Early childhood experiences, caregiver behaviour, and developmental outcomes in low- and middle-income countries

Inaugural dissertation

to

be awarded the degree of Dr. sc. med. presented at the Faculty of Medicine of

the University of Basel

by

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Basel, 09 May 2022

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Basel, 09 May 2022

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Dean
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If we change the beginning of the story, we change the whole story

Raffi Cavoukian

Acknowledgments

My journey to attaining a Ph.D. has been a long and arduous one but has also been very exciting, with lots of learning experiences. I would like to express my most sincere gratitude and appreciation to God Almighty for life, good health, and his grace and strength during the Ph.D. period. The process would not have been successful were it not for the incredible contribution from different individuals and institutions. I am extremely grateful to my supervisors, Prof. Dr. Günther Fink, Prof. Dr. Jürg Utzinger, and Dr. Patricia Kitsao-Wekulo whose invaluable advice, support, and tutelage during my Ph.D. study made the journey bearable and worth every effort invested. Specifically, I am deeply indebted to Prof. Fink, through him, I got generous financial support without which my Ph.D. studies would not have been possible. He always made time for me despite a busy schedule. He reviewed and responded to my work promptly. He was always patient and considerate, and finally, he reminded me I have the academic ability to complete the task. I can only say ***Asante sana*** and God bless.

I am also grateful to Christine Mensch, Laura Innocenti, Eliane Knobel, and many others involved in the administrative tasks at Swiss TPH, with special thanks to Prof. Utzinger the Director of the Swiss Tropical and Public Health Institute. My fellow Ph.D. students: thank you for always being available and willing to engage in intellectual discourse as well as for the social support whenever I needed it. In addition, I would like to thank all those at the African Population and Health Research Center (APHRC) who supported this work, particularly my co-authors on the papers that form different chapters of this dissertation. Your contributions were immense and will forever be remembered. Special gratitude to Dr. Kitsao-Wekulo and Dr. Elizabeth Kimani-Murage who were the principal investigators of the two projects from which I obtained data for two of the chapters that constitute my dissertation. Pat and Liz, your intellectual contribution, unconditional support, and timely encouragement will forever be remembered. My colleagues at APHRC; Kenneth Okelo, Nelson Langat, Ruth Muendo, Milka

Wanjohi, and Gershim Asiki thank you for your emotional support, reviews, and guidance during the entire Ph.D. period. To the administration and leadership at APHRC led by Dr. Catherine Kyobutungi, thank you for your support and an opportunity to continue working professionally during my study period.

Last but not least, I must thank my wife Judy and our daughters for their love, encouragement, and patience during the study period, most of which I was away. Without their tremendous understanding, encouragement, and sacrifice, it would be impossible for me to complete my Ph.D.

Acronyms and abbreviations

ADHD	Attention Deficit and Hyperactive Disorder
APHRC	African Population and Health Research Center
ASQ-3	Ages and Stages Questionnaires version three
BFCI	Baby Friendly Community Initiative
BFHI	Baby-Friendly Hospital Initiative
CCD	Care for Child Development
CHMT	County Health Management Team
cRCT	cluster-Randomized Control Trial
EBF	Exclusive Breastfeeding
ECCE	Early Childhood Care and Education
ECD	Early Childhood Development
HAZ	Height-for-age *z*-scores
IPA	Innovations for Poverty Action
IYCF	Infant and Young Child Feeding
KMC	Kangaroo Mother Care
LMIC	Low- and Middle-Income Country
LN	Letter Naming
MICE	Multiple Imputations by Chained Equations
MICS	Multiple Indicator Cluster Survey
NACSOSTI	National Commission for Science Technology and Innovation
PPT	Pencil Tapping Test
PRIDI	Regional Project on Child Development Indicators
PSI	Parental Stress Index
PVT	Picture Vocabulary Test
RAN	Rapid Automatized Naming
RCT	Randomized Controlled Trial
SSA	Sub-Saharan Africa
TPR	Tactile Pattern Reasoning

WHO	World Health Organization
ZaMCAT	Zambia Child Assessment Test
ZECDP	Zambia Early Childhood Development Project

Glossary

Ages and stages questionnaire: A parent-reported developmental screening tool that pinpoints developmental progress in children between the ages of 1 month to 5 ½ years

Baby-friendly community initiative: A community-based initiative to protect, promote, and support breastfeeding, optimal complementary feeding, and maternal nutrition

Baby-friendly hospital initiative: A facility-based initiative to improve the role of maternity services to enable mothers to breastfeed babies for the best start in life

Caregivers: Anyone taking care of or is responsible for young children, in any setting, and may include the mothers, fathers, and other significant members of the family

Developmental delays: Happen when a child's progression through predictable developmental phases slows, stops, or reverses

Developmental potential: Achieved when children acquire developmental competencies for later academic, behavioural, socio-emotional integration, and economic capabilities

Early childhood development: A period of rapid and critical development usually between conception up to the child's third birthday

Exclusive breastfeeding: Refers to feeding infants on breast milk only, be it directly from the breast or expressed, except for vitamins, mineral supplements, or medicine

Kangaroo mother care: A method of care for preterm infants that involves infants being carried, usually by the mother (may include other members of the family), with skin-to-skin contact to promote breastfeeding and maintain warmth

Nurturing care: Multilayered dynamic concept to promote human capital development from preconception to early childhood through stable environments that promote health and nutrition, provide protection from threats, and ensure opportunities for learning and relationships that are emotionally supportive and responsive

Responsive caregiving: The ability of the caregiver to notice, understand and respond to the child's signals in a timely and appropriate manner

Early childhood stimulation: The interaction between young children and their caregivers, providing children with the opportunity to learn about their environment from the earliest age

Summary

Background: Child survival has improved substantially over the past 30 years, with the mortality rate for children under the age of 5 years dropping by 59% due to improved socioeconomic conditions, health systems, and access to health services. Despite the improvements in mortality, more than one-third of children in low- and middle-income countries (LMICs) under the age of 5 years may currently not achieve their full developmental potential. Failure to achieve these important foundational skills will likely have negative consequences for countries' long-term developmental and economic potential. For this reason, early childhood development (ECD) is increasingly recognized as a key public health policy concern in many LMICs.

Goal and objectives: This Ph.D. dissertation aims to show how maternal behavioural can improve the development of young children and how early acquisition of these developmental skills contribute to the long term outcomes of the children. In addition, the dissertation expands the available evidence base on the impacts of early life behaviours and experiences on the developmental trajectories of young children. Specifically, this Ph.D. focuses on how early childhood experiences and caregiver (including fathers) behaviour shape the developmental outcomes for children across different ages in LMICs. The evidence generated in this dissertation is intended to provide a basis to support future policy formulation and implementation of ECD programmes, as well as interventions to successfully support the growth and development of children in low-resource settings.

Procedures: We analyzed data from four related studies conducted in Kenya, Zambia, and Brazil. The first paper used data analyzed as part of the São Paulo Western region cohort and assessed the association between kangaroo mother care (KMC) and child development for children born preterm. The second paper used data analyzed as part of a cluster-randomized control trial (cRCT) conducted in western Kenya to assess the association between exclusive

breastfeeding (EBF) and child development. The third paper employed data analyzed as part of the longitudinal assessment of a community-led parenting empowerment intervention in Kenya and Zambia, focusing on the association between maternal stimulation activities and child development. The final paper looked at slightly older children to assess which domains of early childhood development is particularly relevant for later schooling outcomes, readily analyzing data drawn from a larger Zambia Early Childhood Development Project (ZECDP).

Principal findings: The first three studies strongly and consistently highlight the critical role caregiver behaviour plays for the healthy development of children; KMC for children born preterm, EBF for at least 6 months, and maternal stimulation were all highly predictive of positive child outcomes. The level of caregiver involvement often determined developmental gains or gaps. In the last paper, we showed how important these early life developmental milestones are for later schooling outcomes. Together, the studies highlight not only the critical role of early childhood development but also the extent to which child outcomes can be improved by rather basic behaviours and activities that are feasible and easily implementable in low-resource settings.

Conclusions/significance: The results presented suggest that positive early childhood experiences and caregivers' practices have a positive impact on children's development. Taken together, this dissertation highlights the strong association between maternal activities/behaviours and the developmental outcomes of children as well as how early experiences determine developmental trajectories. Across chapters three, four, and five, the results provide evidence that the practice of KMC, EBF, and maternal stimulation improves the development of cognitive skills. In chapter six, the results indicate that cognitive skills are vital in positive schooling outcomes, especially as it relates to being in the expected grade in the adolescent period. The results of this dissertation contribute to the body of literature on how

early childhood experiences and caregivers' behavioural practices shape the developmental outcomes of children living in low-resource settings.

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CHAPTER 1: INTRODUCTION

Child survival has improved substantially from 1990 to 2019 with under-five mortality dropping by 59%, due to improved socioeconomic conditions, health systems, and access to health services (1). Despite a reduction in mortality rates, it is still estimated that more than a third of children in low- and middle-income countries (LMICs) under the age of 5 years may currently not achieve their full developmental potential. Over 60% of these children are concentrated in sub-Saharan Africa (SSA). Children in a majority of these countries continue to be exposed to multiple risks, including malnutrition, poor health, poverty, and unstimulating home environment with few opportunities for early learning and responsive care (2, 3). These combined risks have adverse effects on children's early cognitive, communication, motor, and socio-emotional development. Early acquisition of the aforementioned skills is predictive of children's survival, health, nutrition, education, and later labour outcomes.

Failure to achieve these important aspects of development early in life implies undermining countries' long-term developmental and economic potential. As such, early childhood development (ECD) has increasingly become a key policy concern in many LMICs. Countries in low-and middle-income record the highest number of children at risk of not achieving their full development potential, therefore the most effective interventions programs that support the acquisition of key developmental skills are vital. Major focus should be given to children residing in countries in sub- Saharan Africa (SSA). This Ph.D. dissertation aims at expanding the available evidence base on the impacts of early life behaviours and experiences on the development of children and their developmental trajectories. Specifically, this Ph.D. focuses on how early childhood experiences and caregiver (including fathers) behaviour shape the developmental outcomes of children across different ages in LMICs. We anticipate that the evidence provided in this dissertation can support future policy formulation and implementation

of ECD programmes and that the resulting interventions will successfully support the growth and development of children in low-resource settings.

To assess how early childhood experiences and caregivers' behaviours influence the developmental outcomes of children, we analyzed data from four related studies conducted in Kenya, Zambia, and Brazil. The first paper assessed the association between kangaroo mother care (KMC) and child development was analyzed as part of the São Paulo Western region cohort (4). The cohort comprises all children born at São Paulo's University Hospital (HU USP) between 1 April 2012 and 31 March 2014. Our sample consisted of only children born prematurely (born before 37 weeks of gestation). The main exposure variable was reported KMC efforts by the caregivers, while outcomes variables were cognitive and physical development. Cognitive outcomes were measured using the Regional Project on Child Development Indicators (PRIDI) scale. Information on gestational length was extracted from medical records from the University.

The second paper assessed the association between exclusive breastfeeding, and child development was analyzed as part of a cluster-randomized control trial (cRCT) conducted in the western part of Kenya from May 2017 to December 2021. Women were recruited when they visited health facilities during the third trimester of their pregnancy. Children were first assessed at the age of two months with subsequent follow-ups. The general objective of the trial was to establish the feasibility and effectiveness of the health facility-based ECD interventions. The analysis for the study used in this dissertation was limited to reported EBF activities by the caregivers. The main outcome was child development at 6 months and which was assessed using the Ages and Stages Questionnaire-Third Edition (ASQ-3).

The third paper focused on the association between maternal stimulation and child development and was analyzed as part of the longitudinal data from a community-led parenting empowerment intervention that was implemented in Kenya and Zambia. Children's

developmental outcomes in terms of their gross and fine motor skills, language, socio-emotional, and physical development were measured using the ASQ-3. Maternal activities were assessed using a standard questionnaire that focused on four main domain-specific maternal activities that included cognitive, communication motor, and socio-emotional activities.

The final paper looked at slightly older children in an attempt to assess which domains of early childhood development are particularly relevant for later schooling outcomes. Data analyzed were drawn from a larger Zambian Early Childhood Development Project (ZECDP). The study was launched in 2010 to determine the effect of the early childhood environment, health, and education on children's development before and throughout their schooling period. We collected data on schooling progression during follow-up with 333 adolescents when they were, on average, 15 years old. This marked the stage that they should have entered secondary school, assuming normal progression. The predictor variables were executive functioning, cognition (non-verbal reasoning), early literacy, receptive language, expressive language, fine motor skills, and social-emotional skills while the outcome variable was being in an age-appropriate grade (being on track), current school enrolment (child still in school), and grade repetition (if any).

The first three studies strongly and consistently highlight the critical role that caregiver behaviour plays for the healthy development of children. We found that KMC for children born preterm, EBF for at least 6 months, and maternal stimulation are all highly predictive of child outcomes. There were remarkable developmental gaps between caregivers engaging, and caregivers not engaging in such activities. In the last paper, we showed how important these early life developmental milestones are for later schooling outcomes. Taken together, these studies highlight not only the importance of ECD but also the extent to which child outcomes can be improved by basic behaviours and activities that were feasible even in low-resource settings.

CHAPTER 2: LITERATURE REVIEW

2.1 The concept of early childhood development

Early childhood development (ECD) is generally defined as the period from conception to usually 3 years (5). ECD is a "maturational and interactive process, resulting in an ordered progression of perceptual, motor, cognitive, language, socio-emotional, and self-regulation skills" (6). Current literature has focused on the first few years of life, which are considered the most sensitive period for brain development, with about 90% of a child's physical brain developed by the age of 5 years (7). ECD comprises the cognitive, sensory-motor, and socio-emotional domains. These domains are interdependent and influenced by the nutrition, health, and psychological status of the child (2, 8-10). Maturational and interactive processes occur as a result of the interaction between the child, its environment, and the family context (3, 11). ECD also lays the foundation for physical, emotional, and intellectual well-being for the rest of a child's life (10, 12). The early years are the most effective – and cost-effective –period in human life to ensure that individuals thrive and achieve their optimal development (13).

2.2 Early childhood experiences and risks associated with poor development

In the course of their development, children are exposed to different experiences that either affect their health nutrition, and developmental outcomes positively or negatively. Adverse experiences such as abuse, neglect, and poor nutrition have been linked to reduced adult education, employment, and income (14, 15). On the other hand, childhood experiences such as good parenting, home stimulation, and responsive caregiving are key predictors of positive adolescence and adult functioning (16). Early experiences could be biological or may emanate from the environment where children live. The biological factor may include stunting due to malnutrition and environmental factors may emanate from poverty that may lead to

exposure to toxins and violence. Early childhood stunting and exposure to absolute poverty are key risks for poor development.

Globally, about 149 million children are stunted with the majority from LMICs (17). Stunting has been linked to increased morbidity and mortality in children under the age of 5 years due to infections such as pneumonia and diarrhoea. Growth failure resulting from poor nutrition is also associated with reduced stature in adulthood (18). Poverty has been shown to have a negative impact on the health, development, and educational attainment of children. Many children living in poverty are susceptible to a range of health problems, poor nutritional outcomes, chronic diseases, and overall poor development (19). Poor or delayed development in children is associated with poor performance in school, school dropout, and poor labour market outcomes, which lead to economic dependency, crime, violence, drug misuse, and adult-onset of communicable diseases. Early achievement of domains in children is linked to later academic achievement, career outcomes, and socially well-adjusted individuals in society (20). The evidence asserts that poor development during the early years of a child may negatively affect how children perform in school and later adulthood life.

Developmental delays in childhood may result from biological, psychological, or environmental risk factors or an interplay of the three. Children fail to thrive or are faced with developmental delays due to factors such as maternal drug addiction, diseases, poor maternal nutrition, or because of existing environmental challenges such as an unstimulating home environment, exposure to toxic stress, exposure to violence, and maternal challenges such as maternal depression (3). Child-related factors such as malnutrition or childhood diseases also have detrimental effects (21). Further, poor health and a high prevalence of HIV in the community also contribute to poor development in children. All these risks result from exposure to chronic poverty. Children and families growing up in poverty and low-income households experience many difficulties such as health inequalities, poor performance in school, and poor

nutritional outcomes. They have an increased likelihood of exposure to environmental toxins, household stresses, and violence, which in turn affect their optimal development (2). Early childhood development can be affected by a combination of socioeconomic, environmental, nutritional, and social factors during the first few years of life (2, 22).

Biological factors have a wide influence on the development of children. The primary biological risks at birth are preterm birth and complication emanating from childbirth. Prematurity is one of the leading causes of under-5 mortality with about one million deaths every year (23). Children who are born preterm also have higher rates of neurodevelopmental disabilities (24). Maternal prenatal experiences such as poor maternal nutrition, infection, and substance abuse during pregnancy also can have detrimental effects on the development of children (2, 25). Poor maternal nutrition during pregnancy has been associated with a decrement in children's cognitive development (25, 26) while lack of folic acid during the same period has been linked to deficits in fine motor and cognitive skills (27). Maternal infection and drug abuse during pregnancy can also undermine healthy development (28, 29). Prenatal maternal infections have been linked to children's socioemotional difficulties (30), autism, attention deficit, and hyperactive disorders (ADHD), and schizophrenia in adulthood (31). Substance abuse during pregnancy can harm foetal brain development and result in learning disabilities, mental health disorders as well as neural adaptations (28).

Early infant nutrition is another important biological factor that influences children's development (2). Studies from LMICs revealed that infants who are poorly fed usually exhibit sub-optimal development in their later years (32). Chronic undernutrition, iodine deficiency, and iron deficiency anaemia are among the main nutritional risk factors for development (33). Stunting, which is defined as low height-for-age, is the result of chronic or recurrent undernutrition and is usually associated with poor maternal health and nutrition (34). Stunting

in the early childhood period is strongly associated with cognitive functioning and schooling outcomes (8, 35), but may not be related to psychosocial and motor outcomes.

The contexts or environments where children live influence their physical, cognitive, and socio-emotional development. Contextual factors may be related to the individual child, parent, family, or community (2). Parental factors which are mainly related to physical and mental well-being are key determinates of children's health and developmental outcomes. What happens to the caregiver before, during, and after pregnancy has significant implications on the development of children. For example, maternal depression during and after pregnancy may compromise healthy development in children (36) since they are unable to provide stimulation or be responsive (37).

Family factors such as socioeconomic status have implications on the development of a child. High-quality childcare experiences have a stronger positive effect on later development (38), while children who grow up in highly chaotic home environments or homes with economic constraints are predisposed to fewer early learning opportunities. These children often experience instances of child abuse, neglect, and other forms of maltreatment. Caregivers in such homes may be unresponsive and expose children to violence and other forms of maltreatment thereby compromising children's health, nutrition, and developmental outcomes. Family factors may also include social support and protection measures to avert the effect of poverty (13). Social support may include unconditional cash transfers, building caregiver's capacity through training and skills development as well as other health and nutritional programmes such as food donations and medical camp check-ups.

Environmental toxins, heavy metals, and household air pollutions have great impacts on the development of children (2). These forms of pollution are transmitted through the air that children and their caregivers breathe, the water they use, and the food items consumed. Caregivers and children living in poor urban settings face greater risks. Environmental

exposures such as toxic chemicals are associated with poor preconception and prenatal development. Such exposures may lead to foetal death, malformation, altered growth, or functional abnormalities (39). For example, a developing foetus is prone to chemical exposures due to the sensitivity of the period of development potentially impacting later development (40). Furthermore, when toxic substances such as methylmercury cross the placenta, the child may experience motor deficit or mental retardation.

2.3 Essential intervention programmes

Several early intervention programmes that support children's growth and development have been shown to have significant benefits for both the child and the mother (41) and can avert the effects of developmental delays. Some of these interventions include care for child development, parenting interventions, and nutritional interventions (13). These interventions have the potential to improve child development and reduce loss of potential among children in low-and middle-income countries (3, 42). Caregivers play a major role in the implementation of these interventions. These interventions when delivered through health, nutrition, education, and social protection services, are evidenced to yield better outcomes for children including those with developmental disabilities (13). These activities when integrated into home visits and nutritional programs by health workers have yielded better results, particularly in low-resource settings (43).

Preventive and promotive interventions yield better outcomes and are less costly compared to later corrective interventions (44). The interventions increase the possibilities of positive outcomes for children by enhancing their development and minimizing developmental delays (11, 12). These interventions establish a strong basis for children's academic success, health, and general wellbeing. Children who receive early developmental intervention such as care for child development acquire skills that are necessary for the improvement of social, adaptive, and a requisite knowledge base for early learning early (45). Early intervention programmes

improve cognition and academic achievements, behaviour and emotional competencies, educational progress and attainment, social welfare, and labour market success (46). They also lay a foundation that improves a child's life and provides greater opportunities for later development. These interventions can be implemented within the family's home, community, health facilities, and child development centers (11). Among children experiencing poor development, the early childhood intervention programmes can prevent the consequences of early academic failure and school behavioural problems: dropping out of school, delinquency, unemployment, and psychological and physical morbidity in adulthood (20).

2.4 Caregivers' behaviours and child development

Caregivers play a central role in the development of children. This assertion is strongly reflected in the nurturing care framework for early childhood development launched by the World Health Organization (WHO) in 2018 (47). Nurturing care aims at giving children opportunities for early learning through interactions that are responsive and emotionally supportive. Nurturing care is premised on the notion that all children irrespective of their economic status and living situation, when provided with a stimulating and responsive environment, can acquire the necessary skills needed for their development. Good health, adequate nutrition, safety and security, responsive caregiving, and opportunities for early learning form the five interrelated and inseparable components of nurturing care (48). Nurturing care can also mean encouraging children to freely and truly explore their environment and interact with their caregivers and other intimate family members thus promoting their development and protecting them from the effect of adversities.

Among the components of nurturing care, the one on good health, which comprises both physical and mental health, suggests the need for ensuring the health and wellbeing of children and their caregivers. For good health to be achieved in children, their caregivers must monitor their physical and emotional development, be sensitive to their needs by responding with love

and ensure that they get the right treatments at the appropriate time using appropriate health services. In addition, children should be protected against danger both at home and outside. They should live in a clean environment free from infection. Healthcare services such as antenatal care during pregnancy and postnatal care such as immunization have positive benefits for children and can lower the risks of developmental delays (49). Childhood vaccines have positive benefits not only for disease prevention but also for cognitive achievements, schooling, and economic productivity outcomes (50). Caregivers' mental health during and after pregnancy may relate to later children's outcomes. Further, children of depressed mothers are at higher risk of developing insecure attachment and are more likely to suffer impaired adaptive functioning which consequently leads to conduct disorders (51).

Adequate nutrition is the second component of nurturing care. Nutrition encompasses maternal and child nutrition and includes early interventions such as early initiation to breastfeeding and EBF for at least 6 months, micronutrients supplements for mother and child, and management of malnutrition. Micronutrients are important for the adequate growth and development of children. Lack of key micronutrients such as zinc, iron, and vitamin A have demonstrated growth faltering in children. Additional micronutrient supplements can have positive growth for children who may experience negative growth outcomes (52). Early initiation and EBF on the other hand have positive benefits on later development outcomes for children. Breast milk contains all the nutrients the child needs during the first 6 months of life (53). Apart from the short-term benefits such as prevention of diarrhoea and pneumonia, breast milk also has long-term benefits such as reducing the risks of obesity and being overweight in late childhood (54).

Opportunities for early learning is the third component of the nurturing care intervention. In their early years, children acquire basic but very useful learning and social skills that set a strong foundation for their later abilities to function in their everyday environment. After birth,

infants respond to facial expressions, gentle touch, and soothing sounds. The capacity of newborns to express simple emotions through facial expressions and movements guides caregivers to understand and respond in ways that help infants to calm, feed, sleep stay alert and interact with others. Caregivers play a central role in enhancing learning opportunities for their children (55). As such, it is imperative to empower the caregivers to learn how babies respond to them since this is important for the babies' rapidly growing brain. Studies have shown that caregiver-child interactions are highly beneficial not only during the early years of a child but also have lasting effects into adulthood (56). Activities such as touching, talking, smiling, reading books, and engaging in age-appropriate play build strong neural connections that help in the growth of the child's brain and prepare the child for future learning. Caregivers provide a foundation for early learning when they make eye contact and follow the child's lead in vocalizing the child's bubbles right from birth. When caregivers are sensitive, responsive, predictable, and loving, they facilitate the child's early social and emotional development, promote secure emotional attachment between child and caregiver and help the child to learn. Whatever happens during the first years of life matters a lot because it sets either a sturdy or a fragile stage for the stages that follow.

Responsive caregiving which is related to opportunities for early learning is the fourth component of the nurturing care framework. Responsive caregiving is the ability of the caregiver to notice, understand and respond to the child's signals in a timely and appropriate manner. Responsive caregiving is the most essential of all the components of the nurturing care framework as it ensures children's health, nutrition, safety, and security and also creates opportunities for early learning. Responsive caregiving is linked to the positive development of children. For example, effective responsive caregiving has been found to associate positively with later socioemotional development (57). In addition, responsive caregiving has also been found to associate positively with increased adolescent human capital in key domains such as cognitive and social adjustment more so for children with cumulative adversities (58).

Childhood programmes such as KMC and EBF are also netted within the nurturing care framework. KMC programme, which traces its origin back in Colombia in 1978, is a widely practiced intervention that supports the survival and development of children born preterm or children of low birth weight. KMC is continued skin-to-skin contact between the mother (and other caregivers including the father) and infant during the postnatal period in the hospital and is usually extended to the home of the caregiver. The intervention has increasingly been recognized because for its benefits to both the caregiver and the child. KMC reduces neonatal mortality amongst preterm babies (gestational duration <37 weeks) in the hospital, and is highly effective in reducing severe morbidity and/or preventing infection as well improve neurodevelopment (59, 60). In addition, KMC improves maternal-infant attachment as well as increases the duration of exclusive breastfeeding (59). In the long run, KMC has positive effects on cognitive functioning (61), social and behavioural protective effects (62), and physical growth and development (63) for individuals born prematurely.

To achieve optimal growth, health, and development, WHO has recommended EBF for infants for the first six months of life. Exclusive breastfeeding is the practice of giving t infants only breast milk with no liquids or solid food for six months (64). However, children can still be given oral rehydration, minerals, and medicine. EBF has many benefits for infants both in the short and long run; it is also effective in preventing infection thereby reducing morbidity and mortality in infants. Infants especially those in LMICs are prone to childhood illnesses such as diarrhea or pneumonia which are easily managed when children are exclusively breastfed. In addition, EBF is the most cost-effective way to address developmental delay in children. Existing literature has shown that children who are exclusively breastfed have better language outcomes (65), and improve the acquisition of cognitive skills and enhancement of social development (66).

In summary, evidence underlines the critical importance of responsive and nurturing care for the development of children. This work provides further evidence on three specific behaviours in LMIC settings and also documents the long-term returns to improvements in ECD.

Chapter 3: Kangaroo mother care for preterm infants and child development – evidence from São Paulo, Brazil

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This paper has been published in **Early Child Development and Care**
19 Feb 2021, https://doi.org/10.1080/03004430.2021.1885393

Abstract

Globally, an estimated 15 million children are born prematurely each year. This results in a high burden of under-five mortality and neurodevelopmental disability. Kangaroo Mother Care (KMC) is a key intervention to support the development of preterm infants, with well-documented benefits in clinical trials. However, evidence on the impact of KMC in routine care settings remains limited. This paper examines the associations between maternal Kangaroo Mother Care efforts and child development among preterm infants born at the University Hospital of São Paulo, Brazil. The study was designed as an observational prospective cohort study with a focus on preterm infants who were exposed to KMC. The primary study outcomes were physical development (HAZ) and cognitive development at age 3. Birth outcomes, as well as gestational length estimates, were extracted from the hospital records. Practicing Kangaroo Mother Care was positively associated with physical development (+0.91 SD, 95% confidence intervals [0.126, 1.695]), and cognition (+0.37 SD, [0.034, 0.806]) of preterm children. The

results presented suggest that KMC has the potential to improve children's cognitive and physical development. New programs to increase KMC uptake in the setting studied may be beneficial for both mothers and their preterm children.

Keywords: Preterm children, Kangaroo mother care, cognitive, stunting, physical development.[1]

Introduction

Globally, an estimated 15 million children are born prematurely each year (1, 2). Preterm birth complications are a leading cause of under-five mortality, causing more than one million deaths per year (3). In addition to the much higher mortality risk, children born preterm face higher rates of neurodevelopmental disability as well as delays in their physical and cognitive abilities more generally (4-9)

A growing body of literature has highlighted that early intervention programs for preterm infants can positively influence developmental outcomes with cognitive benefits that persist (10). Kangaroo Mother Care (KMC) is increasingly recognized as one of the most effective interventions in this area (11). The key element of KMC is extensive skin-to-skin contact between mothers or other caregivers including fathers and their infants during the postnatal period at the hospital. Ideally, these activities are then continued at home until the child gains a normal weight. Skin-to-skin contact has been shown to increase attachment, enhance mothers' ability to breastfeed, and stimulate the child (12, 13). Several recent studies have underscored the effectiveness and cost-effectiveness of KMC in particular for reducing infant mortality among preterm and low birth weight children, but also for reducing the likelihood of severe illness and infections, and for reducing the average length of stay at the hospital (14-18).

Abbreviation: KMC: Kangaroo Mother Care; HAZ; height-for-age *z*-scores; PRIDI: The Regional Project on Child Development Indicators; SD: standard deviation.

Furthermore, KMC has been shown to improve infant and child health and growth of children (19) and to decrease the risk of postpartum depression and maternal stress (20, 21).

In many settings, KMC has been integrated into routine health care to monitor the growth and development of preterm infants. KMC has been used within primary health care systems to enhance breastfeeding, for the management of suspected infection, and for improving child survival for preterm children (19, 22). KMC has also been useful in enhancing early discharge from the hospital with adequate follow-up to the child (23-25). Despite the presumably large benefits of KMC, limited evidence exists on the use and impact of KMC in routine care settings. This paper aims to address this gap by using newly collected data on infant health and child development within a cohort of children born at the University Hospital of São Paulo between 2012 and 2014. As part of the cohort study, mothers of preterm infants were asked to report on their KMC activities after birth. Children's cognitive and physical development was then assessed through a home-based assessment by trained staff at age 3. In Brazil, the Kangaroo program is a public policy that encompasses other care practices and includes other family members. Our study is limited to the practices as reported by the mother, thus Kangaroo Mother Care.

Methods

Study Procedures

The study was designed as an observational prospective cohort study conducted in São Paulo Municipality, Brazil. The São Paulo Western region cohort includes all children born to local residents at the University Hospital of São Paulo between April 1, 2012, and March 31, 2014 (26). The study is limited only to the children born in this hospital. Children were revisited and re-assessed as part of a 3-year follow-up conducted between June 2015 and March 2018. Prior to the visits, qualified field interviewers were trained on ethics, expected behavior during the household visits, and assessment methods. Caregivers were either contacted by phone or

through a personal visit to schedule the actual interview. All interviewers were conducted at children's homes. The entire visit including interviews and child assessments lasted for about 90 minutes. Our study was restricted to children born prematurely during this period (born before 37 weeks of gestation). Data on birth outcomes including gestational length were directly extracted from the University Hospital's electronic records. The gestational age of all children was assessed by the delivering health worker using the Capurro method (27). The Capurro allows for an accurate assessment of gestational age when data on the last menstrual period or early ultrasound results are not available (28).

Data on KMC and development at age 3 were collected through interviews during home visits by trained data collectors. Mothers of preterm children were asked to report on their KMC activities, including the frequencies and duration of each mother-child interaction in the preterm period. Records with missing information on KMC engagement were excluded from the study.

Exposure and Outcome Variables

The main exposure variable of interest in our subsample was the practice of KMC as reported by the caregivers. As part of their interview, caregivers reported whether they engaged in KMC, as well as the number of times per week it was practiced. The primary outcomes for this study were children's cognitive and physical development at 3 years of age. Cognitive development was measured through direct observation using the PRIDI scale. The PRIDI scale has been used widely in Latin America alongside other assessment tools to assess children's developmental outcomes (29, 30). The PRIDI was developed to generate high-quality regionally comparable data on child development. PRIDI measures children's development between 24 -59 months and covers cognition, language and communication, socio-emotional, and motor domains (31). The PRIDI tool captures not only domains of child development but also factors associated with ECD such as contextual variables around the child, the parent, and the community. The PRIDI

tool is easy to use and can be administered by trained lay workers. PRIDI scores were corrected for the biological age of children.

Anthropometric information (height and weight) were collected for each of the child by the trained assessors at children's homes. Height-for-age *z*-scores (HAZ) were computed using the World Health Organization (WHO) Anthro software (32). Stunting was defined as HAZ<-2.

Statistical Analysis

Data analysis was completed in three steps. First, we used descriptive statistics to characterize the study population. Socio-demographic and clinical data included a child's age and weight at birth, caregiver's age at delivery, caregiver's education level, caregiver's marital status as well as family receipt of social transfers (bolsa familia). Second, we estimated unconditional associations between KMC practicing and cognitive and physical development. Third, we estimated multivariable linear regression adjusting the estimated associations for caregiver's age (indicators for ages <=20 and ages >=35), childbirth weight (categorized into <1500g, 1500-1999g, 2000–2499g, and >=2500g), child's sex, caregiver's schooling, caregiver's higher schooling, receipt of social support, caregiver's marital status, and wealth index. Finally, we stratified the HAZ with the child's weight at birth (<2500g and > 2500g) and caregiver's education level (basic education or less and secondary education or higher). Data analysis was performed using STATA 15.0 for Windows (STATA Corporation, College Station, TX) (33).

Results

Out of the 3620 children assessed at age three, 254 (7%) were born prematurely. From this subsample of premature children, the KMC questionnaire was administered to 139 mothers. Out of this sample, 26 mothers reported having engaged in KMC, while 113 mothers reported not have engaged in KMC activities. **Table 1** summarizes caregivers'-children's socio-demographic characteristics by KMC status. 23% of mothers were under age 20 at the time of

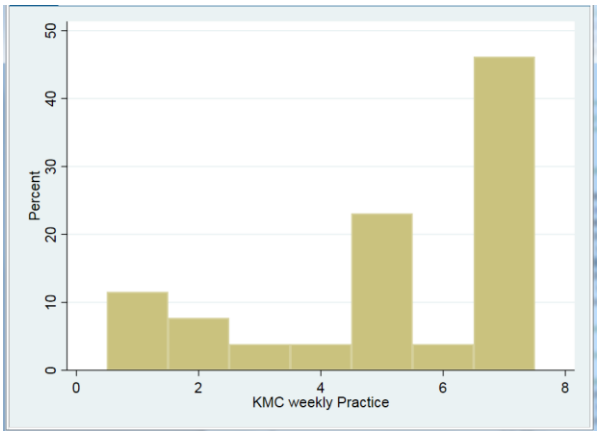
birth, and 10% of mothers were 35 or older. 7.9% of children born before week 37 of gestation had a birth-weight of below 1500 grams, while 54.7% of children had a birth-weight in the normal range (>=2500 grams). 51.8% of children were female, and 25.9% of families received social transfers (bolsa familia). On average, mothers practicing KMC were slightly younger and had infants with substantially lower weight at birth. Differences in social transfer receipts were small.

Table 1. Maternal and Child Socio-demographic Characteristics

	NO KMC (N=113)		**KMC (N=26)**		**TOTAL**	
	N	%	N	%	N	%
Age of mother at birth						
Below 20	24	21.2	8	30.8	32	23
Between 20 - 34	77	68.1	16	61.5	93	66.9
Above 34	12	10.6	2	7.7	14	10.1
Child's weight at birth (grams)						
Under 1500g	2	1.8	9	34.6	11	7.9
Between 1500 - 1999	8	7.1	7	26.9	15	10.8
Between 2000 - 2499	31	27.4	6	23.1	37	26.6
2500 and Above	72	63.7	4	15.4	76	54.7
Child sex						
male	57	50.4	10	38.5	67	48.2
female	56	49.6	16	61.5	72	51.8
Social Support (Bolsa Familia)						
No	82	72.6	18	69.2	100	71.9
Yes	29	25.7	7	26.9	36	25.9

Abbreviations: KMC, Kangaroo Mother Care; g, weight in grams.

Fig. 1**a** and 1. b summarizes the frequency of KMC practice. 46% of mothers engaging in KMC reported engaging in this practice every day. 30% of mothers reported engaging in KMC less than 3 days per week. The median duration of each session was two hours. Only 3 mothers reported practicing 8 or more hours of KMC each day.



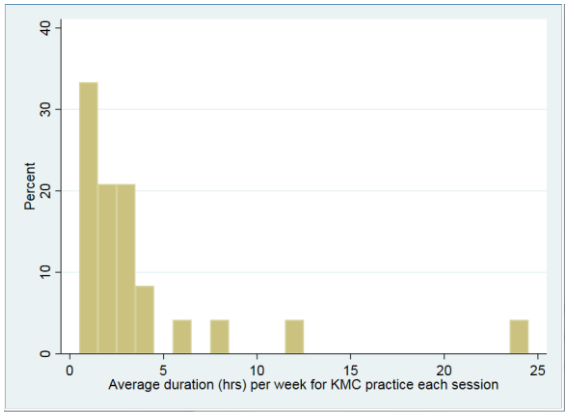


Fig.2 shows estimated kernel densities for height for age z-scores at age 3 by the KMC group. Despite the large negative weight differential at birth, mean HAZ was substantially higher in the KMC group at age 3 (-0.17 vs. -0.96 in the no KMC group), with a pronounced shift of the entire height distribution to the right.

Fig. 2 Density plots HAZ by KMC Group

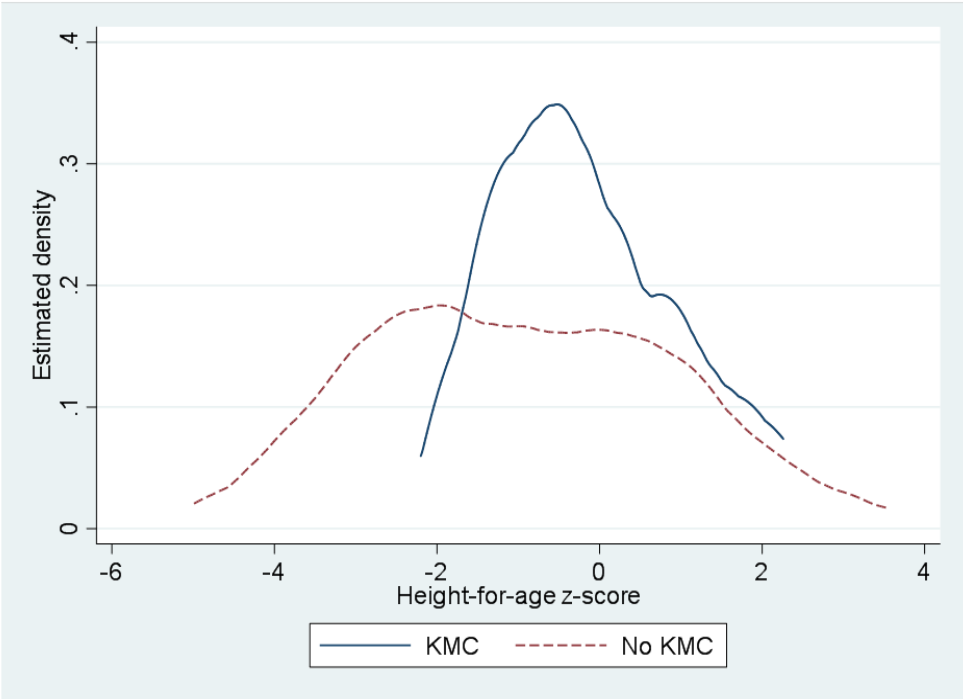


Figure 2 shows the estimated kernel densities for PRIDI z-scores. Once again, mean scores were substantially higher for the KMC group (0.50 vs. -0.09 in the no KMC group), with particularly large differences in the left tail of the distribution (z-scores < -2).

Fig. 3. Distribution of PRIDI score by KMC Group

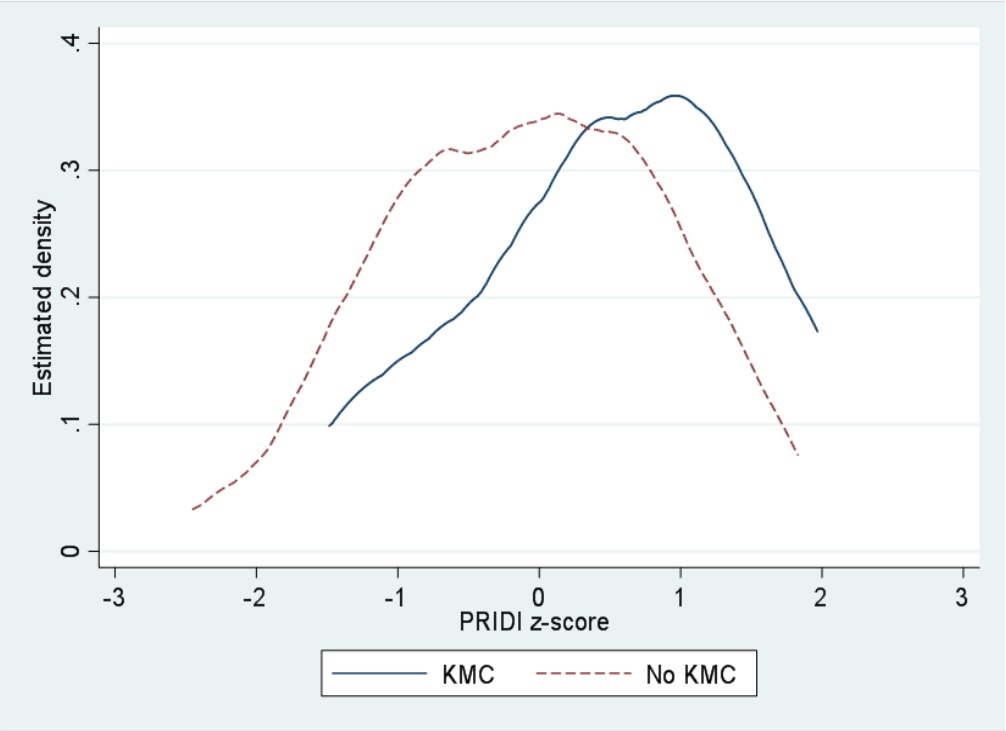


Table 2 shows crude and adjusted association between HAZ, stunting, PRIDI and KMC exposure. In unadjusted models, practicing KMC was associated with a 0.79 SD increase in HAZ (95% CI [0.22 - 1.36]), a 29 percentage point reduction in stunting (-0.41, -0.17) and a 0.59 SD increase in PRIDI scores (0.11 - 1.07). After adjusting for covariates, estimated associations were 0.91 SD for HAZ (0.13, 1.70), -25 percentage points for stunting (-0.44, -0.05), and 0.39 SD for PRIDI (-0.03, 0.81, p-value = 0.07).

Table 2. Crude and adjusted associations between practicing KMC and child outcomes

Outcome Variables[a]	HAZ (n=131)	Stunting (n=131)	PRIDI (n=115)
Crude Estimates			
KMC	0.787***	-0.290***	0.586**
	(0.220, 1.355)	(-0.410, -0.170)	(0.105, 1.067)
Adjusted Estimates	(n=128)	(n=128)	(n=113)
KMC	0.910**	-0.245**	0.386*
	(0.126, 1.695)	(-0.444, -0.0469)	(-0.0337, 0.806)

Abbreviations: KMC, Kangaroo Mother care, HAZ, height-for-age z-scores, PRIDI (acronym in Spanish), Regional Project on Child Development Indicators.

Each column represents the results of the linear regression model, with 95% confidence intervals. The models are adjusted for the full list of all covariates in table 1. These included maternal age, child's weight at birth, age at assessment, gender, caregivers' education, marital status, bolsa familia receipt, and household assets.

*** p<0.01, ** p<0.05, * p<0.1

Table 3 shows the results of the stratified analysis. When we stratified the sample by caregiver education, positive associations between KMC and HAZ were primarily found for mothers with limited education. When we stratified the sample by birth weight, protective effects of similar magnitudes were found for children with birth weight above and below 2500 grams, but neither effect was statistically significant due to the relatively large standard errors.

Table 3. Stratified Association between Practicing KMC and HAZ

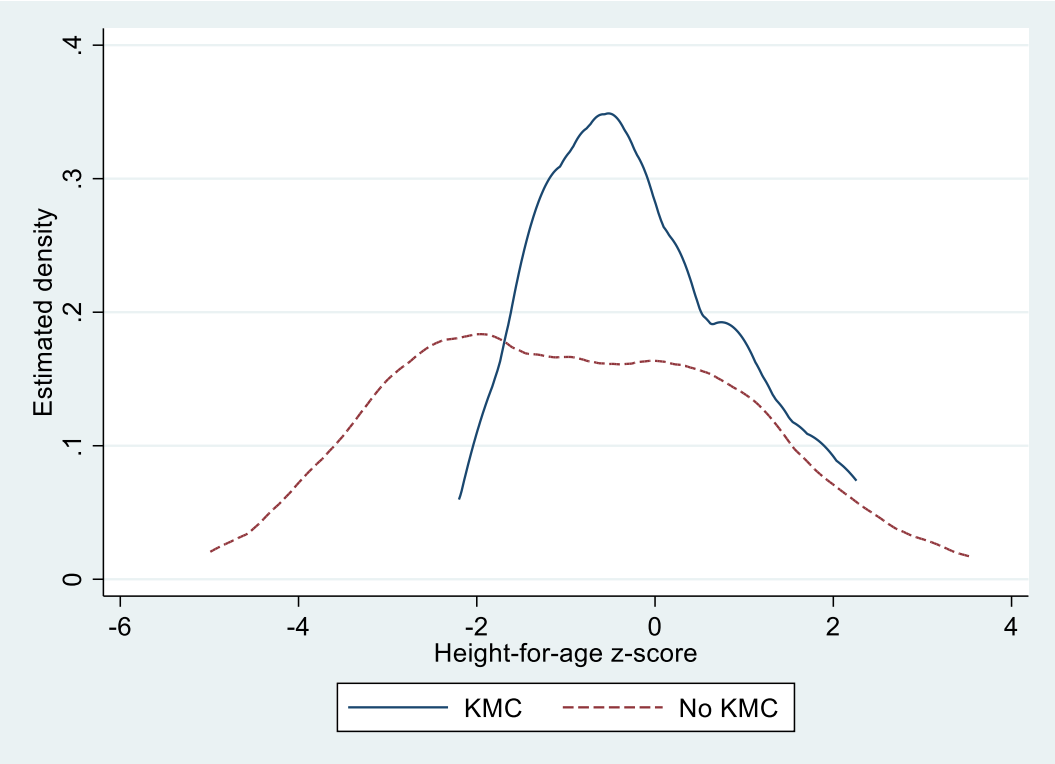
Outcome variable: Height-for-age z-scores				
	Sample			
(N==139)	Basic education or less	Secondary education or higher	Birth weight - <2500g	Birth weight - >= 2500g)
KMC	1.022**	0.169	0.586	0.798
	(0.003, 2.04)	(-1.37, 1.71)	(-1.15, 2.32)	(-0.16, 1.76)
Observations	58	70	60	68

Notes: All models adjust for the full set of covariates in Table 1. Coefficients displayed based on linear regressions, with 95% confidence intervals in parentheses

*** p<0.01, ** p<0.05, * p<0.1

To further illustrate the observed positive associations, we show the estimated distributions of HAZ by the KMC group in Figure 4. While only one child (4%) in the KMC group had HAZ < -2, the same was true for 35 children (33%) without KMC.

Fig. 4 Distribution of HAZ by KMC Group



Discussion

In this paper, we used a novel data set from São Paulo Brazil to estimate the empirical associations between Kangaroo Mother Care (KMC) and child development among children born prematurely. Our results suggest that practicing KMC may have large protective effects on children born prematurely, both in terms of their cognitive and in terms of their physical development. These findings are consistent with other studies of preterm (19, 34-37) or low birth weight infants (38). In general, these studies found relatively large benefits of KMC on children's development. However, existing studies associating KMC with cognitive development have been mostly conducted mainly in high-income countries. Our study shows that positive impacts of KMC on child development, and particularly on cognitive development, can also be expected in low-resourced settings.

A large pool of documented evidence has recorded a high risk faced for cognitive development for preterm infants (39-41). These risks are well visible in the data presented in this study, with an average HAZ of -0.8 at age 3 among preterm children in the sample. Rather remarkably, these risks seem almost exclusively restricted to children not benefitting from KMC, with an average HAZ of close to zero among children benefitting from KMC, and an average HAZ of -1.0 among children not benefitting from KMC. These differences observed at age three are definitely not due to the initial advantages of children in the KMC group: the median gestational length in the KMC group was 33 weeks, compared to a gestational length of 36 weeks in the group of children without KMC. Children benefitting from KMC do not only seem to be able to close this initial gap, but also appear to be substantially better developed at age 3. From a behavioral perspective, it is of course, possible that mothers practicing KMC may on average be more engaged with children more generally than mothers opting against it. We controlled for several potential factors in our empirical models, but cannot fully rule out residual confounding factors in our analysis. Given the rather large associations observed in fully

adjusted models, it seems unlikely that residual confounding would fully explain the observed patterns (42).

Several limitations of this study should be noted. First, the overall sample size was small, limiting the statistical power of the study. Second, the observational nature of this study does not fully allow us to rule out confounding. While we include several critical confounders in the model, KMC practice may be correlated with other parental factors positively contributing to child development. Third, we only have information about the KMC during the hospital stay and are not able to assess the extent to which KMC was practiced at home. Additionally, the mothers were interviewed three years after birth, and thus likely that they did not remember all of the details of their early childhood interactions. Notwithstanding these limitations, our results indicate that even relatively limited engagement with KMC during the first days of life may be highly beneficial for preterm infants. Our study does not allow us to directly understand the KMC mechanism, but the main links highlighted in the literature (12-17) such as bonding, breastfeeding, stimulation, are likely to apply in this setting as well. Further research will be needed to confirm the results of this study and to identify optimal and minimal dosing of KMC.

Despite the presumably large benefits of KMC and the official hospital commitment to this program, our findings revealed that only about 20% of the women with preterm infants practiced KMC in the 2012-2014 period. Similarly, low rates of KMC uptake have also been noted in several other countries (19). Low uptake of KMC may be related to stress and stigma associated with having a preterm child, lack of standardized measures, and poor understating of KMC benefits (19, 43), but may also reflect a lack of knowledge about KMC by families and healthcare workers and local cultural practice (43, 44). Further research will be needed to better understand the main barriers in this setting as well as to identify the most effective ways to support mothers and their infant children during the post-natal period generally.

Conclusion

Kangaroo Mother Care is a well-established program and has been accepted in many countries as a public health policy with potential benefits for preterm children and their caregivers. Our study suggests that the potential to improve children's cognitive and physical development in an urban Brazilian context is large. Despite this, uptake remains low, and major efforts will be needed to further engage mothers with KMC.

Ethics approvals and consent to participate

Ethics approvals were obtained from the University Hospital of São Paulo. Informed consent was obtained from all the participants before the interviews. As part of the consenting process, the study purpose and procedures were explained to the caregivers, and families were made aware that they can end the assessment at any point of time or skip any question they were not comfortable with. Caregivers were also provided with the PI's contact information in case they had any questions regarding the study or wanted to obtain further information.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Availability of data and materials: The datasets used in analysis during the current study are available from the corresponding author on request.

Acknowledgment: We would like to acknowledge and thank the staff at the University Hospital of São Paulo as well as all study subjects for their support of this study.

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Chapter 4: Associations between exclusive breastfeeding (EBF) duration and children's developmental outcomes: evidence from Siaya County, Kenya

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This paper has been published in **PLOS ONE**

31 March 2022, https://doi.org/10.1371/journal.pone.0265366

Abstract

Background

Exclusive breastfeeding (EBF) during the first six months of life is widely promoted as a key strategy to enhance child health, growth, and development. Even though a high proportion of children in Kenya are currently breastfed exclusively, relatively little is known regarding the developmental benefits during the first year of life. The paper aims to establish the association between EBF and early childhood developmental outcomes among children aged between 0 - six months in Kenya.

Methods

We used data collected as part of a cluster-randomized controlled trial conducted in Bondo sub-County in Western Kenya to assess the associations between exclusive breastfeeding and development in the first year of life. The primary exposure variable was exclusive breastfeeding, and the outcome variable was child development as measured by the Ages and Stages Questionnaire – Third Edition (ASQ-3).

Results

We analyzed data for 570 children ages 0 - 6 months at the time of the interview. Breastfeeding children exclusively between 3 – 6 months was associated with a 0.61 SD increase in overall ASQ-3 scores in the adjusted model. When specific domains are considered in the adjusted models, the estimated associations between EBF in the 3 - 6 months period and ASQ scores were 0.44 SD for communication, 0.34 SD for gross motor, and 0.36 SD for problem-solving with small differences in fine motor and socioemotional.

Conclusion

EBF in the 3 – 6 months age range has positive associations with child development, especially for communication, gross motor and problem-solving. Programs encouraging mothers to continue EBF in this period may have substantial benefits for children.

Keywords: exclusive breastfeeding, child development, early childhood, children, milestones

Introduction

The period from conception to a child's third year represents the most critical time in the life of a child. This period lays the foundation for the achievement of critical developmental milestones enabling children to reach their full potential (1). Recent findings indicate that millions of children in low and middle-income countries (LMICs) fail to achieve their developmental potential (2). The majority of these children live in rural or poor urban settings of sub-Saharan Africa (SSA) (3). The main causes of poor child development include malnutrition, chronic poverty, and inadequate cognitive and social-emotional stimulation (1, 4). Understanding children's growth and development in complex settings within SSA are important for the design of strategies and interventions that can enhance the achievements of such potentials (4). Loss of human potential during early childhood periods is associated with later poor schooling and labor outcomes eventually perpetuating the intergenerational cycle of poverty (5).

Exclusive breastfeeding (EBF) for the first six months as recommended by the World Health Organization (WHO) is currently considered one of the most effective ways to enhance children's healthy growth and development (6). Children who are exclusively breastfed for six months have been found to have better nutritional outcomes (7, 8), reduced morbidity (9, 10), and improve early child development (11, 12). In the long run, breastfeeding has been linked to a lower risk of obesity, asthma, diabetes, and cancer as well as infant mortality (13). In addition, breastfeeding can enhance mother-child interaction thereby improving bonding between the mother and the child (14). For mothers, breastfeeding lowers the risks of being overweight, postpartum bleeding as well as risks of diabetes, and breast cancer (15). EBF has a strong association with the early achievement of cognitive, social-emotional, language, and fine motor skills (16-20), making it the most effective early intervention program for children.

Globally, 44% of children are currently estimated to be exclusively breastfed up to six months of age (6). EBF rates remain low in many parts of Africa despite major efforts to promote this practice in the last three decades (21). Kenya remains among the few countries in Africa that have made major progress in EBF rates, with percentages of children breastfed for at least six months rising from 32% to 61%, between 2008 to 2014 (22). The increase in breastfeeding rates is due to intense awareness campaigns on the importance of EBF by the Ministry of Health and early intervention programs such as Baby-Friendly Community Initiative (BFCI) and Baby-Friendly Hospital Initiative (BFHI) currently being implemented in some parts of Kenya (23). Despite the relatively large benefits of EBF reported in other settings, little is known about the benefits of EBF for at least six months and its impact on children's developmental outcomes in Kenya. The current paper aims to establish the association between EBF and early childhood developmental outcomes among children aged between 0-6 months in Kenya. Further, the current paper contributes to the body of literature on the association between EBF and early childhood development among children in sub-Saharan Africa.

Materials and methods

Study design

We used data collected as part of a cluster-randomized controlled trial that sought to evaluate the impact of an early childhood development intervention delivered through the health system (24). Within the study site, 18 public health facilities (clusters) were randomly selected from each of the six wards. The trial comprised a pre-intervention (baseline) survey and a longitudinal follow-up of the caregiver-child dyads for a period of 27 months. The first post-birth follow-up was conducted between September and December 2018, while the second post-birth follow-up was completed between May and August 2019.

Study site

The study was conducted in Bondo sub-County in Siaya County, Western Kenya. Siaya County is one of the 47 counties (devolved system of government) formed in 2010 after the promulgation of the current Kenyan constitution. Counties in Kenya are semi-autonomous and are further administrative sub-divided into six sub-counties (Bondo, Ugenya, Ugunja, Alego-Usonga, Gem, and Rarieda). Siaya County is situated along the shores of Lake Victoria where fishing is the main economic activity. As of 2019, the county had a population of 993, 183 (25). Women of reproductive age represent about 23% of the population and the total fertility rate is 4.2, slightly higher than the national rate of 3.9 (26). About 22.8 percent of the children in the County below 5 years are stunted (lower than the national rate of 25%) with 12.6 percent of the children in the same category being underweight compared with the national rate of 11% (27, 28). With an average household size of 3.8, the Bondo sub-county had a population of 197, 883 (95,962 males, 101,917 females) and 20453 children below the age of three years (25) by 2019.

Study sample

The study sample consisted of 792 pregnant women recruited at baseline (pre-birth) and followed up 570 and 610 primary caregiver-child dyads at post-birth one and two data collection rounds respectively. The details of the recruitment process and the design are provided in the baseline report (29). We used data from the post-birth 1 and post-birth 2 data collection time points irrespective of the study arm for the study reported in this paper. At post-birth 1, the majority of the children were between 1 - 2 months old with some children extending up to 7 months. At post-birth 2, the majority of the children were between 9 – 11 months old with the youngest child being 4 months and the oldest child being 15 months. Our sample consisted of children 0 – 6 months irrespective of the round of data collection.

Exposure and outcome variables

The main exposure variable was the practice of EBF as reported by the caregivers during the two rounds of data collection. We defined EBF according to the WHO indicator for infant and young child feeding (IYCF) practices (30), that is, giving only breast milk to the infant (directly from the breast or expressed) and nothing else to drink or eat except for vitamin/mineral supplements or medicines. Non-exclusive breastfeeding was defined as the child having been given other liquids and/or foods other than breast milk. As part of the survey interview, all caregivers were asked "Apart from breast milk, has your child ever been given any food or liquid?" (Yes= 1, No = 0). Children were classified as exclusively breastfed (EBF=1) if the mother reported that they had not given any other foods or liquids and not exclusively breastfed (EBF=0) if the mother reported that they had ever given the child other foods or liquids. We further categorized the EBF stage as per the age range at which the child was observed, that is, 0 – 2 months (onset of EBF) and 3 – 6 months (core EBF period). The primary outcome of interest for the current paper was child development at the age at which the child was observed, between 0 – 6 months.

Child development was measured using the Ages and Stages Questionnaire – Third Edition (ASQ-3) (31). The ASQ has been validated and used in Zambia (32) and has also been used in Kenya to assess children's developmental outcomes (33). The domains captured in the ASQ-3 include communication, gross motor, fine motor, problem-solving and personal-social development. The questionnaires were administered by trained field interviewers and relied on caregiver self-reported responses. Six age-specific questions (items) were asked under each domain. Responses were quantified as follows: "Yes" (=10 points) if the child was able to perform the activity; "Sometimes" (=5 points) if the child tried and failed but the caregiver reported that the child could perform the activity; and, "No" (=0 points) if the child was unable to perform the activity. Responses to all the items in each domain were summed to obtain an aggregate score.

Data were collected at the health facility during the intervention implementation period. All the caregivers were interviewed at the facility as they come to the facility for immunization services. Data were gathered by field interviewers who were trained in conducting interviews with mothers/caregivers. The assessors had at least a bachelor's degree level of education in child development or related subjects and had experience with the administration of the ASQ tool. We used the ASQ tool to obtain information on child development as part of both follow-up rounds and also inquired about feeding practices in each round.

Covariate measures

Based on the literature (34-37), we included in our model other covariates that appear to be related to EBF and child development as control variables. The variables included caregiver mean age (in years), occupation, marital status, family size (number of children), family assets (wealth index), and caregivers' education. Caregiver occupation was conceptualized as either currently employed (including self-employment or small-scale business) or not employed. Marital status was categorized as married or not (divorced, single, or widowed). The number of children consisted of other children the caregiver lived with (including non-biological children), apart from the index child. Caregiver education was categorized as primary education, secondary education, and above secondary education (college and vocational education). The wealth quintile was measured using a household asset scale. Assets such as radio, cellphones, bicycles, motorbikes, television, flush toilet, fridge, and piped water were included in the principal component analysis. The predicted value of the first principal component was then used to divide households into wealth quintiles. In addition, we included information on children's characteristics such as gender which was obtained during the interview with the mother. All covariates were measured at pre-birth using a structured questionnaire.

Ethics

Ethics approval was obtained from Amref Health Africa's Ethics and Scientific Review Committee. Permission to conduct the study was first obtained from the National Commission for Science, Technology, and Innovation (NACOSTI) and later from the Siaya County Health Management team (CHMT) before data collection. Written, informed consent was sought and obtained from study participants before any data were collected. For respondents who could not read and write, a thumbprint was taken as a signature. Confidentiality of the data and the participants' privacy were respected at all times. Consenting was done at every round of data collection. Consent documents and the questionnaires were translated into Kiswahili (the national language) and Dholuo (the local language in the study area). The study was registered under trial registration number ISRCTN11561283

Statistical analysis

We presented continuous variables using means and SD. Categorical variables were summarized as frequencies and percentages. Simple linear regression analyses were performed to estimate the unconditional association between the practice of EBF and ASQ scores overall, as well as during specific sub-periods: the onset period (0 - 2 months), and the core EBF period (3-6 months). We created an age integer variable for the children observed between 0 -6 months irrespective of the data collection round or time point. To re-examine the association of EBF on ASQ scores conditional on observable characteristics, we performed multiple linear regression including all the aforementioned covariates. Further, we controlled for treatment groups of the larger study in these models.

Further, we conducted a multivariable analysis to examine the association between each of the ASQ domains during the 3-6-month age range and EBF. We presented the results in a standardized regression coefficient where we used clustered standard errors in our analysis.

Data analysis was performed using STATA version 16.0 for Windows (STATA Corporation, College Station, TX) (38)

Results

We analyzed data for 570 children ages 0 - 6 months at the time of the interview. A total of 270 children were observed at one month, 163 at two months, 76 at three months, 34 at four months, 18 at five months, and 9 at 6 months. In addition, we analyzed 433 between 0-2 months and 137 between 3 – 6 months. Descriptive statistics of the analytical sample are presented in **Table 1a**. In the pooled sample, 86% of the children aged 0 – 6 months were exclusively breastfed. The proportion was higher (88%) for children in the 0-2-month age category with a drop to 73% for children in the 3-6-month age range. About 53% of the children in the EBF group and 42% in the non-EBF group were female. On average, caregivers in the sample were 26 years old, with about two children per family. Most of the caregivers (64.2 %) in the EBF group had at least primary education. Nearly two-thirds of the caregivers (64.8%) in the EBF group and 73% in the non-EBF group were employed. A high proportion (80%) of the caregivers were married. The ASQ mean score for children who were exclusively breastfed in the 3 – 6 age category was 55.1 compared to 51.5 for those not exclusively breastfed in that age category (**Table1b**), these differences were significant ($p = 0.004$).

Table1a: Descriptive statistics (caregivers' baseline characteristics)

	Exclusively breastfed	Not exclusively breastfed	*p-value*
Child/Caregiver's characteristics	**N=492**	**N=78**	
Child Female	261 (53.1)	33 (42.3)	0.078
No of children, mean (SD)	2.4(1.8)	2.4(1.9)	0.954
0 – 2 months, N (%)	381 (77.4)	52 (66.7)	0.039
3 – 6 months, N (%)	111 (73.1)	26 (26.9)	0.039
0 – 6 months, N (%)	492 (86.3)	78 (13.7)	0.000
Caregiver age, mean (SD)	26.7(5.9)	25.7(6.3)	0.162
Primary education, N (%)	318 (64.2)	54 (69.2)	0.428
Secondary education, N (%)	150 (30.5)	19 (24.4)	0.271
Above secondary, N (%)	24 (4.9)	5 (6.4)	0.567
Caregiver employed N (%)	319 (64.8)	57 (73.1)	0.154
Caregiver married, N (%)	423 (86.0)	62 (79.5)	0.135
Wealth quintile 1	111 (22.6)	14 (18.0)	0.360
Wealth quintile 2	134 (27.4)	24 (30.8)	0.517
Wealth quintile 3	54 (11.0)	15 (19.2)	0.038
Wealth quintile 4	93 (18.9)	15 (19.2)	0.945
Wealth quintile 5	100 (20.3)	10 (12.8)	0.119

Table1b: ASQ Scores	**Exclusively breastfed**		**Not Exclusively breastfed**		***P-value***
Mean ASQ-scores 0- 2 months	52.0	9.9	52.3	7.5	0.447
Mean ASQ-scores 3- 6 months	55.1	6.2	51.5	7.4	0.004
Mean ASQ-scores 0- 6 months	52.7	9.3	52.0	7.4	0.829

As shown in **Fig 1**, the rates of EBF dropped rapidly across the age range. During the first month, higher proportions (over 80%) of children were exclusively breastfed. The rates drastically reduced to below 50% during the sixth month.

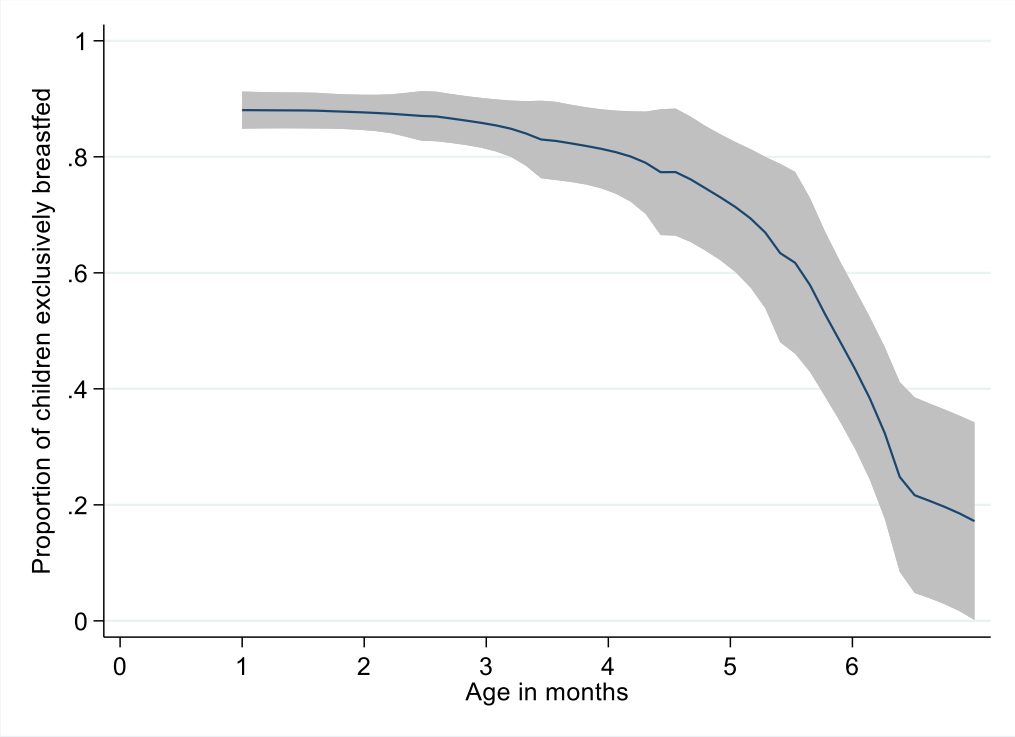

Fig 1 proportion of exclusive breastfeeding by age in months

Information on the crude and the adjusted association between EBF and the children's ASQ-3 mean scores are provided in **Table 2**. In the unadjusted model, being exclusively breastfed between 3 – 6 months was associated with a 0.53 SD increase in overall ASQ scores (95% CI [0.03 - 1.03]). After adjusting for other covariates, EBF was associated with a 0.61 SD increase in ASQ-3 mean scores in this age range (95% CI [0.19 - 1.03]). Crude and adjusted models did not show any association between ASQ-3 mean scores at the 0-2 months age range, and the overall period (0-6 months). As shown in further detail in **Fig 2**, major differences in developmental outcomes were observed for the 3–6-month period, while only minor differences were observed for the early period.

We presented adjusted associations between the practice of EBF during the 3-6-month period and all the ASQ domains separately (**Table 3**). The estimated associations between EBF in the

3–6-month period and ASQ scores were 0.44 SD for communication; (95% CI [0.08 - 0.79]), 0.34 SD for gross motor; (95% CI [0.01 - 0.66]), and 0.36 SD problem solving; (95% CI [0.05 - 0.66]) with small differences in fine motor and personal social skills.

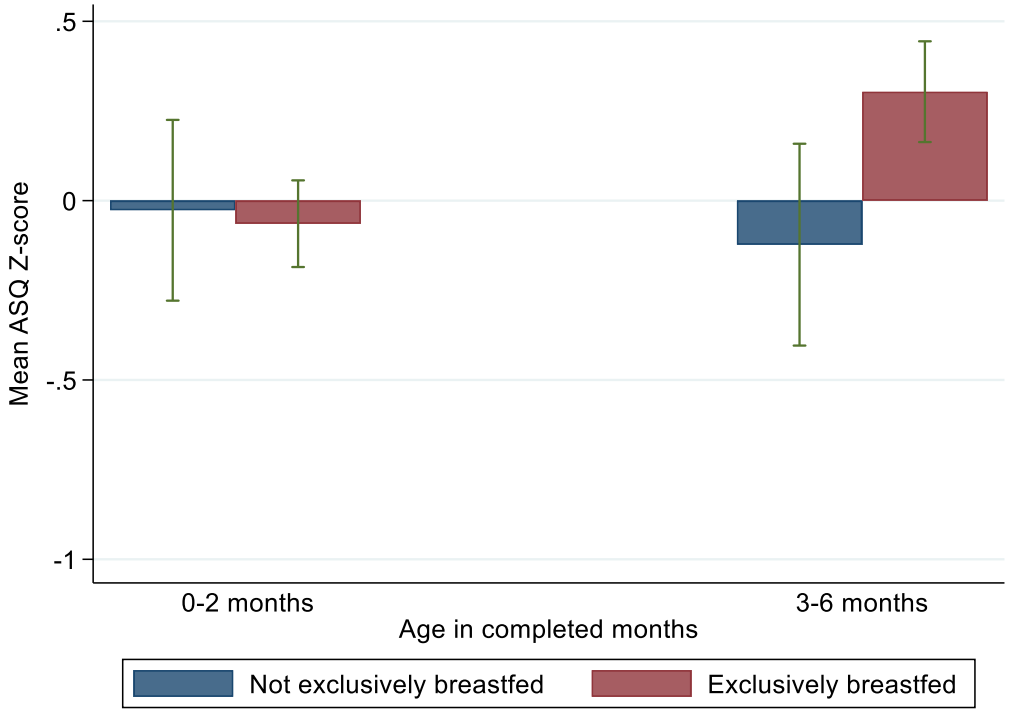

Fig 2 Children's mean ASQ Z – scores and age groups in months by EBF group

Table 2: Unadjusted and adjusted regression for the associations between current EBF and child development (ASQ scores) ages 0-6 months

	Unadjusted associations			Adjusted associations		
VARIABLES	0 - 6 months	0 - 2 months	3 - 6 months	0-6 Months	0-2 months	3 - 6 months
Exclusive breastfeeding	0.11	-0.04	0.53**	0.23	0.19	0.61***
	(-0.23 - 0.45)	(-0.53 - 0.45)	(0.03 - 1.03)	(-0.05 - 0.52)	(-0.20 - 0.58)	(0.19 - 1.03)
Caregiver age				0.01	0.00	0.01
				(-0.02 - 0.03)	(-0.02 - 0.03)	(-0.02 - 0.04)
Caregiver employed				-0.07	-0.16	0.24*
				(-0.29 - 0.15)	(-0.39 - 0.07)	(-0.01 - 0.49)
Caregiver married				0.02	0.16	-0.22
				(-0.44 - 0.48)	(-0.39 - 0.72)	(-0.54 - 0.09)
No of children				-0.04	-0.07	-0.00
				(-0.15 - 0.08)	(-0.19 - 0.05)	(-0.10 - 0.09)
Child female				0.03	0.13	-0.26**
				(-0.14 - 0.20)	(-0.08 - 0.34)	(-0.50 - -0.01)
Secondary				0.02	0.03	-0.03
				(-0.25 - 0.29)	(-0.28 - 0.34)	(-0.32 - 0.26)
Above secondary				-0.31**	-0.53**	0.03

				(-0.60 - -0.01)	(-1.03 - -0.03)	(-0.40 - 0.46)
Wealth quintile 2				0.01	0.00	-0.02
				(-0.22 - 0.24)	(-0.26 - 0.26)	(-0.48 - 0.44)
Wealth quintile 3				0.20	0.16	0.16
				(-0.04 - 0.44)	(-0.13 - 0.46)	(-0.34 - 0.66)
Wealth quintile 4				0.15	0.13	0.05
				(-0.14 - 0.44)	(-0.17 - 0.42)	(-0.41 - 0.51)
Wealth quintile 5				0.29**	0.29**	0.41*
				(0.02 - 0.56)	(0.01 - 0.57)	(-0.07 - 0.89)
Constant	-0.09	-0.03	-0.23	0.03	-0.05	0.06
	(-0.43 - 0.24)	(-0.41 - 0.36)	(-0.80 - 0.35)	(-0.88 - 0.95)	(-1.10 - 1.00)	(-0.84 - 0.97)
Observations	570	433	137	570	433	137

Each column represents the results of the regression coefficients for ASQ_Zscores in each age, with 95% confidence intervals. The models are also adjusted for the intervention arm and the rounds of data collection.
*** p<0.01, ** p<0.05, * p<0.1

Table 3: Adjusted association between EBF and early childhood development (ECD) domains at 3 - 6 months (core EBF period)

VARIABLES	Communication	Gross motor	Fine motor	Problem-solving	Personal-social
Exclusive breastfeeding	0.44**	0.34**	0.40*	0.36**	0.58*
	(0.08 - 0.79)	(0.01 - 0.66)	(-0.02 - 0.82)	(0.05 - 0.66)	(-0.05 - 1.21)
Observations	137	137	137	137	137

Each column represents the results of the linear regression model for each of the ASQ domains, with 95% confidence intervals. The models are adjusted for the full list of all covariates in **Table 1** including the intervention arm and round of data collection. These included caregiver age, caregiver employed, number of children, child's age at assessment, gender, caregivers' education, marital status, household assets. ***p<0.01, **p<0.05, *p<0.1.

Discussion

We compared children who were exclusively breastfed to those who were not across different ages between 0-6 months. Our results show that large percentages of infants were reported to be exclusively breastfed in the first three months of life, with rapid declines in the subsequent months. Our results suggest that infants who were exclusively breastfed between the 3-6-month period showed better development compared to those who were not. In addition, we found that infants who were exclusively breastfed during the core EBF period had higher scores in communication, gross motor, and problem-solving compared to their counterparts. Our findings show that 88% were exclusively breastfed during the first two months and over 70% between ages 3 – 6 months reflect the efforts by the Ministry of Health that have included key early intervention programs such as nurturing care and BFCI. High proportions of EBF during the first two months of breastfeeding are expected since most children are still taken for immunization visits. The cessation of EBF after two months has been linked to returning to work/businesses, perceived low milk quantity, and negative perception of EBF (39-42).

Previous studies on the associations between breastfeeding and child development found that short periods (0-2 months) of breastfeeding did not show any significant differences between children exclusively breastfed and those who were not since the percentage differences were minimal (43). These existing findings compare to the current study that has shown no association during the first two months of breastfeeding; mainly because most children are exclusively breastfed during the first two months of EBF. The Kenyan government supports breastfeeding mothers during the first three months of the child's life by provision of paid leaves for those working (44). During this period, more than 85% of children in our sample were exclusively breastfed hence no differences were observed in terms of developmental outcomes. Associations between EBF and general child development are documented in the literature (11, 12, 45-47). While these studies did not use ASQ-3 and were conducted in both

low and high-income settings, the age of assessment for the developmental outcomes ranged from birth to the first child's birthday.

Our findings at 3- 6 months, which indicated that EBF was associated with child development corroborate with existing literature that has found large benefits of EBF on infant development at 4 months (11). On the other hand, our results indicate that children who are not exclusively breastfed may display poor development, poor health, and nutritional outcomes and may not achieve their developmental potential. Our findings on poor development for the children not exclusively breastfed corroborate those from a study conducted by Khan and Islam in 2017 (7) on Bangladeshi children that found that a lack of EBF up to six months had negative consequences on the health such as frequent diarrhea or fever and nutritional outcomes such stunting or underweight. Also, EBF has been found to have a protective effect against pertussis-like illnesses such as Diphtheria or tetanus for children exclusively breastfed for at least 6 months (48). The association between EBF and language development that was evidenced in our study extends the results of previous studies, which showed profound effects on the early acquisition, and development of receptive and expressive language at six months (16, 49). Our findings that EBF is positively linked to socioemotional development are consistent with other previous studies (11, 20) that found a positive effect of breastfeeding on social development for both infants and older children. These findings relate to previous studies (11, 12) that correlated EBF with achievements of cognitive milestones in infants (50). Early acquisition of language, cognitive skills have a sustained impact on the later academic achievement with an enhanced enrollment of the children (51, 52) and more importantly, these domains are useful indicators of overall development during the early years. Our study also suggests a link between EBF and gross motor skills for children younger than six months, which has not been found in other recent studies (53). While we did not find any sustained effect of exclusive breastfeeding

on socioemotional development and fine motor skills, previous studies have documented these relationships, but for children older than six months (11, 20).

There are some limitations worth noting. First, child development measures relied on the primary caregiver's self-report which may raise the possibility of social desirability bias among the caregivers. Secondly, children were classified as exclusively breastfed if mothers reported current breastfeeding as well as never having given the child any food or liquids. The responses were dependent on whether the caregivers were able to remember these activities. In addition, the definition of EBF differs from the conventional definition that uses 24 our recall, and again this may raise the possibility of recall biases.

Conclusion

The results presented in this paper indicate a relatively strong association between EBF and child development in the 3–6-month age range, especially for communication, gross motor, and problem-solving domains. A key policy priority should therefore focus on the promotion of EBF in this period when many mothers stop EBF in practice.

Acknowledgment

We would like to acknowledge and thank the evaluation team from the African Population and Health Research Center (APHRC) who conducted the cluster-randomized controlled trial for allowing us to use part of the data and for their support during the analysis of the data. Also, we would like to thank the PATH team and the department of health in Siaya County for facilitating the study and cooperation throughout the study period. We also thank all the children and their caregivers who agreed to participate in the study.

Authors' contributions

Conceptualization and data curation: SO EKM PKW KO. Formal analysis: SO GF NL PKW. Funding acquisition: **SO EKM PKW.** Investigation**: SO EKM PKW KO NL. Methodology: SO EKM PKW KO NL CO JU GF.** Project Administration **SO KO EKM PKW.** Writing – Original Draft Preparation**: SO EKM PKW CO GF.** Writing – Review & Editing**: SO EKM PKW KO NL CO JU GF**

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Chapter 5: Maternal stimulation and early child development in sub-Saharan Africa: evidence from Kenya and Zambia

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This paper has be revised and resubmitted to BMC Public Health

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Abstract

Background: Despite major improvements in child survival over the past decade, many children in low and middle-income countries (LMICs) continue to not reach their developmental potential due to malnutrition, poor health, and lack of stimulation. Maternal engagement and stimulation have been identified as one of the most critical inputs for healthy development. However, relatively little evidence on the links between maternal stimulation and child development exists in sub-Saharan Africa. The paper aims to identify the general associations between maternal stimulation and child development in Kenya and Zambia as well as to identify the activities that have the strongest associations with developmental outcomes in this setting.

Methods: This descriptive study uses three rounds of a novel prospective data collected in Kenya and Zambia. In round 1, children were on average 10 months old; in round 2, 25 months, and in round 3, 36 months. The primary exposure of interest was maternal stimulation, which we grouped into cognitive, language, motor, and socio-emotional activities. The outcome of interest was child development measured through the third edition of the Ages and Stages Questionnaire (ASQ-3). Linear regression models were used to estimate the associations between child development and overall maternal stimulation and domain-specific maternal stimulation.

Results: We analyzed 560 caregiver-child dyads in round 1, 405 in round 2, and 300 in round 3 across the two countries. Maternal stimulation scores was associated with a 0.55SD (95% CI [0.44 - 0.66]) increase in ASQ z-score at round 1, a 0.25 SD (95% CI [0.11 - 0.40]) at around 2 and a 0.23 SD (95% CI [0.10 - 0.35]) at round 3. For domain-specific, associations were largest for cognitive and socioemotional stimulation with round 1 coefficients of 0.43 SD (95% CI [0.28 - 0.57]) and 0.28 SD (95% CI [0.14 - 0.41]) respectively. The association were largest

for language at round 2 (0.33 SD (95% CI [0.20 - 0.45]) and motor activities at round 3 (0.33 SD (95% CI [-0.02 - 0.36]).

Conclusion: Our study suggests a large positive link between maternal stimulation activities and children's developmental outcomes in poor rural settings.

Trial registration: NA (not a clinical trial).

Keywords: Maternal stimulation, child development, early learning, responsive caregiving, motor activities, cognitive activities, language activities socio-emotional activities.

Introduction

Globally, child survival has greatly improved in the past three decades with under-five mortality declining by 59% from 1990 to 2019 (1). Among other things, improved access to healthcare services and better socio-economic development have likely contributed to these positive trends (2). Despite these large improvements in child survival, over 60% of the children living in sub-Saharan Africa (SSA) are still at risk of not reaching their developmental potential (3, 4). Poor development in children can result from malnutrition, poor health, poverty, lack of stimulation, limited opportunities for early learning, and unresponsive caregiving (5). Developmental delays in children pose greater risks to children not only to their health outcomes but also to human capital and general wellbeing across the life course. Children who fail to achieve their developmental potential often experience lower academic achievement and reduced incomes in adulthood, contributing to a vicious cycle of poverty (6, 7).

Providing children with opportunities for early learning through the creation of a stimulating environment offers primary caregivers with a unique opportunity to have lifelong positive impacts on their children (8, 9). Stimulation activities that may be beneficial for children are very diverse, including activities such as reading with the child, storytelling, singing songs,

taking the child outside the home for a walk, playing with the child, telling the child names of objects, and drawing objects with the child. These activities can improve children's psychological wellbeing (10), early language acquisition (11, 12), the development of executive functioning (13), and socio-emotional skills, and boost the early acquisition of fine and gross motor skills (14).

Evidence has demonstrated the importance of maternal stimulation in high-income settings (15, 16). However, relatively little evidence associating maternal stimulation activities and child development exists in sub-Saharan Africa. This study aims to fill this gap using a novel prospective data set from Kenya and Zambia. The paper has two main objectives: first, to identify the general associations between maternal stimulation and early childhood development, and second, to identify the activities that show the strongest associations with developmental outcomes in this setting.

Materials and Methods

Study design

This is a descriptive study using longitudinal data from a community-led parenting empowerment intervention currently being implemented in Kenya and Zambia.

Study sites

In **Kenya**, data was collected in Nyando sub-County, Kisumu County, specifically in Ayucha, Border 1, and Wanganga villages in Onjiko-Awasi Ward. Kisumu is located in western Kenya along the shores of Lake Victoria. According to the 2019 census, Kisumu County has a population of about 1,155,574 (17) including 202,519 children under the age of five. The infant mortality rate in Kisumu County is estimated at 54 per 1000 live births. More than half of pregnant women (54%) deliver at home although the attendance of antenatal care uptake is relatively high with an estimated 71% of women attending at least 3 times. The proportion of

women using modern contraceptives remains low at 27% compared with the national average of 46% (18).

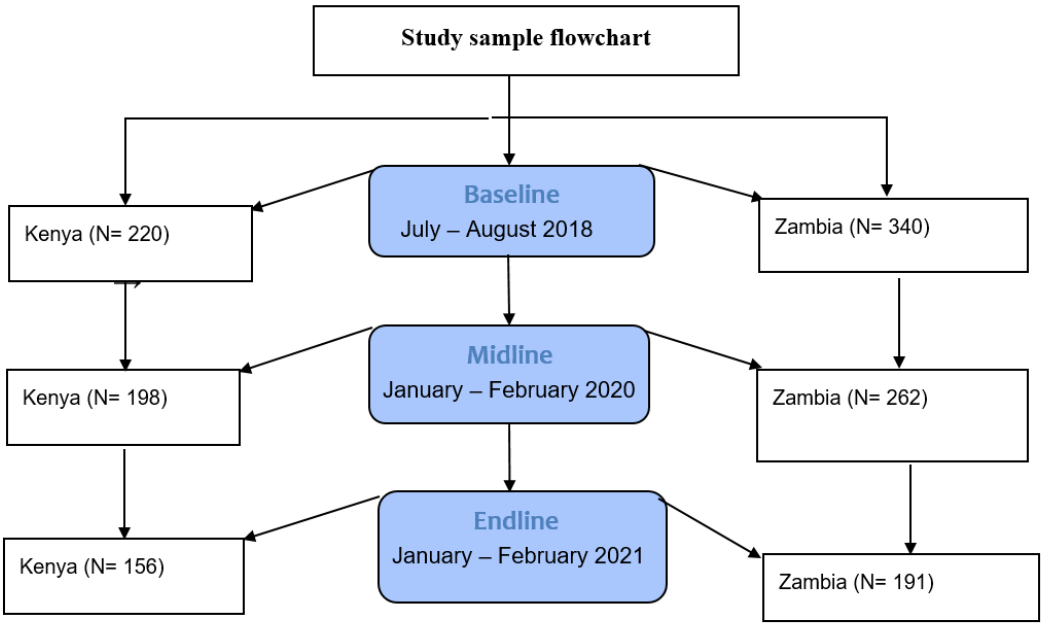
Nyando sub-County has some of the poorest health and development indicators in Kisumu County. The sub-County has lower than average uptake of immunization (76.6%, compared to the county average of 82%) and a lower proportion of mothers who had deliveries assisted by skilled attendants (59.4% compared to 70.4% in the county). The proportion of mothers who attended four ANC visits is about 48.4% compared to 49.7% in the county. In addition, the greater Nyanza region has an HIV prevalence rate of 19.3% against a national average of 5.9% (19) which has greatly affected the County.

In **Zambia**, the study was conducted in the Mwantaya and Chamuka Wards, which are located in Chisamba District in Zambia's Central province. The population in Chisamba District is was 103,983 in 2010 (20). HIV prevalence rate of 13.4% in Central Province is higher than the national rate in rural Zambia (9.1%). Malnutrition rates are extremely high, with 42.1% of children under five exhibiting stunted growth. Only 46.5% of mothers have deliveries by skilled attendants and less than a quarter (14.4%) of the population has no formal education (21). According to 2010, the total population in the greater Chamuka area was 21,210, with 10,685 males and 10,525 females with 3,833 households. Mwantaya Ward is sparsely populated, with little infrastructure and only one health clinic (21).

Study sample

In Kenya, 220 mother-infant pairs were recruited across three sub-locations and enrolled in the study during the baseline phase. In Zambia, 340 mother-infant were recruited at baseline across 10 villages within the wards. The study participants were later interviewed at midline and endline (**Fig. 1**). During the follow-up, 198 and 262 were recruited and interviewed in Kenya and Zambia respectively during the midline data collection while 156 and 191were recruited and interviewed in Kenya and Zambia respectively as endline.

Figure 2: Study sample flowchart



Exposure and Outcome variables

The primary exposure of interest was maternal stimulation. Maternal stimulating activities were collected in all three rounds and grouped into four domains based on the primary area of development targeted by the activity: cognitive, language, motor, and socio-emotional activities. **Appendix 1** shows the complete list of activities by domain**.**

The main outcome variable for this paper was child development measured through the Third Edition of the Ages and Stages Questionnaire (ASQ-3)(22). The ASQ-3 relies on caregiver reports and has been validated and used in Zambia (23) as well as Kenya (24). The ASQ-3 covers five developmental domains (communication, gross motor, fine motor, problem-solving, and personal-social) as well as an overall development score. The ASQ-3 was administered by trained field interviewers where all responses were recorded electronically using tablets.

Covariates

To reduce the risks of confounding, we controlled for caregiver age (in years), caregiver employment status, marital status, number of children, family wealth index, and caregivers' education status in our models. Caregiver employment status was conceptualized as either currently employed (including self-employment or small-scale business) or not employed. Marital status was categorized as married or not (divorced, single, or widowed). The number of children consisted of all the children the caregiver lived with, including non-biological children, apart from the index child. Caregiver education was categorized as no education (caregivers who reported no education), primary education, secondary education and above (including college and vocational training), and above secondary education (college and vocational education). To divide households into wealth quintiles, we used principal component analysis. The specific assets included were household ownership of a radio, a cellphone, a bicycle, a motorbike, a television, a flush toilet, a fridge, as well as access to piped water. The predicted value of the first principal component was then used to divide households into wealth quintiles. Further, we included caregiver stress levels as measured by the parental stress index (PSI) (25). In addition, we included information on children's characteristics such as gender, which was obtained during the interview with the mother. The covariates were included based on the existing literature and were collected at the same time ASQ-3 questionnaires were also being administered.

Statistical analysis

We began our analysis with basic descriptive statistics of the study population. Continuous variables were presented using means and SDs while categorical variables were summarized as frequencies and percentages. Second, we performed simple linear regression analyses to estimate the unconditional associations between child development (ASQ scores) and overall maternal stimulation as well as domain-specific maternal stimulation. In addition, linear

regression analyses were also performed to estimate the unconditional association between overall maternal stimulation and each of the ASQ domains. Third, we performed multiple linear regression including all the aforementioned covariates as well as controlling for country fixed effects and intervention arm. We used standardized scores for the main exposure and outcome variables in all the models. Data analysis was performed using STATA version 16.0 for Windows (STATA Corporation, College Station, TX) (26)

Results

We analyzed 560 caregiver-child dyads in round 1, 405 in round 2, and 300 in round 3 across the two countries. Descriptive statistics at the baseline of the full sample are presented in **Table 1a**. Respondents interviewed were above 25 years of age. Less than 10% did not have education in both countries. 34% of women in Kenya were employed and 50% of the women in Zambia. 80% of women in Kenya were married, compared to 70% of the women in Zambia. **Table 1b** shows overall trends in exposure and outcome variables**.** ASQ mean scores in Kenya increased from 37.5 at baseline, to 47.6 at midline and dropped to 46.9 at endline. In Zambia, ASQ mean scores increased from 37.0 at baseline, to 47.3 at midline and 48.7 at endline. Overall mean stimulation activities increased substantially from 0.48 at baseline to 0.88 at endline. Motor activities showed the greatest improvement from 0.22 at baseline to 0.88 at endline. **Appendix 1** shows all activities in each domain. The progression of the maternal stimulation activities is further presented in **Appendix figure 2**. The upward trend looks similar across all rounds for the overall stimulation and all domain-specific stimulation activities per country with major changes seen between rounds 1 and 2.

Table 1a: Descriptive statistics at baseline

	Kenya (N=220)		Zambia (N= 340)	
Child/Caregiver's Characteristics	**Mean/%**	**SD**	**Mean/%**	**SD**
Caregiver age (years), mean (SD)	26.7	8.7	27.4	8.3
Caregiver Education				
No Education N (%)	4(1.8)	-	33(9.7)	-
Primary Education, N (%)	160(72.7)	-	214(62.9)	-
Secondary and above, N (%)	56(25.5)	-	93(27.4)	-
Caregiver employed	76 (34.6)	-	175(51.5)	-
Caregiver married	184(83.6)	-	245(71.4)	-
Wealth quintile 1	55(25.0)	-	88(25.9)	-
Wealth quintile 2	63(28.6)	-	75(22.1)	-
Wealth quintile 3	28(12.7)	-	76(22.4)	-
Wealth quintile 4	41(18.6)	-	57(16.8)	-
Wealth quintile 5	33(15.0)	-	44(12.9)	-
Parental stress index, mean (SD)	8.3	7.5	7.4	4.5
Number of children, mean (SD)	3.2	1.7	3.1	2.1
Child female, N (%)	114 (51.8)	-	170(50.0)	-

Table 1b: ASQ means scores and maternal stimulation characteristics

Maternal stimulation activities, mean (SD)		**Kenya**		**Zambia**	
Round	**Variables**	**Mean/%**	**SD**	**Mean/%**	**SD**
Baseline	ASQ means scores	37.5	20.3	37.0	18.1
	Stimulation Domain			**The proportion of activities completed**	
	Overall stimulation	0.48		0.56	
	Cognitive stimulation	0.64		0.63	
	Language stimulation	0.37		0.48	
	Motor stimulation	0.22		0.43	
	Socioemotional stimulation	0.68		0.67	
Midline	ASQ means scores	47.6	11.2	47.3	10.8
	Stimulation Domain			**Proportion of activities completed**	
	Overall stimulation	0.81		0.80	
	Cognitive stimulation	0.87		0.80	
	Language stimulation	0.70		0.72	
	Motor stimulation	0.83		0.80	
	Socioemotional stimulation	0.84		0.85	

Endline	ASQ means scores	46.9	10.1	48.7
	Stimulation Domain	**Proportion of activities completed**		
	Overall stimulation	0.88		0.82
	Cognitive stimulation	0.93		0.83
	Language stimulation	0.78		0.78
	Motor stimulation	0.88		0.83
	Socioemotional stimulation	0.92		0.85

ASQ scores are presented in terms of means of the total sum scores for each of the individual ASQ domains. Overall stimulation scores represent the mean sum of the total of each of the domain-specific stimulation scores across the three rounds. Each of the domain-specific activities is presented in terms of means.

Table 2 presents both crude and adjusted associations between overall maternal stimulation activities and children's ASQ z-scores for the three rounds of data collection. In the unadjusted model, maternal stimulation scores was associated with a 0.55SD (95% CI [0.44 - 0.66]) increase in ASQ z-score at round one, a 0.25 SD (95% CI [0.11 - 0.40]) at around two and a 0.23 SD (95% CI [0.10 - 0.35]) at round 3. The results looked almost identical when a full set of covariates were included (Table 2, cols 4-6).

Information on the adjusted associations between domain-specific stimulation activities and children's ASQ mean scores are presented in **Table 3**. Associations were largest for cognitive and socioemotional stimulation with round one coefficients of 0.43 SD (95% CI [0.28 - 0.57]) and 0.28 SD (95% CI [0.14 - 0.41]) respectively. Associations were largest for language at round two (0.33 SD (95% CI [0.20 - 0.45]) and motor activities at round three (0.33 SD (95% CI [-0.02 - 0.36]).

Table 2: Unadjusted and adjusted associations between overall maternal stimulation and child development for overall (Round 1-3)

	Unadjusted			Adjusted		
VARIABLES	**Round 1**	**Round 2**	**Round 3**	**Round 1**	**Round 2**	**Round 3**
Maternal stimulation[a]	0.55***	0.25***	0.23***	0.55***	0.25***	0.25***
	(0.44 - 0.66)	(0.11 - 0.40)	(0.10 - 0.35)	(0.42 - 0.67)	(0.10 - 0.41)	(0.12 - 0.37)
Primary education				0.09	-0.19	0.17
				(-0.28 - 0.46)	(-0.50 - 0.13)	(-0.21 - 0.56)
Secondary education & above				0.28	-0.14	0.18
				(-0.12 - 0.68)	(-0.47 - 0.20)	(-0.23 - 0.59)
Caregiver age				0.01	0.00	0.00
				(-0.00 - 0.02)	(-0.00 - 0.01)	(-0.01 - 0.01)
Caregiver employed				0.12	0.02	-0.10
				(-0.08 - 0.32)	(-0.14 - 0.18)	(-0.29 - 0.09)
Caregiver married				0.03	-0.15	0.02

				(-0.19 - 0.26)	(-0.36 - 0.05)	(-0.20 - 0.24)
Number of children				0.01	0.01	0.00
				(-0.04 - 0.07)	(-0.03 - 0.04)	(-0.04 - 0.04)
Caregiver's stress level				0.01	-0.01	-0.02
				(-0.02 - 0.04)	(-0.04 - 0.02)	(-0.05 - 0.02)
Wealth quintile 2				0.01	0.19	-0.17
				(-0.26 - 0.29)	(-0.06 - 0.44)	(-0.42 - 0.07)
Wealth quintile 3				0.15	0.07	-0.18
				(-0.14 - 0.44)	(-0.18 - 0.33)	(-0.42 - 0.07)
Wealth quintile 4				0.24*	0.13	-0.16
				(-0.03 - 0.51)	(-0.11 - 0.37)	(-0.41 - 0.10)
Wealth quintile 5				0.13	0.23*	0.01
				(-0.18 - 0.44)	(-0.03 - 0.49)	(-0.26 - 0.27)
Constant	-0.03	0.17***	0.17***	-0.59**	0.24	0.11
	(-0.15 - 0.08)	(0.06 - 0.27)	(0.06 - 0.28)	(-1.17 - -0.01)	(-0.22 - 0.70)	(-0.52 - 0.74)

	560	405	300	560	405	300

Each column represents the results of the linear regression model for the ASQ scores, with 95% confidence intervals. Columns 1- 3 represent the unadjusted associations between the overall stimulation with the ASQ z-scores. Columns 4-6 represent the adjusted associations of the same model. The control variables included are caregiver age, caregiver employed, number of children, child sex, caregivers' education, marital status, household assets, and caregiver's stress level. Columns 4-6 also included the study arm and country as controls. ***p<0.01, **p<0.05, *p<0.1.

Note: [a] scores were standardized (z-score)

Table 3: Adjusted associations between domain-specific stimulation and child development (Rounds 1-3)

	Round 1	Round 2	Round 3
Cognitive stimulation	0.42***	-0.03	0.05
	(0.27 - 0.58)	(-0.16 - 0.09)	(-0.14 - 0.24)
Language stimulation	-0.05	0.33***	-0.04
	(-0.22 - 0.12)	(0.20 - 0.45)	(-0.19 - 0.11)
Socioemotional	0.27***	-0.11	0.12
	(0.14 - 0.41)	(-0.28 - 0.05)	(-0.09 - 0.33)
Motor stimulation	-0.11	0.10	0.17*
	(-0.29 - 0.06)	(-0.06 - 0.26)	(-0.02 - 0.36)
Constant	-0.90***	0.07	0.28
	(-1.43 - -0.37)	(-0.32 - 0.46)	(-0.23 - 0.79)
Observations	560	405	300

Each column represents the results of the linear regression model for the ASQ z-scores, with 95% confidence intervals. Columns represent the adjusted associations between the domain-specific stimulation with the ASQ z-scores. The control variables included are caregiver age, caregiver employed, number of children, child sex, caregivers' education, marital status, household assets, and caregiver's stress level. Further, the columns also included the study arm and country as controls. ***p<0.01, **p<0.05, *p<0.

The adjusted estimates for the associations between overall maternal stimulation activities for each of the rounds and ASQ domains are presented in **Table 4.** Across all rounds, the largest associations were observed for the personal social domain (0.39 SD; 95% CI [0.32 - 0.47]) while the smallest associations were observed for the gross motor domain (0.20 SD; [0.13 - 0.26]). The same was true for round one where we found the largest associations for the personal-social domain (0.68 SD; [0.55 - 0.82]). In Round 2, the largest associations were found for fine (0.21 SD; 95% CI [0.05 - 0.38]) and in round 3, the largest associations were found for

gross motor skills (0.32 SD; 95% CI [0.17 - 0.47]), although differences across domains appeared smaller in these two later rounds. **Fig 3** further compares average ASQ scores across wealth quintiles and rounds. In Zambia, developmental differences appear relatively small initially but then increase over time. In Kenya, developmental differences were rather large in round 1, decreased a bit in round 2, and then increased again in round 3.

Figure 3: Children ASQ scores by round and country comparing bottom and top quintiles

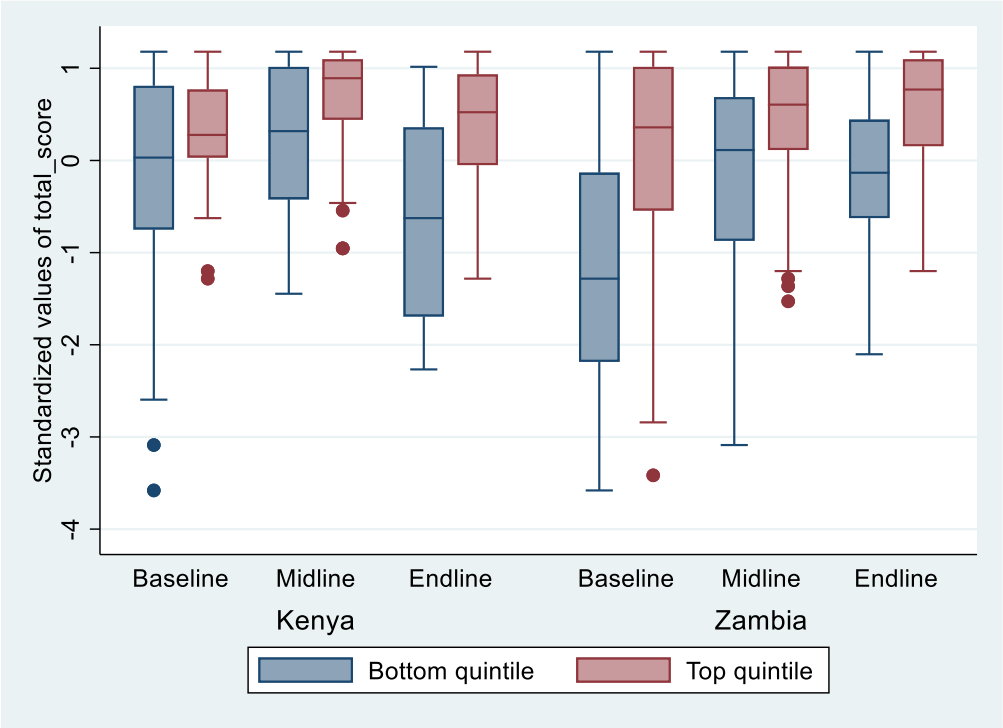


Table 4: Adjusted associations between maternal stimulation per round and individual ASQ domains

ASQ Domain:	Communication	Problem-solving	Fine-motor	Gross motor	Personal-social
Overall maternal stimulation	0.29***	0.28***	0.21***	0.20***	0.39***
	(0.22 - 0.36)	(0.22 - 0.35)	(0.14 - 0.27)	(0.13 - 0.26)	(0.32 - 0.47)
Constant	-0.13	-0.20	0.01	0.05	-0.16
	(-0.46 - 0.19)	(-0.54 - 0.13)	(-0.31 - 0.33)	(-0.27 - 0.38)	(-0.50 - 0.18)
Observations	1,367	1,367	1,367	1,367	1,367
Maternal stimulation round 1	0.36***	0.34***	0.38***	0.40***	0.68***
	(0.23 - 0.49)	(0.21 - 0.46)	(0.27 - 0.50)	(0.29 - 0.51)	(0.55 - 0.82)
Constant	-0.09	-0.29	0.41	0.12	0.05
	(-0.66 - 0.47)	(-0.85 - 0.27)	(-0.11 - 0.94)	(-0.39 - 0.63)	(-0.57 - 0.68)
Observations	560	560	560	560	560
Maternal stimulation round 2	0.17**	0.19**	0.21**	0.20**	0.10*
	(0.02 - 0.33)	(0.04 - 0.34)	(0.05 - 0.38)	(0.03 - 0.37)	(-0.02 - 0.22)

Constant	0.09	0.22	-0.16	0.03	0.15
	(-0.45 - 0.63)	(-0.36 - 0.79)	(-0.70 - 0.39)	(-0.53 - 0.59)	(-0.31 - 0.60)
Observations	405	405	405	405	405
Maternal stimulation round 3	0.27***	0.17**	0.16**	0.32***	0.24***
	(0.14 - 0.41)	(0.02 - 0.32)	(0.00 - 0.32)	(0.17 - 0.47)	(0.09 - 0.40)
Constant	-0.05	-0.16	0.10	-0.07	-0.23
	(-0.59 - 0.50)	(-0.73 - 0.42)	(-0.55 - 0.75)	(-0.57 - 0.44)	(-0.80 - 0.34)
Observations	300	300	300	300	300

Discussion

This study investigated the associations between maternal stimulation activities and the developmental outcomes of children in rural Kenya and Zambia. Our results indicate that maternal stimulation activities show on average strong positive associations with the overall development of children in these two countries, with the strongest associations in the first round, when children were on average only 9 to 10 months old. Results on the relative importance of domain-specific stimulating activities appear more mixed, with cognitive and socioemotional activities being most predictive of developmental outcomes in round 1, language activities being most predictive in round 2, and motor activities being most predictive of outcomes in round 3. Overall, this suggests that the exact type of activity is potentially less important than the engagement of caregivers per se, which is in line with the broader nurturing care framework (27, 28).

Consistent with other studies, our findings suggest that exposing children to early stimulation activities such as reading, talking, and singing have the potential to improve the acquisition of language and cognitive skills (29), which can contribute to their school readiness and later academic achievements. Acquisition of cognitive abilities, which is one of the most important capabilities of children, and is also to language development (30), also appears to be closely linked to stimulation activities. The links between cognitive development and maternal stimulation have been studied extensively (16). The finding contributes to the understanding that early exposure to telling stories, talking, playing, or naming objects improves children's cognitive abilities; which form the basis for later academic outcomes. In addition, our finding that related motor development and maternal stimulation at an early age corroborates earlier findings (14) linking the acquisition of gross and fine motor skills are associated with home stimulation. The finding on motor stimulation agrees with earlier findings that stimulating activities such as kicking the ball, jumping, dancing, and picking up small objects are relevant

for the achievement of motor skills. According to our study, maternal activities such as a hug, kiss, or speaking warmly to the child have been associated with the development of social and emotional capabilities. These findings support previous research that have shown that children acquire social and emotional skills when they are exposed to a warm and responsive environment (31). The results of our study suggest that increasing caregiver-child interactions could be an effective tool to enhance the development of children living in disadvantaged settings such as rural areas. Policymakers and program implementers should therefore focus on the parenting programs that aim to improve caregivers' stimulation knowledge and practices to best support children's developmental outcomes.

The study presented several limitations. While we were able to follow children's development over time, our measures of child development exclusively relied on the primary caregiver's self-report and thus be subject to social desirability and reporting bias. In addition, there are a limited amount of activities in each of the domains studied, which limited our ability to estimate domain-specific activity effects. . There was also a fair amount of attrition over time, which reduced the power of this study. Finally, the study adopted the cross-sectional analysis that may lead to confounding. We adjusted for an extensive number of covariates, but of course, cannot rule out residual confounding.

Overall, this study shows rather large positive short-term associations between caregiver-child interactions and child development. Long-term follow-up studies will be needed to understand the long-term effect of this behavior on the later schooling trajectories, academic achievements, and labor outcomes.

Conclusion

This study suggests large positive links between maternal stimulation activities and children's developmental outcomes in poor rural settings. Many of the activities relevant for children under age 3 are relatively easy to do, require only minimal materials, and are also not too much

time from caregivers. Programs encouraging such caregiver-child interactions may help provide children with the nurturing care and stimulation they need in early life.

Acknowledgment

We would like to acknowledge and thank the evaluation team from the African Population and Health Research Center (APHRC) who conducted the main study for allowing us to use part of the data and for their support during the analysis of the data. We would also like to thank the Episcopal Relief & Development team together with their development partners Zambia Anglian council and ADS-Nyanza for facilitating the study and cooperation throughout the study period. Also, we thank the department of health in Nyando sub-County and the Ministry of Health Chisamba district office for supporting the study. Finally, we also thank all the children and their caregivers who agreed to participate in the study.

Author contributions

Silas Onyango - Questionnaire development, data collection, manuscript concept, manuscript writing, statistical analysis, discussion, corresponding author. **Patricia Kitsao-Wekulo** - Project manager, data collection, questionnaire development, data collection, manuscript concept, manuscript writing, discussion. **Nelson Langat** - Data collection, data recapitulation, manuscript concept, statistical analysis. **Kenneth Okelo** - Questionnaire development data collection data recapitulation, manuscript writing. **Dawn Murdock** – Questionnaire development, data recapitulation, discussion. **Jürg Utzinger**- Manuscript concept, manuscript writing, discussion. **Günther Fink**- Statistical analysis, theoretical framework, manuscript concept, manuscript writing discussion, overall guidance. All the authors read and approved the final manuscript.

Funding

Data used in this paper were collected as part of a quasi-experiential trial. The trial received funding from Conrad N. Hilton Foundation.

Availability of data

The datasets used in the current study are available from the corresponding author on request.

Declaration

Ethics approval and consent to participate

Ethics approval was obtained from Amref Health Africa's Ethics and Scientific Review Committee for Kenya. In addition, permission to conduct the study was first obtained from the National Commission for Science, Technology, and Innovation d (NACOSTI) and later from the Kisumu County Health management team before data collection. In Zambia, ethics approval was obtained from *ERES* Converge institutional review board (IRB) and also from the ministry of health. Written informed consent was sought and obtained from study participants before any data were collected. For respondents who could not read and write, a thumbprint was taken as a signature. Confidentiality of the data and the participants' privacy were respected at all times. Consenting was done at every round of data collection. Consent documents and interview guides were translated into Kiswahili (the national language) and Dholuo (the local language) while in Zambia, the documents were translated into four main Zambian languages (Bemba, Nyanja, Lozi, and Tonga).

Consent for publication

Not applicable

Competing interest

All the authors declare no conflict of interest

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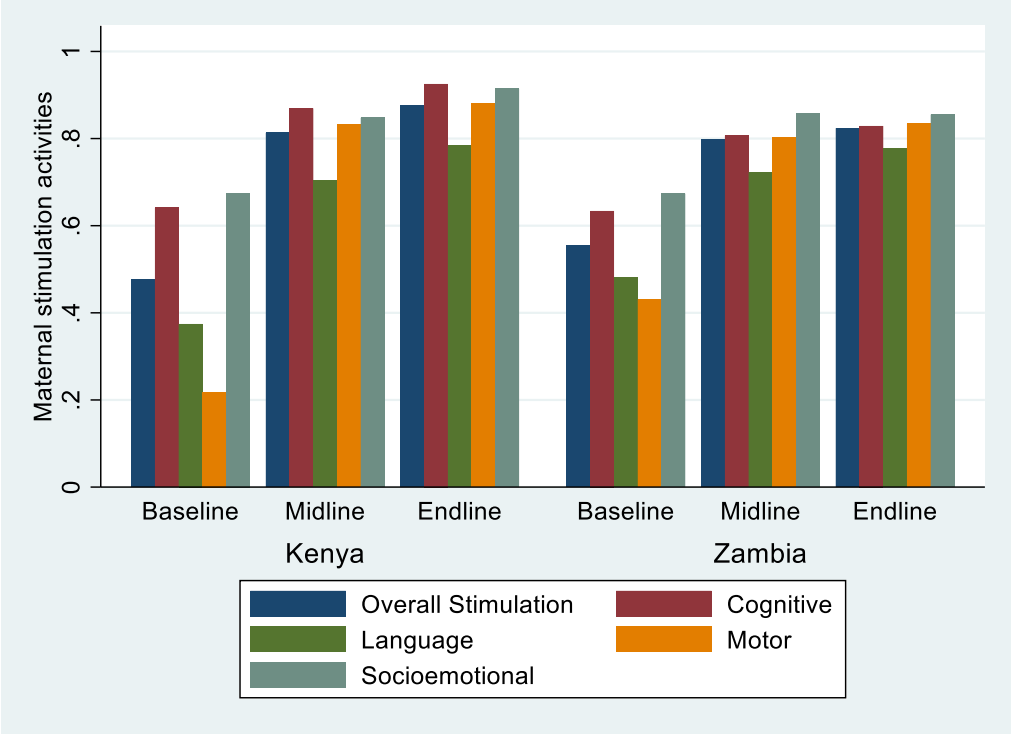
Appendices

Appendix 1: Maternal stimulation activities

Developmental Areas	Activities with Children
COGNITIVE (Intellectual)	▪ Provide play materials to the child, including household objects, outdoor objects, toys ▪ Spend time naming things or objects with the child ▪ Play counting games or count with the child ▪ Ask the child questions about what he or she is doing ▪ Take the child outside the compound or yard ▪ Play together
COMMUNICATION (Language)	▪ Sing with or to the child ▪ Tell stories to the child; encourage the child to tell stories ▪ Look at pictures or read books to the child ▪ Talk to the child while you are doing chores, and/or explain to the child what you are doing ▪ Talk with the child during meals or when feeding the child
MOTOR SKILLS – Fine and Gross)	▪ Provide small objects for picking up ▪ Provide material for the child to draw with ▪ Encourage the child to run, dance, jump ▪ Encourage the child to kick or throw balls

SOCIAL- EMOTIONAL	▪ Encourage the child to play with siblings, other children, or family members ▪ Take the child to activities outside the home, such as community or church events ▪ Ask the child to help do simple chores appropriate to their age ▪ Sit with the child during the main meal of the day ▪ Teach about religious or spiritual practices ▪ Hug or kiss the child ▪ Pick up and hold the baby or child when she or he is crying ▪ Carry and hold the baby ▪ Speak to the child in a warm, positive tone of voice ▪ Praise the child for her or his accomplishments ▪ Comfort the child after she or he gets hurt or scared ▪ Feed the child or assist him or her to eat

Appendix 2: Maternal stimulation activities by round and country



Chapter 6: Relative importance of early childhood development domains for schooling progression: Longitudinal evidence from the Zambian Early Childhood Development Project

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This paper has been published in **International Journal of Educational Development** 30 June 2021

https://doi.org/10.1080/03004430.2021.188539, Elsevier, vol. 85(C)

Abstract

While the effects of early childhood development on later educational outcomes have been widely studied in western countries, rigorous evidence from sub-Saharan African countries is limited. This longitudinal study uses domains of Zambian children's development at age six as predictors of educational enrollment and attainment at age 15. Fine motor, receptive language, and early literacy skills were most strongly associated with on-track enrollment. Fine motor skills were most predictive of enrollment. Cognitive, socio-emotional, and executive functioning skills predicted grade repetition. Overall, the results suggest substantial

heterogeneity in the associations between domains of early childhood development and adolescent schooling outcomes.

Keywords: Early childhood development, grade repetition, dropout, enrollment, school attainment, adolescent

Introduction

During the early childhood period, young children acquire a set of complex skills and functional competencies that determine their later schooling progression and academic achievement (1-3). The pace and sequence at which these skills and competencies are acquired are dependent on children's early environments. Early adversity can undermine children's physical, cognitive, and socio-emotional development, and shape later academic achievement (4). Lack of adequate nutrition, lack of psychological stimulation at home, and lack of responsive caregiving have been highlighted in the literature as primary risk factors for healthy development (5, 6).

Children's early development is complex and multidimensional; several domains of early development have been linked to children's social integration, schooling attainment, and career outcomes (7-9). For instance, early gross motor skills are essential for manipulating environments and for gaining early exposure to different experiences. Fine motor skills are essential for daily living activities such as feeding, playing, and dressing but are also linked to constructs such as eye-hand coordination, which is critical for writing and reading skills (10, 11). Well-developed writing skills can improve children's reading (12), comprehension, and can help children connect with what they read, know, and understand (13, 14).

Early acquisition of language skills influences the acquisition of other essential skills, the formation of concepts as well as social interactions with peers and teachers (15). Both receptive and expressive language skills are essential for children's interaction with their environment and participation in schooling activities (15). Social and emotional skills - which comprise

children's ability to understand and regulate emotions, show compassion, and maintain healthy relationships – form the basis for all learning-related activities (16). Antisocial behaviors such as withdrawal or aggression have been linked to poor academic performance, grade retention, and higher dropout rates (16-18). The ability to control attention, emotions as well as complete multiple tasks has also been shown to be a good predictor of academic performance in children (19-23). Last, and maybe most obviously, non-verbal intelligence can be detected early in the child's life and can have a profound influence on the motor, social, and communication skills that are essential for children's schooling outcomes (24-27).

Several factors have been linked to the development and acquisition of key domains in children. These factors include maternal education, maternal age, employment, and household wealth index, among others (28-31). Existing evidence suggests that these factors positively influence the association between early development in children's domains and their later schooling progression (32). Also, child-level factors such as child's age, sex, early exposure to early childhood development programs, and early enrolment are important factors for the development of skills in these domains (33-36).

Conceptually, all domains of children's early development have the potential to impact children's educational careers, social life, and general wellbeing. However, the relative importance of these domains for children's longer-term success in low-resourced schooling systems remains understudied in countries in sub-Saharan Africa (SSA). The current paper aims to contribute to this growing area of research using recently collected longitudinal data from the Zambia Early Childhood Development Project (ZECDP). The ZECDP was launched in Zambia in 2010 to determine the effect of the early childhood environment, health, and education on children's development before and throughout their academic progression (37).

Background and Context

Globally, about 17% of school-age children and adolescents were out of school in 2018; nearly 30% of these children live in SSA (38). Dropping out of school, which has been linked to increased risk of criminal behavior, reduced economic potential, increased prevalence of illiteracy, and poor health outcomes, has profound social and economic effects for children, their families, and the larger community (39-42). A range of strategies has been explored to reduce dropout and grade repetition rates in developing countries, including encouraging parental involvement in their children's academics, improving school efficiency, and enacting policies that enhance compulsory education (43, 44). Empirically, grade repetition and school dropout appear closely linked (45, 46). While repeating grades would ideally allow weaker students to catch up and master learning materials, children who repeat grades have been found to have lower self-esteem, poor peer relationships, and negative attitudes towards school, all contributing to an increased risk of dropping out of school (43, 44, 47).

In many low-and middle-income countries, education holds a central position in national agendas. In Zambia, for example, the national *Vision 2030* plan views education as a key strategy towards improving the country's social and economic development (48). School dropout and grade repetition pose major challenges to the country. In 2016, grade repetition was 6.7% for grades 1-7 and 1.6% for grades 8-12 with a national completion rate of 77% to grade 9 and 36% to grade 12 (49). With a per capita income of US$ 1305 in 2019 (50), Zambia remains one of the poorest countries in SSA. Zambia's population was 18.2 million in 2019 (51), with about two-thirds living in rural areas (52). Only 6% of women and 8% of men ages 15-49 have higher education and one-third of women and 18% of men were illiterate in 2017 (52). Early sexual debut, teenage pregnancies, sexual abuse, early marriages, poverty, and child labor have been identified as key risk factors for low school retention in Zambia (53).

To assess how each of the developmental domains influences schooling outcomes in the Zambian context, the project team created a locally designed child assessment tool, the Zambia Child Assessment Test (ZamCAT) (37). After two rounds of piloting and tool adjustments, the first representative assessment of children was conducted between July and December 2010 (37). A total of 1686 5- and 6-year old children in six Zambian provinces (Copperbelt, Eastern, Luapula, Lusaka, Southern, and Western) was assessed in 2010. In 2019, we conducted a follow-up study to assess the schooling progression of a subsample of these children and to link their academic progress to their development before school entry.

Materials and Methods

Study design and site

The current study used an observational prospective cohort design. Data analyzed in this paper were collected in Zambia's Lusaka, Luapula, and Eastern provinces (**Figure 1**). These three provinces are representative of the extreme ends of the regional distribution. Lusaka is the capital area of the country, almost exclusively urban and relatively wealthy. In 2018, Luapula and Eastern provinces were among the poorest areas of the country, with child poverty rates of 84% and 79.9% respectively (54). Eastern and Luapula also have the highest proportion (78 and 72% respectively) of females who have not completed their primary education. The proportion of men who have not completed primary education was 70%, 63%, and 40% in Eastern, Luapula, and Lusaka provinces, respectively (52).

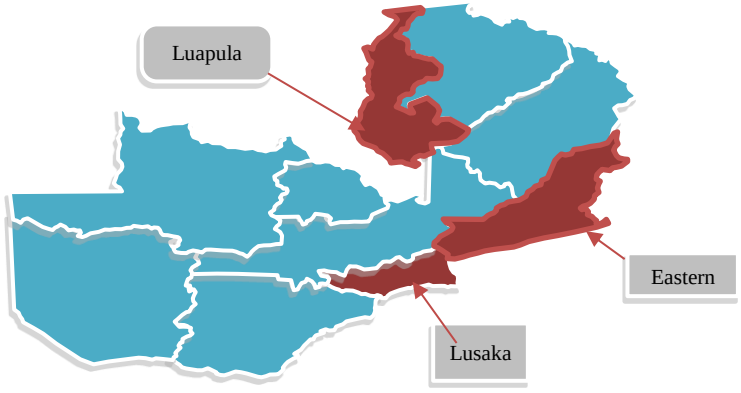

Figure 1: A map of Zambia showing the location of the study regions

Sample and study procedures

A two-stage cluster random sampling approach was employed for the recruitment of children in 2010. In the first stage, 82 enumeration areas (clusters) from the 2000 Zambia census were randomly selected for the study. In the second stage, all children born in 2004 in these clusters were listed and up to 25 children in each cluster enrolled in the study. If there were fewer than 25 children in each cluster, all eligible children were assessed; if more than 25 lived in a cluster, a randomization process was used to select the 25 participants. Out of the original 1686 5- and 6-year old children assessed in 2010, 686 children assessed in Eastern (139), Luapula (202), and Lusaka (345) provinces were targeted by the follow-up study conducted in 2019. We finally interviewed a total of 333 children (Eastern 117, Luapula 109, and Lusaka 107), which constitutes 48.5% of the 2010 participants in the sampled clusters. The remainder could not be located (N = 282), two children had died, and 69 parents did not consent to participate in the follow-up study. Adolescents living in the informal settlement areas in Lusaka and those from rural clusters that had dropped out of school and moved to the cities to look for jobs were more difficult to trace, and thus less likely to be part of the sample.

For the follow-up study, we designed a questionnaire that captured information on demographic and socio-economic variables, relative household wealth, risk behaviors, household shocks, personality, and plans after high school. Some of the items included in the questionnaire were adapted from questionnaires that have been validated and used in other settings (55, 56). For example, questions on demographics, education background, and household shock were adapted from the Multiple Indicator Cluster Survey (MICS) used in Zimbabwe (56). A language adaptation procedure was followed in translating the questionnaire from English to the local languages (Bemba, Nyanja, Tonga, and Lozi). This was meant to ensure that the conceptual integrity of the original items was retained in the translation. Qualified data collectors with at

least a bachelor's degree were recruited and trained by Innovations for Poverty Action (IPA) Zambia to track the children and conduct the interviews. To track children in each cluster, we used information that was collected in 2010 including children's and parents' names as well as parents' phone numbers. We contacted parents via phone to make an appointment with the child ahead of the actual interview. Where this was not possible, we contacted headteachers of all the schools in the study area to help find respondents. Village headmen also directly supported the tracing of the children.

All assessments were conducted in one of the four main Zambian local languages (Bemba, Nyanja, Tonga, and Lozi) unless caregivers or children indicated a preference for conducting the interviews and assessments in English.

Variables

Predictor Variables

We assessed seven developmental domains that were measured in 2010 (37): executive functioning, non-verbal cognitive skills, early literacy, receptive and expressive language, fine motor skills, socio-emotional skills, and task orientation. Between 2009 and 2010, a detailed tool to assess children's development was developed by a local team and validated through two rounds of piloting (37). The final ZaMCAT instruments were adapted to the four main Zambian languages (Bemba, Nyanja, Tonga, and Lozi). We have provided a summary of the measures used in the section that follows. Additional information on the translation, validation, and use of the assessment tools is provided elsewhere (37).

Executive functioning

Executive functioning entails the ability of the child to control impulses, regulate emotions, stay focused, and sustain attention. We assessed two domains of executive function in 2010: attention and delayed gratification. Attention was measured using the Pencil Tapping Test

(PTT) (37, 57). The PTT assessment assesses children's ability to comply with simple tapping rules in the absence and presence of distracting tasks. The ability of the children to delay gratification was tested using an adapted version of the marshmallow test (58). Specifically, the assessor offered the child candy at the beginning of the caregiver interview, which took 20 to 30 minutes. The assessor instructed the child that they would get a second piece of candy if they could hold onto the first piece of candy until the interview with the caregiver was completed. Both PPT and the marshmallow test have been validated and used to assess children in other similar settings (59, 60).

Non-verbal cognitive skills

To assess children's non-verbal cognitive skills, tactile pattern reasoning (TPR), as well as a standard NEPSY Block Test (61) were administered to children. In the 10-item TPR, sequences of objects similar to those found in Kaufman's battery were displayed (62), and children were asked to identify the next object in the sequence (for example, an ABAB_ pattern). The impetus for the development of the TPR was to avoid two-dimensional stimuli that some children in Zambia, many of whom did not have books in the home, found difficult to engage with. Children also completed a standard block test in which they were asked to replicate (build) structures such as towers or basic buildings shown on a paper diagram (37). The test measures children's ability to capture, analyze, and replicate abstract forms.

Early literacy and reading skills

To assess children's early literacy and reading skills, Letter Naming (LN) and Rapid Automatized Naming (RAN) (63) were used. RAN is a predictor of reading skills in children (64, 65). During this assessment, children were asked by the assessor to name a sequence of familiar objects as fast as possible. In the LN task, children were given a piece of paper

containing all 26 letters of the alphabet in random order and asked to identify as many of the letters as possible within two minutes.

Receptive and expressive language

Children's receptive language skills were assessed using a locally developed Picture Vocabulary Test (PVT) (66). Similar approaches have been used in other sub-Saharan African countries, including Kenya, to examine differences in vocabulary development (67). The PVT was developed locally, in collaboration with native speakers of each of the four main Zambian languages. The development team reviewed existing picture vocabulary tests and conducted content validity and cultural relevance analyses. Initial word lists and illustrations were developed and tested across the languages, with dropping items that did not perform equally well across languages being dropped. The four language versions of the PVT were piloted in two rounds prior to use in the baseline data collection, with adjustments made to ensure adequate difficulty. In this 30-item assessment, children were presented with a sequence of spoken words and then asked to match each word to one of the four displayed pictures by either touching or pointing to the matching image (44). This assessment was developed for use in Zambia's four most widely spoken languages. To assess children's expressive language skills, the assessors asked the children to tell a story about something they liked. The assessor then scored these stories from 0 (non-response) to 5 (strong response) based on the length, complexity, and grammatical correctness of the response.

Fine Motor

Fine motor skills relate to children's ability to effectively carry out tasks involving smaller objects, such as holding and using pencils and chalk. As part of the fine motor assessment, children were asked to copy letters, numbers, and shapes such as triangles on a piece of paper. Children were also asked to complete locally and culturally appropriate tasks such as beading, tying shoelaces, unbuttoning and buttoning of shirts, and playing traditional games.

Socio-Emotional development

Parents were asked 20 questions describing the overall behavior of their children. For each question, the parent or caregiver was asked to indicate whether or not the child displayed specific behavior on a rating scale as follows: "never", "sometimes", "usually" or "always". To generate a score, a linear scale was applied, assigning 0-3 points for each item.

Task orientation

Task orientation scores have been shown to predict cognitive, executive, and socio-emotional outcomes in previous studies (68). For task orientation, assessors rated the child's compliance with directives, attention level, behavior, and concentration on a given activity during the assessment.

Outcome Variables

The current study used three measures of schooling progression assessed in 2019 as outcome variables: being on track in terms of current grade attainment (on-track enrollment), current school enrollment (child still in school), and grade repetition (if any). On-track enrollment was defined as a child having reached secondary schooling in 2019. According to official guidelines, children in Zambia are supposed to enter primary school at age seven and to progress to secondary school after having completed seven years of primary school, i.e. when they are 13. Given that all children in the sample were born in 2004, they should have entered school in January 2011 and completed primary school at the end of 2017. We allowed for one extra year and still classified children as being on track if they had just entered secondary school in 2019 as it is common for children in Zambia to begin their primary schooling at age seven. All children who were no longer in school were included in the category of those, not on track.

Current school enrollment was defined as the child still being in school in 2019, independent of the grade attained. For grade repetition, children were asked to state whether they had ever repeated a grade independent of their current enrollment.

Covariates

Children's sex, mother's age, mother's education, household wealth quintile, exposure to early childhood care and education (ECCE), and early school entry variables were included as potential confounders that could affect the association between the ECD domains and schooling progression. For maternal education (primary education or less and secondary education or higher), we separated primary from secondary and higher educational attainment. The wealth quintile was measured by a household asset scale. Assets such as radio, cellphones, bike, stove, private sanitation, shoes for the child, bed for the child, and piped water were included in the principal component analysis. The predicted value of the first principal component was then used to divide households into wealth quintiles.

Statistical Methods

We began our analysis with a basic description of the cohort, including descriptive statistics for all variables of interest. We then used logistic regression models to estimate the associations between individual ECD domains and schooling progression. In the first step, we regressed all three schooling outcomes (current enrollment, being on track, and grade repetition) on each domain separately. In the second step, we estimated multivariable regression models adjusting the estimated association for maternal education early school enrollment, exposure to ECCE, and child sex that may confound the observed (unadjusted) associations. In the last step, we ran forward and backward selection models to determine the most predictive variables. In both forward and backward selection models, variables were kept in the model at each step as long as their *p*-values were < 0.1. All missing predictor variables were imputed using multiple imputations by chained equations (MICE) (69). All statistical analyses were conducted in Stata version 16. Associations were considered statistically significant at $p < 0.05$.

Results

Descriptive statistics for the full sample are presented in **Table 1.** The average age of mothers in our sample was 25 years. As expected, families in Lusaka were substantially wealthier than those in Luapula and Eastern Provinces, with mean wealth quintile scores of 3.36, 2.06, and 2.26, respectively. On average, 43% of the children were on track in terms of grade attainment (**Figure 2**). The proportion of children on track was lowest among males in Eastern (53%) and highest among males in Lusaka (above 90%). On average, gender differences in being on track in terms of grade attainment were small, with a noticeable male advantage only in Lusaka.

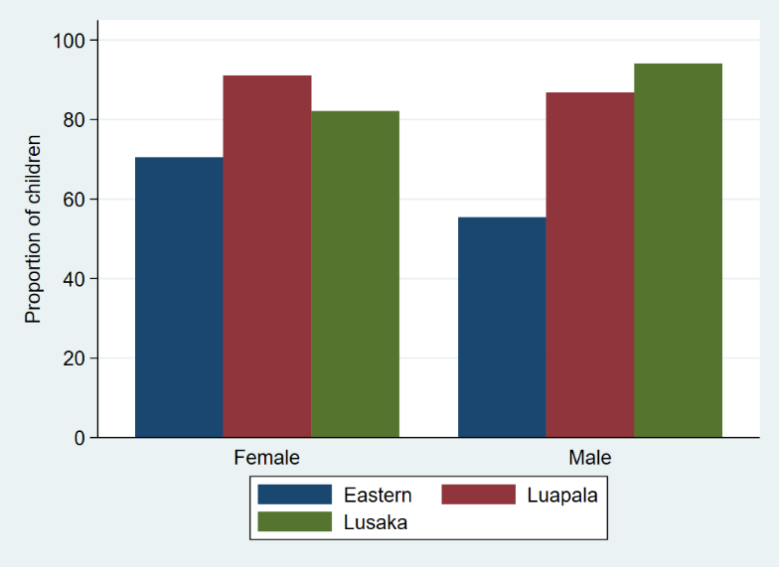

Figure 2: Proportion of children on track of grade attainment

Overall, 80% of the children interviewed were still in school. As shown in **Figure 3**, enrollment rates were highest among males in Lusaka and females in Luapula (94% and 91%, respectively), and lowest among males (55%) in Eastern province.

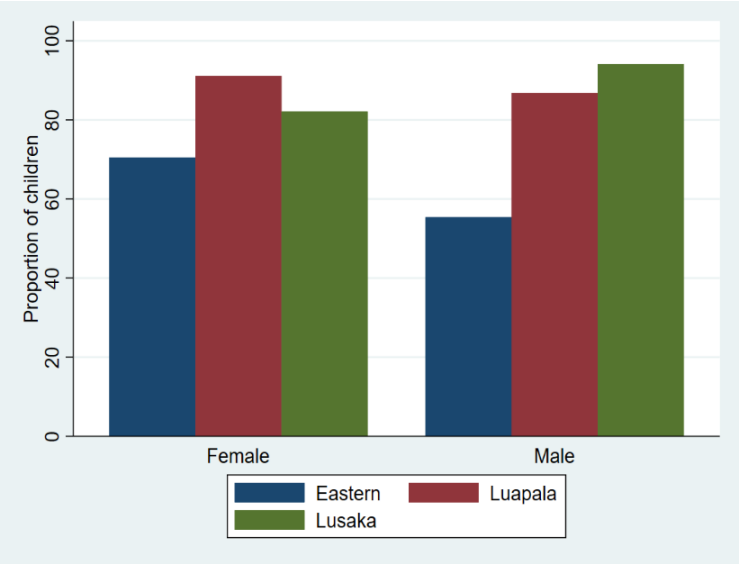

Figure 3: Enrollment status per province

Overall, 32% of the children interviewed had repeated at least one grade by 2019. As **Figure 4** shows, 43% percent of females and 40% of males in Luapula had repeated a grade. Grade repetition was least common in Lusaka, where 21% of females and about 30% of males had repeated a grade.

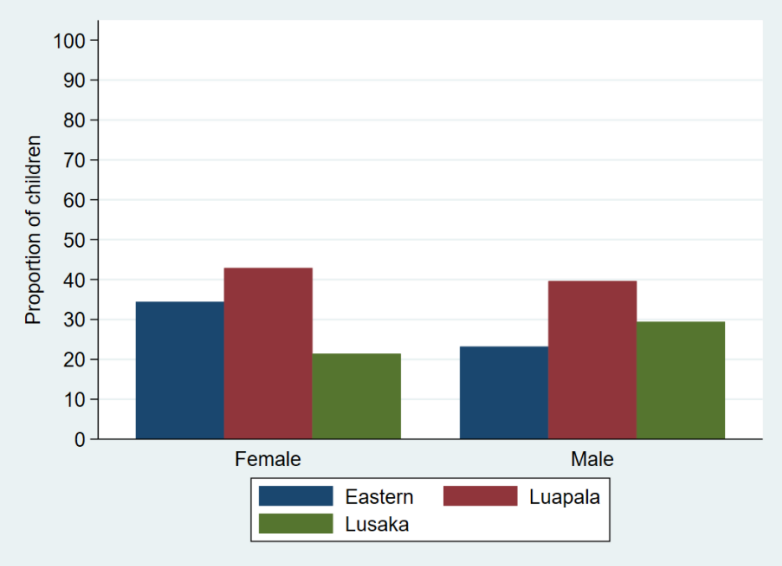

Figure 4: Grade repetition per province

Table 2 presents unadjusted associations between schooling progression and domain-specific ECD measures. The strongest associations were found between on track enrollment and fine motor (OR 1.86; 95% CI 1.36 - 2.53) as well as the picture vocabulary task (OR 1.39; 95% CI 1.03 - 1.87). A 1-unit SD increase in fine motor skills and picture vocabulary scores was

associated with an 86% and 39% increase in the odds of being on track, respectively. For school enrollment, an association was found for the fine motor (OR 1.37; 95% CI 0.97 - 1.93) and early literacy (OR 1.60; 95% CI 1.01 - 2.51) domains. Each standard deviation increase in fine motor and early literacy was associated with a 37% and 60% increase in the odds of the child still being in school, respectively. Socio-emotional (OR 0.63; 95% CI 0.48 - 0.82), and tactile patterns (OR 0.68; 95% CI 0.49 - 0.92) showed protective associations with grade repetition, while attention was associated with an increased risk of grade repetition (OR 1.57; 95% CI 1.20 - 2.06).

Appendix 1 -3, shows models where each predictor is tested separately conditional on a full set of covariates. **Table 3** shows our main multivariable results. Columns 1-3 show the results of models including all predictor variables. Columns 4-6 and columns 7-9 show the same results using forward and backward selection models. Across all models, fine motor (OR 1.79; 95% CI 1.36 - 2.38) and early literacy skills (OR 1.28; 95% CI 0.98 - 1.66) displayed the strongest associations with on-track enrollment. Fine motor skills were found to be predictive of school enrollment (OR 1.34; 95% CI 0.97 - 1.85). A larger number of variables appeared predictive for grade repetition. Higher socio-emotional (OR 0.63; 95% CI 0.48 - 0.82) and tactile pattern recognition scores (OR 0.69; 95% CI 0.52 - 0.92) were found to be associated with lower odds of grade repetition, while poor attention scores were associated with increased odds of grade repetition (OR 1.54; 95% CI 1.18 - 2.01).

Discussion

In the current paper, we used prospectively collected data to assess the relative importance of multiple domains of early childhood development on adolescent schooling outcomes in Zambia. Our findings suggested substantial regional disparities in terms of enrolment and grade repetition. This finding corroborates previous evidence from Zambia and other similar settings that suggest higher educational attainment as well as lower dropout and grade repetition rates

for children in urban areas compared to their counterparts in rural areas (70-72). Overall, we found early fine motor skills to be most predictive of on-track enrollment. Early development in fine motor skills has been linked to positive outcomes in kindergarten (73-75) and has also been shown to be predictive of formal schooling (10) and mathematics scores (11) in other settings.

We also found positive, even if somewhat less consistent links between receptive language skills and on-track enrollment. These findings are consistent with other studies (76, 77) linking early language skills to schooling outcomes. We also found some positive associations between early literacy and on-track enrollment. Given that our fine motor scale also included some letter copying tasks, all three main predictors of on-track enrollment could be interpreted as measures of school readiness, i.e. as evidence for school preparedness is essential for staying on track in the Zambian school system. Interestingly, we found very little evidence that cognition or executive functioning predicted school progression, which suggests that basic vocabulary and literacy appear to dominate children's behavioral and other cognitive traits in this setting.

Grade repetition appeared to be more directly affected by other domains. The protective associations with socio-emotional behavior seen in this study are consistent with the previous literature (18), and the same holds for children's cognitive skills (78). Results are more surprising for children's attention. Earlier studies have found that executive functioning is the foundation for reading acquisition (79), improves social adjustment and academic achievement (80), and is a predictor of math and reading achievement at kindergarten (20, 81). We found that children performing better on the pencil tapping task on average faced a higher risk of grade repetition. Further research is needed to better understand the links between children's ability to focus attention and the risk of grade repetition in this setting.

Even though the current study is the first attempt, in our knowledge, to estimate the relationship between multiple domains of early childhood development and schooling outcomes in sub-

Saharan Africa using a prospective longitudinal design, it is important to note its limitations. First, as the study was conducted in three provinces in Zambia with only a subset of the original 2010 sample interviewed in 2019, it may not be appropriate to generalize these results to other provinces in Zambia and other countries in SSA. Second, although our analyses controlled for early school entry and exposure to early childhood experiences along with other background characteristics, there may be other critical variables that were not measured and therefore not accounted for in our models. Third, our outcome measures relied on the responses provided by the adolescents and may not have been fully accurate. Ideally, these responses should have been validated through school registers or reports, but this was not possible within the constraints of this study. Fourth, we note that the fine motor skills task included items asking children to copy letters and numbers presented to them, meaning that there may have been some conceptual overlap with early literacy skills. Fifth, during the follow-up, we could not locate many of the participants, particularly those living in urban clusters at baseline. While it was clear that children who were not located were predominantly from urban areas, our data do not allow us to directly assess the extent to which differential follow-up rates affected the main study results. Finally, there could be services or support that schools and communities may provide to children; these interventions may influence the enrollment and academic achievements of these children. Even though our analysis controlled for other covariates, it may be possible that such interventions could have biased our findings either positively or negatively.

The results presented in this study suggest less than half of children in Zambia remain on track with respect to their educational attainment at age 15 and that about 20 percent have already dropped out of school. These numbers are disconcerting; efforts should not only be made to ensure universal access to preschool and primary education, but also to support primary and secondary school enrollment more generally. Our findings indicate that the early life of a child may have profound impacts on later schooling outcomes, and therefore support broader access to early (prior to primary school entry) learning opportunities. While such learning

opportunities may in some cases be offered at home, universal access to at least one year of kindergarten will likely be the most effective way to reduce inequalities in school readiness in the long run.

Conclusion

The results presented in this paper suggest that early literacy and early childhood fine motor skills are most predictive of positive adolescent schooling outcomes in Zambia. Efforts to enhance the early acquisition of these particular skills as well as efforts to improve school readiness more broadly have the potential to substantially improve educational outcomes and to reduce regional disparities in the long run.

Acknowledgments

We would like to thank the original ZECDP team as well as the IPA Zambia team for all their hard work during the data collections in 2010 and 2019. We would also want to thank the heads of schools and community leadership for supporting the tracing of the children and permission to work in the schools and the community. Finally, we would want to thank all the children and their caregivers who agreed to participate in this follow-up.

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Table 1: Total number, mean, SD, and percentages of all ECD measures and covariates per province that were included in the analysis. (N=333)

	EASTERN (N=117)			LUAPULA (N=109)			LUSAKA (N=107)		
VARIABLES	**N**	**M or %**	**SD**	**N**	**M or %**	**SD**	**N**	**M or %**	**SD**
Wealth quintile (Mean, SD)	117	2.26	1.1	109	2.06	1.25	107	3.36	1.33
Mother age (Mean, SD)	108	26.12	7.16	87	26.71	6.73	79	25.41	6.46
Picture vocabulary test[a)] (Mean, SD)	117	-0.62	1.06	109	-0.01	1.03	107	0.17	0.95
Expressive language test [a)] (Mean, SD)	111	-0.2	1.08	102	-0.1	1.12	94	0.18	1
Tactile pattern reasoning test [a)] (Mean, SD)	117	-0.29	0.96	109	-0.31	0.93	107	0.06	1.09
Block test[a)] (Mean, SD)	117	-0.27	0.82	109	0.2	1.01	107	0.14	1.07
Pattern reasoning [a)] (Mean, SD)	117	-0.24	0.66	109	-0.06	0.9	107	0.29	1.45
Fine motor skills [a)] (Mean, SD)	117	-0.44	1.09	109	-0.14	1.07	107	0.16	0.88
Letter naming[a)] (Mean, SD)	106	-0.34	0.45	108	-0.15	0.9	107	0.42	1.42
Rapid automatized naming [a)] (Mean, SD)	111	0.1	0.87	108	0.23	0.64	96	-0.12	1.4
Social-emotional skills [a)] (Mean, SD)	115	0.18	1.09	109	0.23	0.95	107	0.31	0.84
Task orientation [a)] (Mean, SD)	115	0.05	1.07	108	0.25	0.77	106	0.13	0.78
Pencil tapping [a)] (Mean, SD)	117	-0.25	0.93	109	0.12	1.13	107	0.18	0.96
Delayed gratification [a)] (Mean, SD)	114	-1.03	0.06	105	-1.05	0.08	105	-1.06	0.09
Any ECCE (N %)	27	23.1		21	19.6		62	58.1	
In school 2010 (N %)	13	11.1		44	40.6		62	57.9	
Mother primary education (N %)	89	76.3		71	64.8		56	52.3	
Mother secondary or higher (N %)	9	7.5		35	31.8		46	43	
Child Female (N %)	61	52.1		56	51.4		56	52.3	

Notes: [a)] All test scores were normalized to mean zero and standard deviation 1 within the full 2010 sample.

Table 2: Unadjusted associations between ECD domains and schooling outcomes (N=333)

Outcome	On track	Enrolled	Repeat
Task Orientation	1.05	1.33	0.90
	(0.75 - 1.47)	(0.93 - 1.91)	(0.64 - 1.26)
Attention Test (AT)	0.97	1.12	1.57***
	(0.75 - 1.25)	(0.82 - 1.54)	(1.20 - 2.06)
Delayed gratification (EF)	0.20	0.64	0.98
	(0.01 - 4.96)	(0.01 - 30.53)	(0.04 - 25.62)
Fine Motor	1.86***	1.37*	1.23
	(1.36 - 2.53)	(0.97 - 1.93)	(0.91 - 1.66)
Social-Emotional	1.24	1.19	0.63***
	(0.96 - 1.60)	(0.89 - 1.59)	(0.48 - 0.82)
NEPSY Block Test	0.82	0.89	0.98
	(0.62 - 1.09)	(0.63 - 1.26)	(0.73 - 1.31)
Tactile pattern reasoning	0.99	0.75	0.68**
	(0.74 - 1.34)	(0.52 - 1.07)	(0.49 - 0.92)
Picture Vocabulary Test	1.39**	1.14	0.98
	(1.03 - 1.87)	(0.83 - 1.57)	(0.73 - 1.31)
Expressive language	0.89	0.93	1.17

	(0.68 - 1.17)	(0.67 - 1.28)	(0.88 - 1.54)
Letter Naming	1.29*	1.60**	0.86
	(0.98 - 1.71)	(1.01 - 2.51)	(0.65 - 1.15)
RAN	0.77*	0.92	1.01
	(0.59 - 1.00)	(0.67 - 1.27)	(0.78 - 1.31)
Observations	333	333	333
ciEform in parentheses	*** p<0.01, ** p<0.05, * p<0.1		

Notes: Logistic regression model with odd ratios;
Statistics shown in parentheses are 95% confidence intervals for the unadjusted ECD measures

Table 3: Estimated associations conditional on other domains (N=333)

	All measures/domains included			Forward selection			Backward selection		
Outcome	On track	Enrolled	Repeat	On track	Enrolled	Repeat	On track	Enrolled	Repeat
Task Orientation	1.06 (0.72 - 1.56)	1.29 (0.85 - 1.96)	0.86 (0.60-1.22)						
Attention Test (AT)	0.83 (0.61 - 1.12)	0.92 (0.63 - 1.35)	1.53*** (1.14 - 2.06)			1.54*** (1.18 - 2.01)			1.54*** (1.18 - 2.01)
Delayed gratification (EF)	2.70 (0.06 - 114.95)	12.91 (0.13 - 1,328.76)	0.80 (0.02 - 27.05)						
Fine motor	1.83*** (1.29 - 2.61)	1.33 (0.89 - 1.98)	1.31 (0.95 - 1.80)	1.79*** (1.36 - 2.38)	1.34* (0.97 - 1.85)	1.20 (0.91 - 1.59)	1.78*** (1.30 - 2.43)	1.42** (1.04 - 1.93)	1.20 (0.91 - 1.59)
Social-emotional	1.19	1.21	0.61***			0.63***			0.63***

			(0.46 -					
	(0.90 - 1.59)	(0.87 - 1.67)	0.81)			(0.48 - 0.82)		(0.48 - 0.82)
NEPSY Block								
Test	0.80	0.93	0.97				0.79	
			(0.71 -				(0.59 -	
	(0.58 - 1.10)	(0.64 - 1.36)	1.31)				1.07)	
Tactile pattern								
reasoning	1.04	0.87	0.72**			0.69**		0.69**
			(0.52 -					
	(0.73 - 1.48)	(0.58 - 1.29)	1.00)			(0.52 - 0.92)		(0.52 - 0.92)
Picture								
Vocabulary Test	1.33*	0.96	0.91				1.26	
			(0.66 -				(0.93 -	
	(0.95 - 1.87)	(0.65 - 1.42)	1.23)				1.71)	
Expressive								
language	0.88	0.97	1.20					
			(0.89 -					
	(0.65 - 1.18)	(0.67 - 1.39)	1.62)					
Letter Naming	1.28	1.52	0.87	1.28*	1.44		1.22	
			(0.64 -	(0.98 -			(0.92 -	
	(0.93 - 1.76)	(0.89 - 2.59)	1.19)	1.66)	(0.92 - 2.25)		1.60)	

Rapid Automatized Naming	0.86 (0.63 - 1.17)	1.03 (0.72 - 1.48)	0.95 (0.71 - 1.25)						
Observations	333	333	333	333	333	333	333	333	333

Notes: All models control for household wealth quintile, child sex, mother educational attainment level, mother age, region, and exposure to ECCE as well as early enrolment**.**

We used logistic regression model. Statistics shown in parentheses are 95% confidence intervals. The asterisks (*** p<0.01, ** p<0.05, * p<0.1) denote

Statistical significance level with *** highly significant and * show some levels of association.

Columns 1-3 show estimated associations when all covariates are included.

Columns 4-6 show the results of a forward selection search process.

Columns 7-9 show the results of a matching backward selection search.

Appendices

Appendix 1: Adjusted associations between the child being on track 2019 and domain-specific development in 2010 (N=333)

	Model 1	Model 2	Model 3	Model 4	Model 5
Wealth Quintile	1.85***	1.75***	1.77***	1.81***	1.83***
	(1.47 - 2.33)	(1.40 - 2.19)	(1.41 - 2.21)	(1.45 - 2.28)	(1.45 - 2.31)
Child female	0.93	0.96	0.96	0.96	0.96
	(0.55 - 1.57)	(0.58 - 1.59)	(0.58 - 1.58)	(0.58 - 1.60)	(0.57 - 1.62)
Mothers' primary Education	3.18*	2.71	2.48	3.72*	3.09
	(0.83 - 12.27)	(0.77 - 9.58)	(0.71 - 8.75)	(0.98 - 14.15)	(0.80 - 12.00)
Mother's Secondary or higher	4.56**	4.25**	3.99**	5.55**	4.20*
	(1.05 - 19.79)	(1.069 - 16.88)	(1.006 - 15.86)	(1.30 - 23.76)	(0.97 - 18.13)
Mothers age	1.00	1.00	1.00	1.00	0.99
	(0.96 - 1.04)	(0.96 - 1.05)	(0.96 - 1.05)	(0.96 - 1.05)	(0.95 - 1.03)
Eastern Region	0.87	0.78	0.77	0.84	1.11
	(0.42 - 1.80)	(0.39 - 1.57)	(0.38 - 1.56)	(0.41 - 1.72)	(0.53 - 2.33)
Luapula Region	1.29	1.23	1.19	1.35	1.51
	(0.64 - 2.62)	(0.62 - 2.44)	(0.60 - 2.37)	(0.67 - 2.73)	(0.74 - 3.12)
Exposure to ECCE 2010	0.80	1.19	1.23	1.13	1.16
	(0.35 - 1.83)	(0.55 - 2.57)	(0.57 - 2.69)	(0.51 - 2.47)	(0.52 - 2.58)
Early Enrollment	2.42**	2.48**	2.34**	2.35**	2.21**

	(1.10 - 5.34)	(1.16 - 5.29)	(1.05 - 5.20)	(1.10 - 5.01)	(1.00 - 4.90)
Task Orientation			1.26		
			(0.92 - 1.73)		
Attention Test (AT)			1.03		
			(0.79 - 1.34)		
Delayed gratification (EF)			1.29		
			(0.04 - 41.05)		
Fine Motor	1.92***				
	(1.45 - 2.56)				
Social-Emotional		1.23			
		(0.94 - 1.59)			
NEPSY Block Test				0.99	
				(0.74 - 1.31)	
Tactile pattern reasoning				1.45**	
				(1.09 - 1.93)	
Picture Vocabulary Test					1.48***
					(1.11 - 1.98)
Expressive language					0.97
					(0.75 - 1.26)
Letter Naming					1.27*
					(0.96 - 1.69)

Rapid Automatized Naming					0.87
					(0.65 - 1.15)
Observations	333	333	333	333	333
ciEform in parentheses	*** p<0.01, ** p<0.05, * p<0.1.				

Notes: Statistics shown in parentheses are 95% confidence intervals. Full adjustments including all the covariates used in the analysis.
Model 1: Fine motor with covariates.
Model 2: Social-emotional with covariates.
Model 3: Executive Functioning with covariates.
Model 4: Cognition with covariates.
Model 5: Language with covariates.

Appendix Table 2: Adjusted associations between a child being in school 2019 and domain-specific development in 2010 (N=333)

VARIABLES	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Wealth_quintile	1.46**	1.47***	1.46**	1.50***	1.56***
	(1.09 - 1.96)	(1.10 - 1.96)	(1.08 - 1.96)	(1.12 - 2.01)	(1.15 - 2.13)
Child female	0.84	0.86	0.85	0.83	0.85
	(0.46 - 1.54)	(0.47 - 1.58)	(0.46 - 1.56)	(0.46 - 1.52)	(0.47 - 1.57)
Mothers' primary Education	2.38*	2.25	2.52*	2.54*	2.43*
	(0.85 - 6.69)	(0.80 - 6.34)	(0.89 - 7.16)	(0.89 - 7.22)	(0.85 - 6.93)
Mother's Secondary or higher	3.79*	3.81*	4.87**	4.04**	3.67*
	(0.97 - 14.88)	(0.97 - 14.95)	(1.20 - 19.82)	(1.03 - 15.88)	(0.93 - 14.55)
Mothers age	1.02	1.02	1.02	1.02	1.01
	(0.97 - 1.07)	(0.97 - 1.07)	(0.98 - 1.03)	(0.97 - 1.07)	(0.96 - 1.05)

Eastern Region	0.64	0.59	0.55	0.60	0.71
	(0.28 - 1.47)	(0.26 - 1.35)	(0.24 - 1.28)	(0.26 - 1.35)	(0.30 - 1.66)
Luapula Region	1.54	1.55	1.40	1.60	2.01
	(0.60 - 3.96)	(0.61 - 3.96)	(0.54 - 3.64)	(0.62 - 4.10)	(0.72 - 5.56)
Exposure to ECCE 2010	0.21***	0.25***	0.23***	0.25***	0.27***
	(0.08 - 0.56)	(0.10 - 0.66)	(0.08 - 0.63)	(0.095 - 0.67)	(0.101 - 0.70)
Early Enrollment	6.06***	6.51***	6.12***	6.44***	5.08***
	(2.03 - 18.10)	(2.18- 19.47)	(1.94 - 19.28)	(2.15 - 19.31)	(1.68 - 15.36)
Fine Motor	1.41**				
	(1.03 - 1.93)				
Social-Emotional		1.23			
		(0.90 - 1.68)			
Task Orientation			1.31		
			(0.94 - 1.81)		
Attention Test (AT)			1.09		
			(0.77 - 1.54)		
Delayed gratification (EF)			13.52		
			(0.191 - 958.032)		
NEPSY Block Test				1.05	
				(0.740 - 1.475)	
Tactile pattern reasoning				1.11	

				(0.797 - 1.557)	
Picture Vocabulary Test					1.02
					(0.733 - 1.420)
Expressive language					1.07
					(0.796 - 1.441)
Letter Naming					1.44
					(0.880 - 2.363)
Rapid Automatized Naming					1.08
					(0.777 - 1.503)
Observations	333	333	333	333	333

Notes: Statistics shown in parentheses are 95% confidence intervals. Full adjustments including all the covariates used in the analysis.
Model 1: Including all covariates and fine motor.
Model 2: Social-emotional with covariates.
Model 3: Executive Functioning with covariates.
Model 4: Cognition with covariates.
Model 5: Language with covariates.

Appendix Table 3: Adjusted associations between grade repetition by 2019 and domain-specific development in 2010 (N=333)

	Model 1	Model 2	Model 3	Model 4	Model 5
Wealth_quintile	0.99	1.03	0.99	0.99	0.98
	(0.80 - 1.22)	(0.84 - 1.28)	(0.80 - 1.22)	(0.80 - 1.22)	(0.79 - 1.21)
Child female	0.85	0.83	0.86	0.85	0.82
	(0.53 - 1.38)	(0.51 - 1.35)	(0.53 - 1.40)	(0.52 - 1.37)	(0.51 - 1.34)
Mothers' primary Education	1.99	1.99	2.27	1.68	1.77
	(0.67 - 5.87)	(0.68 - 5.79)	(0.75 - 6.91)	(0.56 - 5.05)	(0.60 - 5.29)
Mother's Secondary or higher	1.50	1.42	1.66	1.30	1.39
	(0.44 - 5.17)	(0.42 - 4.86)	(0.47 - 5.86)	(0.37 - 4.52)	(0.40 - 4.862)
Mothers age	1.04**	1.04**	1.05**	1.04**	1.05**
	(1.00 - 1.09)	(1.00 - 1.09)	(1.01 - 1.089)	(1.00 - 1.09)	(1.00 - 1.09)
Eastern Region	1.35	1.35	1.34	1.25	1.20
	(0.66 - 2.75)	(0.65 - 2.90)	(0.65 - 2.75)	(0.61 - 2.56)	(0.58 - 2.50)
Luapula Region	1.79*	1.99*	1.81*	1.78	1.69
	(0.91 - 3.53)	(1.10 - 4.10)	(0.90 - 3.62)	(0.890 - 3.54)	(0.84 - 3.42)
Exposure to ECCE 2010	0.57	0.74	0.67	0.71	0.58
	(0.26 - 1.25)	(0.34 - 1.58)	(0.31 - 1.45)	(0.33 - 1.53)	(0.27 - 1.28)
Early Enrollment	1.97*	1.92*	1.44	2.00*	2.25**
	(0.95 - 4.08)	(0.91 - 4.04)	(0.66 - 3.12)	(0.97 - 4.12)	(1.06 - 4.78)

Fine Motor	1.10				
	(0.85 - 1.41)				
Social-Emotional		0.68***			
		(0.52 - 0.88)			
Task Orientation			0.93		
			(0.70 - 1.23)		
Attention Test (AT)			1.40**		
			(1.07 - 1.81)		
Delayed gratification (EF)			1.15		
			(0.04 - 32.25)		
NEPSY Block Test				0.96	
				(0.73 - 1.27)	
Tactile pattern reasoning				0.83	
				(0.63 - 1.09)	
Picture Vocabulary Test					0.93
					(0.71 - 1.21)
Expressive language					1.17
					(0.92 - 1.501)
Letter Naming					0.85
					(0.64 - 1.12)
Rapid Automatized Naming					0.95

					(0.74 - 1.23)
Observations	333	333	333	333	333
ciEform in parentheses	*** p<0.01, ** p<0.05, * p<0.1				

Notes: Statistics shown in parentheses are 95% confidence intervals. Full adjustments including all the covariates used in the analysis.
Model 1: Including all covariates and fine motor.
Model 2: Social-emotional with covariates.
Model 3: Executive Functioning with covariates.
Model 4: Cognition with covariates.
Model 5: Language with covariates.

Chapter 7: Discussion and conclusion

The main aim of this dissertation was to assess how early childhood experiences and caregivers' behaviors can influence the developmental outcome of children in LMICs. To achieve this objective, we analyzed data from four related studies that were conducted in Kenya, Zambia, and Brazil. The first three studies assessed how caregivers' behaviors and practices were associated with the developmental outcomes of the children. The studies investigated how the efforts made by caregivers to practice important activities that include KMC, EBF, or stimulating, and responsive caregiving influence the acquisition of vital developmental skills that children need to survive and thrive. The fourth paper investigated how early acquisition of these developmental milestones influences later schooling outcomes in adolescence.

The overall results of the studies indicate that positive early childhood experiences and caregivers' practices have a positive impact on the acquisition of skills necessary for children's development. Exposing children born preterm to KMC has the potential to improve their physical development and cognitive skills, especially at age three. On the other hand, breastfeeding infants exclusively for at least six months may enable children to acquire necessary childhood developmental outcomes, especially in communication, gross motor, and cognitive skills. Also, when caregivers exposed their children to stimulation activities in their early years, there is an indication that the children may gain important developmental skills in the areas of cognitive, socio-emotional, language, and motor skills. Finally, children with well-developed fine motor skills in their early years are likely to be in school later in adolescence while children with well-developed cognitive, socio-emotional, and executive functioning skills are likely not to repeat a grade later in their adolescence.

Taken as a whole the results presented in this dissertation have highlighted the strong association between maternal activities/behaviors with the developmental outcomes of children as well as how early experiences would determine the later developmental trajectories. The

practice of KMC, EBF, and maternal stimulation seems to improve the development of cognitive skills across the first three papers in this dissertation with large positive associations between the early acquisition of cognitive skills and positive schooling outcomes in the fourth study. Put differently, the results show that caregivers' activities such as KMC, EBF, and stimulation all have positive associations with the early acquisition of cognitive skills in young children irrespective of age and birth status. Further, early acquisition of cognitive skills has a positive influence on the schooling outcome later in adolescence. The interpretation is that a combination of KMC, EBF, and early maternal stimulation may indicate a larger effect on the cognitive development of children born preterm since the three have separate associations with the acquisition of such cognitive skills. In addition, a combination of EBF and early maternal stimulation may also have larger effects on the acquisition of cognitive skills for term children.

The result of this dissertation shows a close relationship between early maternal activities such as breastfeeding, complementary feeding, and supplementation with children's developmental outcomes especially for cognitive skills are related to previous findings (67). As indicated in our study, early acquisition of cognitive skills has a positive association with schooling outcomes such as good academic performance which also corroborates with the earlier findings (68). Cognitive abilities are important for successful learning as it forms the basis for the acquisition of other important skills such as communication and executive functions skills. Early acquisition of cognitive abilities builds key skills such as impulse control, planning, and monitoring. These skills are important for building the basis for later academic performance. In addition, cognitive skills such as concentration, and strong attention plans are strong indicators of good academic performance. These skills are built at the onset of child growth and development as indicated in the studies. Our findings imply that parental efforts to promote these activities are therefore vital and should be considered with utmost urgency as it will avert any risks of poor development of these important skills. The finding further suggests

that creating a responsive and stimulating environment with opportunities for early learning is very important for the development of young children.

7.1. Public health and clinical relevance

Previous studies have noted that most children growing up in LMICs are faced with many adversities preventing them from achieving key human potential. Our study has shown that early maternal activities and practices toward young children provide strong foundations for the later development of children. For example, our finding that early acquisition of fine motor skills and early literacy increases the likelihood of adolescents being in school has many public health implications. The inability of the children to achieve the relevant milestones at their early ages may result in them being less prepared for school and less able to benefit from the schooling activities. Poor development in turn negatively affects their labor outcome leading to a loss of about 20% of adult wages per child (69, 70), and this loss results in circles of poverty. Risks of poor development that have been identified include malnutrition and lack of cognitive stimulation at home. Our finding has shown that the practice of exclusive breastfeeding, KMC, and early maternal stimulation have positive associations with the later development of children and can easily be followed to avert the effect of poor development on the overall growth of the children, their health, and later income.

Health and income are intertwined and heavily influence each other. Good health simply means favorable income, while poor health is heavily associated with low income. The ability to breastfeed, work, provide food and earn a living is all dependent on the health and income status of the family. People living in poverty are often less educated, have less knowledge about health promotional activities, and have poor access to healthcare services. Addressing the root causes of poor development may result in better schooling outcome that leads to higher earnings in the future. Good academic outcomes and higher-earning basically signify better health

outcomes to the families that may also indicate fewer hospital visits. Our study is relevant as it has provided key early practices that when properly utilized as stated in the policy document, may result in the positive development of children and avert the effects of poor development. KMC, for example, has a great impact on the reduction of neurodevelopment difficulties in children which is a serious public health concern. Improving neurodevelopment in children may reduce the costs of taking care of such children in already resource-constrained settings.

Developmental delays in young children especially children born preterm may be prevented if health workers could provide early guidance and special assistance to the caregivers to effectively expose children to KMC, EBF, and early cognitive stimulation. Systematic studies have revealed a strong association between exposing children to KMC and how this can improve the uptake of EBF (71). Efforts by the health workers to encourage these activities may be useful in the overall development of children. In the early years of a child's life, routine health and nutrition services are often the only means to consistently reach children and their caregivers. The expansion of routine maternal and child health and nutrition services to integrate early childhood development services has been recommended to effectively reach and support young children's development. In many LMICs, the health system is often the only existing infrastructure that can consistently and regularly reach young children and as such, may be used to facilitate the delivery of ECD interventions.

Apart from the achievements of cognitive skills and physical development that have been documented in our study, KMC also has clinical benefits for the overall development of preterm children. For example, KMC reduces mortality, morbidity and prevents infection in children. Also, KMC is an effective therapy to relieve procedural pain and reduce the risk for neurodevelopment in children (59, 60). If not effectively managed, children born preterm may face many challenges including the development of neurodevelopmental disabilities that delay their developmental outcomes. Children with neurodevelopmental challenges face inadequacies

in neurological and brain functioning resulting in impairments in cognition, communication, mobility, or social interaction. With such, these children may not achieve their potential by acquiring the most basic skills required for daily living and academic activities. Even though the adoption of KMC as the routine clinical practice remains variable and underutilized in many LMICs, the KMC is a feasible, natural, and cost-effective way to support overall growth and development from the clinical perspective.

Our results have also shown that exclusive breastfeeding for at least six months is vital in the achievement of key milestones for child development. Like KMC, EBF has numerous health benefits for children and their mothers. For example, breastmilk provides excellent nutrition to infants, and children exclusively breastfed for six months have fewer infections, the respiratory illness which reduces hospitalization. With our results showing EBF as a key contributor to children's development, health care providers have a major role in promoting it as it is the cost-effective practice to promote the development of children in poor income settings. Later development in adolescence and even adulthood have significant implications on the childhood experiences and how responsive the caregivers were. Negative health outcomes that are quite expensive can be prevented with these simple and cost-effective activities.

7.2 Strength and limitations

The studies included in this dissertation are drawn from longitudinal studies conducted in different settings in LMICs. Through the longitudinal nature of these studies, it was possible to explore patterns of change and dynamics of caregivers' behaviors and activities as well as observe children's developmental outcomes at different ages. These explorations strengthen the associations between the exposures and the outcome of interest under each chapter. In addition, we included in all the chapters most of the known confounders and effect modifiers from the literature further strengthening the relationship between exposure and outcome variables.

Though we used data from different settings with different methodologies, the population-based design of our studies favors the generalizability of our findings to different settings in LMICs.

We also noted some limitations in each study. Even though we accounted for other covariates, there could be other practices that may be correlated with other parental factors positively contributing to child development. The factors that may include early intervention programs, and government initiatives such as nutritional supplementation may positively contribute to the development of children. In addition, our measures of child development exclusively relied on the primary caregiver's self-report thus being subject to social desirability and reporting bias. This was also the case with the adolescents for the schooling outcome. Also, our outcome measures for the adolescents equally relied on the responses provided by the adolescents and may not have been fully accurate. Moreover, we did not conduct a direct assessment of the children to ascertain accurately their development outcomes.

7.3 Conclusion

The evidence presented in this dissertation indicates that parental behavioral activities in key areas of early stimulation, KMC, and exclusive breastfeeding may be effective in improving the developmental outcomes of children, especially cognitive skills. Also, the evidence presented suggests that early acquisition of cognitive skills has a positive impact on the later schooling outcomes for adolescents. Further, the dissertation contributes to the body of literature on the importance of early childhood experiences and caregivers' behavioral practices and how these shape the developmental outcomes of children living in low-resourced settings.

As a recommendation, further research should determine the effectiveness of these programs implemented as interventions following the guidelines and recommendations by the World Health Organization (WHO). In addition, more long-term longitudinal studies should be conducted to ascertain the sustained impact of these programs later on schooling and labor outcomes. For children born preterm, early intervention programs that combine KMC, EBF and

early cognitive stimulation should be given priority as this may have an impact on the achievement of cognitive skills useful for later schooling outcomes. To meet the developmental needs of all children, the role of parental interactions should be emphasized.

Curriculum vitae

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