 (99.4)	-	225 (63.7)	121 (34.3)	344 (100.0)
Middle	340 (33.5)	339 (99.7)	-	233 (68.7)	134 (39.5)	323 (99.7)
High	319 (31.4)	317 (99.7)	-	239 (75.4)	132 (41.6)	309 (100.0)
GPC-Uganda						
Maternal education						
None/primary	1205 (70.1)	13 (100.0)	-	755 (69.2)	563 (51.6)	725 (85.2)
Secondary	440 (25.6)	427 (100.0)	-	296 (74.4)	227 (57.0)	276 (83.1)
Higher	75 (4.4)	71 (100.0)	-	61 (91.0)	55 (82.1)	38 (77.5)
Household wealth level						
Low	3897 (45.6)	2818 (99.2)	-	1797 (72.9)	1404 (57.0)	1387 (69.8)
Middle	1688 (19.7)	1206 (99.3)	-	754 (72.8)	586 (56.6)	567 (66.9)
High	2966 (34.7)	2046 (99.3)	-	1300 (72.5)	1011 (56.4)	1007 (68.6)

CIGNIS - Zambia						
	Total	**Ever breastfed**	**Breastfeeding initiation within 1 hour after birth**	**Exclusive breastfeeding ≥4 months**	**Exclusive breastfeeding ≥6 months**	**Continued breastfeeding ≥1 year**

Maternal education						
None/primary	269 (33.2)	253 (94.1)	-	-	-	154 (60.9)
Secondary	309 (38.1)	292 (94.5)	-	-	-	198 (67.8)
Higher	233 (28.7)	215 (92.3)	-	-	-	145 (67.4)
Household wealth level						
Low	325 (40.1)	309 (95.1)	-	-	-	200 (64.7)
Middle	162 (20.0)	149 (92.0	-	-	-	95 (63.8)
High	324 (39.9)	302 (93.2)	-	-	-	202 (66.9)
BFPH - Zambia						
Maternal education						
None/primary	57 (15.2)	-	-	18 (31.6)	-	-
Secondary	211 (56.4)	-	-	78 (37.0)	-	-
Higher	106 (28.3)	-	-	32 (30.2)	-	-
Household wealth level						
Low	178 (47.6)	-	-	65 (36.5)	-	-
Middle	178 (47.6)	-	-	59 (33.1)	-	-
High	18 (4.8)	-	-	4 (22.2)	-	-

Not all participants in the total sample had information on all the breastfeeding indicators.
*Percentages and counts are weighted estimates

Association between socioeconomic status indicators and breastfeeding

The distribution of the breastfeeding indicators by maternal socioeconomic status for each cohort is presented in Table 5.3. Supplementary Table 5.3 presents the unadjusted and adjusted cohort-specific risk ratios for the association of maternal education and household wealth with the breastfeeding indicators. Figure 5.1 and Figure 5.2 show the pooled results from the meta-analysis of the adjusted risk ratios.

Ever breastfed

There was no difference in ever breastfeeding between mothers with secondary (aRR 1.00, 95%CI 0.99 - 1.02) or tertiary (aRR 1.00, 95%CI 0.98 - 1.02) education and those with primary or no education in PMA-Cohort1-Ethiopia (Supplementary Table 5.3). Estimates for CIGNIS-Zambia showed no evidence of a difference in ever breastfeeding by maternal educational level. The meta-analysis showed no evidence that breastfeeding differed by maternal educational level (Figure 5.1A).

The cohort-specific analysis showed some evidence that mothers from middle (aRR 1.01, 95% CI 0.99-1.03) and higher (aRR 1.03, 95% CI 1.01-1.04) wealth households were slightly more likely (1-3% higher) to ever breastfeed compared to mothers from low-wealth households in PMA-Cohort1-Ethiopia (Supplementary Table 5.3). However, in the CGINIS-Zambia cohort, there was some evidence that mothers from middle (aRR 0.95, 95% CI 0.91-1.00) and higher (aRR 0.96, 95% CI 0.93-1.00) wealth households were less likely to ever breastfeed than mothers from low-wealth households. Heterogeneity in the cohort-specific estimates (Figure 5.1B) was high (middle-wealth: I^2=80.5%, P = 0.02; higher-wealth: I^2=91.1%, P < 0.001).

Early initiation of breastfeeding

Mothers with secondary education (aRR 1.11, 95%CI 1.02 – 1.22) were more likely to initiate breastfeeding within one hour after birth than those with primary or no education in PMA-Cohort1-Ethiopia (Supplementary Table 5.3). There was no evidence of an association in the much smaller PMA-MNH-Ethiopia (secondary: aRR 0.98, 95%CI 0.65 – 1.50; tertiary: aRR 1.07, 95%CI 0.74 – 1.53). In the meta-analysis (Figure 5.1C), there was evidence that mothers with secondary education (aRR 1.11, 95%CI 1.01 – 1.21, P=0.03) were more likely to initiate breastfeeding within one hour after birth than those with primary or no education, but there was no evidence of a difference with tertiary education (aRR 0.98, 95%CI 0.82 – 1.17, P=0.84).

The patterns of the estimates in both the PMA-Cohort1-Ethiopia and PMA-MNH-Ethiopia cohorts were consistent with mothers from middle and higher wealth households being more likely to initiate breastfeeding within one hour after birth than mothers from low wealth households, but there was no clear evidence of an association within individual cohorts. When the estimates were combined in the meta-analysis (Figure 5.1D), there was evidence that mothers from middle-wealth households were more likely to initiate breastfeeding within the first hour after birth than mothers from low-wealth households (aRR 1.12, 95%CI 1.01 – 1.24, P=0.04), but there was little evidence of association for the higher-wealth versus low-wealth group comparison (aRR 1.08, 95%CI 0.95 – 1.22, P=0.26).

Exclusive breastfeeding for at least four months

There was some evidence that mothers with secondary education in Karonga-HDSS-Malawi and GPC-Uganda and those with tertiary education in PMA-Cohort1-Ethiopia and GPC-Uganda were more likely to exclusively breastfeed for at least four months than those with primary or no education (Supplementary Table 5.3). In the meta-analysis (Figure 5.2A), there was evidence of substantial heterogeneity in the estimates across the cohorts (secondary: I^2=63.0%, P = 0.06; tertiary: I^2=93.4%, P < 0.001).

There was no evidence of a difference in exclusive breastfeeding for at least four months between mothers from middle-wealth and those from low-wealth households in both the cohort-specific analysis (Supplementary Table 5.3) and meta-analysis (Figure 5.2B). For the higher-wealth group, there was some evidence in Karonga-HDSS-Malawi that mothers from higher-wealth households were more likely to exclusively breastfeed for at least four months than those from low-wealth households (aRR 1.15, 95%CI 1.03 – 1.28), but no evidence of an association in the other cohorts. There was high heterogeneity in the higher-wealth versus low-wealth group analysis (I^2=72.8% P = 0.05).

Exclusive breastfeeding for at least six months

In the cohort-specific analysis, there was no clear evidence for a difference in exclusive breastfeeding for at least six months between mothers with secondary education and those with primary or no education (Supplementary Table 5.3). In the meta-analysis (Figure 5.2C), mothers with secondary education were slightly more likely than those with primary or no education to exclusively breastfeed for six months (aRR 1.08, 95%CI 1.00 – 1.16, P=0.06). In GPC-Uganda, mothers with tertiary education were more likely to exclusively breastfeed for at least six months than those with primary or no education (aRR 1.61, 95%CI 1.40 – 1.84), but there was no evidence of association in PMA-Cohort1-Ethiopia (Supplementary Table 5.3). The meta-analysis (Figure 5.2C) shows high heterogeneity in the tertiary education group (I^2=94.7%, P<0.001).

In the cohort-specific analyses (Supplementary Table 5.3) and meta-analysis (Figure 5.2D), there was no evidence for a difference in exclusive breastfeeding for at least six months between mothers from middle-wealth (pooled effect aRR 0.99, 95%CI 0.93 – 1.06, P=0.87) or higher-wealth (pooled effect aRR 0.99, 95%CI 0.92 – 1.06, P=0.73) households and those from low-wealth households.

Continued breastfeeding for one year or longer

In the cohort-specific analyses, there was no clear evidence for a difference in continued breastfeeding for at least one year between mothers with secondary or tertiary education and those with primary or no education (Supplementary Table 5.3), although the adjusted estimates for the tertiary education group were consistently below 1 (aRR 0.90 to 0.94). In the meta-analysis (Figure 5.2E), there was some evidence that mothers with tertiary education were less likely to continue breastfeeding for at least one year compared to those with primary or no education (aRR 0.93, 95%CI 0.88 – 0.99, P=0.02), but there was no evidence for an association in the secondary education group (aRR 0.99, 95%CI 0.97 – 1.01, P=0.46).

The cohort-specific estimates (Supplementary Table 5.3) and meta-analysis (Figure 5.2F) showed no evidence that continued breastfeeding for at least one year differed between mothers from middle-wealth households and those from low-wealth households. For higher-wealth, there was evidence for an association in CIGNIS-Zambia where mothers from higher-wealth households were less likely to continue breastfeeding for at least one year than those from low-wealth households (aRR 0.89, 95%CI 0.82 – 0.97), but no evidence of association in the other cohorts. Heterogeneity was high in the high-wealth group (I^2=79.9%, P=0.02).

Sensitivity analysis excluding known HIV-positive mothers

The results from the sensitivity analysis excluding known HIV-positive mothers did not differ substantially from the results of the main analysis, except for ever breastfed in the CIGNIS-Zambia cohort where the confidence intervals became narrow, but with only a marginal change (0.01 to 0.04) in the adjusted RRs (Supplementary Figure 5.1 and Supplementary Figure 5.2).

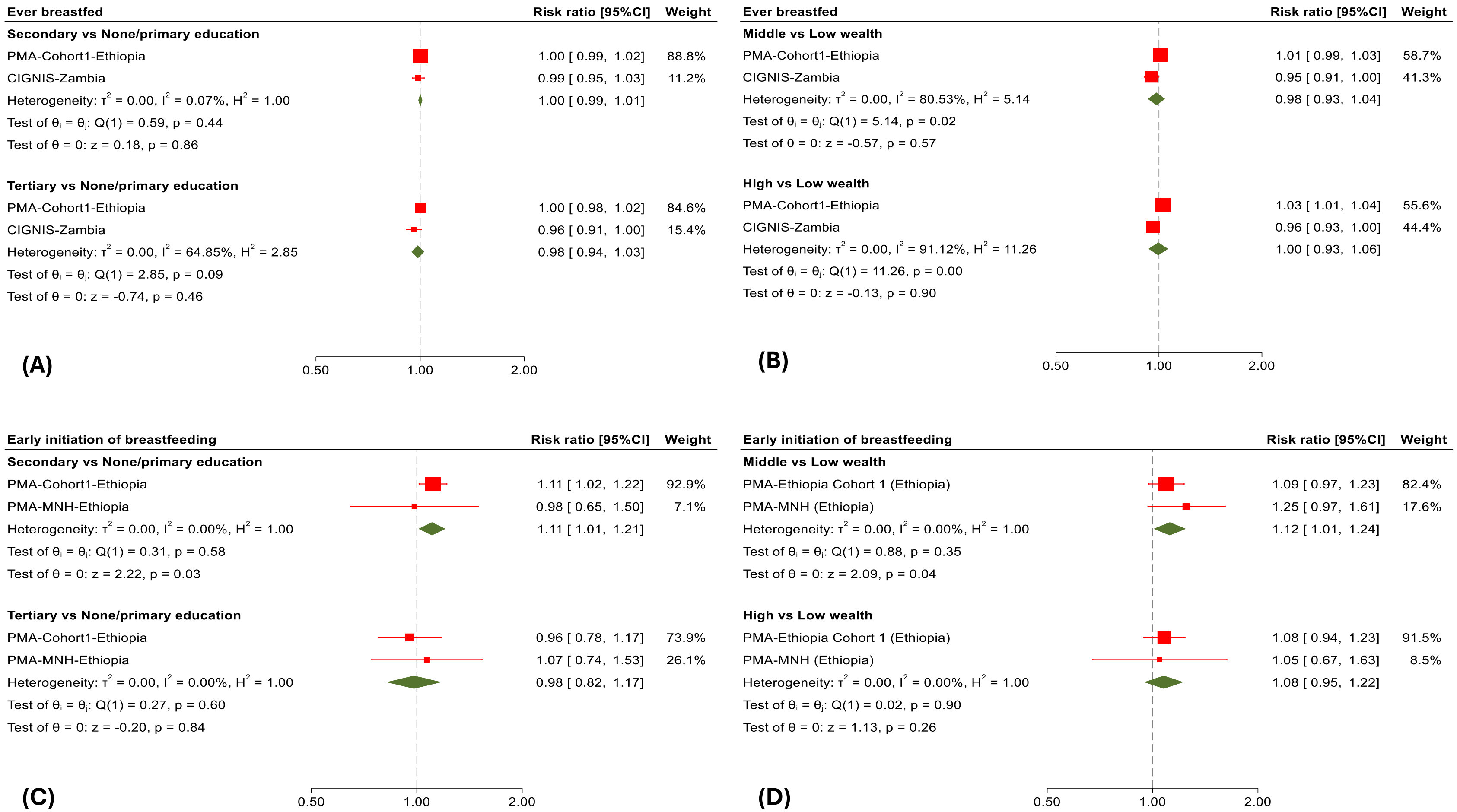

Figure 5.1 The association of maternal education and household wealth with whether a mother ever breastfed (A and B) and breastfe initiation within 1 hour after birth (C and D). The cohort-specific estimates are adjusted risk ratios. PMA-Cohort1-Ethiopia: adjusted for sex, place of residence, maternal age, parity, and maternal marital status. CIGNIS-Zambia: adjusted for child sex, child HIV status, mat HIV status, number of siblings, Maternal age, and maternal marital status. PMA-MNH-Ethiopia: adjusted for child sex, place of resid maternal age, parity, and maternal marital status.

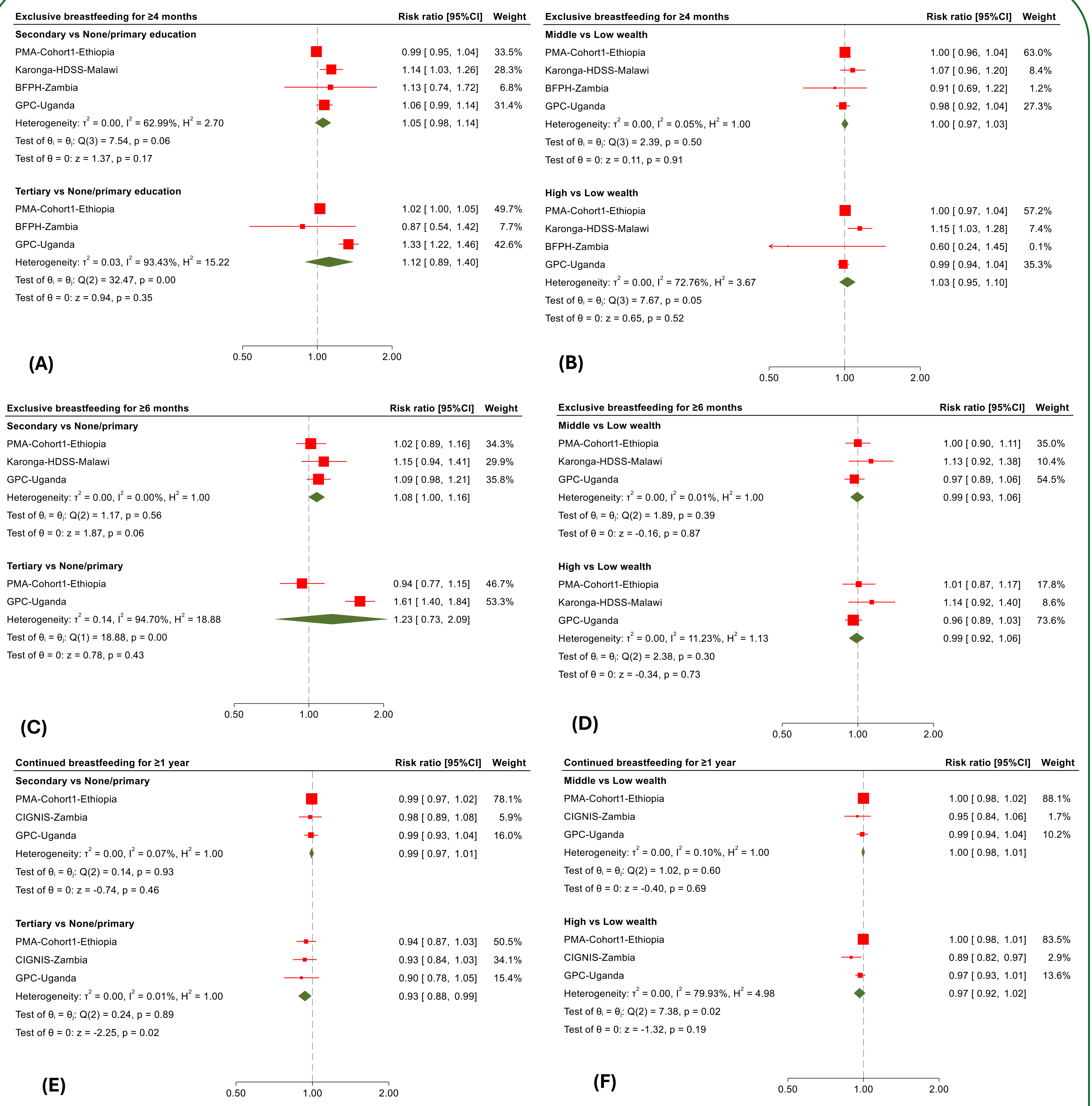

Figure 5.2 The association of maternal education and household wealth with exclusive breastfeeding for ≥4 months (A and B), exclusive breastfeeding for ≥6 months (C and D), and Continued breastfeeding (E and F). The cohort-specific estimates are adjusted risk PMA-Cohort1-Ethiopia: adjusted for child sex, place of residence, maternal age, parity, and maternal marital status. Karonga-HDSS-Malawi: adjusted for child sex, birth order, distance to a tarmac road, maternal HIV status, and maternal age. BFPH-Zambia: adjusted for child sex, maternal age, maternal HIV status, and maternal marital status. GPC-Uganda: adjusted for child sex, maternal age, maternal HIV status, and maternal marital status.

5.6 Discussion

We assessed breastfeeding patterns in six sub-Saharan Africa (SSA) cohorts and examined the association between measures of socioeconomic status (SES) and five breastfeeding indicators. Breastfeeding was nearly universal across all cohorts, with only a small percentage (1-6%) of children never breastfed. The prevalence of early initiation of breastfeeding, assessed from cohorts in Ethiopia, aligned with the average prevalence for Eastern and Southern Africa (65%) but was higher than the global average (47%) and the average prevalence for West and Central Africa (46%) (51,52). We found a higher prevalence of exclusive breastfeeding at four months than at six months, with the largest decline in exclusive breastfeeding rates from four to six months observed in Malawi. This was probably because the children in the Malawi cohort were born around the time the WHO revised the recommendation for exclusive breastfeeding from four to six months (53,54). Exclusive breastfeeding rates during the first six months of life in Ethiopia and Uganda exceeded the WHO's target of 50% prevalence by 2025 (4), but rates across all cohorts, were below WHO's more ambitious target of 70% exclusive breastfeeding prevalence by 2030(4). Almost all mothers in Malawi and Ethiopia, as well as the majority of mothers in Uganda and Zambia, continued breastfeeding one year postpartum. The CIGNIS-Zambia cohort had the lowest continued breastfeeding prevalence of any cohort, probably because mothers in the study received free complementary foods for their infants at six months as part of the study, likely discouraging them from continuing to breastfeed (26).

Overall, there were no clear, consistent socioeconomic patterns in breastfeeding across the SSA cohorts. The sole exception was that, in the meta-analysis, mothers with primary or no education were more likely to breastfeed for a longer duration than those with higher education. In some individual cohorts, middle SES (secondary education or middle-income) or higher SES (higher wealth or tertiary education) had a modest positive or negative effect on certain breastfeeding indicators, but this was inconsistent and mostly only observed in one of the SES categories. Even though the meta-analysis found evidence that mothers of middle SES (secondary education or middle-income) were slightly more likely to initiate breastfeeding early and exclusively breastfeed for six months (in the case of those with secondary education) compared to mothers with low SES (primary or no education, or low wealth), it remains unclear whether these associations were truly driven by socioeconomic advantage and not unmeasured confounders (e.g., variations in magnitude of family support), given the lack of evidence among women of higher SES. However, this could be attributed to the small number of mothers in the higher education group across the cohorts. The estimates for the CIGNIS-Zambia cohort were sensitive to maternal HIV status, particularly ever breastfeeding, likely because the study was conducted at the time of the AFASS (Acceptable, Feasible, Affordable, Sustainable and Safe) recommendations for HIV-infected mothers, suggesting that HIV-infected women could choose replacement feeding instead of breastfeeding (55).

The substantial heterogeneity in estimates for certain breastfeeding indicators across the cohorts may be attributed to variations in study methodology, study year, timing of breastfeeding assessment postpartum, sociocultural factors, and differences in the covariates adjusted in the analysis for each cohort. For example, the lower prevalence of exclusive breastfeeding at four months in the BFPH-Zambia cohort was probably because data on breastfeeding were collected more frequently than in the other cohorts, minimising the possibility of overestimation in maternal reporting of feeding practices.

Similar to our findings, several studies from sub-Saharan Africa and other LMICs found no evidence for a clear socioeconomic pattern in breastfeeding (6,16–18). However, our findings are in contrast to evidence from high-income countries, where there are clear socioeconomic inequalities and patterns in breastfeeding, with higher levels of maternal education and household income associated with a longer duration of any breastfeeding and exclusive breastfeeding (12–15).

In many SSA communities, breastfeeding is a cultural norm, and new mothers face societal expectations to breastfeed (11,56), which likely explains why nearly all mothers in this study breastfeed. In addition, the majority of mothers in SSA have access to strong informal breastfeeding support from peers and family (57), which helps fill in breastfeeding knowledge gaps for mothers with no formal education. This support system may explain the absence of clear socioeconomic disparities as it promotes equity in breastfeeding by levelling the playing field and eliminating any potential breastfeeding advantage mothers with higher education may have over those with little to no education. Also, in some cultures, infant and young child feeding decisions are largely influenced by grandmothers and mothers-in-law (11,57), regardless of the mother's socioeconomic status. Their preferences, which may include the early introduction of complementary foods (10), may potentially diminish any benefits higher socioeconomic status may have on breastfeeding practises, as observed in this study. These breastfeeding-related cultural norms differ across countries and may further explain the heterogeneity in the estimates for the associations across the cohorts analysed.

Furthermore, mothers with higher levels of formal education are more likely to work outside the home (58) and may struggle to adhere to recommended breastfeeding practices when returning to work after childbirth (10,57), resulting in early cessation. It is also common for working mothers to leave their babies with family members, usually grandmothers, who may introduce new foods to the child (10). Less educated mothers are more likely to breastfeed for a longer duration, probably because they are more likely to be self-employed or work for family members with more flexibility for childcare. Additionally, earlier studies have shown that breastmilk substitutes are expensive (59), making them relatively accessible to mothers with high SES who may be returning to work less than six months postpartum, resulting in the early introduction of other types of milk. Also, mothers with higher SES may perceive formula feeding as a status symbol, demonstrating their wealth and ability to provide their infants with expensive baby food, often incorrectly perceived to be more nutritious than breastmilk. Indeed, studies have shown that the use of breastmilk substitutes is more common among mothers with higher SES than those with low SES in LMICs (16,17).

Our study has several strengths, including analysis of a large, diverse sample of mothers from multiple SSA countries across different periods, allowing us to capture nuances across regions and study periods. In addition, we assessed multiple breastfeeding indicators, allowing for the assessment of the impact of SES on short- and long-term breastfeeding outcomes. The use of meta-analysis to pool estimates across the cohorts increased the power of the study to detect a difference. However, heterogeneity for some comparisons precluded the interpretation of pooled estimates. The main limitation of this study is that breastfeeding data was self-reported by mothers, and recall or social desirability biases may have resulted in misclassification of children. For example, in the PMA-Cohort1-Ethiopia, the question about when (minutes, hours, or days) mothers initiated breastfeeding after birth was asked six weeks after childbirth. Previous studies in Ethiopia have shown that most mothers are unable to recall the exact timing of breastfeeding initiation several weeks after birth, mainly based on a single question of when breastfeeding was initiated (60,61). Mothers likely provided responses that they considered socially acceptable rather than their actual practices. This could explain the higher prevalence of breastfeeding initiation in the Ethiopian cohorts. Nevertheless, most cohorts collected breastfeeding data at multiple time points, at regular intervals, in the first 2-3 years postpartum, so recall bias and misclassification are likely minimal. Data for this analysis were from four countries, so caution should be exercised in generalising our findings beyond these country settings. Future studies are encouraged to collect data on social support and cultural breastfeeding norms to clarify their role in the relationship between SES and breastfeeding in SSA.

5.7 Conclusion

Despite the high acceptance of breastfeeding in SSA, healthcare providers must continue to promote breastfeeding to sustain the relatively high breastfeeding rates. Further studies to understand the factors influencing breastfeeding in SSA could inform strategies to improve optimal breastfeeding rates. Researchers investigating the impact of breastfeeding on outcomes such as childhood illnesses, cognitive and educational achievements, and nutrition in SSA should carefully consider the implications of these findings for their research, particularly the lack of consistent socioeconomic patterns in breastfeeding.

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5.9 Supplementary materials

Supplementary Table 5.1 Cohort description and breastfeeding measurement

Cohort acronym	Country	Cohort description	Measurement of breastfeeding
PMA-Cohort1-Ethiopia	Ethiopia	This was a prospective population-based cohort study conducted in six Ethiopian regions (Tigray, Oromia, Amhara, SNNP [Southern Nations, Nationalities and Peoples], Afar, and Addis Ababa) between 2019 and 2021 as part of the Performance Monitoring for Action Ethiopia (PMA-Ethiopia) survey. A multistage sampling method was used to sample 2869 (response rate 99.6%) women between the ages of 15 and 49 who were pregnant or had given birth within the previous six months from 32614 households. The pregnant women were followed up at six weeks, six months, and one year postpartum. For recently postpartum women (<6 weeks), the baseline survey and six-week postpartum interview were completed at enrolment. Singleton births were included in this analysis.	Information on infant feeding practices was collected through interviews with mothers at six weeks, six months, and one year postpartum. Among the questions were whether the mother had ever breastfed the child, when they first breastfed after delivery, if they were currently breastfeeding, and what they had fed the child in the previous 24 hours. At the 6-month visit, mothers were asked the age at which they started giving their babies other foods and drinks. At the one-year visit, mothers were asked if they had breastfed their child in the previous 24 hours.
PMA-MNH-Ethiopia	Ethiopia	This was a prospective population-based cohort study conducted in the Southern Nations, Nationalities and Peoples' region of Ethiopia between 2016 and 2017 (31). A multistage sampling procedure was used to sample 329 pregnant women from 10 399 households. The study participants were 15-49 years old, at least six months pregnant, and regular members of selected households. Data on pregnancy and sociodemographic characteristics were collected before birth. After delivery, participants were followed up at seven days, six weeks, and six months postpartum, and information about childbirth services, vaccinations, postnatal care, and feeding practices was collected. Singleton births were included in this analysis.	Information on infant feeding practices was collected during the postpartum follow-up visits at seven days, six weeks, and six months after birth. Mothers were asked how long after birth they started breastfeeding and what they fed their child in the 24 hours preceding each visit. Sufficient information was not collected to determine exclusive breastfeeding at six months.
Karonga-HDSS-Malawi	Malawi	The Karonga Health and Demographic Surveillance System (HDSS) site is located in northern Malawi(32) and includes 42,000 individuals living in 7000 households(33,34). The population is mainly rural, with residents engaged in subsistence farming, fishing, and trading. The site began with a baseline census between 2002 and 2004, and births to women in the baseline survey were recorded, and the newborns were enrolled. The site conducts ongoing surveillance, gathering data on socioeconomic factors, demographics, household characteristics, and vital events. Data on the children born between 2002 and 2004 were analysed.	Breastfeeding information was collected when the children in the cohort were 0-3 months and again when they were about one year. Mothers were asked if they had ever breastfed the child and the age of the child when other kinds of milk, foods, and drinks were introduced. At the one-year visit, mothers were asked if they breastfed the child in the 24 hours preceding the visit.

GPC-Uganda	Uganda	The General Population Cohort (GPC) is a prospective population-based cohort study in rural Southwestern Uganda established in 1989(25). The study site is in Kalungu district, approximately 120 km west of Kampala. The primary economic activities of the residents are subsistence agriculture and small-scale trading. Annual surveys collect routine data on household members and housing characteristics and possessions. In 1999, child health surveys were introduced as part of the GPC to gather detailed information on children under thirteen(35). Data on the children born between 2000 and 2011 were analysed.	Breastfeeding data were collected annually from mothers whose children participated in child surveys. The mothers were asked if they had ever breastfed the child if they were currently breastfeeding, and the age of the child when they stopped breastfeeding. Mothers were also asked the age of the child when other kinds of milk, foods, and liquids were introduced.
CIGNIS-Zambia	Zambia	This was a randomised, double-blind, controlled trial conducted in Chilenje, Lusaka, Zambia, between 2005 and 2009(26). It aimed to investigate the effects of locally produced complementary foods on stunting in infants at 18 months of age. Mother-infant pairs were recruited at the Chilenje government clinic if the child was six months old and did not have a severe clinical condition, and the mother consented to feed the child the complementary food for a year and make monthly clinic visits. Overall, 811 mother-infant pairs were recruited and monitored monthly for 12 months. Infants were randomly assigned to receive either a richly fortified locally produced porridge or porridge with conventional fortification. On assessment at age 18 months, there was no difference in the proportion stunted between the intervention and the control groups. Children from both arms of the trial were included in this analysis.	During each monthly clinic visit, mothers were asked about their current breastfeeding status. For mothers who had stopped breastfeeding, additional information was gathered on when they stopped. Data were not collected on when other foods and fluids were introduced.
BFPH-Zambia	Zambia	This was a prospective cohort study conducted between 2001 and 2003 in Chilenje, Lusaka, Zambia to investigate the risk for subclinical mastitis, breast milk HIV viral load and postpartum morbidity among HIV-infected and uninfected Zambian women (27,28). Women were recruited from the Chilenje clinic at 32 to 34 weeks gestation if they lived within the Chilenje clinic area, attended antenatal care at the clinic, knew their HIV status, and planned to breastfeed after delivery. Eleven postpartum follow-up visits (3, 7, 10, and 14 days and at 3, 4, 5, 6, 9, 12, and 16 weeks) were made to monitor and collect maternal and child health information from eligible women up until 16 weeks postpartum.	At each postpartum visit, mothers were asked about infant feeding practices, including whether the child was breastfeeding, and if water, other kinds of milk, foods, or liquids were introduced. The breastfeeding information was collected for four months postpartum.

Supplementary Table 5.2 Distribution of breastfeeding indicators across participants characteristics by cohorts

	Total	Ever breastfed	Breastfeeding initiation within 1 hour after birth	Exclusive breastfeeding for ≥4 months	Exclusive breastfeeding for ≥6 months	Continued breastfeeding for ≥1 year
PMA-Cohort1-Ethiopia*						
Child sex						
Male	1049 (51.1)	1004 (97.9)	695 (67.1)	863 (94.3)	617 (67.4)	974 (97.0)
Female	1004 (48.9)	961 (98.5)	670 (67.7)	813 (93.9)	594 (68.6)	953 (98.0)
Residence						
Urban	465 (22.2)	442 (99.2)	308 (70.0)	394 (95.2)	269 (65.0)	424 (92.7)
Rural	1631 (77.8)	1560 (98.0)	1056 (66.7)	1317 (93.9)	965 (68.7)	1544 (98.8)
Maternal age						
<20	192 (9.3)	176 (98.4)	122 (63.6)	156 (95.6)	113 (69.0)	180 (98.0)
20-29	1094 (53.3)	1062 (98.8)	752 (69.6)	910 (94.9)	662 (69.1)	1030 (96.8)
≥30	767 (37.4)	728 (97.2)	491 (65.2)	611 (92.6)	435 (66.0)	719 (98.4)
Number of previous births						
0	358 (17.1)	336 (97.9)	214 (64.4)	302 (95.2)	201 (63.3)	323 (93.9)
1	458 (21.9)	443 (99.6)	291 (65.0)	383 (96.7)	276 (69.7)	439 (97.8)
2-3	588 (28.0)	560 (97.9)	401 (70.2)	482 (94.8)	362 (71.3)	555 (97.8)
≥4	691 (33.0)	663 (97.8)	457 (68.1)	545 (91.4)	395 (66.2)	651 (98.7)
Marital status						
Married	1993 (95.2)	1902 (98.1)	1309 (67.8)	1626 (94.1)	1163 (67.3)	1876 (97.6)
Unmarried	100 (4.8)	98 (100.0)	55 (59.3)	84 (94.6)	71 (79.2)	91 (94.3)
PMA-MNH-Ethiopia*						
Child sex						
Male	187 (58.1)	-	111 (61.4)	-	-	-
Female	135 (41.9)	-	88 (65.4)	-	-	-
Residence						
Urban	37 (11.3)	-	25 (72.1)	-	-	-
Rural	292 (88.7)	-	174 (62.0)	-	-	-
Maternal age						
<20	37 (11.2)	-	22 (66.0)	-	-	-
20-29	169 (51.5)	-	112 (69.1)	-	-	-
≥30	123 (37.3)	-	65 (54.2)	-	-	-
Number of previous births						
0	0 (0.0)	-	0 (0.0)	-	-	-
1	67 (20.6)	-	44 (68.4)	-	-	-
2-3	82 (25.4)	-	48 (60.8)	-	-	-
≥4	175 (54.0)	-	106 (62.2)	-	-	-
Marital status						
Married	319 (97.1)	-	190 (62.0)	-	-	-
Unmarried	10 (2.9)	-	9 (96.7)	-	-	-
Karonga HDSS-Malawi						
Child sex						
Female	670 (47.9)	667 (99.7)	-	477 (71.5)	271 (40.6)	646 (99.7)
Male	730 (52.1)	725 (99.4)	-	498 (68.7)	282 (38.9)	697 (99.0)
Birth order						
1	325 (24.6)	324 (100.0)	-	207 (63.9)	113 (34.9)	314 (98.4)
2-3	444 (33.6)	441 (99.3)	-	313 (71.0)	179 (40.6)	423 (99.8)
4 or more	551 (41.7)	547 (99.5)	-	395 (72.2)	226 (41.3)	529 (99.6)
Distance to Tarmac road						
Within 1km	714 (51.0)	709 (99.6)	-	520 (73.3)	312 (44.0)	680 (99.3)
More than 1km	685 (49.0)	682 (99.6)	-	454 (66.6)	240 (35.2)	662 (99.4)
Maternal HIV status						
Negative	1138 (81.3)	1133 (99.6)	-	775 (68.4)	435 (38.4)	1095 (99.5)

Positive	44 (3.2)	44 (100.0)	-	33 (75.0)	22 (50.0)	43 (100.0)
Unknown	217 (15.5)	214 (99.1)	-	166 (77.6)	95 (44.4)	204 (98.1)
Maternal age						
<20	213 (20.4)	212 (100.0)	-	135 (63.7)	76 (35.8)	208 (100.0)
20-29	580 (55.6)	577 (99.6)	-	399 (69.1)	214 (37.1)	555 (99.8)
≥30	251 (24.0)	249 (99.2)	-	181 (72.7)	106 (42.6)	242 (100.0)

	Total	Ever breastfed	Breastfeeding initiation within 1 hour after birth	Exclusive breastfeeding for ≥4 months	Exclusive breastfeeding for ≥6 months	Continued breastfeeding for ≥1 year
GPC-Uganda						
Child sex						
Male	4798 (50.8)	3523 (99.3)	-	2148 (71.4)	1670 (55.5)	1622 (68.4)
Female	4639 (49.2)	3288 (99.3)	-	2056 (73.0)	1582 (56.2)	1430 (68.1)
Maternal age						
<20	658 (16.7)	579 (99.8)	-	378 (75.9)	267 (53.6)	328 (81.8)
20-29	2173 (55.2)	1923 (100.0)	-	1301 (74.8)	1030 (59.2)	1116 (84.0)
≥30	1108 (28.1)	1007 (99.9)	-	629 (66.2)	478 (50.3)	573 (84.0)
Marital status						
Married	3008 (77.6)	2715 (100.0)	-	1816 (72.7)	1407 (56.3)	1608 (84.3)
Unmarried	869 (22.4)	757 (99.9)	-	472 (71.6)	353 (53.6)	399 (81.8)
Maternal HIV status						
Positive	267 (2.8)	211 (100.0)	-	133 (68.9)	91 (47.1)	95 (62.5)
Negative	3672 (38.9)	3294 (99.9)	-	2173 (72.7)	1682 (56.2)	1919 (85.0)
Unknown	5498 (58.3)	3306 (98.6)	-	1898 (71.9)	1479 (56.0)	1038 (50.4)
CIGNIS-Zambia						
Child sex						
Male	385 (47.5)	364 (94.5)	-	-	-	235 (64.6)
Female	426 (52.5)	396 (93.0)	-	-	-	262 (66.2)
Child HIV status at 18 months						
Negative	599 (73.9)	561 (93.7)	-	-	-	437 (77.9)
Positive	18 (2.2)	16 (88.9)	-	-	-	8 (50.0)
Unknown	194 (23.9)	183 (94.3)	-	-	-	52 (28.4)
Number of siblings						
0	676 (83.4)	633 (93.6)	-	-	-	412 (65.1)
1-2	133 (16.4)	125 (94.0)	-	-	-	83 (66.4)
3	2 (0.2)	2 (100.0)	-	-	-	2 (100.0)
Maternal age						
<20	90 (11.1)	88 (97.8)	-	-	-	53 (60.2)
20-29	504 (62.1)	481 (95.4)	-	-	-	320 (66.5)
≥30	217 (26.8)	191 (88.0)	-	-	-	124 (64.9)
Maternal HIV status						
Negative	564 (69.5)	561 (99.5)	-	-	-	419 (74.7)
Positive	177 (21.8)	131 (74.0)	-	-	-	29 (22.1)
Unknown	70 (8.6)	68 (97.1)	-	-	-	49 (72.1)
Marital status						
Married	204 (25.2)	188 (92.2)	-	-	-	108 (57.5)
Unmarried	607 (74.8)	572 (94.2)	-	-	-	389 (68.0)
BFPH-Zambia						
Child sex						
Female	197 (52.8)	-	-	74 (37.6)	-	-
Male	176 (47.2)	-	-	54 (30.7)	-	-
Maternal age						
<20	69 (18.4)	-	-	23 (33.3)	-	-
20-29	253 (67.7)	-	-	89 (35.2)	-	-
≥30	52 (13.9)	-	-	16 (30.8)	-	-

Maternal HIV status						
Negative	188 (50.3)	-	-	66 (35.1)	-	-
Positive	186 (49.7)	-	-	62 (33.3)	-	-
Marital status						
Married	273 (73.0)	-	-	89 (32.6)	-	-
Unmarried	101 (27.0)	-	-	39 (38.6)	-	-

Not all participants in the total sample had information on all the breastfeeding indicators.

*Percentages and counts are weighted estimates

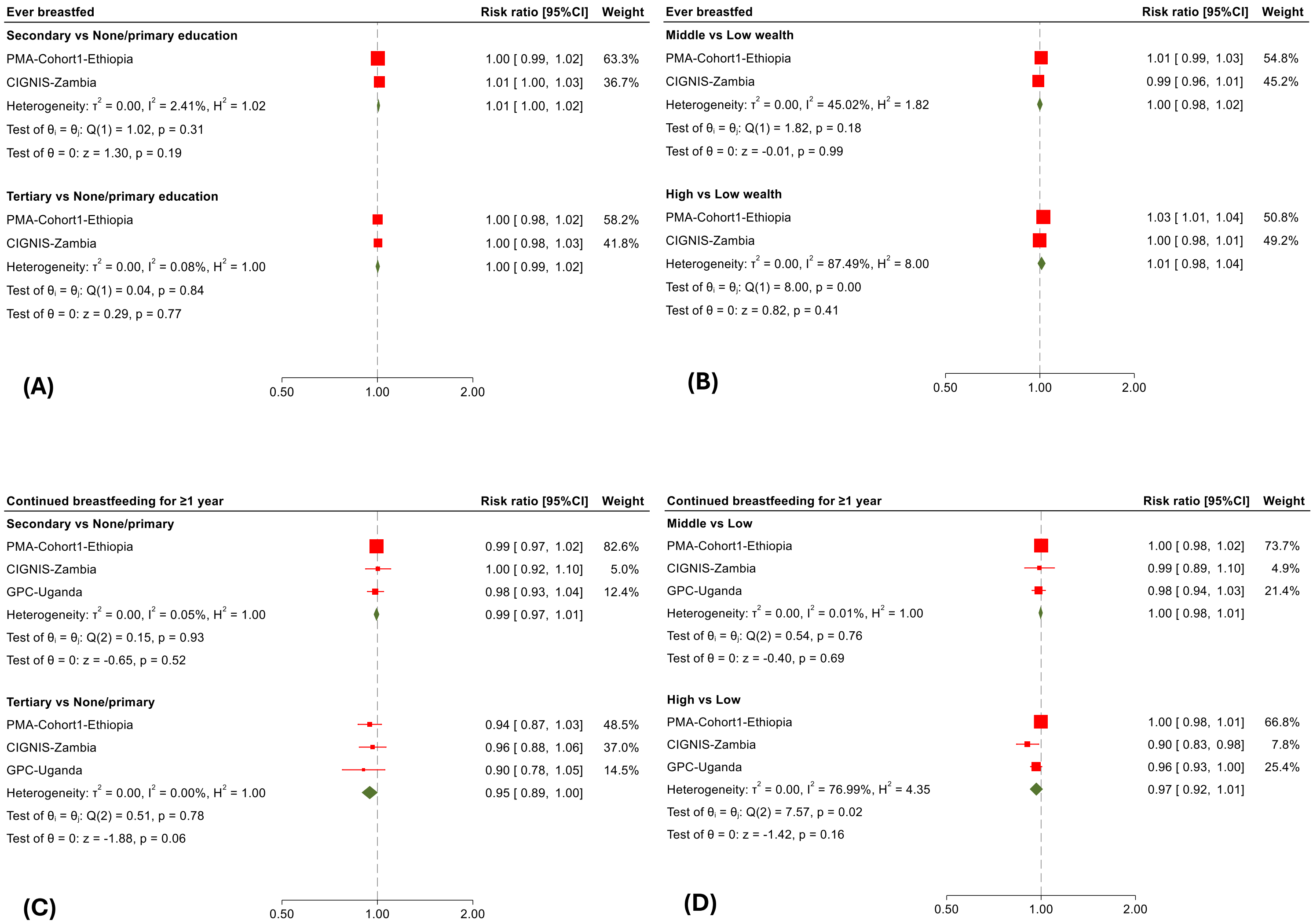
Supplementary Table 5.3: Cohort-specific risk ratios (RR) from univariable and multivariable Poisson regression models for the association of maternal education and household wealth with breastfeeding indicators.

	Ever breastfed		Breastfeeding initiation within 1 hour after birth		Exclusive breastfeeding for ≥4 months		Exclusive breastfeeding for ≥6 months		Continued breastfeeding for ≥1 year	
	Crude RR (95%CI)	**Adjusted RR (95%CI)**	**Crude RR (95%CI)**	**Adjusted RR (95%CI)**	**Crude RR (95%CI)**	**Adjusted RR (95%CI)**	**Crude RR (95%CI)**	**Adjusted RR (95%CI)**	**Crude RR (95%CI)**	**Adjusted RR (95%CI)**
PMA- Cohort1-Ethiopia										
Maternal education	n=1965		n=1990		n=1751		n=1751		n=1945	
None/primary	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Secondary	1.01 (0.99 - 1.02)	1.00 (0.99 - 1.02)	1.10 (1.00 - 1.21)	1.11 (1.02 - 1.22)	1.01 (0.96 - 1.05)	0.99 (0.95 - 1.04)	1.00 (0.88 - 1.14)	1.02 (0.89 - 1.16)	0.97 (0.95 - 0.99)	0.99 (0.97 - 1.02)
Tertiary	1.01 (0.99 - 1.03)	1.00 (0.98 - 1.02)	0.95 (0.78 - 1.16)	0.96 (0.78 - 1.17)	1.04 (1.01 - 1.08)	1.02 (1.00 - 1.05)	0.89 (0.73 - 1.09)	0.94 (0.77 - 1.15)	0.91 (0.83 - 1.00)	0.94 (0.87 - 1.03)
Household wealth level	n=1965		n=1990		n=1751		n=1751		n=1945	
Low	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Middle	1.01 (0.99 - 1.03)	1.01 (0.99 - 1.03)	1.08 (0.96 - 1.22)	1.09 (0.97 - 1.23)	1.00 (0.96 - 1.04)	1.00 (0.96 - 1.04)	0.99 (0.89 - 1.11)	1.00 (0.90 - 1.11)	1.00 (0.98 - 1.01)	1.00 (0.98 - 1.02)
High	1.02 (1.01 - 1.04)	1.03 (1.01 - 1.04)	1.08 (0.96 - 1.21)	1.08 (0.94 - 1.23)	1.02 (0.98 - 1.05)	1.00 (0.97 - 1.04)	0.97 (0.87 - 1.09)	1.01 (0.87 - 1.17)	0.97 (0.95 - 0.99)	1.00 (0.98 - 1.01)
PMA-MNH-Ethiopia										
Maternal education			n=312							
None/primary	-	-	1.00	1.00	-	-	-	-	-	-
Secondary	-	-	1.03 (0.73 - 1.45)	0.98 (0.65 - 1.50)	-	-	-	-	-	-
Tertiary	-	-	1.17 (0.81 - 1.69)	1.07 (0.74 - 1.53)	-	-	-	-	-	-
Household wealth level			n=312							
Low	-	-	1.00	1.00	-	-	-	-	-	-
Middle	-	-	1.23 (0.93 - 1.63)	1.25 (0.97 - 1.61)	-	-	-	-	-	-
High	-	-	1.07 (0.77 - 1.49)	1.05 (0.67 - 1.63)	-	-	-	-	-	-
Karonga - HDSS - Malawi										
Maternal education					n=996		n=996			
None/primary	-	-	-	-	1.00	1.00	1.00	1.00	-	-
Secondary	-	-	-	-	1.10 (1.00 - 1.21)	1.14 (1.03 - 1.26)	1.09 (0.90 - 1.32)	1.15 (0.94 - 1.41)	-	-
Household wealth					n=972		n=972			
Poorest	-	-	-	-	1.00	1.00	1.00	1.00	-	-
Middle	-	-	-	-	1.08 (0.97 - 1.20)	1.07 (0.96 - 1.20)	1.14 (0.94 - 1.39)	1.13 (0.92 - 1.38)	-	-
Least poor	-	-	-	-	1.17 (1.06 - 1.30)	1.15 (1.03 - 1.28)	1.20 (0.98 - 1.46)	1.14 (0.92 - 1.40)	-	-

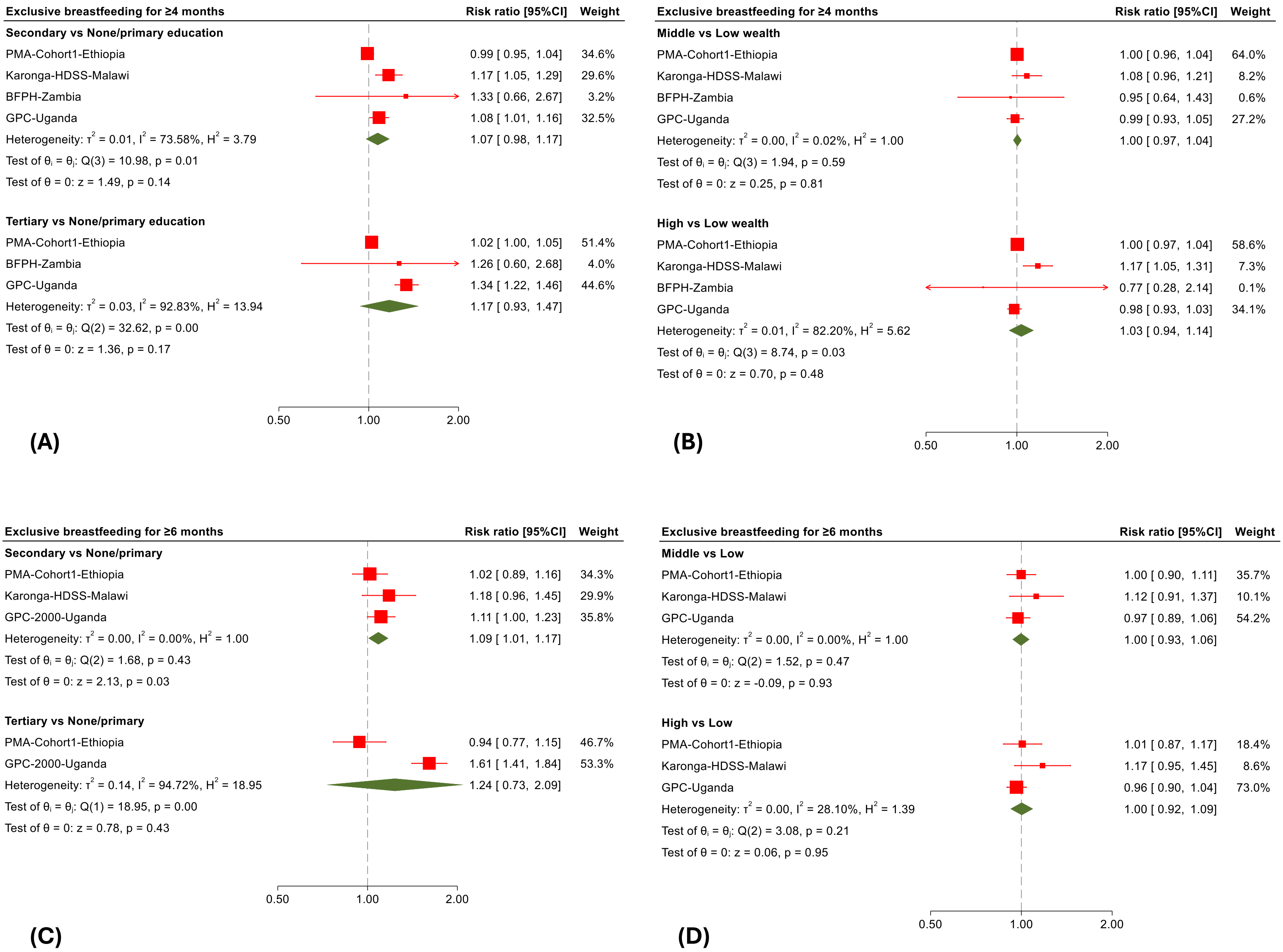
	Ever breastfed		Breastfeeding initiation within 1 hour after birth		Exclusive breastfeeding for ≥4 months		Exclusive breastfeeding for ≥6 months		Continued breastfeeding for ≥1 year	
	Crude RR (95%CI)	**Adjusted RR (95%CI)**	**Crude RR (95%CI)**	**Adjusted RR (95%CI)**	**Crude RR (95%CI)**	**Adjusted RR (95%CI)**	**Crude RR (95%CI)**	**Adjusted RR (95%CI)**	**Crude RR (95%CI)**	**Adjusted RR (95%CI)**
GPC-Uganda										
Maternal education					n=1553		n=1553		n=1227	
None/primary	-	-	-	-	1.00	1.00	1.00	1.00	1.00	1.00
Secondary	-	-	-	-	1.07 (1.00 - 1.15)	1.06 (0.99 - 1.14)	1.10 (0.99 - 1.22)	1.09 (0.98 - 1.21)	0.98 (0.93 - 1.04)	0.99 (0.93 - 1.04)
Tertiary	-	-	-	-	1.32 (1.21 - 1.43)	1.33 (1.22 - 1.46)	1.59 (1.40 - 1.80)	1.61 (1.40 - 1.84)	0.91 (0.78 - 1.06)	0.90 (0.78 - 1.05)
Household wealth level					n=3015		n=3015		n=2318	
Low	-	-	-	-	1.00	1.00	1.00	1.00	1.00	1.00
Middle	-	-	-	-	0.98 (0.92 - 1.04)	0.98 (0.92 - 1.04)	0.97 (0.89 - 1.06)	0.97 (0.89 - 1.06)	1.00 (0.95 - 1.05)	0.99 (0.94 - 1.04)
High	-	-	-	-	0.98 (0.94 - 1.03)	0.99 (0.94 - 1.04)	0.96 (0.89 - 1.03)	0.96 (0.89 - 1.03)	0.98 (0.94 - 1.02)	0.97 (0.93 - 1.01)
CIGNIS - Zambia										
Maternal education	n=811								n=760	
None/primary	1.00	1.00	-	-	-	-	-	-	1.00	1.00
Secondary	1.00 (0.97 - 1.05)	0.99 (0.95 - 1.03)	-	-	-	-	-	-	1.11 (0.98 - 1.26)	0.98 (0.89 - 1.08)
Tertiary	0.98 (0.94 - 1.03)	0.96 (0.91 - 1.00)							1.11 (0.97 - 1.27)	0.93 (0.84 - 1.03)
Household wealth level	n=811		-	-	-	-	-	-	n=760	
Low	1.00	1.00							1.00	1.00
Middle	0.97 (0.92 - 1.02)	0.95 (0.91 - 1.00)	-	-	-	-	-	-	0.99 (0.85 - 1.14)	0.95 (0.84 - 1.06)
High	0.98 (0.94 - 1.02)	0.96 (0.93 - 1.00)	-	-	-	-	-	-	1.03 (0.92 - 1.16)	0.89 (0.82 - 0.97)
BFPH - Zambia										
Maternal education					n=373					
None/primary	-	-	-	-	1.00	1.00	-	-	-	-
Secondary	-	-	-	-	1.18 (0.77 - 1.79)	1.13 (0.74 - 1.72)	-	-	-	-
Tertiary					0.96 (0.59 - 1.54)	0.87 (0.54 - 1.42)	-	-	-	-
Household wealth level	-	-	-	-	n=373					
Low					1.00	1.00	-	-	-	-
Middle	-	-	-	-	0.91 (0.69 - 1.21)	0.91 (0.69 - 1.22)	-	-	-	-
High	-	-	-	-	0.61 (0.25 - 1.48)	0.60 (0.24 - 1.45)	-	-	-	-

PMA-Cohort1-Ethiopia: adjusted for child sex, place of residence, maternal age, parity, and maternal marital status.

PMA-MNH-Ethiopia: adjusted for child sex, place of residence, maternal age, parity, and maternal marital status.
Karonga-HDSS-Malawi: adjusted for child sex, birth order, distance to a tarmac road, maternal HIV status, and maternal age.
GPC-Uganda: adjusted for child sex, maternal age, maternal HIV status, and maternal marital status.
BFPH-Zambia: adjusted for child sex, maternal age, maternal HIV status, and maternal marital status.
CIGNIS-Zambia: adjusted for child sex, child HIV status, maternal HIV status, number of siblings, Maternal age, and maternal marital status.



Supplementary Figure 5.1 The association of maternal education and household wealth with whether a mother ever breastfed (A and B) and continued breastfeeding for one year or longer (C and D) among known HIV-negative mothers. The cohort-specific estimates are adjusted risk ratios. PMA-Cohort1-Ethiopia: adjusted for child sex, place of residence, maternal age, parity, and maternal marital status. CIGNIS-Zambia: adjusted for child sex, child HIV status, number of siblings, Maternal age, and maternal marital status. GPC-Uganda: adjusted for child sex, maternal age, maternal HIV status, and maternal marital status.



Supplementary Figure 5.2 The association of maternal education and household wealth with exclusive breastfeeding for ≥4 months (A and B) and exclusive breastfeeding for at least six months (C and D) among known HIV-negative mothers. The cohort-specific estimates are adjusted risk ratios. PMA-Cohort1-Ethiopia: adjusted for child sex, place of residence, maternal age, parity, and maternal marital status. Karonga-HDSS-Malawi: adjusted for child sex, birth order, distance to a tarmac road, maternal HIV status, and maternal age. BFPH-Zambia: adjusted for child sex, maternal age, maternal HIV status, and maternal marital status. GPC-Uganda: adjusted for child sex, maternal age, maternal HIV status, and maternal marital status.

CHAPTER 6

Paper 4

Effects of exclusive breastfeeding on educational attainment and longitudinal trajectories of grade progression among children in a 13-year follow-up study in Malawi

CHAPTER 6: PAPER 4 - EFFECTS OF EXCLUSIVE BREASTFEEDING ON EDUCATIONAL ATTAINMENT AND LONGITUDINAL TRAJECTORIES OF GRADE PROGRESSION AMONG CHILDREN IN A 13-YEAR FOLLOW-UP STUDY IN MALAWI

6.1 Introduction

This chapter focuses on objective 3, aiming to investigate the potential association between exclusive breastfeeding duration in infancy and later educational attainment at school age using longitudinal birth cohort data from the Karonga Health and Demographic Surveillance System site in Malawi (Karonga HDSS). The chapter comprehensively analyses primary school progression among children in rural Malawi, examining whether children were age-appropriate for their grade between ages six and thirteen. It also highlights the critical points when children begin to fall behind in school and explores the diverse trajectories of grade progression. The effect of exclusive breastfeeding duration on age-for-grade attainment and trajectories of grade progression is assessed.

In addendum 1, the data is further explored to specifically investigate the confounding effect of socioeconomic factors on the potential association between exclusive breastfeeding duration and educational attainment. Additionally, addendum 2 examines the association between exclusive breastfeeding duration and grade repetition. In a meta-analysis, estimates from the analysis on grade repetition are combined with findings from a South African study identified through the systematic review presented in Chapter Two to determine the pooled effect of exclusive breastfeeding duration on grade repetition.

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Effects of exclusive breastfeeding on educational attainment and longitudinal trajectories of grade progression among children in a 13-year follow-up study in Malawi

Author: Shamsudeen Mohammed et al
Publication: Scientific Reports
Publisher: Springer Nature
Date: Jul 14, 2023

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Student ID Number	LSH1902998	**Title**	Mr
First Name(s)	Shamsudeen		
Surname/Family Name	Mohammed		
Thesis Title	Effects of breastfeeding duration on educational attainment of children and adolescents in sub-Saharan Africa: A multisite analysis of longitudinal data		
Primary Supervisor	Laura Oakley		

If the Research Paper has previously been published please complete Section B, if not please move to Section C.

<u>SECTION B – Paper already published</u>

Where was the work published?	Scientific Reports		
When was the work published?	14 July 2023		
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For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	I requested the data from the Karonga Health and Demographic Surveillance System (HDSS) site in Malawi, cleaned the data, and planned and conducted the analysis with guidance from my supervisors. I also conducted the literature search for the study and prepared the manuscript for submission to the journal. My supervisors provided critical input on interpreting, discussing, and presenting the results.

SECTION E

Student Signature	
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Date	9th April 2024

6.2 Published paper

scientific reports

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Effects of exclusive breastfeeding on educational attainment and longitudinal trajectories of grade progression among children in a 13-year follow-up study in Malawi

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The benefits of exclusive breastfeeding (EBF) for infant health and survival are well documented. However, its impact on educational outcomes has been contested and poorly researched in Africa. It has been hypothesised that positive associations reported in high-income countries can be attributed to residual confounding by socioeconomic status (SES). Our study investigated whether EBF duration in infancy is associated with educational attainment and age-for-grade attainment trajectories at school-age in rural Malawi. Longitudinal data on 1021 children at the Karonga demographic surveillance site in Malawi were analysed. Breastfeeding data were collected 3 months after birth and again at age one. The school grade of each child was recorded each year from age 6 until age 13. We calculated age-for-grade based on whether a child was at, over, or under the official expected age for a grade. Generalised estimating equations estimated the average effect of breastfeeding on age-for-grade. Latent class growth analysis identified age-for-grade trajectories, and multinomial logistic regression examined their associations with EBF. Maternal-child characteristics, SES, and HIV status were controlled. Overall, 35.9% of the children were exclusively breastfed for 6 months. Over-age for grade steadily increased from 9.6% at age 8 to 41.9% at age 13. There was some evidence that EBF for 6 months was associated with lower odds of being over-age for grade than EBF for less than 3 months (aOR = 0.82, 95%CI = 0.64–1.06). In subgroup analyses, children exclusively breastfed for 6 months in infancy were less likely to be over-age for grades between ages 6–9 (aOR = 0.64, 95%CI = 0.43–0.94). Latent class growth analysis also provided some evidence that EBF reduced the odds of falling behind in the early school grades (aOR = 0.66, 95%CI = 0.41–1.08) but not later. Our study adds to the growing evidence that EBF for 6 months has benefits beyond infant health and survival, supporting the WHO's recommendation on EBF.

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Optimal breastfeeding has been linked to improved cognitive development and higher intelligence test scores in several studies. For example, in a systematic review and meta-analysis of studies mainly from high-income countries that controlled for home stimulation and measures of socioeconomic status, breastfed children scored 3.4 points higher on intelligence tests than non-breastfed children[1]. Not only has breastfeeding been linked to improved cognitive functions, but there is growing evidence of a positive association between breastfeeding and educational outcomes[2–5]. In high-income countries, the evidence supporting these positive associations has been relatively consistent over the last few decades. Heikkila et al.[2], for example, found higher educational achievement among five-year-olds in the United Kingdom who were exclusively breastfed for a longer duration. In Australia, ten-year-olds who were predominantly breastfed for 6 months had higher academic scores than those who were breastfed for less than 6 months[4]. Among adolescents in the United States, being breastfed was associated with a higher grade point average compared to those not breastfed[5].

While the exact mechanism is unclear, it has been proposed that certain components of human breastmilk, including human milk oligosaccharides, arachidonic acid, and docosahexaenoic acid, modulate the neurodevelopmental processes of the newborn brain in the first few months after birth, a time of rapid growth and maturation of the brain[6–9]. From this perspective, if breastfeeding truly has a biological (direct nutritional) effect on intelligence and educational outcomes, we should observe it across all populations and settings, not just in high-income countries. For instance, breastfed children have a reduced risk of childhood gastrointestinal and respiratory tract infections across populations regardless of country income level[10].

Nevertheless, in low and middle-income countries (LMICs), the evidence on the effects of breastfeeding on intelligence and educational outcomes is unclear and mostly inconsistent with those from high-income countries[11,12]. In Brazil, for example, Victora et al.[13], found that children breastfed for 12 months or more had 0.91 more years of education than those breastfed for less than 1 month. Among children aged 6–18 in India, breastfeeding for more than 12 months was associated with 0.12–0.19 more years of education than breastfeeding for less than 12 months[14]. However, no association was observed between breastfeeding and educational attainment when Horta et al.[15], studied birth cohorts in the Philippines, Guatemala, India, and Brazil. Similarly, a recent study in Turkey found no evidence of an association between breastfeeding and academic performance[16].

Some have questioned the consistent positive effects of breastfeeding on educational outcomes in studies conducted in high-income countries because of the conflicting results from low-income settings. It has been suggested that the positive effects observed in high-income countries may be attributable to residual confounding resulting from insufficient statistical control for socioeconomic status and not a direct effect of breastmilk[12,13,17,18]. This hypothesis is supported by the fact that in high-income settings, women with higher socioeconomic status breastfeed longer than those with lower socioeconomic status, and maternal education strongly correlates with offspring cognitive abilities and educational outcomes[13,19–21].

Studies from sub-Saharan Africa are scarce in this decades-old debate. In a recent systematic review, we found that only two studies have investigated the effects of breastfeeding on educational attainment in sub-Saharan Africa[12]. Both studies were conducted in South Africa. One found weak evidence for an association between exclusive breastfeeding and grade repetition[22], while the other study found no evidence of an association between breastfeeding and school attainment or completion[15]. However, generalising the South African findings to other African countries would be naive, given the varying associations reported in earlier studies from different settings. There are also important differences in childhood adversities (such as HIV exposure) and non-socioeconomic (sociocultural, political, and educational system-related) factors that affect educational attainment across sub-Saharan African countries[23]. In addition, previous studies, including those carried out in high-income settings, examined educational attainment at one point in time. It is possible that these studies might have missed a child's educational attainment at other time points because academic growth is not always linear. Using longitudinal birth cohort data from the Karonga Health and Demographic Surveillance System (HDSS) in Malawi, we examined primary school progression over eight years and assessed the effects of exclusive breastfeeding duration on educational attainment and age-for-grade attainment trajectories from age six when the children started primary school through to age 13.

Methods

Participants and data. We used prospective, longitudinal data from the Karonga HDSS in northern Malawi. The HDSS is situated in the southern part of the Karonga District and includes 42,000 individuals living in 7000 households[24,25]. Most of the population lives in rural areas, and a majority of them engage in subsistence farming, fishing, and trading. The HDSS undertakes continuous demographic surveillance in the area to collect socioeconomic, demographic, and household-level data and information on vital events and migration of individuals of all ages[26]. It started with a baseline census between 2002 and 2004. Births to women in the baseline survey were reported, and field staff enrolled the children as part of the demographic surveillance follow-up visits[27]. Data were collected on maternal and child characteristics, including child anthropometry, birth characteristics, breastfeeding and other feeding practices, and household socioeconomic status when the children were 0–3 months old. The birth cohort was revisited at age 12 months, and the feeding data and other infant and family characteristics were updated. Annual surveys and re-census were conducted in the HDSS to periodically update existing data and collect new information, including children's schooling, anthropometry, and vital events. For the present analysis, we restricted the study population to birth cohort members between the ages of six and 13 (primary school age in Malawi) with at least one data point on current primary school grade. In Malawi, school enrolment at public primary schools is free, and children do not have to pass an entrance examination to enrol in school[24].

Study measures. *Outcome variable.* The main outcome of this study was age-for-grade, defined as the age at which a child would be expected to enter a given grade if they had begun primary school on time and advanced without repeating or skipping a grade[28]. In this cohort, 96.3% (n = 953) of the children started primary school at age six or earlier, 3.4% (n = 34) started at age 7, and 0.3% (n = 3) started at age 8, so age-for-grade was primarily a measure of progress. Information on the current grade of each child in the cohort was collected at multiple time points starting in 2007, when they were about four years old and updated annually until 2015, when they were about thirteen years old. Public primary schools in Malawi consist of eight grades, and children are expected to enter grade 1 at age six and continue for eight years until they complete grade eight at age thirteen. For example, children are expected to enter grades 5, 6, and 7 at ages 10, 11, and 12, respectively. We calculated age-for-grade based on whether a child was at, over, or under the official expected age for entry into a grade for all the time points for which data were available for a given child. A child was considered under-age for grade if they were one or more years younger than the official age for the grade, on-time if they were of the official age or one year older than the official age for the grade, and over-age if they were two or more years older than the official age for the grade[24,29]. Over-age for grade is a sign that a child is struggling academically, leading them to repeat grades. Six children did not have data on age-for-grade and were excluded from further analysis (Fig. 1). Three of the six children with no current grade record were never enrolled, and three left school (one each at the ages of 5, 6, and 11), and their records were not taken.

Exposure variable. Exclusive breastfeeding in the first 6 months after birth is the main exposure. Mothers reported information on breastfeeding and other infant feeding practices at baseline when the children were 0–3 months old and at follow-up when the average age of children was 12 months (SD = 0.03 months). Mothers were asked if the child was breastfeeding and how old the child was when other kinds of milk, formula, water, solid foods, and other foods were introduced. We defined exclusive breastfeeding as feeding a child with only breastmilk in the first 6 months after birth. The duration of exclusive breastfeeding was categorised into 0–2 months, 3–5 months, and 6 months. We excluded from the analysis the few children (n = 32, 3.1%) who were exclusively breastfed for longer than the recommended 6 months.

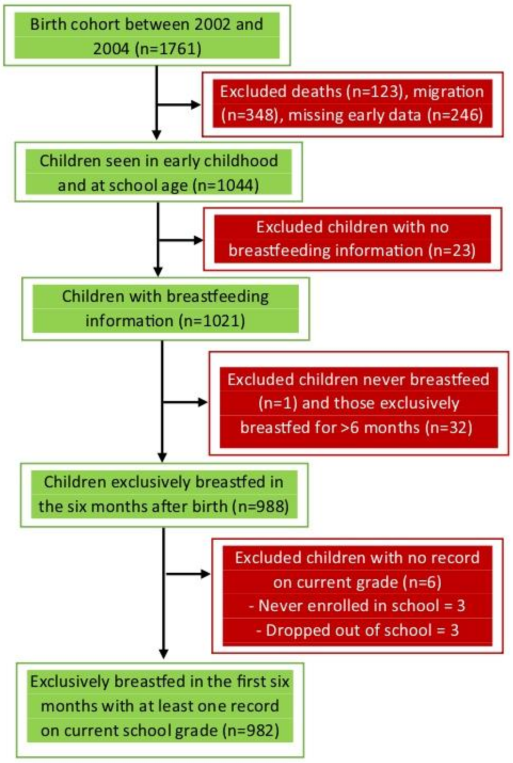

Figure 1. Flow of study subjects (The cohort was defined as in Sunny et al.[27] which gives more detail on the exclusions).

Potential confounders and moderators. Potential confounding variables were identified based on prior research[5,12,30] and included child sex, household wealth at birth, age of mother at birth, birth order of child, maternal HIV status, maternal education, paternal education, maternal occupation, paternal occupation, and distance to a tarmac road. The estimation of household wealth at birth was based on a principal component analysis of household items, dwelling characteristics, ownership of consumer durables, and utility access, as described in an earlier publication[27]. In addition, we decided a priori to assess whether the association between breastfeeding and educational attainment varied by sex and age at school assessment (6–9 and 10–13 years).

Data analysis. We estimated the number of children exclusively breastfed for 0–2 months, 3–5 months, and 6 months to determine the prevalence of exclusive breastfeeding. The characteristics of the children were summarised and stratified by the exclusive breastfeeding groups. Age-for-grade was recoded as a binary response variable with 1 = over-age for grade and 0 = underage/on-time for grade. Three sets of analyses were performed to determine the association between exclusive breastfeeding and age-for-grade.

First, binary logistic regression was used to model the association between exclusive breastfeeding and being over-age for grade using one observation per child and restricting the analysis to schooling assessments at the point closest to age 11.5 years (mid-point between 10 and 13), as most children had information on current grade at these ages. However, this approach does not make use of the longitudinal nature of the data and repeated schooling assessment.

In the second approach, we used generalised estimation equations (GEE)[31] with an exchangeable correlation structure to estimate the effect of exclusive breastfeeding duration on age-for-grade measured at multiple time points between ages 6 and 13, taking into account the lack of independence between repeated school grade measurements for each child. In addition, the GEE approach can handle unbalanced data (uneven number of assessments per individual) and generate unbiased estimates even if the within-cluster correlation structure is misspecified[32,33]. We fitted separate GEE models for children aged 6–9 and 10–13 and for girls and boys because we hypothesised that the effect of exclusive breastfeeding on age-for-grade is likely to differ by age and sex[5,12].

However, since the GEE approach estimates the average population effects of exposure on the outcome, this can mask important differences between hidden subgroups of the study population since academic growth can be nonlinear. For example, some children may perform poorly in early grades but catch up in the later grades, while others who did well in the early grades may do poorly in later grades. When such heterogeneity is ignored, results may be biased[34].

Hence, the third approach used Latent Class Growth Analysis (LCGA)[35] to identify unobserved homogenous subgroups (latent classes) within the study population that shared common trajectories of grade progression from age 6–13 using the "traj" macro in Stata[36]. LCGA is a person-centred technique that uses repeated measures of a single outcome variable across age or time to delineate a latent class model in which the classes represent different trajectories for the outcome variable[37,38]. The underlying assumption of LCGA is that individuals designated to the same latent class follow the same pattern of change over time[39,40].

Unconditional models with one through to five latent classes were tested through an iterative process using a combination of linear, quadratic, and cubic polynomial functions (trajectory shape) in a logit model for the longitudinal binary outcome, age-for-grade. Models with more than five classes produced anomalous growth curves, and the model fit statistics started to deteriorate and, in most cases, failed to converge. Age at school assessment was the indicator of time. We included only children with at least three school assessments in the LCGA. The maximum probability assignment rule[41] was used to assign participants to the latent class they had the highest posterior membership probability.

To determine the optimal number of latent classes, we compared the Bayesian information criterion [BIC] and Akaike Information Criterion [AIC]) values of the fitted latent class models. Lower BIC and AIC values indicate a balance between good model fit and parsimony[40,42–45]. However, because they are highly sensitive to sample size, researchers are advised to use BIC and AIC values in conjunction with other measures of model adequacy[42–44]. Thus, in addition to the information criteria, we utilised a number of model adequacy diagnostics, including the average posterior probability (AvePP) of class assignment, entropy (a measure of the accuracy of class classification), class size, and the practical interpretability (meaningfulness) of the latent class trajectories. Values of entropy near 1 (minimum 0.5), AvePP $\geq$ 0.70, and at least 5% of participants in each class have been proposed as indicators of high assignment accuracy though there are no conventional cut-offs[40,42–45]. We plotted individual-level grade progressions in each class of the latent class models to examine the meaningfulness and plausibility of the trajectories and how well they captured individual-level age-for-grade patterns. Because there are no definitive decision criteria, it is suggested that the selection of the optimal model balances between meaningful trajectories and model adequacy[35,40,42,43]. We used the approach described to model separate latent class trajectories for girls and boys because of differences in their academic progression[46].

The participants probabilities of belonging to each trajectory class were used as a categorical variable in a multivariable multinomial logistic regression model to determine the association between exclusive breastfeeding duration and the latent age-for-grade trajectories. We used the trajectory with better grade progression as the reference group. In all the analyses, we adjusted for the baseline confounders outlined in the directed acyclic graph in Fig. 2, with these covariates included as categorical variables using the groupings presented in Table 1. All analyses were performed using Stata version 17.

Missing data. The amount of data missing at baseline was low, ranging from 0.3% (maternal education and maternal occupation) to 5.4% (paternal occupation) (see online Supplementary Table 1). Missing data mechanisms of baseline confounding variables were investigated and assumed to be missing at random. We performed multiple imputations by chained equations (MICE) in Stata to minimise bias and loss of precision and power

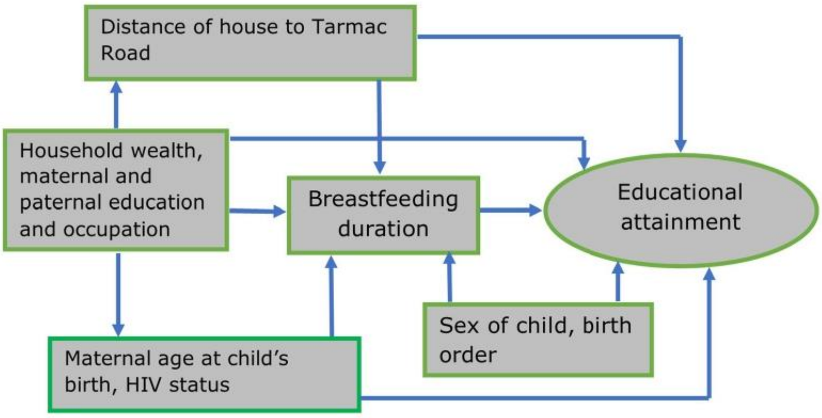

Figure 2. Directed acyclic graph showing the relationship between the exposure, outcome, and confounding variables.

from discarding observations with missing values[47]. Thirty imputed datasets were generated under fifteen iterations for each imputation model. All variables in the substantive analyses were included in the imputation models to predict the distribution of the missing values. However, only six of the ten baseline confounding variables with missing data were imputed (maternal education, maternal occupation, paternal education, paternal occupation, household wealth, and birth order). We did not impute missing values in the outcome variable. The substantive analyses described above were conducted on the imputed dataset, and the estimates combined and standard errors estimated using Rubin's rules[48]. For the multinomial logistic regression analysis, separate MICE models were fitted for the entire sample as well as for boys and girls.

In sensitivity analysis, we repeated the binary logistic regression, multinomial logistic regression, and GEE analyses using only individuals with complete data to assess the reliability of our substantive analysis that used imputed data.

Ethical consideration. The National Health Sciences Research Committee in Malawi (protocol number #1072) and the Research Ethics Committee of the London School of Hygiene and Tropical Medicine (protocol number #6303) granted ethical approval for the primary study. Permission and informed consent were sought from traditional leaders and village headmen, and verbal informed consent for participation was obtained from each household head and participating household members (parents provided informed consent for their children's participation) after the purpose of the surveillance were explained. Those who refused to give consent were not interviewed[25,27]. Ethics approval for the present analysis was granted by the research ethics committee of the London School of Hygiene and Tropical Medicine (Ethics Ref: 26468). In addition, we confirm that the analysis was performed in accordance with relevant guidelines/regulations, and in accordance with the Declaration of Helsinki.

Results

Characteristics of the study sample. There were 1761 births to women in the HDSS between 2002 and 2004, and 1044 were successfully followed up for at least 4 years (Fig. 1). Loss to follow-up was largely due to migration, deaths, and missing early data. 1021 children had information about breastfeeding practices and were prospectively followed for six to thirteen years. Descriptive statistics in Table 1 show that slightly more than half (51.9%) of the children were male, and half (50.2%) lived within 1 km of a tarmac road. There were 227 (23.1%) first-order births, and 58.8% of the mothers were between the ages of 20 and 30 when the children in the cohort were born. While 40.7% of the children's fathers had at least some secondary education, only 20.2% of their mothers had the same level of education. Both parents were largely subsistence farmers. The majority (87.5%) of the mothers were HIV-negative, and only 2.7% were known to be HIV-positive. Almost all the children were breastfed (99.9%).

Duration of exclusive breastfeeding. Most (45.8%) children were exclusively breastfed for 3–5 months (Table 1). Only 35.9% were exclusively breastfed for the recommended 6 months. There was no sex difference in the prevalence of exclusive breastfeeding and no significant association between maternal education and duration of exclusive breastfeeding. However, the prevalence of exclusive breastfeeding for 6 months was higher with increasing household wealth and paternal education. Mothers who did not work exclusively breastfed for a longer duration than those who were subsistence farmers. Similarly, children whose fathers were unemployed were more likely to be exclusively breastfed for 6 months than those whose fathers were subsistence farmers. The

	Total (n = 1021)	Children exclusively breastfed in first 6 months (n = 988)[a]	Duration of exclusive breastfeeding		
			0–2 months	3–5 months	6 months
	n (%)	n (%)	n (%)	n (%)	n (%)
All			181 (18.3)	452 (45.8)	355 (35.9)
Sex of child					
Female	491 (48.1)	477 (48.3)	80 (16.8)	219 (45.9)	178 (37.3)
Male	530 (51.9)	511 (51.7)	101 (19.8)	233 (45.6)	177 (34.6)
Maternal HIV status					
Negative	893 (87.5)	867 (87.8)	167 (19.3)	396 (45.7)	304 (35.0)
Positive	28 (2.7)	27 (2.7)	3 (11.1)	11 (40.7)	13 (48.2)
Unknown	100 (9.8)	94 (9.5)	11 (11.7)	45 (47.9)	38 (40.4)
Mother education					
None/incomplete primary	493 (48.3)	476 (48.3)	97 (20.4)	219 (45.0)	160 (33.6)
Complete primary	320 (31.3)	308 (31.3)	57 (18.5)	138 (44.8)	113 (36.7)
Any secondary	205 (20.1)	201 (20.4)	27 (13.4)	94 (46.8)	80 (39.8)
Missing	3 (0.3)	–			
Father education					
None/incomplete primary	233 (22.8)	224 (23.9)	48 (21.4)	114 (50.9)	62 (27.7)
Complete primary	342 (33.5)	333 (35.5)	58 (17.4)	147 (44.1)	128 (38.4)
Any secondary	395 (38.7)	381 (40.6)	66 (17.3)	168 (44.1)	147 (38.6)
Missing	51 (5.0)	–			
Mother occupation					
Not working	207 (20.3)	200 (20.3)	36 (18.0)	78 (39.0)	86 (43.0)
Subsistence farmer	792 (77.5)	768 (78.0)	145 (18.9)	364 (47.4)	259 (33.7)
Others	19(1.9)	17 (1.7)	0 (0.0)	8 (47.1)	9 (52.9)
Missing	3 (0.3)	–			
Father occupation					
Not working	52 (5.1)	50 (5.3)	10 (20.0)	21 (42.0)	19 (38.0)
Subsistence farmer	601 (58.9)	587 (62.8)	121 (20.6)	274 (46.7)	192 (32.7)
Others	313 (30.6)	298 (31.9)	41 (13.8)	133 (44.6)	124 (41.6)
Missing	55 (5.4)	–			
Household wealth at birth					
Poorest	349 (34.2)	339 (35.3)	72 (21.2)	157 (46.3)	110 (32.5)
Middle	336 (32.9)	324 (33.8)	65 (20.1)	138 (42.6)	121 (37.4)
Least poor	307 (30.1)	296 (30.9)	39 (13.2)	142 (48.0)	115 (38.8)
Missing	29 (2.8)	–			
Age of mother at birth					
< 20	209 (20.4)	203 (20.5)	45 (22.2)	89 (43.8)	69 (34.0)
20–30	600 (58.8)	583 (59.0)	99 (17.0)	278 (47.7)	206 (35.3)
> 30	212 (20.8)	202 (20.5)	37 (18.3)	85 (42.1)	80 (39.6)
Birth order of child					
1	227 (22.2)	223 (23.4)	55 (24.7)	101 (45.3)	67 (30.0)
2–3	332 (32.5)	321 (33.7)	48 (15.0)	158 (49.2)	115 (35.8)
4 or more	424 (41.5)	409 (42.9)	73 (17.9)	176 (43.0)	160 (39.1)
Missing	38 (3.7)	–			
Distance to tarmac road					
Within 1 km	513 (50.2)	493 (49.9)	78 (15.8)	224 (45.5)	191 (38.7)
More than 1 km	508 (49.8)	495 (50.1)	103 (20.8)	228 (46.1)	164 (33.1)

Table 1. Distribution of exclusive breastfeeding duration according to sociodemographic characteristics of the study population. [a]Excludes children who were exclusively breastfed for more than 6 months (n = 32).

order of births was associated with exclusive breastfeeding, with a greater percentage of children of higher birth order more likely to be exclusively breastfed for 6 months than those of lower birth order.

Age-for-grade. Of the eight possible time points at which age-for-grade was assessed, 1.9% had all eight recorded, 24.1% had 7, 43.3% had 6, and 13.8% had 5, and the remainder had between one and four school assessments. At age six, data on age-for-grade was collected for 895 children. The number of children increased to 951 at age seven but subsequently decreased to 902 at age nine, 821 at age 11, 485 at age 12, and 63 at age 13 (Fig. 3A). The earliest children began to fall behind in school was age eight, and the proportion of children under-age or on time for grades steadily decreased. By age 13, no child was underage-for-grade, and 41.9% of the children were 1 year older than their grade level. A similar upward trend was observed until age twelve for children who were 2–3 years over-age for their grades. Figure 3B shows that more boys than girls were assessed at each age of schooling. However, girls were more likely than boys to be underage and on-time for a grade.

Association between exclusive breastfeeding duration and age-for-grade at age 11.5. Using binary logistic regression, we found no evidence of an association between exclusive breastfeeding duration and age-for-grade between ages 10–13 in the overall sample and sex-stratified analyses (Table 2). Results based on complete case analysis excluding participants with missing data were consistent with this finding (Supplementary Table 5).

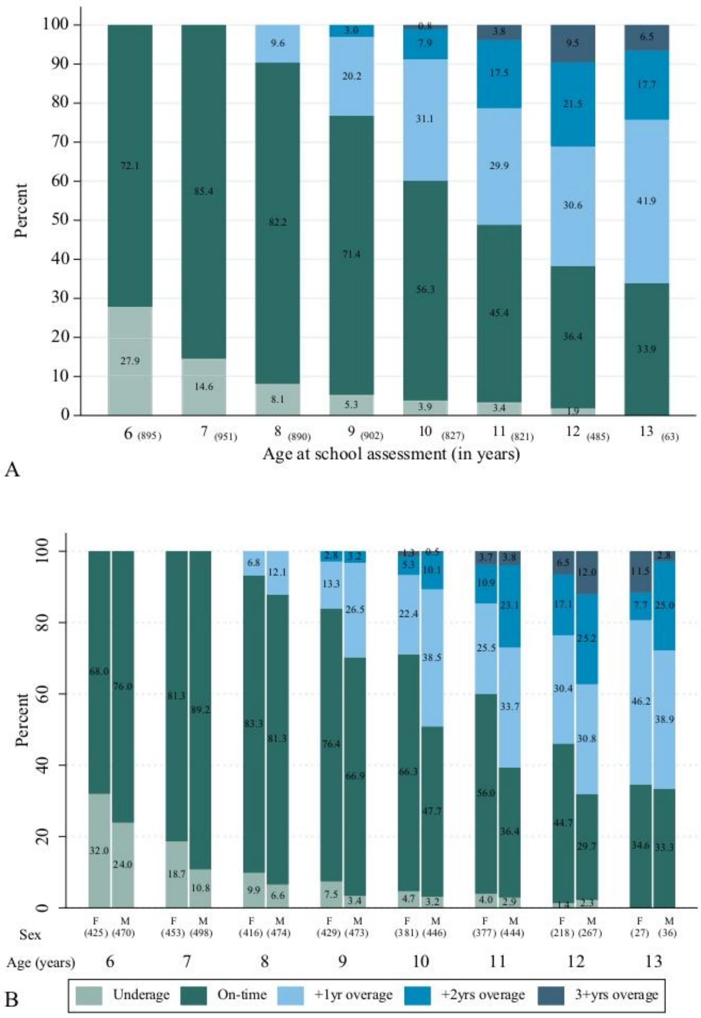

Figure 3. Distribution of age-for-grade by (**A**) age and (**B**) age and sex [F = female M = male]. Note: underage = one or more years younger than the official grade age; on time = at the official grade age; +1yr overage = one year older than the official grade age; +2yrs overage = two years older than the official grade age; and 3+yrs overage = three or more years older than the official grade age. Numbers in parentheses represent the number (n) of children in each group.

	N	Age-for-grade: Underage or on-time for grade n (%)	Age-for-grade: Overage for grade n (%)	Unadjusted odds ratio (95% CI)	P-value	Adjusted odds ratio (95% CI)	P-value
Model 1 age 6–13 Both sexes: duration of exclusive breastfeeding (n = 887)							
0–2 months	161	73 (45.3)	88 (54.7)	1.00	0.36	1.00	0.85
3–5 months	409	208 (50.9)	201 (49.1)	0.80 (0.56–1.16)		0.92 (0.62–1.38)	
6 months	317	165 (52.1)	152 (47.9)	0.76 (0.52–1.12)		1.01 (0.66–1.53)	
Model 2 Girls, Age 6–13: duration of exclusive breastfeeding (n = 417)							
0–2 months	69	40 (58.0)	29 (42.0)	1.00	0.85	1.00	0.46
3–5 months	196	121 (61.7)	75 (38.3)	0.85 (0.49–1.49)		0.86 (0.47–1.58)	
6 months	152	91 (59.9)	61 (40.1)	0.92 (0.52–1.65)		1.16 (0.62–2.18)	
Model 3 Boys, Age 6–13: duration of exclusive breastfeeding (n = 470)							
0–2 months	92	33 (35.9)	59 (64.1)	1.00	0.37	1.00	0.85
3–5 months	213	87 (40.9)	126 (59.1)	0.81 (0.49–1.34)		1.04 (0.60–1.80)	
6 months	165	74 (44.8)	91 (55.2)	0.69 (0.41–1.16)		0.92 (0.52–1.62)	

Table 2. Binary logistic regression analysis of the association between exclusive breastfeeding duration and age-for-grade attainment at age 11.5 (mid-point of age 10–13) in Malawi (n = 887). Note: We controlled for child's sex, household wealth at birth, age of mother at birth, birth order of child, maternal HIV status, mother education, father education, mother occupation, father occupation, and distance to a tarmac road in the adjusted analysis. MICE was used to impute missing values in household wealth (n = 29), birth order (n = 38), mother education (n = 3), father education (n = 51), father occupation (n = 55), and mother occupation (n = 3).

	Unadjusted odds ratio (95% CI)	P-value	Adjusted odds ratio (95% CI)	P-value
Model 1 Age 6–13 Both sexes: Duration of exclusive breastfeeding (n = 982)				
0–2 months	1.00	0.003*	1.00	0.13*
3–5 months	0.81 (0.63–1.04)		0.90 (0.70–1.14)	
6 months	0.68 (0.52–0.88)		0.82 (0.64–1.06)	
Model 2 Age 6–9 Both sexes: Duration of exclusive breastfeeding (n = 972)				
0–2 months	1.00	< 0.001*	1.00	0.02*
3–5 months	0.75 (0.53–1.08)		0.87 (0.61–1.24)	
6 months	0.50 (0.34–0.74)		0.64 (0.43–0.94)	
Model 3 Age 10–13 Both sexes: Duration of exclusive breastfeeding (n = 891)				
0–2 months	1.00	0.19	1.00	0.88
3–5 months	0.80 (0.57–1.12)		0.91 (0.64–1.30)	
6 months	0.72 (0.50–1.03)		0.93 (0.64–1.35)	
Model 4 Girls, Age 6–13: Duration of exclusive breastfeeding (n = 475)				
0–2 months	1.00	0.18	1.00	0.56
3–5 months	0.92 (0.60–1.40)		0.91 (0.59–1.39)	
6 months	0.71 (0.46–1.09)		0.80 (0.52–1.24)	
Model 5 Boys, Age 6–13: Duration of exclusive breastfeeding (n = 508)				
0–2 months	1.00	0.08	1.00	0.50
3–5 months	0.77 (0.57–1.05)		0.91 (0.68–1.22)	
6 months	0.69 (0.49–0.95)		0.83 (0.61–1.13)	

Table 3. Generalised estimating equations analysis of the effects of exclusive breastfeeding duration on age-for-grade attainment among children aged 6–13 in Malawi (N = 982). Note: We controlled for child's sex, household wealth at birth, age of mother at birth, birth order of child, maternal HIV status, mother education, father education, mother occupation, father occupation, and distance to a tarmac road in the adjusted analysis. MICE was used to impute missing values in household wealth (n = 29), birth order (n = 38), mother education (n = 3), father education (n = 51), father occupation (n = 55), and mother occupation (n = 3). *Test for linear trend.

Association between exclusive breastfeeding duration and repeated measures of age-for-grade attainment from age 6 through to 13. In the generalised estimations equation analysis (Table 3), adjusted results provided some evidence that children exclusively breastfed for 6 months were less likely to be over-age for grade than those exclusively breastfed for less than 3 months (aOR = 0.82; 95%CI = 0.64–1.06). When we stratified the analysis by age, results from the adjusted analysis showed evidence of a dose–response effect of exclusive breastfeeding duration on age-for-grade between ages 6 and 9. Children exclusively breastfed for 6 months had 36% lower odds of being over-age for grades between ages six and nine than those exclusively breastfed for less than 3 months (aOR = 0.64; 95%CI = 0.43–0.94). There was no evidence of an association between exclusive breastfeeding duration and age-for-grade between ages 10 and 13. In the sex-stratified analysis, the adjusted results showed no evidence of an association between exclusive breastfeeding and age-for-grade. Complete case analysis excluding participants with missing data produced consistent results (Supplementary Table 6).

Latent class growth trajectories and patterns of grade progression. The few children with less than three school grade records were excluded from LCGA (n = 63). Following the evaluation of the goodness of fit statistics and model adequacy diagnostics for the fitted latent classes (Supplementary Table 2), the three-class and four-class models were considered suitable candidates to appropriately capture the grade progression of the study sample. These models both had more than 20% of participants in each class and entropy values within the acceptable range (three-class model = 0.82; four-class model = 0.64). The four-class model had the lowest BIC (− 1544.69) and AIC (− 1515.54) values, whereas the classes in the three-class model had the highest AvePP of assignment values and odds of correct classification. However, the trajectories of the four-class model best represented individual-level grade progression, demonstrated acceptable class separation, and were practically meaningful (Supplementary Fig. 1). Based on these assessments, the four-class model was selected as the optimal model.

Each trajectory was named based on the shape of the curve and the age at which the children in that trajectory started to fall behind in school (Fig. 4). Trajectory 1 represented children over-age for grade in the early grades of primary school, starting from around age 8 (falling behind from early grades). Children in trajectory 2 were over-age for grades in middle primary school when they were about 9–10 years (falling behind from middle grades). Those in trajectory 3 became over-age for grades at the terminal stages of primary school when they were about 11–12 (falling behind from terminal grades). Trajectory 4 represents children on time for all the grades from age six to thirteen (consistently on time for grades).

We evaluated the sex-stratified latent class models using the approach described (Supplementary Tables 3, 4, Supplementary Figs. 2 and 3) and found that a four-class model was optimal for both girls and boys (Fig. 5A and B).

Table 4 shows the distribution of the overall age-for-grade trajectories across the participants' sociodemographic characteristics. Overall, 24.1% of the children progressed without falling behind; 26.9% started falling behind in the terminal grades, and 28.7% and 20.3% started falling behind in the middle and early grades, respectively. A greater percentage of the children who fell behind in early grades were boys. The percentage of children consistently on time for grades increased with increasing paternal education and household wealth. Being consistently on time for grade was more common among later-order births and children living within 1 km of a tarmac road.

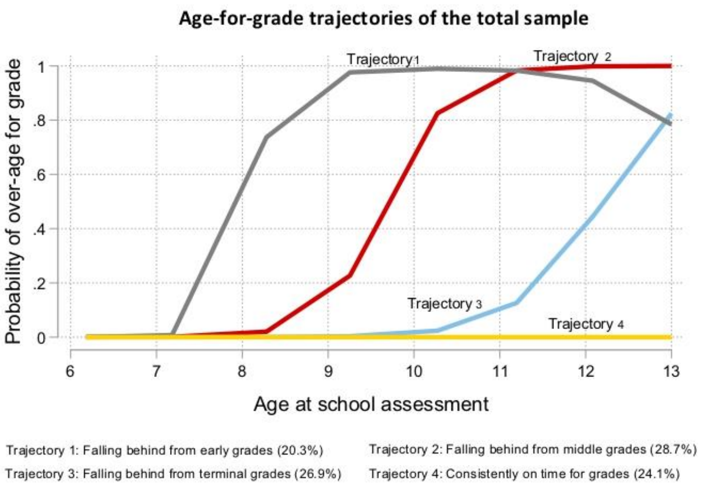

Figure 4. Age-for-grade attainment trajectories based on latent class growth modelling of schooling data from age 6 to 13 (Early grades = grades 1–3, middle grades = grades 4–6 and terminal grades = grades 7–8).

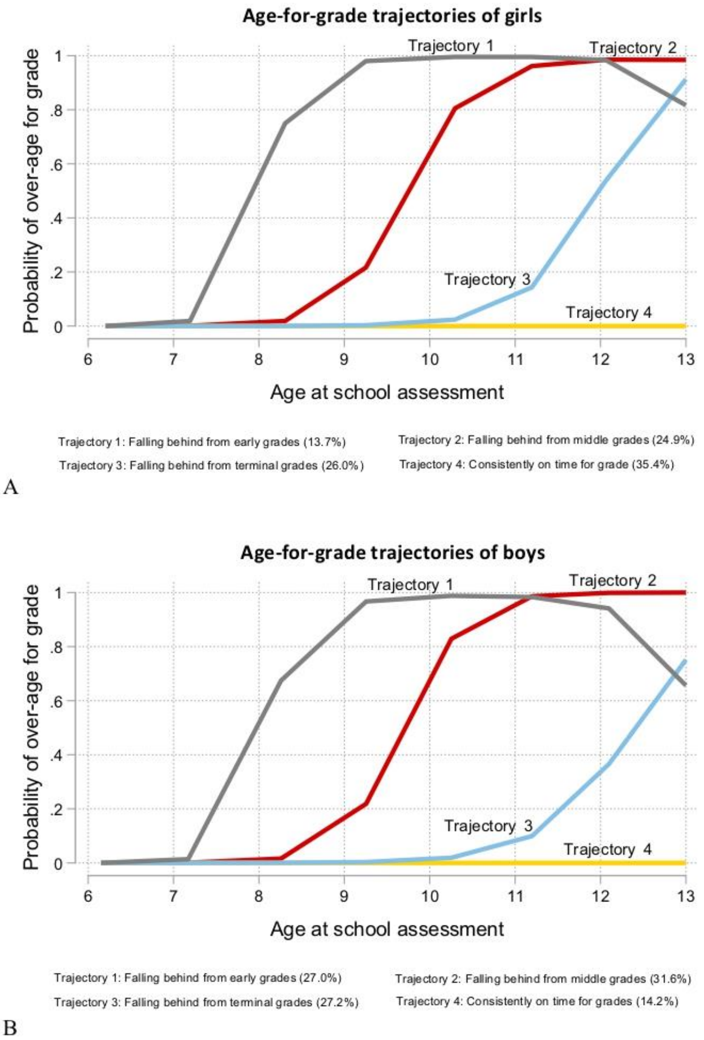

Figure 5. Age-for-grade attainment trajectories of (**A**) Girls and (**B**) Boys based on latent class growth modelling of schooling data from age 6 to 13 (Early grades = grades 1–3, middle grades = grades 4–6 and terminal grades = grades 7–8).

Association between exclusive breastfeeding duration and age-for-grade trajectories identified through latent class growth modelling. Compared to being consistently on time for grades, children exclusively breastfed for 6 months were less likely to fall behind in early grades than those exclusively breastfed for less than 3 months in the unadjusted (OR = 0.48; 95%CI = 0.30–0.77) and adjusted (aOR = 0.66; 95%CI = 0.41–1.08) analyses (Table 5). There was no association between exclusive breastfeeding and later age-for-grade trajectories. In the sex-stratified analysis, there was no association between exclusive breastfeeding and age-for-grade trajectories in both the girls and boys subgroups. However, the pattern of the odds ratios was more apparent and consistent for boys than it was for girls. Complete case analysis excluding participants with missing data produced similar results (Supplementary Table 7).

Discussion

We used prospective, longitudinal data to examine whether exclusive breastfeeding duration in the first 6 months after birth is associated with educational attainment and age-for-grade trajectories between ages 6 and 13. We saw some evidence of a reduced likelihood of over-age for grade in children exclusively breastfed for 6 months

	Categories	Age-for-grade trajectories: Trajectory 1 — Falling behind from early grades n (%)	Trajectory 2 — Falling behind from middle grades n (%)	Trajectory 3 — Falling behind from terminal grades n (%)	Trajectory 4 — Consistently on time for grade n (%)
Overall	Age-for-grade trajectories	193 (20.3)	273 (28.7)	256 (26.9)	230 (24.1)
Duration of exclusive breast-feeding	0–2 months	44 (23.6)	46 (17.5)	40 (16.0)	36 (16.2)
	3–5 months	89 (48.1)	119 (44.8)	119 (48.0)	97 (43.6)
	6 months	53 (28.3)	100 (37.7)	89 (36.0)	89 (40.1)
Sex of child	Female	65 (33.5)	113 (41.4)	142 (55.4)	132 (57.6)
	Male	128 (66.5)	160 (58.6)	114 (44.6)	98 (42.4)
Maternal HIV status	Negative	172 (89.1)	251 (91.9)	224 (87.4)	198 (86.3)
	Positive	3 (1.6)	6 (2.2)	7 (2.9)	8 (3.3)
	Missing	18 (9.3)	16 (5.9)	25 (9.7)	24 (10.4)
Mother education	None/incomplete primary	127 (65.8)	149 (55.1)	104 (40.7)	87 (38.1)
	Complete primary	44 (22.6)	82 (30.2)	91 (35.8)	83 (36.2)
	Any secondary	22 (11.6)	40 (14.7)	61 (23.5)	59 (25.7)
Father education	None/incomplete primary	68 (37.2)	76 (29.1)	40 (16.6)	30 (14.0)
	Complete primary	68 (37.2)	97 (37.0)	87 (35.6)	74 (34.4)
	Any secondary	47 (25.6)	89 (33.9)	116 (47.8)	111 (51.6)
Mother occupation	Not working	33 (17.2)	38 (14.0)	58 (22.7)	52 (22.6)
	Subsistence farmer	159 (82.2)	230 (84.8)	190 (74.3)	171 (74.5)
	Others	1 (0.6)	3 (1.2)	8 (3.0)	7 (2.9)
Father occupation	Not working	9 (5.1)	12 (4.6)	15 (6.3)	13 (6.3)
	Subsistence farmer	131 (72.0)	169 (58.6)	142 (58.6)	119 (55.6)
	Others	42 (22.9)	80 (30.8)	85 (35.1)	82 (38.1)
Household wealth at birth	Poorest	87 (47.0)	112 (42.1)	71 (28.5)	54 (24.4)
	Middle	62 (33.5)	91 (34.3)	85 (34.0)	75 (33.6)
	Least poor	36 (19.5)	62 (23.6)	93 (37.5)	94 (42.0)
Age of mother at birth	< 20	47 (24.6)	50 (18.3)	53 (20.9)	45 (19.7)
	20–30	102 (52.8)	165 (60.6)	149 (58.2)	134 (58.2)
	> 30	44 (22.7)	57 (21.1)	54 (20.9)	51 (22.1)
Birth order of child	1	47 (25.4)	57 (21.6)	56 (22.5)	48 (21.9)
	2–3	52 (28.3)	88 (33.6)	90 (36.2)	79 (35.6)
	4 or more	85 (46.3)	118 (44.9)	102 (41.3)	94 (42.5)
Distance to tarmac road	Within 1 km	68 (35.2)	132 (48.4)	143 (55.8)	128 (55.7)
	More than 1 km	125 (64.8)	141 (51.6)	113 (44.2)	102 (44.3)

Table 4. Distribution of the overall age-for-grade trajectories of children with three or more repeated school assessments according to sociodemographic characteristics of the study sample (n = 952). Note: Early grades = grades 1–3, middle grades = grades 4–6 and terminal grades = grades 7–8.

compared to those exclusively breastfed for less than 3 months. Latent class growth analysis indicated that the effect was on those falling behind in the early grades of primary school rather than those who fell behind later. While the width of the confidence intervals and modest effects should be interpreted with caution, they are similar to the association found in the saving brains cohort in KwaZulu-Natal, South Africa, where researchers investigated the effects of exclusive breastfeeding on grade repetition in children aged 7–11 years[22]. Additionally, in a prespecified age subgroup analysis, we found evidence of a dose–response relationship between exclusive breastfeeding and educational attainment. Children exclusively breastfed for a longer duration in infancy were less likely to be over-age for grade at 6–9 years.

Our finding on the effects of exclusive breastfeeding on age-for-grade trajectories is novel, as no previous study has investigated breastfeeding's effect on longitudinal trajectories of grade progression among homogenous subgroups. The majority of studies, including those that assessed educational attainment at multiple time points, used methods that assumed study participants progressed at the same level and estimated the average effect of breastfeeding on attainment, ignoring the nuances in progression in the population. The use of various analytical methods adds to the robustness of our findings. Unlike previous studies, our study population was almost entirely breastfed, and maternal education was not associated with the duration of exclusive breastfeeding. Even though adjustment for confounders, including socioeconomic status, generally attenuated the association between exclusive breastfeeding and age-for-grade in some subgroups, our ORs were consistent with reduced odds of falling behind in early school grades with longer duration of exclusive breastfeeding.

	Falling behind from early grades vs consistently on time for grade		Falling behind from middle grades vs consistently on time for grade		Falling behind in terminal grades vs consistently on time for grade	
	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)
Model 1 age 6–13 Both sexes: duration of exclusive breastfeeding (n = 921)						
	P = 0.001	P = 0.07	P = 0.47	P = 0.68	P = 0.12	P = 0.20
0–2 months	1.00	1.00	1.00	1.00	1.00	1.00
3–5 months	0.76 (0.46–1.17)	0.90 (0.57–1.43)	0.95 (0.63–1.43)	1.06 (0.69–1.62)	1.11 (0.90–1.38)	1.13 (0.90–1.41)
6 months	0.48 (0.30–0.77)	0.66 (0.41–1.08)	0.87 (0.57–1.32)	1.10 (0.71–1.71)	0.91 (0.74–1.12)	0.94 (0.76–1.16)
Model 2 Girls, Age 6–13: duration of exclusive breastfeeding (n = 438)						
	P = 0.07	P = 0.25	P = 0.72	P = 0.35	P = 0.65	P = 0.79
0–2 months	1.00	1.00	1.00	1.00	1.00	1.00
3–5 months	0.99 (0.49–2.02)	1.01 (0.46–2.20)	1.01 (0.55–1.85)	0.99 (0.52–1.89)	1.24 (0.89–1.73)	1.25 (0.88–1.76)
6 months	0.56 (0.26–1.19)	0.67 (0.30–1.48)	1.10 (0.60–2.01)	1.28 (0.67–2.43)	1.02 (0.73–1.40)	1.04 (0.75–1.44)
Model 3 Boys, Age 6–13: duration of exclusive breastfeeding (n = 483)						
	P = 0.006	P = 0.07	P = 0.21	P = 0.67	P = 0.07	P = 0.09
0–2 months	1.00	1.00	1.00	1.00	1.00	1.00
3–5 months	0.65 (0.36–1.19)	0.87 (0.47–1.60)	0.91 (0.51–1.62)	1.13 (0.61–2.09)	1.00 (0.75–1.32)	1.01 (0.76–1.35)
6 months	0.42 (0.22–0.79)	0.57 (0.30–1.10)	0.71 (0.39–1.29)	0.93 (0.49–1.78)	0.81 (0.62–1.07)	0.83 (0.63–1.10)

Table 5. Multinomial logistic regression analysis of the association between exclusive breastfeeding duration and age-for-grade trajectories among children aged six to thirteen in Malawi. P-values are from the test for linear trend. Note: We controlled for child's sex, household wealth at birth, age of mother at birth, birth order of child, maternal HIV status, mother education, father education, mother occupation, father occupation, and distance to a tarmac road in the adjusted analysis. MICE was used to impute missing values in household wealth (n = 29), birth order (n = 38), mother education (n = 3), father education (n = 51), father occupation (n = 55), and mother occupation (n = 3).

Our results are consistent with several earlier studies in varying settings[2,4,13,14,49]. Richards et al.[50], for example, found a dose–response relationship between breastfeeding and higher educational attainment in the 1946 British birth cohort. In Brazil, longer breastfeeding duration was linked to more years of schooling completed at age 18 than breastfeeding for less than 1 month in a population with no socioeconomic patterning of breastfeeding[49]. Using data on sibling pairs from the National Longitudinal Study of Adolescent Health in the United States, Rees and Sabia found that breastfeeding was associated with a higher grade point average and a higher likelihood of graduating from high school and enrolling in college[51].

The mechanisms underlying the improved educational attainment of optimally breastfed children have yet to be confirmed by research. However, one of the primary ways that breastfeeding may improve academic performance is through its role in brain development. Breastmilk contains a variety of nutrients and bioactive compounds necessary for brain development and cognitive function[52–55]. Breastmilk, for example, contains a high concentration of long-chain polyunsaturated fatty acids (LCPUFAs), which are required for brain and nervous system development[52,53]. Docosahexaenoic acid (DHA), one of the LCPUFAs in breastmilk, plays a crucial role in developing neural connections essential for learning and cognition[52,53,56]. Indeed, brain images of children and adolescents revealed that breastfed children have greater cortical thickness and significant increases in white and grey matter volume in many brain regions compared to non-breastfed children[57–61]. In addition to its direct nutritional benefits, breastfeeding promotes mother–child attachment and bonding[62], which have been linked to enhanced cognitive and socioemotional development[63], both of which are essential for academic success. However, studies have found positive effects of breastfeeding on cognitive development even after controlling for home stimulation[3,21].

Our findings confirmed heterogeneity in grade progression across primary school. To promote good primary school progression, educational interventions should consider the trajectories identified in this study, noting when children begin to fall behind. Interventions should prioritise children whose parents are illiterate, children from low-income families, and children whose parents are subsistence farmers, as these children are more vulnerable to falling behind in the early and middle grades. Future research should investigate the mechanisms that underpin the association between breastfeeding and educational outcomes, as well as sex differences and possible mediators. More studies on the subject are warranted in sub-Saharan Africa to contribute to the growing body of literature and broaden understanding of the educational benefits of breastfeeding in the region.

One notable limitation of our study is that only a small number of children were assessed at ages 12 and 13. These small numbers could have reduced the statistical power to detect a difference in older children at the terminal grades. Our analysis did not account for birthweight and gestational age. However, this concern is minimal given that we controlled for known key confounders like parental education, family income, and parental occupation. Since data on exclusive breastfeeding duration were based on maternal recall, we cannot completely rule out the possibility of overreporting due to recall and social desirability bias. However, given that the data were collected in the first 3 months after birth and updated only a few months after the recommended duration for exclusive breastfeeding, any such effects should be minimal. Indeed, our estimated prevalence of exclusive breastfeeding at 6 months is comparable to the 34% reported in the 2015 Malawi Demographic and Health Survey[64] and the 40% reported by Chipojola et al.[65]. Furthermore, it has been shown that, within the first three years after birth, maternal recall is a valid and reliable method for estimating infant breastfeeding[66].

Conclusions

Our findings suggest that a longer duration of exclusive breastfeeding during infancy may promote better grade progression in primary school and decrease the likelihood of being over-age for grade. This finding supports the World Health Organization's recommendation on exclusive breastfeeding by adding to the growing body of evidence that the benefits of exclusive breastfeeding for 6 months extend beyond the known improvements in infant health and survival. It also suggests that the beneficial effects on educational attainment reported in high-income settings are not entirely due to socioeconomic confounding. Policies encouraging exclusive breastfeeding as the primary feeding method for the first 6 months of life may help improve children's and adolescents' educational attainment. We encourage more research into the educational benefits of breastfeeding and its possible mechanisms in sub-Saharan Africa to inform infant feeding recommendations, as the literature on the subject from the region is still sparse.

Data availability

The data supporting this study's findings are available from the Karonga Health and Demographic Surveillance System in Malawi. However, restrictions apply to the availability of these data, which were used under license for the current study and are not publicly available. The data are, however, available from the corresponding author (SM) upon reasonable request and with permission of the director of the Karonga Health and Demographic Surveillance System in Malawi.

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Author contributions

S.M., E.W., C.C., J.R.G., M.M., and L.L.O. conceived and designed the study. S.M. conducted the data analysis with guidance from E.W., C.C., J.R.G., M.M., and L.L.O. SM prepared the first draft of the manuscript, and E.W., C.C., J.R.G., M.M., L.L.O., B.S.S., A.C.C., E.M., S.M.M., A.L.N.D., and F.K. provided critical input on the interpretation, discussion and presentation of the results. All authors contributed, revised, and approved the final version of the manuscript. S.M takes full responsibility for the final content.

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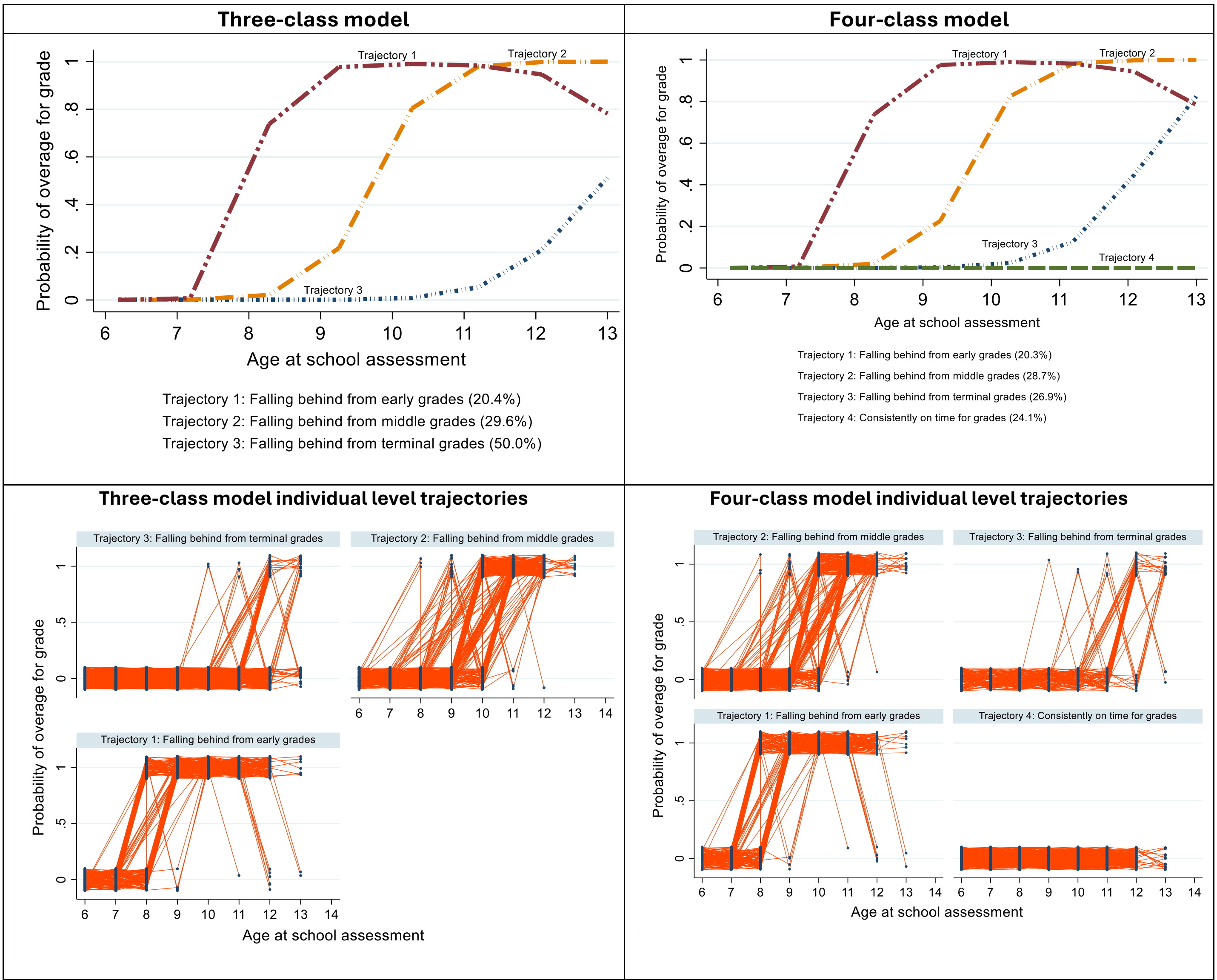
6.3 Supplementary materials

Supplementary Table 1 Multiple imputation models with the number of missing and imputed cases

	Missing	Imputed	Imputation model
Household wealth at birth	29 (2.8%)	29	Ordered logistic regression
Birth order of child	38 (3.7%)	38	Ordered logistic regression
Mother education	3 (0.3%)	3	Ordered logistic regression
Father education	51 (5.0%)	51	Ordered logistic regression
Father occupation	55 (5.4%)	55	Multinomial logistic regression
Mother occupation	3 (0.3%)	3	Multinomial logistic regression

Supplementary Table 2 Goodness of fit statistics and model adequacy diagnostics for LCGM

Latent Model	Bayesian information criteria (BIC)	Akaike Information Criterion (AIC)	Entropy	Number of latent classes	Average Posterior Probability of Assignment (APPA)	Number per class	% of participants per class
1-class model	-2258.25	-2248.54	-				
				1	-	-	-
2-class model	-1620.60	-1606.02	0.85				
				1	0.94	522	54.8
				2	0.96	430	45.2
3-class model	-1545.64	-1518.92	0.82				
				1	0.89	194	20.4
				2	0.90	282	29.6
				3	0.95	476	50.0
4-class model	-1544.69	-1515.54	0.64				
				1	0.89	193	20.3
				2	0.84	273	28.7
				3	0.68	256	26.9
				4	0.57	230	24.1
5-class model	-1624.22	-1585.35	0.68				
				1	-	-	-
				2	0.64	413	43.4
				3	0.91	139	14.6
				4	0.92	400	42.0
				5	-	-	-

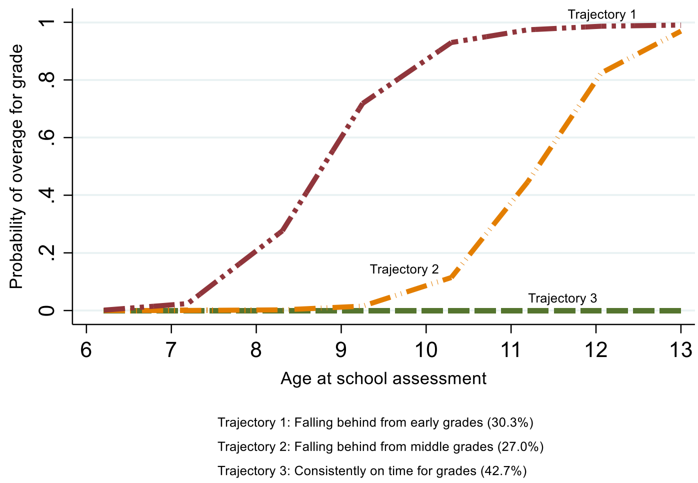


Supplementary Figure 1: Trajectories of three-class and four-class latent class models and individual level age-for-grade progression

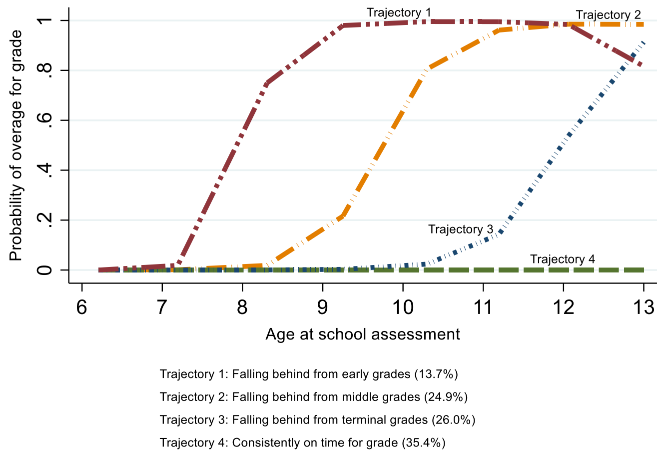
Supplementary Table 3 Goodness of fit statistics and model adequacy diagnostics of girls for LCGM

Latent Model	Bayesian information criteria (BIC)	Akaike Information Criterion (AIC)	Entropy	Number of latent classes	Average Posterior Probability of Assignment (APPA)	Number per class	% of participants per class
1-class model	-943.39	-935.17	-				
				1	-	-	-
2-class model	-680.21	-667.87	0.84				
				1	0.95	299	66.2
				2	0.95	153	33.8
3-class model	-672.33	-655.87	0.66				
				3	0.94	137	30.3
				2	0.89	122	27.0
				1	0.77	193	42.7
4-class model	-666.72	-637.92	0.62				
				1	0.88	62	13.7
				2	0.86	113	24.9
				3	0.92	118	26.0
				4	0.64	160	35.4
5-class model	-696.21	-663.30	0.70				
				1	-	-	-
				2	0.94	132	29.2
				3	0.89	70	15.5
				4	0.76	250	55.3
				5	-	-	-

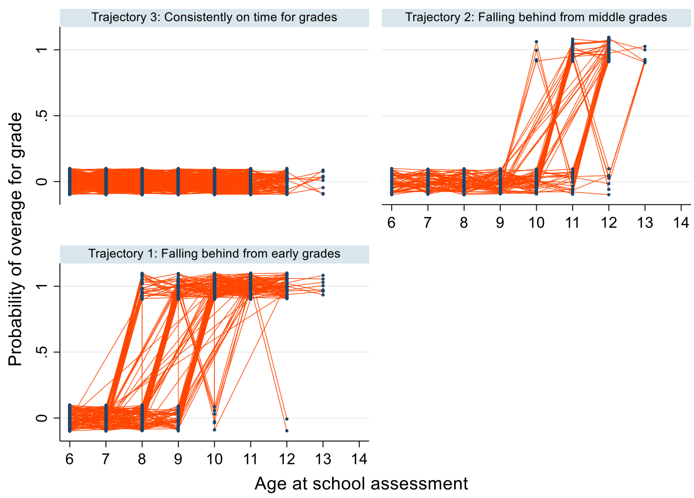
Three-class model



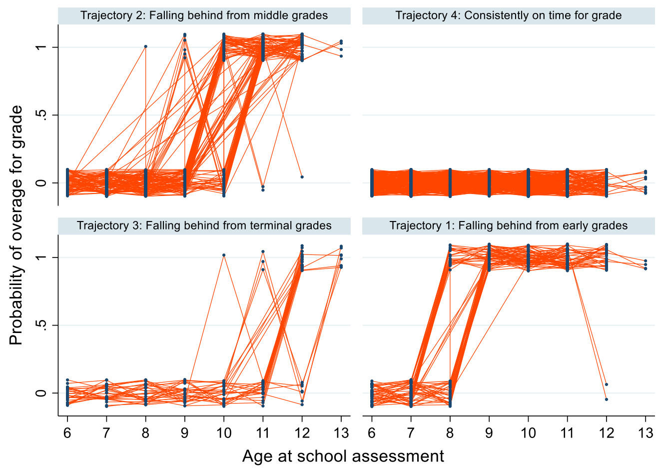
Four-class model



Three-class model individual level trajectories



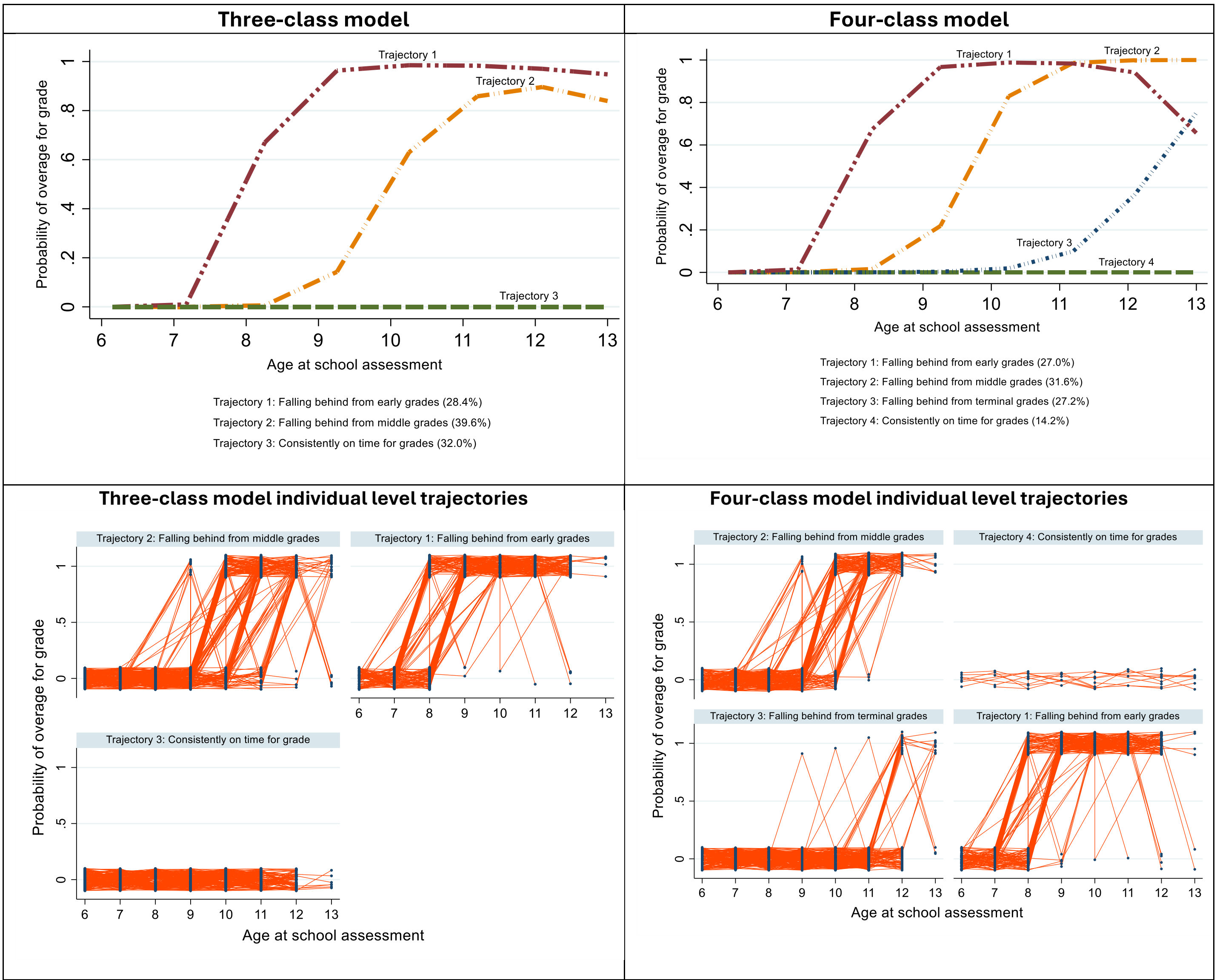
Four-class model individual level trajectories



Supplementary Figure 2: Trajectories of three-class and four-class latent class models and individual level age-for-grade progression of girls

Supplementary Table 4 Goodness of fit statistics and model adequacy diagnostics of boys for LCGM

Latent Model	Bayesian information criteria (BIC)	Akaike Information Criterion (AIC)	Entropy	Number of latent classes	Average Posterior Probability of Assignment (APPA)	Number per class	% of participants per class
1-class model	-1269.15	-1260.72	-				
				1	-	-	-
2-class model	-935.31	-922.67	0.86				
				1	0.95	219	44.0
				2	0.95	281	56.0
3-class model	-921.59	-898.41	0.81				
				2	0.93	142	28.4
				1	0.91	198	39.6
				3	0.93	160	32.0
4-class model	-896.20	-870.91	0.68				
				1	0.90	135	27.0
				2	0.85	158	31.6
				3	0.65	136	27.2
				4	0.71	71	14.2
5-class model	-958.88	-918.84	0.78				
				1	-	-	-
				2	0.93	255	48.7
				3	-	-	-
				4	0.79	173	27.8
				5	0.92	72	23.5



Supplementary Figure 3: Trajectories of three-class and four-class latent class models and individual level age-for-grade progression of boys

Supplementary Table 5 Binary logistic regression analysis of the association between exclusive breastfeeding duration and age-for-grade at age 11.5 (mid-point of age 10-12) in Malawi (Complete case analysis)

	N	Age-for-grade		Unadjusted odds ratio (95% CI)	P-value	Adjusted odds ratio (95% CI)	P-value
		Underage or on-time for grade	Overage for grade				
		n (%)	n (%)				
Model 1 Both sexes: Duration of exclusive breastfeeding (n=784)							
0-2 months	144	68 (47.2)	76 (52.8)	1.00	0.65	1.00	0.97
3-5 months	355	177 (49.9)	178 (50.1)	0.90 (0.61 - 1.33)		1.04 (0.68 - 1.58)	
6 months	285	148 (51.9)	137 (48.1)	0.83 (0.55 - 1.24)		1.06 (0.68 - 1.64)	
Model 2 Girls: Girls (n=375): Duration of exclusive breastfeeding							
0-2 months	62	38 (61.3)	24 (38.7)	1.00	0.89	1.00	0.50
3-5 months	175	105 (60.0)	70 (40.0)	1.06 (0.58 - 1.91)		1.05 (0.55 - 2.02)	
6 months	138	80 (58.0)	58 (42.0)	1.15 (0.62 - 2.12)		1.38 (0.71 - 2.69)	
Model 3 Boys: Boys (403): Duration of exclusive breastfeeding							
0-2 months	82	30 (36.6)	52 (63.4)	1.00	0.37	1.00	0.63
3-5 months	177	69 (39.0)	108 (61.0)	0.90 (0.53 - 1.55)		1.12 (0.63 - 2.02)	
6 months	144	65 (45.1)	79 (54.9)	0.70 (0.40 - 1.22)		0.89 (0.48 - 1.63)	

Note: We controlled for child's sex, household wealth at birth, age of mother at birth, birth order of child, maternal HIV status, mother education, father education, mother occupation, father occupation, and distance to a tarmac road in the adjusted analysis.

Supplementary Table 6 Generalised estimating equations analysis of the effects of exclusive breastfeeding duration on age-for-grade among school-aged children in Malawi (Complete case analysis)

	Unadjusted odds ratio (95% CI)	P-value	Adjusted odds ratio (95% CI)	P-value
Model 1 Both sex and all ages: Duration of exclusive breastfeeding (n=867)				
0-2 months	1.00		1.00	
3-5 months	0.90 (0.69 - 1.17)	0.01*	0.99 (0.77 - 1.28)	0.13*
6 months	0.71 (0.54 - 0.94)		0.83 (0.64 -1.09)	
Model 2 Age 6-9 Bothe sexes: Age 6-9: Duration of exclusive breastfeeding (n=857)				
0-2 months	1.00		1.00	
3-5 months	0.86 (0.59 - 1.26)	0.001*	0.98 (0.67 - 1.43)	0.02*
6 months	0.52 (0.34 - 0.80)		0.63 (0.42 - 0.97)	
Model 3 Age 10-13 Both sexes: Age 10-13: Duration of exclusive breastfeeding (n=788)				
0-2 months	1.00		1.00	
3-5 months	0.90 (0.63 - 1.29)	0.30	1.04 (0.72 - 1.51)	0.86
6 months	0.76 (0.53 - 1.11)		0.95 (0.65 - 1.41)	
Model 4 Girls, all ages: Girls: Duration of exclusive breastfeeding (n=425)				
0-2 months	1.00		1.00	
3-5 months	1.04 (0.66 - 1.63)	0.22	1.04 (0.66 - 1.65)	0.48
6 months	0.77 (0.49 - 1.23)		0.85 (0.53 - 1.36)	
Model 5 Boys, all ages: Boys: Duration of exclusive breastfeeding (n=443)				
0-2 months	1.00		1.00	
3-5 months	0.85 (0.62 - 1.17)	0.14	0.99 (0.73 - 1.34)	0.44
6 months	0.71 (0.51 - 1.00)		0.84 (0.61 - 1.16)	

*Test for linear trend

Note: We controlled for child's sex, household wealth at birth, age of mother at birth, birth order of child, maternal HIV status, mother education, father education, mother occupation, father occupation, and distance to a tarmac road in the adjusted analysis.

Supplementary Table 7 Multinomial logistic regression analysis of the association between exclusive breastfeeding duration and age-for-grade trajectories among school-aged children in Malawi (Complete case analysis)

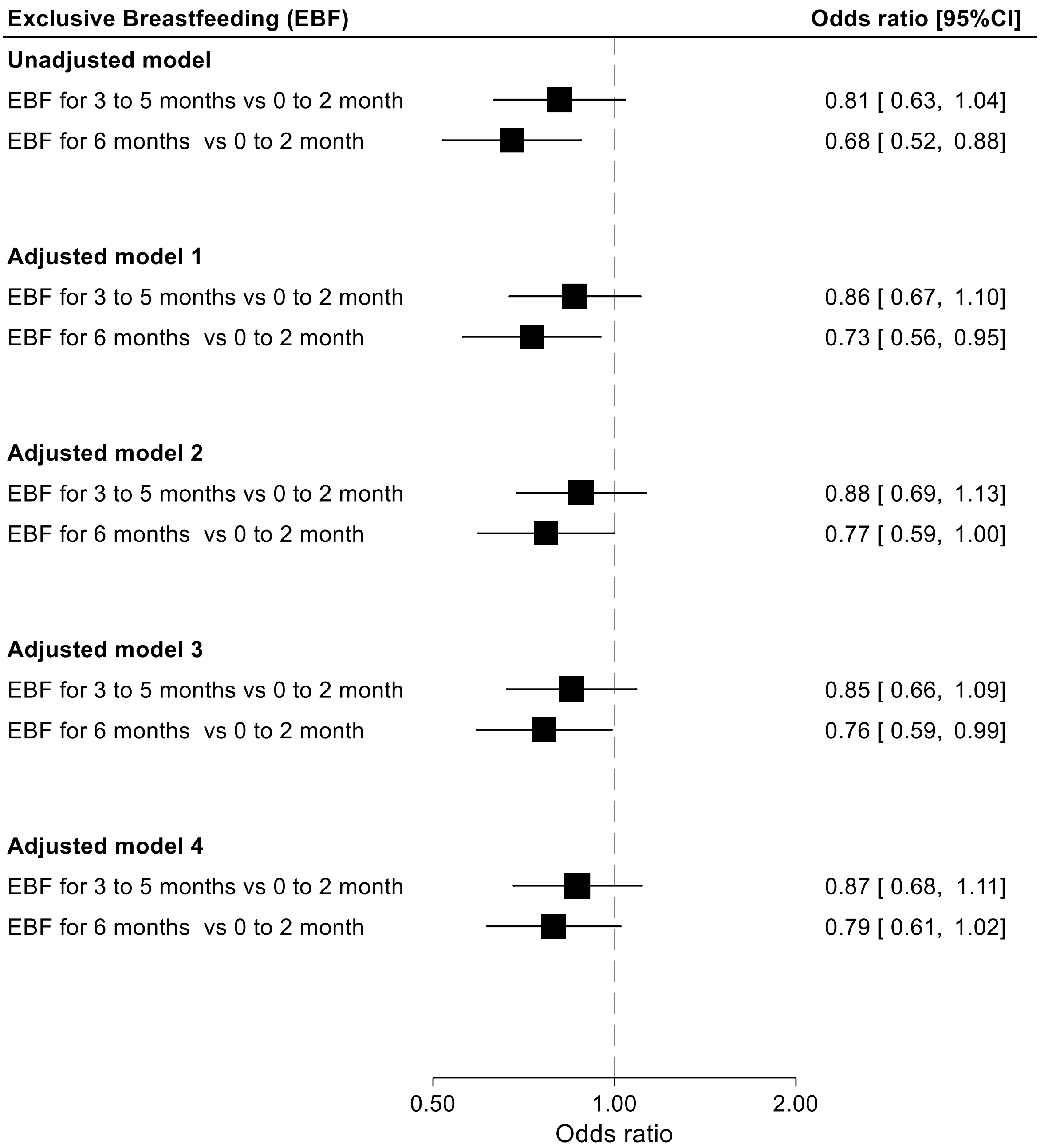
	Falling behind from early grades vs consistently on time for grade		Falling behind from middle grades vs consistently on time for grade		Falling behind in terminal grades vs consistently on time for grade	
	OR (95% CI)	**aOR (95% CI)**	**OR (95% CI)**	**aOR (95% CI)**	**OR (95% CI)**	**aOR (95% CI)**
Model 1 Both sexes and all ages: Duration of exclusive breastfeeding (n=812)						
0-2 months	1.00	1.00	1.00	1.00	1.00	1.00
3-5 months	0.89 (0.55 - 1.42)	1.06 (0.65 - 1.74)	1.05 (0.68 - 1.61)	1.17 (0.75 - 1.82)	1.12 (0.89 - 1.42)	1.14 (0.90 - 1.45)
6 months	0.53 (0.32 - 0.87)	0.69 (0.41 - 1.16)	0.91 (0.58 - 1.41)	1.13 (0.71 - 1.78)	0.94 (0.75 - 1.17)	0.95 (0.76 - 1.19)
Model 2 Girls, all ages: Girls: Duration of exclusive breastfeeding (n=329)						
0-2 months	1.00	1.00	1.00	1.00	1.00	1.00
3-5 months	1.15 (0.54 - 2.45)	1.21 (0.53 - 2.78)	1.33 (0.69 - 2.56)	1.25 (0.63 - 2.52)	1.25 (0.88 - 1.78)	1.25 (0.87 - 1.79)
6 months	0.67 (0.30 - 1.49)	0.76 (0.33 - 1.78)	1.40 (0.73 - 2.69)	1.53 (0.76 - 3.07)	1.08 (0.77 - 1.52)	1.08 (0.77 - 1.52)
Model 3 Boys, all ages: Boys: Duration of exclusive breastfeeding (n=420)						
0-2 months	1.00	1.00	1.00	1.00	1.00	1.00
3-5 months	0.76 (0.40 - 1.45)	1.01 (0.51 - 2.00)	0.89 (0.48 - 1.65)	1.13 (0.59 - 2.19)	1.00 (0.73 - 1.37)	1.03 (0.75 - 1.42)
6 months	0.42 (0.21 - 0.82)	0.55 (0.27 - 1.11)	0.62 (0.33 - 1.17)	0.84 (0.43 - 1.66)	0.81 (0.60 - 1.09)	0.83 (0.62 - 1.12)

Note: We controlled for child's sex, household wealth at birth, age of mother at birth, birth order of child, maternal HIV status, mother education, father education, mother occupation, father occupation, and distance to a tarmac road in the adjusted analysis.

6.4 ADDENDUM 1: SOCIOECONOMIC CONFOUNDING ON THE ASSOCIATION BETWEEN EXCLUSIVE BREASTFEEDING DURATION AND EDUCATIONAL ATTAINMENT IN MALAWI

This section presents results from the Malawi analysis, with a particular focus on understanding the specific influence of maternal and paternal socioeconomic factors on the relationship between the duration of exclusive breastfeeding and educational attainment. While these factors were adjusted for in the published analysis presented earlier in this chapter (Section 6.2), the paper did not clearly show the specific effects of socioeconomic factors on the association to quantify whether these effects vary from socioeconomic confounding effects observed in high-income countries. Given that I have mentioned throughout this chapter and several instances in this thesis that, in contrast to studies in high-income countries, socioeconomic status does not strongly affect the association in sub-Saharan Africa, it is important to show clearly the socioeconomic confounding effect on the association in a sub-Saharan African country.

In addendum 1 Figure 6.1, I show the confounding effect of socioeconomic factors on the association between exclusive breastfeeding and educational attainment in Malawi. Adjustment for only household wealth (adjusted model 1) or only maternal education, maternal occupation, and household wealth (adjusted model 2) only resulted in a minimal reduction in the strength of the effect for the association, and there was still weak evidence that children exclusively breastfed for six months were less likely to be over-age for grade compared to those exclusive breastfed for less than three months, albeit with slightly wider confidence intervals than the unadjusted estimates (EBF for 6 months: unadjusted model = OR 0.68, 95%CI 0.52 – 0.88; adjusted model 1 = aOR 0.73, 95%CI 0.56 – 0.95; adjusted model 2 = aOR 0.77, 95%CI 0.59 – 1.00). Adjustment for paternal education, paternal occupation, and household wealth (adjusted model 3) also only had a marginal effect on the estimates for the association, even less than the effect of maternal socioeconomic factors. There was some evidence, after adjusting for paternal socioeconomic factors, that children exclusively breastfed for six months were less likely to be over-age for grade compared to those exclusively breastfed for less than three months (aOR 0.76, 95%CI 0.59 – 0.99). When I adjusted for both the maternal and paternal socioeconomic factors (adjusted model 4), the strength of the association still only changed marginally, and there remained some evidence, albeit borderline, that children exclusively breastfed for six months were less likely to be over-age for grade compared to those exclusive breastfed for less than three months (aOR 0.79, 95%CI 0.61 – 1.02). These socioeconomic confounding effects are generally minimal compared to those observed in high-income countries.



Addendum 1 Figure 6.1 Generalised estimating equations analysis of the effects of exclusive breastfeeding duration on age-for-grade attainment (over-age for grade vs on-time for grade) among children aged six to thirteen in Malawi. Model 1: Adjusted for household wealth. Model 2: Adjusted for maternal education, maternal occupation, and household wealth. Model 3: Adjusted for paternal education, paternal occupation, and household wealth. Model 4: Adjusted for maternal education, maternal occupation, paternal education, paternal occupation, household wealth.

6.5 ADDENDUM 2: META-ANALYSIS OF THE ASSOCIATION BETWEEN EXCLUSIVE BREASTFEEDING DURATION AND EDUCATIONAL ATTAINMENT

6.5.1 Introduction

Heterogeneity in approaches, indicators, and outcomes among studies investigating the association between breastfeeding and educational attainment often hinders the direct comparison and synthesis of findings through a meta-analysis. Different studies have different definitions, measurements, and classifications of breastfeeding and educational outcomes, as well as different analysis methods and sample age groups. This variability impedes the ability to draw definitive conclusions or generalise findings across diverse populations. Meta-analysis relies on the assumption that studies are sufficiently comparable for statistical combination, but substantial differences make this impractical. For example, in my systematic review on the association of breastfeeding with cognitive development and educational achievement in sub-Saharan Africa (Chapter Two), a meta-analysis was not feasible due to the substantial variations in study designs, breastfeeding measures, and outcome indicators among the studies identified for the review. The heterogeneity across studies further deepens the existing criticism of previous studies for potential residual socioeconomic confounding. It becomes harder to establish whether varying conclusions are due to the true effect of breastfeeding or methodological disparities. A meta-analysis incorporating studies from various countries with different confounding structures could potentially clarify the association between breastfeeding and educational outcomes, highlighting its strength and consistency. In this analysis, I use the longitudinal data from Malawi described in this chapter (section 6.2) to examine the association between breastfeeding and grade repetition so that I can combine these findings in a meta-analysis with Mitchell et al.'s study (1) on the impact of exclusive breastfeeding duration on grade repetition in South Africa. Mitchell et al.'s study was identified through my systematic review (Chapter Two). The published paper presented earlier in this chapter (section 6.2) did not explore grade repetition because age-for-grade is partly a function of grade retention. Indeed, a previous analysis of this Malawi data found a strong correlation between age-for-grade and grade repetition among the children (2).

6.5.2 Methods

The data from Malawi came from the Karonga Health and Demographic Surveillance System in northern Malawi, as described earlier in this chapter (Section 6.2). In both the Malawi cohort and Mitchell et al.,'s study (1), children were classified as exclusively breastfed based on the World Health Organisation's recommendation of feeding the child with only breastmilk and no other foods or liquids in the first six months after birth. To ensure comparability of the exclusive breastfeeding groups in the Malawi cohort with those from Mitchell et al.,'s study (1), I categorised the exclusive breastfeeding duration in the Malawi cohort into three groups: 0-1 month, 2-5 months, and 6 months, following the same categories as Mitchell et al.,'s. The outcome of interest in their study was grade repetition, and the analysis included children aged 7 to 11 years. In the Malawi cohort, information on grade repetition was collected at multiple time points, starting from age four until age 13 for each child. To match the South African study, I used the data on grade repetition between ages 7 and 11 and chose the closest record to age 9.5 years, the average age of the children in the South African study. I used binary logistic regression, similar to Mitchell et al., to estimate the unadjusted and adjusted odds ratios with 95% confidence intervals for the effect of exclusive breastfeeding duration on grade repetition among children aged 7 to 11 years in Malawi. The adjusted odds ratios for both studies were then pooled in a random-effects meta-analysis to estimate the overall effect of exclusive breastfeeding duration on grade repetition. The result of the meta-analysis is presented as a forest plot. Between-study heterogeneity was assessed using I^2, τ^2, and the p-value for heterogeneity (Cochrane's Q statistic). The meta-analysis builds on the findings from my systematic review (Chapter Two) on the association of breastfeeding with cognitive development and educational achievement in sub-Saharan Africa.

6.5.3 Results

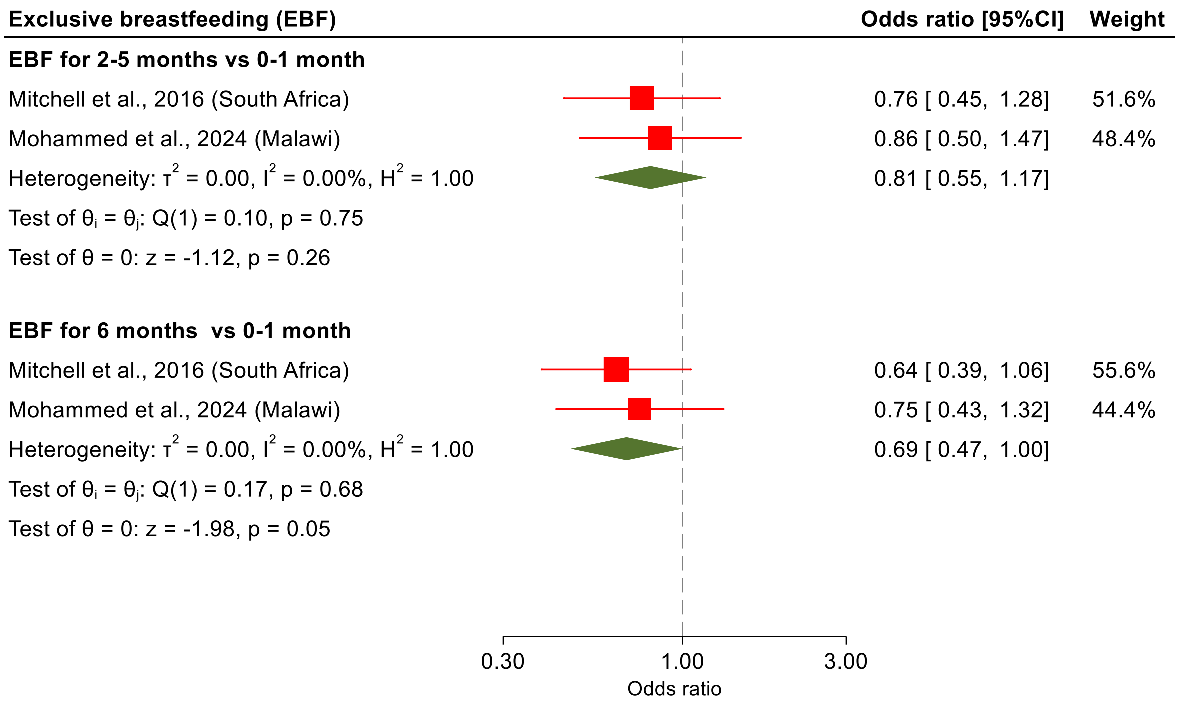
The characteristics of the sample analysed have been presented and discussed earlier in this chapter (Section 6.2). Addendum 2 Table 6.1 presents the logistic regression analysis of the association between exclusive breastfeeding duration and whether a child in the selected sample ever repeated a grade. In both the unadjusted and adjusted analysis, the patterns of the odds ratios were consistent with reduced odds of ever repeating a grade among children exclusively breastfed for longer than one month compared to those exclusively breastfed for 0-1 month, but the confidence intervals were very wide (exclusive breastfeeding for 2-5 months = aOR 0.86, 95%CI 0.50 - 1.47; exclusive breastfeeding for 6 months = aOR 0.75 95%CI 0.43 - 1.32).

Addendum 2 Table 6.1. Binary logistic regression analysis of the association between exclusive breastfeeding duration and grade repetition age 9.5 (mid-point of age 8-11) in Malawi (n=847)

	Total	Never Repeated a grade n (%)	Ever repeated a grade n (%)	Unadjusted odds ratio (95% CI)	P-value	Adjusted odds ratio (95% CI)	P-value
Duration of exclusive breastfeeding							
0-1	66	38 (57.6)	28 (42.4)	1.00		1.00	
2-5	475	301 (63.4)	174 (36.6)	0.78 (0.47 - 1.32)	0.37	0.86 (0.50 - 1.47)	0.53
6 months	306	203 (66.3)	103 (33.7)	0.69 (0.40 - 1.18)		0.75 (0.43 - 1.32)	

Adjusted for child's sex, household wealth at birth, maternal age at birth, birth order of child, maternal HIV status, maternal education, paternal education, maternal occupation, paternal occupation, and distance to a tarmac road.

In the meta-analysis combining the estimates from Malawi and Mitchell et al.'s study (1) from South Africa (Figure 6.2), the pooled estimates show that exclusive breastfeeding for more than one month was associated with reduced odds of ever repeating a grade compared to exclusive breastfeeding for one month or less. The evidence for this association was strongest among children exclusively breastfed for six months (aOR 0.69, 95%CI 0.47 – 1.00) compared to those exclusively breastfed for one month or less. There was no evidence of heterogeneity between the estimates from Malawi and South Africa (I^2=0.00% for both exclusive breastfeeding groups).



Addendum 2 Figure 6.2 Random-effects meta-analysis of the association between exclusive breastfeeding duration and grade repetition. Mitchell et al., (n=842) adjusted for maternal age, maternal education, type of residence, main income provider, and fridge ownership (all measured at birth) and child age, child sex, birth order, birth weight, and HIV exposure. Mohammed et al., (n=847) adjusted for child's sex, household wealth at birth, maternal age at birth, birth order of child, maternal HIV status, maternal education, paternal education, maternal occupation, paternal occupation, and distance to a tarmac road.

6.5.4 Discussion

The finding of the meta-analysis is consistent with previous studies (3) on the effects of exclusive breastfeeding on educational outcomes, including the published results presented in this chapter. This finding further supports the World Health Organization's recommendation that mothers feed their babies only breastmilk in the first six months after birth. To my knowledge, the analysis is the first to pool findings on the association between breastfeeding and educational outcomes in a formal meta-analysis. The findings are discussed further in Chapter Eight.

6.5.5 References

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CHAPTER 7

Paper 5

Breastfeeding duration and educational attainment in rural southwest Uganda: a population-based cohort study

CHAPTER 7: PAPER 5 - BREASTFEEDING DURATION AND EDUCATIONAL ATTAINMENT IN RURAL SOUTHWEST UGANDA: A POPULATION-BASED COHORT STUDY

7.1 Introduction

This chapter addresses objective 3 using longitudinal data from the General Population Cohort, a population-based cohort conducted in rural Southwest Uganda by investigators at the MRC/UVRI & LSHTM Uganda Research Unit. In this chapter, I assess the prevalence of the duration of any breastfeeding among children aged 0 to 2 years in the cohort. Also, I assess the primary school progression of children and examine whether children were age-appropriate for their grade between ages six and twelve years. I then investigate the association between the duration of any breastfeeding and educational attainment in this population-based cohort from Uganda.

RESEARCH PAPER COVER SHEET

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SECTION A – Student Details

Student ID Number	LSH1902998	**Title**	Mr
First Name(s)	Shamsudeen		
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Thesis Title	Effects of breastfeeding duration on educational attainment of children and adolescents in sub-Saharan Africa: A multisite analysis of longitudinal data		
Primary Supervisor	Laura Oakley		

If the Research Paper has previously been published please complete Section B, if not please move to Section C.

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Where is the work intended to be published?	Global Health Action
Please list the paper's authors in the intended authorship order:	Shamsudeen Mohammed, Clara Calvert, Joseph O Mugisha, Makanga Ronald, Gershim Asiki, Judith R Glynn, Laura L Oakley, and Milly Marston
Stage of publication	**In press**

SECTION D – Multi-authored work

For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	I requested the General Population Cohort data from Kyamulibwa HDSS, conducted the data management, planned the data analysis, and conducted the data analysis. I conducted the literature search for the study and prepared the manuscript for submission to the journal. My supervisors provided critical input on interpreting, discussing, and presenting the results.

SECTION E

Student Signature	
Date	8th April 2024

Supervisor Signature	
Date	9th April 2024

7.2 Abstract

Background: Breastfeeding is important for early childhood nutrition and health. The positive effects on educational outcomes may be attributed to socioeconomic factors. Socioeconomic status is not a strong predictor of breastfeeding in sub-Saharan African countries. Yet, few studies have investigated the association between breastfeeding and educational outcomes in these countries.

Objective: This study investigated the association between breastfeeding duration and children's educational attainment in rural Southwest Uganda.

Methods: We analysed longitudinal data on 3018 children who had information on breastfeeding and were followed for at least five years, with at least one primary school grade recorded by 2005. Data on breastfeeding duration were collected from mothers. The highest school grade was recorded repeatedly between ages six and twelve years. We calculated age-for-grade based on whether a child was on, over, or under the official age for a grade. Generalised estimating equations and binary logistic regression estimated the effect of breastfeeding duration on being two years, three or more years, or any years over-age for grade in primary school, adjusting for socioeconomic status and maternal-child characteristics.

Results: Most mothers breastfed for more than a year. Just over one-third breastfed for 18 to 23 months, and thirty percent breastfed for longer. By age eight, 42% of the children were two years over-age for their grade. Three or more years over-age for grade increased from 19% at age nine to 56% at age twelve. Both adjusted and unadjusted estimates were consistent in showing reduced odds for children being two years, three or more years, or any years over-age for grade among children breastfed for 7-12, 13-17, 18-23, and >23 months compared to those breastfed for 0-6 months. However, there was no evidence to support an overall association between breastfeeding duration and being over-age for grade. There was also no evidence of association in the sex and age sub-group analyses.

Conclusion: Even though we found no association between breastfeeding duration and educational attainment, breastfeeding remains important for children's health and nutrition, and mothers should be encouraged and supported to breastfeed for the recommended duration.

7.3 Background

Human breastmilk contains essential macronutrients and micronutrients that provide optimal nutrition for newborn growth and development [1–3]. It also contains many bioactive factors, including immunoglobulins, antimicrobial agents, and anti-inflammatory substances for newborn immunity programming against pathogens [1, 4–6]. In addition to the short-term benefits of breastfeeding, some studies have suggested that optimally breastfed children might also benefit from improved educational outcomes [7–11]. While the protective effects of breastfeeding against pathogens have been established in both low-middle and high-income countries [12, 13], the evidence supporting the suggested positive effects on educational outcomes is largely from high-income countries [9], where socioeconomic status strongly predicts both the pattern and duration of breastfeeding [14–16] and child educational outcomes [17, 18].

It has been hypothesised that the positive effects reported are a manifestation of who breastfeeds in these populations and not a direct biological advantage of breastfeeding [19–22]. Indeed, in studies where socioeconomic confounders are controlled for, the strength of the association often attenuates substantially [10, 23–25]. There are reasonable concerns that the small positive effects that often remain after accounting for socioeconomic status might still be biased by residual confounding from either imperfect measurement of these factors or inadequate adjustment [22, 26, 27]. In a 2002 systematic review with strict inclusion criteria, including a requirement for studies to control for socioeconomic status and stimulation of the child, there was no clear evidence of a positive effect of breastfeeding on intelligence when restricting to high-quality studies [22]. In a 2015 systematic review and meta-analysis that included studies mostly from high-income countries, breastfeeding was associated with higher scores in an intelligence test [28]. However, in a systematic review that included 13 studies from low- and middle-income countries, only five demonstrated a positive association between breastfeeding and cognitive development [21]. None of these reviews included studies from sub-Saharan Africa.

Evidence from sub-Saharan Africa could clarify this association since the duration and pattern of breastfeeding are not strongly influenced by socioeconomic status in the region [14, 29, 30]. Our recent systematic review revealed that only two studies had investigated the breastfeeding-educational-outcomes relationship in sub-Saharan Africa [31], with no studies from Uganda. Neither of the two South African studies identified in the review demonstrated a clear association between breastfeeding and educational outcomes [32, 33], although our recent analysis of data from Malawi found better grade progression among children exclusively breastfed for a longer duration [34]. No clear evidence of association is found in other low- and middle-income countries, including Turkey, Guatemala, and the Philippines [32, 35]. Yet, new evidence from high-income countries continues to show improved educational outcomes among children breastfed for a longer duration [36].

Given the discrepancies in the existing literature, further research is needed, particularly from sub-Saharan African countries, to understand the link between breastfeeding and educational outcomes. Sub-Saharan African countries also differ in childhood adversities, such as HIV exposure, which affect breastfeeding and the achievement of children [37]. The cohort analysed in this study includes mothers and children who are living with HIV [38] in rural Southwest Uganda. Residents of the study villages were followed over several years, and longitudinal data on feeding practices and schooling were collected at multiple time points. This study aimed to investigate whether the duration of breastfeeding in infancy was associated with educational attainment at primary school age using data from a large longitudinal population-based cohort in rural Southwest Uganda.

7.4 Methods

We used longitudinal data from a population-based open cohort (the General Population Cohort) in rural Southwestern Uganda [38, 39]. The cohort site is situated in Kalungu district, 120 km west of Kampala, the capital of Uganda, with a 2014 population of 183 232 [40]. Data on household members, including sociodemographic and housing characteristics, are collected through annual surveys [39]. Residents of the study villages, including children, are offered health care at the General Population Cohort (GPC) clinic located at the Kyamulibwa field station [38]. In 1999, child health surveys were introduced to collect detailed information about children under 13 years, including where they were born, feeding practices, vaccination status, anthropometry, and other child characteristics [39]. Trained field staff collected data using standard individual and household questionnaires moving from house to house [38, 41]. Data collection was supervised by team leaders. Information across surveys was linked using unique participant, village, and household identification numbers issued to residents at their first participation. Details about the cohort, data collection, and management processes are published elsewhere [38, 41, 42]. For this analysis, the sample was restricted to children with information on breastfeeding and at least one primary school grade level measured by the 2005/2006 GPC survey, thereby only including children born between 1987 and 2000.

Retrospective information on breastfeeding practices was collected annually from mothers, including whether the mother ever breastfed the child, how many days after birth she began breastfeeding, the child's current breastfeeding status, and the child's age (in months) when the mother stopped breastfeeding. In the first round in which breastfeeding information was collected in 1999, mothers were asked about the breastfeeding of their older children. In subsequent rounds, breastfeeding information was collected from mothers of children aged 0 - 3 years.

In Uganda, primary school is compulsory and free in public schools, and children are expected to enter grade one at age six and advance from grade 1 to 7 in seven years [43]. For example, children are expected to be in grade 4 at age 9, grade 5 at age 10, and grade 6 at age 11. At each annual survey, mothers or primary caregivers were asked if their child had ever enrolled in school and the child's current grade level. We used this information together with the age of the child at the time of the survey to determine age-for-grade, defined as the expected grade level of a child at a given age if they started primary school at the official entry age without repeating or skipping a grade [34, 44]. We then determined, at each age, whether a child was underage, on-time, or over-age for their current grade level for all time points for which schooling data were available for the child between ages six and 12. For example, for a 9-year-old, being in grade 3 was considered one year over-age, but grade 4 was considered on-time, and grade 5 one-year underage. Until 2005 promotion to the next grade depended on performance, so age-for-grade is a marker of educational attainment. In 2005 automatic promotion was introduced [45] so only schooling data up to 2005 is included. Ethics approval for the present analysis was granted by the research ethics committee of the London School of Hygiene and Tropical Medicine (Ethics Ref: 26468).

Data analysis

Baseline characteristics were summarised using percentages and frequencies. The duration of any breastfeeding was categorised as 0-6 months, 7-12 months, 13-17 months, 18-23 months and >23 months. Frequencies and percentages were used to show the bivariate distribution of the participants characteristics across the breastfeeding groups. We followed UNESCO's guidelines [46, 47] to categorise children as underage for a grade if they were one or more years younger than the expected age for the grade, on-time if they were of the expected age or one year older than the expected age for the grade, and over-age for a grade if they were two or more years older than the expected age for the grade. We used graphs to illustrate the percentage of children underage, on-time, two years over-age, and three or more years over-age at each age from age 6 to 12.

Using binary logistic regression, we first examined the association between the duration of any breastfeeding and being two years, three or more years, or any years over-age for grade in primary school based on one age-for-grade attainment measured between ages 10 and 12. At these ages, children are expected to have completed the transition grade and be in upper primary. A child's age-for-grade attainment at age 11 was first considered, and if this was not available, the attainment at age 12 was considered, and then at age 10 if there was no assessment for the child at age 12.

For age-for-grade attainment measured at multiple time points between ages six and 12, we used Generalised Estimation Equations (GEE) analysis with an exchangeable correlation structure to assess the association between the duration of any breastfeeding and being two years, three or more years, or any years over-age for grade between ages eight and 12. We excluded age-for-grade assessments at ages 6 and 7 from the GEE analysis because no child was over-age for grade at these ages. The analysis accounted for the potential dependence of within-child repeated school measurements. We hypothesised that the effect of breastfeeding duration on educational attainment might differ depending on sex and age; therefore, in addition to the main analysis, we fitted separate GEE models with the repeated age-for-grade assessments for boys and girls, as well as for ages 8-9 and 10-12 years.

In the logistic regression and GEE analyses, we controlled for maternal education, maternal age, maternal HIV status, marital status, place of delivery, mode of delivery, household wealth, child sex, child year of birth, and survey year. Household wealth was estimated based on Principal Components Analysis (PCA) using data on ownership of assets (land, house, car, motorcycle, bicycle, telephone, radio, television, gas stove), dwelling characteristics (roof type, wall materials), livestock ownership, access to utilities (electricity and water), and whether the household employed a house help. There were different measures of household wealth across the survey rounds, with only a few rounds having some common indicators. For the PCA, categorical variables were reclassified as binary variables, and each survey round was analysed independently. For each round, the first component of the PCA was divided into quintiles ranging from lowest to highest household wealth and regrouped as low, middle, and high in the present analysis. Each mother-child dyad was assigned a household wealth that was calculated from indicators collected around the time of the child's birth.

Among the potential confounding variables, the percentage of missing values ranged from 0.4% for the mode of delivery to 40.5% for maternal education (Table 7.1). We used Little's Missing Completely at Random (MCAR) test [48] to check the assumption that the data were MCAR and a chi-square test to examine the distribution of a missing indicator across the covariates. Other covariates predicted missingness, and participants with complete data were systematically different from those with incomplete data. Additionally, Little's MCAR test yielded a significant result ($P<0.001$), suggesting that the data were not MCAR. The pattern of missingness revealed by these tests raised the possibility of biased results if the analyses were restricted to complete cases [49]. To reduce potential bias and loss of precision and power, we used Multiple Imputation by Chained Equations (MICE) to impute missing values in household wealth, place of delivery, mode of delivery, maternal education, and maternal age. Research on multiple imputation demonstrates that imputation can mitigate bias even in cases where the percentage of missing data is high [50]. We included all the variables in our substantive analyses models in the imputation model to ensure that the relationships between the variables of interest were preserved [49, 51]. For each imputed model, forty imputed datasets were generated based on the recommendation that the number of imputations should be at least equal to the proportion of missing observations [49, 51]. Missing maternal HIV status was not imputed; "unknown" was used as a third category to avoid excluding observations.

In addition to the main analysis with imputed data, we performed a sensitivity analysis that only included participants with complete data. In the complete case analysis, we fitted both the binary logistic regression and the GEE models for the total sample. Due to the small sample size in the subgroups, the complete case analysis did not include age and gender subgroup analyses.

7.5 Results

Characteristics of the study sample

The analytic cohort consisted of 3018 children for whom breastfeeding information was available and who were followed for at least five years, with at least one primary school grade recorded by the 2005 to 2006 survey. Table 7.1 presents the characteristics of the study sample. Nearly all the children (97.9%) were delivered through vaginal birth, and 57.8% of the births occurred in a healthcare facility. Just over half of the children were male (52.5%), born between 1990 and 1994 (53.1%), and 39.8% of the mothers were between the ages of 20 and 29 when their children were born. The majority (70.3%) of mothers were known to be HIV-negative; 5.2% tested positive. Maternal education was mostly primary (44.8%), with only 1.5% having a tertiary education.

Breastfeeding duration

Of 3018 children, 5.2% were breastfed for less than seven months, 14.0% for seven to twelve months, and 15.5% for 13 – 17 months (Table 7.1). A little over one-third of mothers (35.1%) breastfed for 18 to 23 months, with 30.2% breastfeeding for more than 23 months. There was no considerable difference in the duration of breastfeeding by child sex, delivery mode, place of birth, or level of household wealth. However, older mothers were more likely to breastfeed for a longer duration than younger mothers, and a higher percentage of mothers with no education and those with primary education breastfed for two years or longer than those with post-primary education. Mothers who tested negative for HIV were more likely to breastfeed for two years or more than those who tested positive.

Table 7.1 Distribution of breastfeeding duration across the characteristics of the study participants

	Total sample	Duration of any breastfeeding				
		0-6 months	7-12 months	13-17 months	18-23 months	>23 months
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
All	3018	157 (5.2)	422 (14.0)	468 (15.5)	1059 (35.1)	912 (30.2)
Child sex						
Male	1584 (52.5)	71 (4.5)	208 (13.1)	259 (16.4)	553 (34.9)	493 (31.1)
Female	1434 (47.5)	86 (6.0)	214 (14.9)	209 (14.6)	506 (35.3)	419 (29.2)
Child year of birth						
1987 - 1989	290 (9.6)	20 (6.9)	45 (15.5)	47 (16.2)	105 (36.2)	73 (25.2)
1990 - 1994	1603 (53.1)	74 (4.6)	197 (12.3)	237 (14.8)	555 (34.6)	540 (33.7)
1995 - 2000	1125 (37.3)	63 (5.6)	180 (16.0)	184 (16.3)	399 (35.5)	299 (26.6)
Mode of delivery						
Vaginal	2955 (97.9)	146 (4.9)	413 (14.0)	459 (15.5)	1041 (35.2)	896 (30.3)
Surgical	50 (1.7)	5 (10.0)	7 (14.0)	8 (16.0)	15 (30.0)	15 (30.0)
Missing	13 (0.4)	6 (46.1)	2 (15.4)	1 (7.7)	3 (23.1)	1 (7.7)
Place of delivery						
Non-facility	1231 (40.8)	60 (4.9)	150 (12.2)	186 (15.1)	462 (37.5)	373 (30.3)
Facility	1744 (57.8)	86 (4.9)	265 (15.2)	278 (15.9)	584 (33.5)	531 (30.5)
Missing	43 (1.4)	11 (25.6)	7 (16.3)	4 (9.3)	13 (30.2)	8 (18.6)
Maternal age						
< 20	351 (11.6)	26 (7.4)	62 (17.7)	66 (18.8)	113 (32.2)	84 (23.9)
20-29	1202 (39.8)	42 (3.5)	158 (13.1)	202 (16.8)	435 (36.2)	365 (30.4)
≥30	727 (24.1)	24 (3.3)	67 (9.2)	116 (16.0)	256 (35.2)	264 (36.3)
Missing	738 (24.5)	65 (8.8)	135 (18.3)	84 (11.4)	255 (34.5)	199 (27.0)
Marital status						
Unmarried	347 (11.5)	11 (3.2)	40 (11.5)	45 (13.0)	125 (36.0)	126 (36.3)
Married	1917 (63.5)	80 (4.2)	243 (12.7)	338 (17.6)	673 (35.1)	583 (30.4)
Missing	754 (25.0)	66 (8.8)	139 (18.4)	85 (11.3)	261 (34.6)	203 (26.9)
Maternal education						
None	49 (1.6)	1 (2.0)	2 (4.1)	9 (18.4)	14 (28.6)	23 (46.9)
Primary	1351 (44.8)	37 (2.7)	154 (11.4)	214 (15.9)	512 (37.9)	434 (32.1)
Secondary	352 (11.7)	18 (5.1)	60 (17.1)	72 (20.4)	107 (30.4)	95 (27.0)
Tertiary	45 (1.5)	2 (4.5)	9 (20.0)	11 (24.4)	10 (22.2)	13 (28.9)
Missing	1221 (40.5)	99 (8.1)	197 (16.1)	162 (13.3)	416 (34.1)	347 (28.4)
Maternal HIV status						
Positive	156 (5.2)	6 (3.9)	25 (16.0)	25 (16.0)	58 (37.2)	42 (26.9)
Negative	2123 (70.3)	86 (4.1)	262 (12.3)	359 (16.9)	745 (35.1)	671 (31.6)
Unknown	739 (24.5)	65 (8.8)	135 (18.3)	84 (11.4)	256 (34.6)	199 (26.9)
Household wealth						
Low	1060 (35.1)	61 (5.7)	144 (13.6)	151 (14.2)	378 (35.7)	326 (30.8)
Middle	577 (19.1)	21 (3.6)	87 (15.1)	100 (17.3)	207 (35.9)	162 (28.1)
High	1189 (39.4)	67 (5.6)	160 (13.5)	190 (16.0)	413 (34.7)	359 (30.2)
Missing	192 (6.4)	8 (4.2)	31 (16.1)	27 (14.1)	61 (31.8)	65 (33.8)

Age-for-grade attainment

At age six, data on age-for-grade was available for 499 children (Figure 7.1). This number increased to 622 at age ten before declining to 525 at age twelve. The percentage of children underage for grade at each age declined from 14.0% at age six to 0.5% at age 11, with no child underage for grade at age twelve. The percentage on-time for grade at each age also declined steadily from 86.0% at age six to 18.1% at age twelve. However, by age eight, 41.6% of the children were two years older than the appropriate age for their grade level, but this percentage dropped to 25.7% at age twelve. In contrast, the percentage three or more years older than the appropriate age for their grade steadily increased from 19.2% at age nine to 56.2% at age twelve (Figure 7.1). At each age, information on age-for-grade was available for more boys than girls. However, a higher percentage of girls than boys were underage for grade from age six to eleven, and girls were also less likely to be over-age for grade than boys (Figure 7.2).

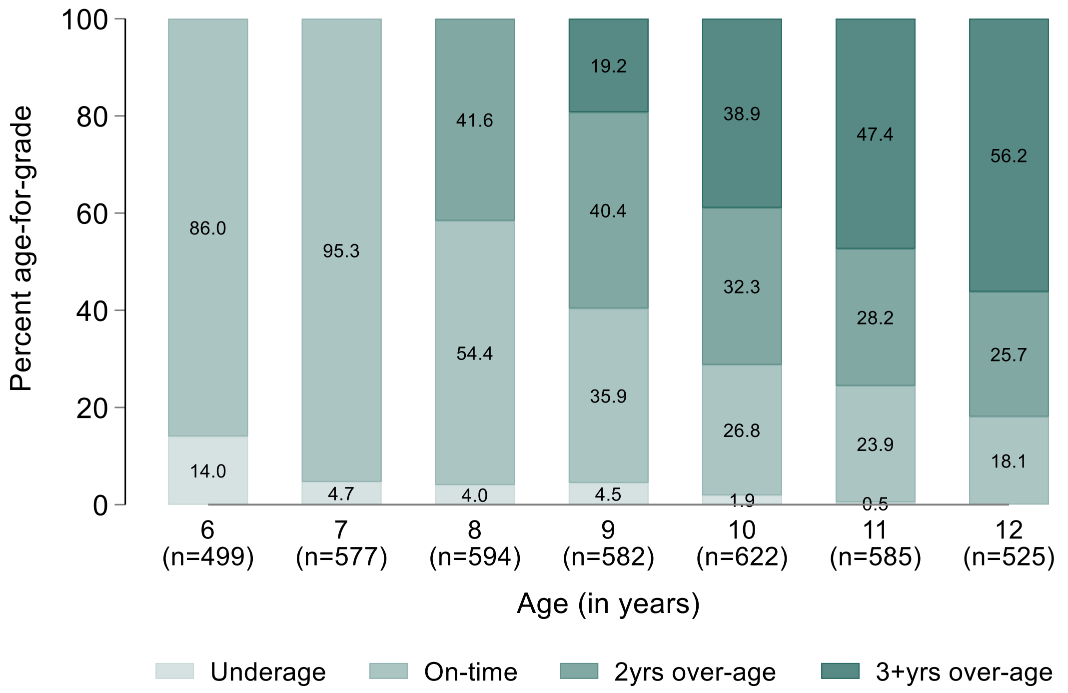

Figure 7.1 Distribution of age-for-grade by child's age at school assessment (Underage = or more years younger than the expected age for a grade; On-time = at the expected age grade or one year older than the expected age for a grade; 2yrs over-age = two years older the expected age for a grade; and 3+yrs over-age = three or more years older than the exp age for a grade for a grade)

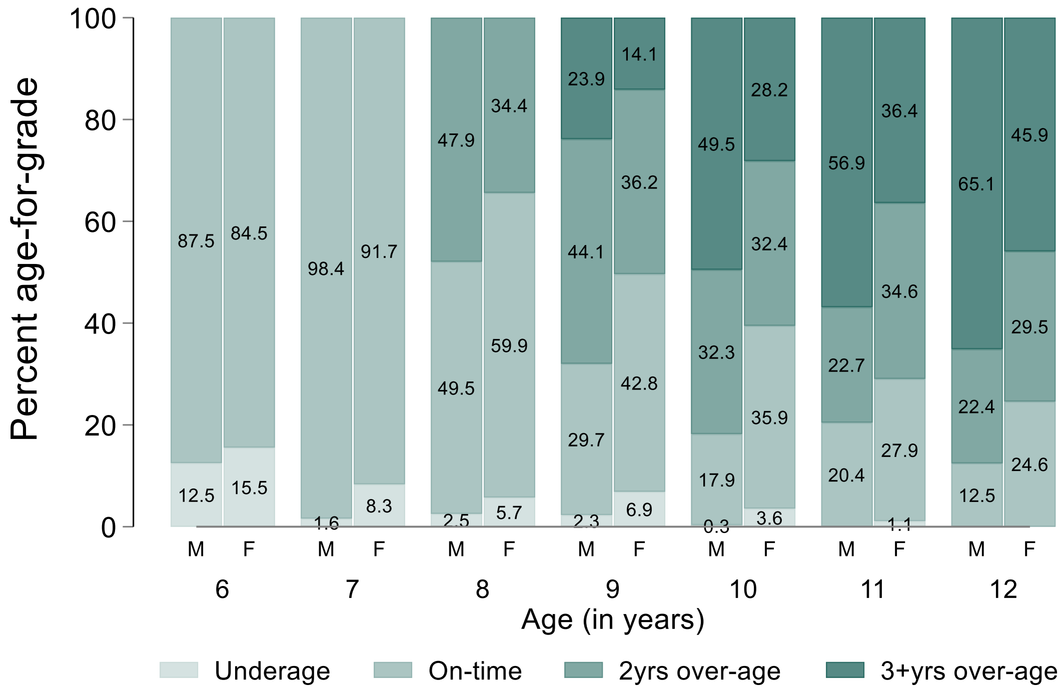

Figure 7.2 Distribution of age-for-grade at each age by child's sex (Underage = one or years younger than the expected age for a grade; On-time = at the expected age for a gra one year older than the expected age for a grade; 2yrs over-age = two years older tha expected age for a grade; and 3+yrs over-age = three or more years older than the expe age for a grade for a grade. [M=Male F=Female])

Association between duration of any breastfeeding and being over-age for grade based on a single age-for-grade assessment between ages 10 and 12 years

Table 7.2 presents the unadjusted and adjusted odds ratios for the association between the duration of any breastfeeding and being two years, three or more years, or any years over-age for grade in primary school based on assessment at one point between ages 10 and 12. In the unadjusted analysis, the odds ratios for being two years, three or more years, or any years over-age for grade among children breastfed for 7-12, 13-17, 18-23, and >23 months were lower compared to those breastfed for 0-6 months, except in the 18-23 months breastfeeding group (OR 1.02, 95%CI 0.49 - 2.11) for two years over-age for grade. After adjusting for confounding factors, the odds ratios strengthened for all breastfeeding categories, including a decrease in the 18-23 months breastfeeding group (aOR 0.95, 95%CI 0.43 - 2.07) for two years over-age for grade. The odds of being two years, three or more years, or any years over-age for grade among children breastfed for 7-12, 13-17, 18-23, and >23 months were lower than those breastfed for 0-6 months. However, there was no evidence of an overall association between breastfeeding duration and over-age for grade (two years: P = 0.82; three or more years: P = 0.50; and any over-age: P = 0.77).

A similar pattern emerged in the unadjusted and adjusted subgroup analyses for boys. Those breastfed for 7-12, 13-17, 18-23, and >23 months had lower odds of being two years, three or more years, or any years over-age for grade compared to those breastfed for 0-6 months, but there was no evidence to support an overall association (two years over-age: P = 0.31; three or more years over-age: P = 0.56; and any over-age: P = 0.43).

For girls, the adjusted and unadjusted odds ratios were suggestive of higher odds for two years over-age for grade in all breastfeeding duration categories (7-12 months [aOR 1.60, 95%CI 0.51 - 4.97]; 13-17 months [aOR 1.31, 95%CI 0.44 - 3.91]; 18-23 months: [aOR 1.41, 95%CI 0.50 - 3.98]; and >23 months [aOR 1.17 95%CI 0.42 - 3.31]) compared to those breastfed for 0-6 months, though there was no evidence for an overall association (P = 0.85). The odds of being three or more years over-age or any over-age for grade among girls were lower in all breastfeeding groups than breastfeeding for 0-6 months after adjustment except in the 7-12 months breastfeeding groups, but there was no evidence for an association.

Results of the complete case analysis involving only the small number of participants with complete observations for all variables differed slightly in the direction of association. However, similar to the main analysis, there was no evidence to support an overall association between breastfeeding duration and over-age for grade (Supplementary Table 7.1).

Table 7.2 Binary logistic regression analysis of the association between duration of breastfeeding and being over-age for grade at one point between ages 10 and 12 in Uganda

	Two years over-age for grade vs on-time for grade		Three or more years over-age for grade vs on-time for grade		Over-age for grade vs on-time for grade	
	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)
Model 1: Both sexes						
Duration of any breastfeeding						
	n = 797		n = 1076		n = 1516	
	P = 0.73	P = 0.82	P = 0.89	P = 0.50	P = 0.86	P = 0.77
0-6 months	1.00	1.00	1.00	1.00	1.00	1.00
7-12 months	0.78 (0.35 - 1.73)	0.77 (0.33 - 1.79)	0.69 (0.34 - 1.40)	0.60 (0.27 - 1.36)	0.72 (0.37 - 1.41)	0.69 (0.33 - 1.41)
13-17 months	0.90 (0.41 - 1.96)	0.87 (0.38 - 2.00)	0.71 (0.35 - 1.42)	0.53 (0.24 - 1.18)	0.77 (0.40 - 1.50)	0.68 (0.33 - 1.37)
18-23 months	1.02 (0.49 - 2.11)	0.95 (0.43 - 2.07)	0.75 (0.39 - 1.43)	0.51 (0.24 - 1.08)	0.84 (0.45 - 1.55)	0.68 (0.35 - 1.33)
>23 months	0.84 (0.40 - 1.74)	0.78 (0.36 - 1.71)	0.74 (0.39 - 1.42)	0.55 (0.26 - 1.15)	0.77 (0.42 - 1.44)	0.65 (0.33 - 1.27)
Model 2: Boys						
Duration of any breastfeeding						
	n = 336		n = 591		n = 796	
	P = 0.28	P = 0.31	P = 0.35	P = 0.56	P = 0.26	P = 0.43
0-6 months	1.00	1.00	1.00	1.00	1.00	1.00
7-12 months	0.29 (0.07 - 1.19)	0.26 (0.06 - 1.20)	0.33 (0.09 - 1.24)	0.31 (0.08 - 1.26)	0.32 (0.09 - 1.14)	0.29 (0.07 - 1.11)
13-17 months	0.52 (0.13 - 2.13)	0.47 (0.10 - 2.14)	0.56 (0.15 - 2.09)	0.43 (0.11 - 1.75)	0.55 (0.15 - 1.98)	0.42 (0.11 - 1.62)
18-23 months	0.55 (0.14 - 2.11)	0.53 (0.13 - 2.28)	0.56 (0.16 - 1.98)	0.44 (0.12 - 1.69)	0.56 (0.16 - 1.91)	0.42 (0.11 - 1.53)
>23 months	0.42 (0.11 - 1.63)	0.40 (0.09 - 1.75)	0.54 (0.15 - 1.91)	0.41 (0.11 - 1.58)	0.50 (0.15 - 1.72)	0.38 (0.10 - 1.39)
Model 3: Girls						
Duration of any breastfeeding						
	n = 461		n = 485		n = 720	
	P = 0.89	P = 0.85	P = 0.50	P = 0.39	P = 0.78	P = 0.79
0-6 months	1.00	1.00	1.00	1.00	1.00	1.00
7-12 months	1.41 (0.51 - 3.93)	1.60 (0.51 - 4.97)	0.96 (0.39 - 2.36)	1.04 (0.37 - 2.97)	1.11 (0.48 - 2.56)	1.20 (0.48 - 3.01)
13-17 months	1.15 (0.42 - 3.14)	1.31 (0.44 - 3.91)	0.58 (0.24 - 1.40)	0.60 (0.21 - 1.68)	0.77 (0.34 - 1.73)	0.88 (0.36 - 2.14)
18-23 months	1.39 (0.55 - 3.53)	1.41 (0.50 - 3.98)	0.67 (0.30 - 1.50)	0.57 (0.22 - 1.47)	0.91 (0.43 - 1.92)	0.85 (0.37 - 1.95)
>23 months	1.19 (0.47 - 3.04)	1.17 (0.42 - 3.31)	0.66 (0.29 - 1.49)	0.64 (0.25 - 1.66)	0.84 (0.39 - 1.78)	0.82 (0.35 - 1.88)

Note: We controlled for maternal education, household wealth, maternal age, maternal HIV status, marital status, place of delivery, mode of delivery, child sex, child year of birth, and survey year.

Association between duration of any breastfeeding and being over-age for grade based on repeated age-for-grade assessments from ages 8 to 12

Table 7.3 shows the unadjusted and adjusted odds ratios for the association between the duration of any breastfeeding and being two years, three or more years, or any years over-age for grade in primary school based on repeated age-for-grade assessments between ages 8 to 12. In the total sample, the unadjusted results were generally consistent with reduced odds of being two years, three or more years, or any years over-age for grade among children breastfed for 7-12, 13-17, 18-23, and >23 months compared to those breastfed for 0-6 months, though there was no evidence of association. After adjusting for confounding factors, the odds ratios for almost all breastfeeding duration groups strengthened, and the odds of being two years, three or more years, or any years over-age for grade were lower in all the breastfeeding groups compared to breastfeeding for 0-6 months. However, there was no strong evidence to support an overall association between the duration of any breastfeeding and being two years (P = 0.99), three or more years (P = 0.48), or any years over-age (P = 0.85) for grade.

In the unadjusted sex-stratified analysis, the odds ratios for boys breastfed for 7-12 months (OR=1.02, 95%CI=0.47 - 2.21), 13-17 months (OR=1.38, 95%CI=0.65 - 2.94), 18-23 months (OR=1.42, 95%CI=0.69 - 2.93), and >23 months (OR=1.49, 95%CI=0.72 - 3.06) were consistent with being more likely to be two years over-age for grade than those breastfed for 0-6 months (p-value = 0.43). The odds ratios weakened slightly after adjustment (7-12 months: OR 0.93, 95%CI 0.39 - 2.18; 13-17 months: OR 1.26, 95%CI 0.55 - 2.92; 18-23 months: OR 1.26, 95%CI 0.56 - 2.83; and >23 months: OR 1.34, 95%CI 0.60 - 3.01), but there was no evidence to support a difference in the odds of being two-years over-age for grade among boys breastfed for varying durations (p-value = 0.60). The odds ratios for the association between breastfeeding duration and being three or more years or any years over-age for grade among boys strengthened after adjusting for confounding factors and were lower in all breastfeeding groups compared to breastfeeding for 0-6 months. However, there was no evidence of an association between breastfeeding duration and being three years or any over-age for grade among boys.

The odds of being two years, three years, or any years over-age for grade were lower in all breastfeeding duration groups than breastfeeding for 0-6 months in both the unadjusted and adjusted sex-stratified analysis for girls, except in the 7-12 months group. However, there was no evidence to support an overall association between the duration of breastfeeding and being two years (p-value = 0.52), three or more years (P-value = 0.30), or any years over-age (P-value = 0.29) for grade among girls.

In the age-stratified analysis, similar patterns emerged in the association between breastfeeding duration and being two years, three or more years, or any years over-age for grade, with odds ratios either attenuating or strengthening after adjustment. However, there was no evidence of an association between breastfeeding duration and being over-age for grade in the age subgroups.

Results of the complete case analysis involving only the small number of participants with complete observations for all variables differed slightly. However, similar to the main analysis, there was no evidence to support an overall association between breastfeeding duration and over-age for grade (Supplementary Table 7.2).

Table 7.3 Generalised estimating equations analysis of the association between breastfeeding duration and being over-age for grade in primary school among children aged 8–12 in Uganda

	Two years over-age for grade vs on-time for grade		Three or more years over-age for grade vs on-time for grade		Over-age for grade vs on-time for grade	
	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)
Model 1: Both sexes at ages 8-12						
Duration of any breastfeeding						
	n = 1729		n = 1668		n = 2368	
	P = 0.97	P = 0.99	P = 0.75	P = 0.48	P = 0.86	P =0.85
0-6 months	1.00	1.00	1.00	1.00	1.00	1.00
7-12 months	0.92 (0.56 - 1.54)	0.95 (0.55 - 1.66)	0.74 (0.45 - 1.22)	0.68 (0.38 - 1.20)	0.82 (0.53 - 1.27)	0.85 (0.52 - 1.39)
13-17 months	0.93 (0.56 - 1.54)	0.91 (0.52 - 1.58)	0.77 (0.47 - 1.27)	0.61 (0.35 - 1.07)	0.83 (0.54 - 1.28)	0.76 (0.47 - 1.24)
18-23 months	1.01 (0.63 - 1.62)	0.98 (0.58 - 1.66)	0.82 (0.52 - 1.30)	0.65 (0.38 - 1.09)	0.90 (0.60 - 1.35)	0.81 (0.51 - 1.29)
>23 months	0.98 (0.61 - 1.58)	0.95 (0.56 - 1.62)	0.85 (0.54 - 1.35)	0.62 (0.37 - 1.06)	0.89 (0.59 - 1.35)	0.80 (0.50 - 1.28)
Model 2: Boys aged 8-12						
Duration of any breastfeeding						
	n = 830		n = 877		n = 1245	
	P = 0.43	P = 0.60	P = 0.35	P = 0.75	P = 0.33	P = 0.64
0-6 months	1.00	1.00	1.00	1.00	1.00	1.00
7-12 months	1.02 (0.47 - 2.21)	0.93 (0.39 - 2.18)	0.66 (0.33 - 1.34)	0.53 (0.21 - 1.33)	0.76 (0.40 - 1.45)	0.71 (0.35 - 1.43)
13-17 months	1.38 (0.65 - 2.94)	1.26 (0.55 - 2.92)	0.88 (0.44 - 1.75)	0.65 (0.26 - 1.63)	1.01 (0.54 - 1.89)	0.93 (0.47 - 1.85)
18-23 months	1.42 (0.69 - 2.93)	1.26 (0.56 - 2.83)	0.96 (0.50 - 1.83)	0.64 (0.27 - 1.51)	1.08 (0.60 - 1.97)	0.94 (0.49 - 1.80)
>23 months	1.49 (0.72 - 3.06)	1.34 (0.60 - 3.01)	1.02 (0.54 - 1.96)	0.65 (0.28 - 1.53)	1.14 (0.63 - 2.07)	0.99 (0.51 - 1.90)
Model 3: Girls aged 8-12						
Duration of any breastfeeding						
	n = 899		n = 791		n = 1123	
	P = 0.46	P = 0.52	P = 0.49	P = 0.30	P = 0.37	P = 0.29
0-6 months	1.00	1.00	1.00	1.00	1.00	1.00
7-12 months	0.86 (0.44 - 1.69)	1.08 (0.51 - 2.29)	0.84 (0.41 - 1.73)	1.11 (0.50 - 2.45)	0.86 (0.47 - 1.59)	1.06 (0.54 - 2.09)
13-17 months	0.62 (0.31 - 1.22)	0.78 (0.36 - 1.65)	0.58 (0.28 - 1.21)	0.70 (0.31 - 1.60)	0.62 (0.33 - 1.14)	0.73 (0.37 - 1.44)
18-23 months	0.76 (0.41 - 1.42)	0.86 (0.42 - 1.74)	0.68 (0.35 - 1.32)	0.74 (0.34 - 1.58)	0.73 (0.42 - 1.29)	0.78 (0.41 - 1.49)
>23 months	0.67 (0.36 - 1.26)	0.75 (0.37 - 1.52)	0.66 (0.34 - 1.30)	0.68 (0.31 - 1.47)	0.68 (0.39 - 1.20)	071 (0.37 - 1.35)
Model 4: Both sexes at ages 8 and 9						
Duration of any breastfeeding						
	n = 1043		n = 683		n = 1151	
	P = 0.95	P = 0.93	P = 0.89	P = 0.91	P = 0.96	P = 0.97
0-6 months	1.00	1.00	1.00	1.00	1.00	1.00
7-12 months	1.05 (0.53 - 2.05)	1.09 (0.51 - 2.34)	1.64 (0.44 - 6.11)	1.41 (0.34 - 5.83)	1.13 (0.59 - 2.14)	1.11 (0.53 - 2.31)
13-17 months	0.96 (0.49 - 1.88)	0.98 (0.45 - 2.13)	1.52 (0.41 - 5.65)	1.15 (0.28 - 4.69)	1.03 (0.54 - 1.96)	0.96 (0.46 - 2.03)
18-23 months	1.00 (0.53 - 1.87)	1.01 (0.49 - 2.09)	1.81 (0.52 - 6.26)	1.29 (0.35 - 4.72)	1.10 (0.60 - 2.01)	1.02 (0.51 - 2.05)
>23 months	1.10 (0.59 - 2.07)	1.14 (0.55 - 2.36)	1.55 (0.44 - 5.45)	1.01 (0.28 - 3.73)	1.16 (0.64 - 2.13)	1.07 (0.53 - 2.18)
Model 5: Both sexes at ages 10-12						
Duration of any breastfeeding						
	n = 876		1167		n = 1626	
	P = 0.82	P = 0.82	P = 0.88	P = 0.55	P = 0.87	P = 0.81
0-6 months	1.00	1.00	1.00	1.00	1.00	1.00
7-12 months	0.87 (0.41 - 1.82)	0.85 (0.37 - 1.93)	0.71 (0.37 - 1.39)	0.75 (0.35 - 1.62)	0.75 (0.40 - 1.41)	0.84 (0.42 - 1.67)
13-17 months	0.87 (0.42 - 1.80)	0.83 (0.37 - 1.86)	0.71 (0.37 - 1.37)	0.62 (0.29 - 1.32)	0.74 (0.40 - 1.38)	0.71 (0.36 - 1.41)
18-23 months	1.01 (0.51 - 1.98)	0.93 (0.43 - 2.02)	0.74 (0.40 - 1.36)	0.58 (0.28 - 1.19)	0.81 (0.46 - 1.44)	0.73 (0.38 - 1.40)

>23 months	0.83 (0.42 - 1.65)	0.77 (0.35 - 1.65)	0.74 (0.40 - 1.37)	0.64 (0.31 - 1.30)	0.76 (0.43 - 1.35)	0.71 (0.37 - 1.36)

Note: We controlled for maternal education, household wealth, maternal age, maternal HIV status, marital status, place of delivery, mode of delivery, child sex, child year of birth, and survey year.

7.6 Discussion

We used population-based cohort data to examine the association between breastfeeding duration and educational attainment in Uganda. Breastfeeding duration in infancy was not associated with age-for-grade attainment during the school-age years. These findings remained consistent when we stratified the sample by sex and age. Despite the lack of evidence for an association, the data showed a consistent trend of lower odds of being over-aged for grade with a longer duration of breastfeeding after controlling for confounders.

Our results are consistent with existing literature on the association of breastfeeding with educational outcomes in sub-Saharan Africa [31]. For example, an analysis of data from the birth-to-twenty cohort study in South Africa found no effect of breastfeeding duration in infancy on subsequent educational outcomes among 17-year-olds [32]. Similarly, when Mitchell et al., [33] studied 7-11-year-olds in rural KwaZulu-Natal, South Africa, they found no conclusive evidence of an association between exclusive breastfeeding and grade repetition. In addition, while our recent analysis of data from a Malawian cohort suggested an association between exclusive breastfeeding and age-for-grade attainment [34], in our earlier systematic review of data from Sub-Saharan Africa, we found no effect of breastfeeding on cognitive development or educational achievement [31].

Various interconnected factors influence educational attainment in sub-Saharan Africa, including cultural and environmental factors, educational quality, and family support [52, 53]. Breastfeeding, while undoubtedly beneficial for infant health and development, may have a limited direct influence on educational outcomes [19, 26, 32, 33]. Studies that found better educational outcomes among optimally breastfed children compared to those with suboptimal breastfeeding, mostly from high-income countries, suggest that this benefit could be attributed to the physiological effect of breastmilk on cognitive development and intelligence [7, 8, 11]. However, given that the actual effects of breastfeeding on cognitive development and performance in intelligence tests are modest [23, 54, 55], it has been argued that these small effects are unlikely to translate into real-world improvements in educational achievement. Although a cluster-randomised Breastfeeding Promotion Intervention Trial in Belarus found a positive effect of breastfeeding on cognitive development [56], a similar large cluster-randomised controlled trial of breastfeeding promotion that markedly increased exclusive breastfeeding in the intervention group in Uganda and Burkina Faso found no effect of exclusive breastfeeding on cognitive development [57, 58].

Residual socioeconomic confounding could account for the reported positive effects of breastfeeding on educational outcomes in predominantly high-income settings. In this study, breastfeeding was not associated with household income, and women with higher education were not more likely to breastfeed. However, in high-income countries, socioeconomic status has a positive impact on breastfeeding patterns and duration. For example, in a study that found better educational outcomes among breastfed children in the United States, mothers of breastfed children were more likely to be employed, have a higher education, and have fewer financial problems [9]. In a recent analysis of data from the Millennium Cohort Study in England, mothers who breastfed for a longer duration were more likely to be educated and of a higher social class [36]. Similar socioeconomic inequality in breastfeeding was found in a New Zealand study sample with higher mean test scores among children who were breastfed [25]. Although these studies account for some measures of socioeconomic status, residual confounding from unobserved or inaccurate measurements of these factors cannot be ruled out.

It is also possible that the discrepancy between our results and those of previous studies that found evidence of a positive association is attributable to differences in the breastfeeding duration groups compared. In this Ugandan cohort, all the children received breastmilk, albeit with varying durations of breastfeeding, with only about 1.0% breastfed for less than one month. However, in most studies that reported a positive association, the effect of breastfeeding duration on educational outcomes among breastfed children is often compared with non-breastfed children [7, 9, 10, 36, 59]. In this analysis, there was no suitable data to investigate the impact of exclusive breastfeeding on attainment or compare the breastfeeding groups to those never breastfed.

Even in high-income countries, where the majority of studies report a positive effect of breastfeeding on educational outcomes, there are some inconsistencies. For example, in a study among 10-year-olds in Australia, the duration of any breastfeeding was not associated with educational outcomes after adjustments, though predominant breastfeeding was associated with higher academic scores [11]. Similarly, when researchers examined the effect of breastfeeding duration on reading and math test scores in American children, they found no significant difference in test scores among the breastfeeding duration groups [59].

Breastfeeding has numerous established health benefits for both the mother and the infant [60, 61]. Even though this study did not find evidence of an association between breastfeeding duration and age-for-grade attainment, our findings should not discourage breastfeeding practices, as breastfeeding plays an essential role in infant nutrition, immunity, and overall well-being [1, 4–6].

An important strength of our study is its longitudinal design, which allowed us to assess educational attainment over time. Also, the sample size was relatively large. The main limitation is the use of retrospective breastfeeding data, which is susceptible to recall bias and social desirability bias, which could result in overreporting. Furthermore, the lack of information on exclusive breastfeeding limits the generalizability of the results. In addition, while efforts were made to control for potential confounding variables, residual confounding cannot be ruled out, and we did not adjust for birthweight, paternal education, and maternal intelligence. However, adjusting for these variables is unlikely to change the conclusion of our findings since it has been shown that they tend to reduce the magnitude of the effect and the strength of the association [7, 8, 36].

The use of age-for-grade as a measure of educational attainment has some limitations. It does not account for factors such as grade repetition due to missed schooling or other unique circumstances. Children from disadvantaged backgrounds might face unobserved obstacles that affect their grade progression, even if they have high academic potential. However, because grade progression in Uganda pre-2005 was largely based on classroom performance, any potential bias is likely minimal. Our findings should be interpreted cautiously, as the total and subgroup analyses were underpowered. Some children were clustered at the level of the mothers, but because over 40% of children were missing maternal identification numbers, we did not include this in our analysis models. Although the data for this analysis were not recent, it is unlikely that the association would change over time if there were a biological explanation for it.

7.7 Conclusion

In this cohort, most mothers breastfed for a longer duration, suggesting widespread cultural acceptance of breastfeeding in Uganda. Even though we found no association between breastfeeding duration and educational attainment, breastfeeding remains an important component of early childhood health and nutrition. Mothers who are able to breastfeed should be encouraged and supported to initiate and continue breastfeeding for at least two years after childbirth. Future research could explore the effects of exclusive breastfeeding and use various measures of educational attainment. Additionally, studies in different sub-Saharan African countries could contribute to a more comprehensive understanding of the relationship between breastfeeding and educational outcomes and whether it has a biological effect on achievement.

7.8 References

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7.9 Supplementary materials

Supplementary Table 7.1 (complete case analysis): Binary logistic regression analysis of the association between duration of any breastfeeding and over-age for grade at one point between ages 10 and 12 in Uganda

	Two years over-age for grade vs on-time for grade		Three or more years over-age for grade vs on-time for grade		Over-age for grade vs on-time for grade	
	OR (95% CI)	**aOR (95% CI)**	**OR (95% CI)**	**aOR (95% CI)**	**OR (95% CI)**	**aOR (95% CI)**
Model 1: Both sexes at ages 10-12						
Duration of any breastfeeding						
	n = 445		n = 574		n = 819	
	P = 0.22	P = 0.67	P = 0.56	P = 0.46	P = 0.54	P = 0.83
0-6 months	1.00	1.00	1.00	1.00	1.00	1.00
7-12 months	0.88 (0.27 - 2.83)	0.98 (0.28 - 3.39)	1.37 (0.47 - 4.00)	1.75 (0.51 - 5.93)	1.15 (0.44 - 3.03)	1.48 (0.52 - 4.21)
13-17 months	1.37 (0.45 - 4.16)	1.15 (0.36 - 3.68)	1.55 (0.55 - 4.38)	1.52 (0.47 - 4.92)	1.47 (0.58 - 3.73)	1.47 (0.54 - 4.00)
18-23 months	1.78 (0.62 - 5.14)	1.53 (0.50 - 4.65)	1.62 (0.60 - 4.39)	1.48 (0.48 - 4.57)	1.69 (0.69 - 4.12)	1.57 (0.60 - 4.10)
>23 months	1.27 (0.44 - 3.70)	1.16 (0.37 - 3.59)	1.98 (0.73 - 5.36)	2.14 (0.69 - 6.68)	1.67 (0.68 - 4.08)	1.74 (0.66 - 4.56)

Note: We controlled for maternal education, household wealth, maternal age, maternal HIV status, marital status, place of delivery, mode of delivery, child sex, child year of birth, and survey year.

Supplementary Table 7.2 (Complete case analysis): Generalised estimating equations analysis of the association between breastfeeding duration and being over-age for grade in primary school among children aged 8–12 in Uganda

	Two years over-age for grade vs on-time for grade		Three or more years over-age for grade vs on-time for grade		Over-age for grade vs on-time for grade	
	OR (95% CI)	**aOR (95% CI)**	**OR (95% CI)**	**aOR (95% CI)**	**OR (95% CI)**	**aOR (95% CI)**
Model 1: Both sexes at ages 8-12						
Duration of any breastfeeding						
	n = 987		n = 932		n = 1323	
	P = 0.36	P = 0.42	P = 0.25	P = 0.31	P = 0.22	P = 0.25
0-6 months	1.00	1.00	1.00	1.00	1.00	1.00
7-12 months	1.14 (0.50 - 2.61)	1.15 (0.46 - 2.86)	1.36 (0.57 - 3.24)	1.86 (0.77 - 4.50)	1.22 (0.61 - 2.47)	1.42 (0.65 - 3.13)
13-17 months	1.24 (0.56 - 2.76)	1.12 (0.47 - 2.68)	1.33 (0.57 - 3.09)	1.45 (0.61 - 3.41)	1.26 (0.64 - 2.49)	1.20 (0.56 - 2.56)
18-23 months	1.48 (0.69 - 3.20)	1.36 (0.58 - 3.19)	1.39 (0.61 - 3.14)	1.50 (0.66 - 3.37)	1.43 (0.75 - 2.76)	1.42 (0.68 - 2.96)
>23 months	1.59 (0.74 - 3.43)	1.53 (0.65 - 3.59)	1.81 (0.80 - 4.09)	1.95 (0.87 - 4.41)	1.67 (0.87 - 3.22)	1.70 (0.81 - 3.57)

Note: We controlled for maternal education, household wealth, maternal age, maternal HIV status, marital status, place of delivery, mode of delivery, child sex, child year of birth, and survey year.

CHAPTER 8
DISCUSSION

CHAPTER 8: DISCUSSION

8.1 Introduction

Researchers have debated the question of whether breastfeeding is associated with educational outcomes for decades, with studies predominantly conducted in high-income countries. Most of these studies suggest that breastfeeding is associated with improved intelligence and better educational outcomes (1–4). However, some have argued that these findings are attributable to selection bias or residual socioeconomic confounding (5–9), as breastfeeding mothers in high-income countries tend to have higher socioeconomic status and education, be in a two-parent family, and generally provide more engaging interactions with their children than mothers who do not breastfeed (1,3,10–15).

However, recent studies (2022 and 2023) in high-income countries (1,2) continue to report better educational and cognitive outcomes in children optimally breastfed compared to those with suboptimal breastfeeding, warranting further investigation of the association in a different setting. In this thesis, I hypothesised that if the reported associations in high-income countries are true biological effects of breastfeeding, we should observe a comparable effect in sub-Saharan African countries. Although studies have investigated this association in high-income countries since 1929 (16), there is a scarcity of evidence on the association from sub-Saharan Africa. This thesis, therefore, assessed whether longer breastfeeding duration during infancy is associated with educational attainment among children in sub-Saharan Africa.

In this chapter, I discuss the key findings and contributions of this thesis, the strengths and limitations, and potential implications of the findings, as well as recommendations and suggestions for future research.

8.2 Key findings

The objectives of this thesis were investigated under two themes. The first theme examined the socioeconomic pattern of breastfeeding practices in sub-Saharan Africa using (1) data from six rounds (2003-2017) of nationally representative cross-sectional surveys from Ghana (Chapter Four) and (2) data from six longitudinal cohort studies conducted in Ethiopia, Malawi, Uganda, and Zambia (Chapter Five). The aim was to determine if these patterns were consistent with those observed in high-income countries and to provide guidance on modelling strategies for examining the effect of breastfeeding on educational outcomes. The second theme of the thesis investigated the principal research question of whether there is an association between breastfeeding and educational attainment in sub-Saharan Africa.

In contrast to patterns observed in high-income countries, the analyses of the six cohorts and the Ghanaian data for the first theme showed no apparent socioeconomic disparities in breastfeeding practices. In Ghana, there was no evidence that exclusive breastfeeding in the first six months after birth and age-appropriate continued breastfeeding between ages six and 11 months varied by maternal education, household income, employment, or paternal education. However, there was evidence that women from low-income households were more likely than those from middle- and high-income households to continue age-appropriate breastfeeding between ages 12 and 23 months, in contrast to the usual pattern observed in high-income countries, where women from more advantaged socioeconomic backgrounds tend to breastfeed for longer durations (10–12,15). In the multisite analysis of the six longitudinal cohorts, the breastfeeding patterns were consistent with those seen in Ghana but inconsistent with the strong socioeconomic disparities in breastfeeding observed in high-income countries (10–12,15). Even though a difference in breastfeeding initiation was observed in some socioeconomic groups in Ethiopia, there was no consistent evidence for a strong positive association between maternal socioeconomic status and breastfeeding overall. In some cases, mothers with lower socioeconomic status breastfed for longer duration than those with higher socioeconomic status, again reflecting a contrast to the usual pattern observed in high-income country settings. Nearly all mothers (94% to 100%) in the cohorts analysed breastfed their children.

My findings align with several previous studies from sub-Saharan Africa. In a study that analysed data from the 2015 to 2019 Demographic and Health Surveys from 16 Sahara African countries, there was no difference in breastfeeding initiation or exclusive breastfeeding in the first six months after birth between women with secondary or higher education and those with no education (18). In a 2021 systematic review of 20 qualitative studies from 11 sub-Saharan African countries, including Malawi, Ghana, Ethiopia and Zambia, maternal employment was identified as a barrier to optimal breastfeeding practices (19). In sub-Saharan Africa, breastfeeding is culturally encouraged and supported by community networks, potentially mitigating the advantages of formal education (20–22). Also, educated mothers often struggle to continue breastfeeding when they return to work, sometimes leading to early cessation and the early introduction of complementary foods by caregivers (19,21). However, less educated mothers with more flexible work arrangements or occupations and limited access to expensive breastmilk substitutes tend to breastfeed for longer periods (23,24). Additionally, in most sub-Saharan African communities, cultural norms, particularly those influenced by elder family members (grandmothers and mothers-in-law), tend to play a substantial role in shaping breastfeeding practices, sometimes more than socioeconomic status (19,21,22).

The findings on the socioeconomic patterns of breastfeeding in sub-Saharan Africa suggest that maternal socioeconomic status may have a weaker confounding influence on the association between breastfeeding and educational outcomes in sub-Saharan Africa compared to high-income countries where socioeconomic status strongly predicts breastfeeding practices. Consequently, the association between breastfeeding and educational attainment or cognitive development in sub-Saharan Africa may differ from those observed in high-income countries, where such associations are often attributed to strong socioeconomic disparities in breastfeeding (5,7,8,25).

For the second theme, the association between breastfeeding and educational attainment in sub-Saharan Africa was investigated through (1) a comprehensive systematic review of the evidence on the association in sub-Saharan Africa before this thesis (Chapter Two) and (2) analyses of data from longitudinal population-based cohort studies in Malawi (Chapter Six) and Uganda (Chapter Seven).

The systematic review identified seventeen studies on cognitive development that met the predefined inclusion criteria, of which only four sufficiently adjusted for known socioeconomic confounding factors such as parental education or occupation and household income indicators. Two of the four studies were conducted in South Africa, one in Uganda and another in Burkina Faso and Uganda. These studies found no evidence supporting an association between breastfeeding and cognitive development. For educational outcomes, the systematic review revealed that only two studies, both conducted in South Africa, ever examined the association between breastfeeding and educational outcomes in sub-Saharan Africa prior to this thesis. The first study, published in 2013 by Horta et al., (26), assessed the effect of ever breastfeeding and the duration of any breastfeeding on the highest grade of schooling attained and completion of 12 or more years of education in the Birth-to-twenty cohort in South Africa (mean age of participants 17.7±0.3). The other study assessed the effect of exclusive breastfeeding duration on grade repetition at ages 7-11 years among children who were part of an intervention to encourage mothers to exclusively breastfeed in KwaZulu-Natal, South Africa (27). Both studies did not find clear evidence of an association between the breastfeeding exposures and educational outcomes.

These findings contradict several previous systematic reviews and meta-analyses, many of which focused on studies from high-income countries. The majority of these previous systematic reviews and meta-analyses suggested that breastfed children or those breastfed for a longer duration had better intelligence and educational outcomes than non-breastfed children (3,4,17,28). Studies from sub-Saharan Africa were not identified for inclusion in most of these earlier systematic reviews and meta-analyses. My systematic review is the first to focus on sub-Saharan Africa, but a meta-analysis was not feasible due to methodological and analytical differences among the studies. Nonetheless, a 2002 systematic review of studies that controlled for socioeconomic status and child stimulation (8) and a 2006 meta-analysis of studies that controlled for maternal IQ and other confounders (5) found no evidence of an association between breastfeeding status and intelligence. Additionally, a 2013 systematic review of studies from developing countries, where over 60% of the studies found no evidence of an association between breastfeeding and intelligence, indicated that the few studies showing some evidence were likely influenced by socioeconomic confounding (7).

In the analysis of longitudinal population-based cohort data from Uganda, I found no evidence for an association between the duration of any breastfeeding and educational attainment in the overall sample or separately for boys and girls. While this finding contradicts the results of a number of previous studies (1,3), it aligns with Horta et al.'s 2013 study in South Africa (26) and some previous studies in Uganda (29–31) that found no association between breastfeeding and cognitive development.

However, in the assessment of the association between exclusive breastfeeding duration (0–2 months, 3–5 months, and 6 months) and educational attainment in Malawi, my findings were inconsistent with those I observed in the Uganda analysis and the systematic review. In Malawi, I found weak evidence that children exclusively breastfed for six months were 18% less likely to be over-age for a grade than those exclusively breastfed for less than three months (aOR 0.82, 95%CI 0.64–1.06). In age subgroup analyses, I found that children exclusively breastfed for six months in infancy were 36% less likely to be over-age for grades between ages six to nine compared to those exclusively breastfed for less than three months (aOR 0.64, 95%CI 0.43–0.94). Further, the children were classified into four age-for-grade trajectories based on the patterns of their grade progression: (1) falling behind from early grades, (2) falling behind from middle grades, (3) falling behind from terminal grades, and (4) consistently on time for grades. There was weak evidence that children exclusively breastfed for six months were less likely to fall behind in the early school grades than those exclusively breastfed for less than three months (aOR 0.66, 95%CI 0.41 - 1.08). There was no evidence of a sex difference in the effect of exclusive breastfeeding duration on educational attainment. The confounding effect of socioeconomic status on the association between exclusive breastfeeding and educational attainment was marginal in Malawi (Chapter Six Addendum 1), which was not surprising given my finding of a lack of strong socioeconomic disparities in breastfeeding behaviour in sub-Saharan African countries, including Malawi (Chapter Five).

In Mitchell et al.'s study (27) comparing grade repetition among children exclusively breastfed for six months to those breastfed for less than two months in South Africa, the estimates were somewhat imprecise (aOR=0.64, 95%CI=0.39–1.06; P-value 0.08), which led the authors to conclude that there was no evidence of association. Nevertheless, the patterns are similar to those I observed in Malawi. The somewhat wide confidence intervals in both my study and that of Mitchell *et al*. could be due to low statistical power. In view of the similar trends observed across both studies, I used the Malawi data to further investigate the impact of exclusive breastfeeding duration (0-1 month, 2-5 months, and 6 months) on grade repetition (as opposed to age for grade) (Chapter Six Addendum 2). For this analysis, I used data on grade repetition recorded at one point closest to age 9.5 years (mean age of the children in Mitchell *et al.*'s study) for children aged 7 to 11 to make the approach similar to Mitchell *et al.*'s study in South Africa. Upon combining the estimates from my Malawi analysis on grade repetition and Mitchell et al.'s study through a random-effects meta-analysis (Chapter Six Addendum 2), the pooled estimates indicated that children exclusively breastfed for more than two months had reduced odds of repeating a grade compared to those exclusively breastfed for less than two months. The strongest evidence for this association was observed among children exclusively breastfed for six months (aOR 0.69, 95%CI 0.47 – 1.00).

A meta-analysis combining Uganda's findings with previous studies was not feasible due to demographic disparities. Horta et al.'s South African study (26), which analysed the effect of breastfeeding duration, included high school-aged participants (mean age 17.7 years), whereas Uganda's cohort consisted of primary school-aged children (ages six to 12 years). Additionally, the linear regression analysis used in Horta et al.'s study was unsuitable for Uganda's skewed breastfeeding duration data.

The discrepancy in findings between the Malawi and Ugandan cohorts could be explained by the fact that the Malawi study focused on exclusive breastfeeding, while the Uganda study considered the duration of any breastfeeding. Exclusive breastfeeding provides greater exposure to essential components of breastmilk, such as long-chain polyunsaturated fatty acids, which have been shown to play a role in cognitive development (32–34). In contrast, any breastfeeding is associated with a reduced frequency of breastfeeding sessions, leading to a lower overall volume of breastmilk consumed and lower exposure to essential breastmilk components than exclusive breastfeeding (35). In addition, non-exclusively breastfed children have a higher risk of infectious diseases (36), including diarrhoea and respiratory tract infections, which can affect early childhood development, school readiness and attendance. Also, exclusively breastfed children are more likely to have more bonding time with their mothers (37), a factor that has been associated with child development(38).

8.3 Strengths and limitations

In the papers presented in chapters two and four to seven, I discussed the strengths and limitations of the individual studies. This section summarises the overall strengths and limitations of the thesis.

Thesis strengths

The main strength of this thesis is the longitudinal design of the cohorts analysed and the inclusion of relatively large and diverse samples from multiple sites across several sub-Saharan African (SSA) countries over different time periods. The diverse samples not only enhanced the generalisability of the study's findings but also created an opportunity to explore differences in breastfeeding practices across several SSA countries. The longitudinal designs also ensured that data on potential confounding factors, breastfeeding exposure, and later educational attainment were collected in a clear temporal sequence, allowing for stronger inferences about the association between breastfeeding and educational outcomes, minimising the risk of reverse causation.

Unlike most previous studies, the data from the Malawi and Uganda cohorts analysed in this thesis included detailed information on children's school grade levels at multiple time points, allowing me to assess the impact of breastfeeding on educational attainment not just at one particular age or primary school grade but throughout the entire duration of primary school. It also offered an opportunity to provide a much deeper understanding of how breastfeeding influences primary school progression. In addition, the fact that age-for-grade was calculated based on UNESCO guidelines (39) (over-age for grade was defined as being two or more years older than the official age for a grade) facilitates meaningful comparisons of my findings with other studies in different settings. It will also enhance the practical application of the findings by facilitating their integration into educational policies and interventions across SSA.

Additionally, the use of latent class growth analysis to identify groups of children with similar grade progression patterns represents a novel approach in studies investigating the effects of breastfeeding on education and a major strength of the analysis using the Malawi data. By moving beyond broad categories like under-age, on-time, and over-age and instead identifying homogeneous subgroups with subtle differences in their grade progression, the analysis minimised misclassification and captured variations in grade progression that traditional methods may have overlooked, leading to a more in-depth understanding of the complex relationship between breastfeeding and educational attainment. However, this was not possible with the Uganda data due to an insufficient number of follow-up data on schooling required for the latent class growth analysis.

In contrast to previous studies criticised for not adjusting sufficiently for socioeconomic confounders, in this thesis, I adjusted for several important socioeconomic factors known to influence the breastfeeding-educational attainment relationship, including maternal education, maternal employment, paternal education, paternal employment, and household income. In addition, specific confounders relevant to the SSA context (40,41), including maternal and child HIV status, were incorporated into the models.

There was a relatively low attrition rate in the cohorts analysed, minimising the risk of attrition-related selection bias. Although there were some losses due to death or migration, further exploration of the data showed no systematic differences between participants who remained in the study and those lost to follow-up.

The collection of breastfeeding information occurred early in the postpartum period for most cohorts, minimising recall bias and strengthening the reliability of maternal reports. In addition, information on breastfeeding practices in some cohorts, including those from Zambia and Ethiopia, was collected at three or more time points in a year, further mitigating potential recall bias. Additionally, most breastfeeding indicators analysed were defined and grouped according to World Health Organization guidelines. This approach not only facilitates comparison with other studies but also ensures the relevance of the findings for shaping breastfeeding education and policies.

Additionally, this thesis has expanded the existing body of literature on the effects of breastfeeding on educational outcomes in SSA, as there was little evidence on the association between breastfeeding and educational outcomes in SSA before the completion of this thesis.

Thesis limitations

Despite the numerous strengths of this thesis, there are some limitations that need to be acknowledged.

Firstly, the thesis relied on self-reported data to assess and describe the type and duration of breastfeeding and children's school grades, introducing potential recall and social desirability biases, which may have impacted the results of the studies. It is plausible that some mothers provided inaccurate information that might have misclassified children into specific breastfeeding types or duration categories. In the Uganda cohort (Chapter Seven), questions about when mothers first introduced other foods or stopped breastfeeding were asked when some children were as old as 12 years old. Nevertheless, except for the Uganda cohort, the majority of children in all cohorts were younger than three years old when the breastfeeding information was collected. It has been shown that maternal recall is a valid and reliable measure of breastfeeding when the duration of breastfeeding is recalled within the first three years after birth (42). It is conceivable that some parents reported school grades they deemed appropriate for their child's age (social desirability bias) rather than the child's true current grade. Mothers may have also reported breastfeeding practices they perceived as socially acceptable given the child's age rather than their actual practices or experiences. Assuming that parents and mothers reported higher grades and longer breastfeeding duration than the reality, these biases could possibly lead to an overestimation of a positive association between breastfeeding and educational attainment. Nevertheless, data on schooling were collected annually for all cohorts, effectively reducing any potential bias in recall.

Secondly, categorising exclusive breastfeeding duration and the duration of any breastfeeding into discrete groups oversimplified the complex nature of breastfeeding patterns, likely resulting in a loss of nuanced information and reduced statistical power for detecting effects within the different categories. Additionally, since children within these broad breastfeeding categories may have varied breastfeeding experiences, the categorisation might have masked important within-category differences and hindered the ability to detect subtle effects of breastfeeding duration on educational attainment. Analysing breastfeeding duration as a continuous variable would have allowed for the exploration of potential nonlinear relationships and critical periods during which breastfeeding may have a substantial impact. Unfortunately, the skewed distribution of the breastfeeding data in the cohorts in which I examined the impact of breastfeeding on educational attainment precluded linear modelling of the association. The decision to categorise breastfeeding duration was driven by the desire to enhance the interpretability and communication of the findings for a broader audience and facilitate comparison with established guidelines and previous studies, as many earlier studies employed similar categorisations of breastfeeding duration. Additionally, because the breastfeeding data were from settings where almost every child is breastfed, there was limited opportunity to explore the impact of ever breastfeeding on educational attainment.

Thirdly, although age-for-grade is an appropriate measure of school progression, its use as a measure of educational attainment or achievement in examining the impact of breastfeeding on schooling has limitations that could bias the findings of the studies in this thesis. It assumes that progression is a reflection of a child's academic performance and abilities. However, many non-academic factors unrelated to a child’s academic abilities may have influenced grade progression in the studied cohorts. For instance, financial constraints might have led to delayed enrollment or absenteeism, resulting in a child being over-aged for grade. Migration, a common occurrence within the HDSS sites, could cause children to switch schools and lose valuable school time, causing them to fall behind. Health issues could also contribute to prolonged absenteeism. A child misclassified as over-age for grade due to these non-academic factors might have been incorrectly perceived as academically struggling, even though their academic performance might have been commensurate with their actual time spent in school. Furthermore, it is possible that, despite failing to meet the overall progress thresholds, students who were over-age for their grade performed better in certain subjects than some children who met the threshold to progress to the next grade. Unfortunately, age-for-grade is unable to capture such milestones in a child's academic journey.

Fourth, the use of latent class growth analysis to identify subgroups of children with similar age-for-grade progression patterns assumes that children within each subgroup follow the same academic trajectory over time. Given the complex nature of grade progression and school performance, this is likely an oversimplification. It is possible that children assigned to the same latent class had varied academic abilities and progression since class assignments are unlikely to be perfect without some misclassification. But, class assignments were based on several fit statistics, including higher odds of correct classification and posterior probability of class assignments to minimise misclassification.

Fifth, despite adjusting for several key confounders, the secondary datasets analysed lacked suitable information on some variables previously shown to influence the breastfeeding-educational attainment relationship, including birthweight, home stimulation, and perhaps most importantly, maternal and paternal cognitive ability. Though adjusting for these variables attenuated observed effects and strength of the association in studies conducted in high-income countries (1,2,13,43,44), their impact may differ in SSA, given the varying determinants of breastfeeding patterns and duration across settings. Therefore, assumptions that additional adjustment for these factors would not change the findings of studies from SSA may not hold. Nevertheless, in Rochat et al.'s study (45) on the association between exclusive breastfeeding and cognitive outcomes in South Africa, controlling for birthweight, home environment, and maternal IQ did not change the direction of estimates and had only a negligible impact on effect estimates.

Sixth, the findings of this thesis may have been biased by residual confounding due to missing data for key confounders such as maternal education, particularly in Uganda. However, multiple imputation using chain equations was employed to minimise the potential bias from this missing data.

Seven, using asset-based approaches to determine household wealth in this study has some limitations. These include the inability to account for differences in the quality of household items among households and the reliance on a limited selection of items, potentially leading to misclassification of households into wealth groups (46,47). Despite these limitations, the use of broad wealth groupings probably minimised any bias from such misclassification (46,47). Also, it has been shown that household wealth indexes are better at capturing socioeconomic status in SSA than other methods (48). Additionally, the cohorts from Malawi and Uganda were drawn from geographically well-defined populations primarily consisting of rural residents.

Eight, another limitation is the lack of distinction between mothers who attended a certain educational level and those who completed that level. For instance, mothers who attended and those who completed secondary school were grouped together in the analysis. These measurement errors and misclassifications in the confounders may have introduced residual confounding after adjustment. Also, the use of parental employment as one of the proxies for socioeconomic status has limitations, as employment status alone does not necessarily indicate higher or lower socioeconomic standing. Both employed and unemployed parents can be found across the socioeconomic spectrum.

Nine, I acknowledge that there are important nuances in breastfeeding practices across SSA countries, and therefore, I make no generalisation of the thesis findings to the entire region.

8.4 Implications of the findings for future research and policies

The findings of this thesis have important implications for both research and policy. The papers in chapters two and four to seven each present specific policy recommendations and research directions based on their context. In this section, I suggest broader research directions based on the overall findings of this thesis to inform future studies that aim to further investigate the association between breastfeeding and educational outcomes. Additionally, specific areas of policy interest are highlighted.

Firstly, given that breastfeeding rates in SSA are not strongly influenced by socioeconomic status, policies aimed at promoting breastfeeding should target all women, regardless of socioeconomic background. These policies should focus on maintaining and reinforcing the high breastfeeding acceptance as well as encouraging optimal breastfeeding practices such as exclusive breastfeeding. In addition, the lack of socioeconomic disparities in breastfeeding raises important questions about what drives the relatively equitable breastfeeding practices across socioeconomic groups in SSA. There may be cultural, social, or health system factors that promote breastfeeding regardless of education, income, or access to resources. Further studies, including mixed methods approaches, are needed to identify these factors and how they influence breastfeeding patterns in SSA countries. Understanding these drivers could inform breastfeeding promotion campaigns and policies in other regions of the world aiming to increase breastfeeding rates, particularly among mothers with lower socioeconomic status who, in high-income countries, tend to have lower breastfeeding rates (10–12,15).

Secondly, the findings of this thesis have important methodological implications for future child health research in SSA. Given the lack of a socioeconomic gradient in breastfeeding, traditional assumptions concerning the role of socioeconomic status in the association of breastfeeding with health, cognition, education, and nutritional outcomes may require critical revaluation. Researchers should carefully evaluate the need for and approach to controlling for socioeconomic status measures in studies examining these complex relationships. This is not to suggest that researchers disregard the potential for socioeconomic status-related confounding altogether. Failing to assess and address this concern could lead to biased estimates and misleading conclusions, as the socioeconomic status effect will vary across settings in SSA. The findings of this thesis underscore the need for a context-specific approach to incorporating socioeconomic status in studies on breastfeeding and child outcomes within SSA. The goal is to ensure that child health research in SSA accurately reflects the unique context and complexities of the region.

Thirdly, the current evidence on the association between breastfeeding and educational attainment in SSA remains limited, and the lack of consistent results from the systematic review, longitudinal analysis, and meta-analysis presented in this thesis underscores the need for further studies. Additional studies with sufficient statistical power could improve the precision of estimates for a clearer interpretation and deepen our understanding of the association.

Fourth, recall bias is a major issue in assessing breastfeeding practices and duration since most studies rely on maternal reports for breastfeeding information. Breastfeeding data should be collected prospectively to minimise this bias. In addition, future studies should consider recruiting mothers and their children in the immediate postpartum period and encouraging mothers to maintain a breastfeeding journal. Mothers should be educated and motivated to document essential details about infant feeding practices, such as the timing and dates of introducing other types of milk, foods, and liquids; the frequency and duration of breastfeeding sessions to assess mother-child bonding; and the timing and dates of breastfeeding cessation, with the assistance of close family members if necessary. This prospective approach will facilitate the determination of 'exclusive breastfeeding since birth'(49), which is a more accurate measure than the 'current status' approach, which is based on the 24-hour recall method (49,50). Additionally, studies should conduct weekly home visits from the immediate postpartum period as this has been shown to minimise recall and social desirability bias(51), thereby improving the accuracy of maternal recall. These visits would also allow for timely recording of the content of the breastfeeding journal. Additionally, where smartphone technology is available, mobile applications could be employed to enable the prompt collection of data on breastfeeding practices.

Fifth, the lack of consistency in defining and categorising breastfeeding across studies exploring this association continues to limit the comparison of findings across studies. To improve comparability and consistency in the literature, future studies should, wherever possible, adopt the World Health Organization's definitions and suggested categorisations of breastfeeding indicators. This standardised approach would lead to a more coherent understanding of the association between breastfeeding and educational outcomes.

Sixth, future studies should assess educational outcomes using standardised measures such as class tests at each grade, school leaving examinations, or national standardised tests to obtain a more detailed understanding of children's academic abilities. Furthermore, consistency in measuring and categorising educational outcomes across studies and settings could improve comparability, thereby enhancing our understanding of the association. Also, longer follow-up of children into secondary and tertiary education could provide a more comprehensive understanding of any effect of breastfeeding on educational outcomes.

Seven, regarding study designs, since randomising children to a method of feeding would be unethical, innovative designs such as quasi-experimental designs (e.g., propensity score matching, regression discontinuity, and instrumental variable techniques) and sibling comparison analysis could be used to minimise the impact of unmeasured and residual confounding in the investigations of the associations. Some previous studies have also employed data from breastfeeding promotion intervention models to reduce bias (31,52,53). Future studies could also involve follow-ups with mother-infant dyads from randomised controlled trials (RCTs) of breastfeeding promotion to collect data on educational outcomes and assess potential associations.

Eight, despite the proposed pathways, the exact mechanism underlying the association between breastfeeding and educational outcomes is unclear in both low- middle- and high-income countries. Future research should explore potential mediators such as nutritional status, neurocognitive development, bonding, childhood illness, and school readiness skills using various mediation analysis techniques.

8.5 Conclusion

This thesis has expanded the scope of breastfeeding research in SSA beyond the existing focus on its health and survival benefits and has deepened our understanding of the complex relationship between socioeconomic factors, breastfeeding, and educational outcomes. It has also revealed the challenges in obtaining longitudinal data for research in SSA, and future researchers should consider the difficulties discussed in Chapter 3 when planning studies that rely on data from secondary sources, such as HDSS sites, in SSA.

Despite the lack of evidence of association between the duration of any breastfeeding and educational attainment in Uganda and the systematic review, the evidence of association observed in the Malawi cohort and the meta-analysis, particularly with exclusive breastfeeding for six months, suggests that exclusive breastfeeding may have specific benefits for educational outcomes, but the evidence is limited.

This finding supports the World Health Organisation's recommendation for exclusive breastfeeding and shows that the benefits of exclusive breastfeeding for six months may go beyond the well-known improvements in infant health and survival. Furthermore, it implies that the better educational outcomes seen in exclusively breastfed children in high-income countries may not be entirely due to socioeconomic confounding.

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