Title: Factors associated with stunting and catch-up growth among under-five children in Nairobi informal settlements

Name of degree: PhD Public Health

Student: Cheikh Mbacké Faye (Number: 1513579)
Email: cfaye@aphrc.org
Address: African Population and Health Research Center
Manga Close, Off Kirawa Road
P.O. Box 10787-00100
Nairobi, Kenya

PhD Supervisor Professor Sharon Fonn, University of the Witwatersrand, School of Public Health, 27 St Andrews Road, Johannesburg Parktown 2193, South Africa. Email: Sharon.Fonn@wits.ac.za

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Dédicaces

Je dédie ce travail à mes défunts parents, que la terre leur soit légère. Ce travail est la consécration du soutien sans faille de mon adorable épouse, Fatimata Talla, et de mes enfants chéris, Ndeye Fatou, Khadidja et Mouhamad. Merci pour votre compréhension et votre patience. Ce travail est aussi dédié à mes frères et sœurs et à mes amis d'enfance ; vos encouragements m'ont été inestimables. À mes collègues de travail, ce travail est aussi dédié pour leur soutien et conseils prodigués tout au cours de cette traversée.

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Acronyms and Abbreviations

AMREF	African Medical and Research Foundation
APHRC	African Population and Health Research Center
DHS	Demographic and Health Survey
EA	Eastern Africa
GEE	Generalized Estimating Equations
HAZ	Height-for-age z-score
HR	Hazard Ratio
KEMRI	Kenya Medical Research Institute
LMIC	Low and Middle Income Countries
MCH	Maternal and Child Health
MDG	Millennium Development Goal
NUHDSS	Nairobi Urban Health and Demographic Surveillance System
PCA	Principal Component Analysis
PhD	Doctor of Philosophy
SD	Standard Deviation
SDG	Sustainable Development Goal
SSA	Sub-Saharan Africa
UNICEF	United Nations International Children's Emergency Fund
WHO	World Health Organization

Abstract

Background

Malnutrition is among the most important causes of child mortality in the world as it accounts for about half of the deaths among under-five children. Its chronic form, stunting, can have dramatic effects during childhood and later life. Monitoring linear growth is then central to child survival and health. This study aimed to investigate factors associated with child stunting and recovery from stunting by five years. I first looked at the determinants of child linear growth; then investigated the family influence on decisions around child nutrition; and finally identified the factors associated with recovery from stunting by five years among under-five children in the two Nairobi's informal settlements.

Methods

The study used longitudinal data for the period 2007-2012 from 1917 under-five children recruited between birth and 23 months, and followed-up until they reached five years. In addition, qualitative data were collected using in-depth interviews with children's mothers and caregivers. Quantitative and qualitative data were analyzed separately using multivariable modelling and deductive coding respectively, but then interpreted in a complementary approach.

Findings

The findings show that 58% of the children were stunted, and about 45% of them were able to recover from stunting before they reached five years. Also, child weight at birth, immunization status, and exclusive breastfeeding up to six months, are key determinants of linear growth among under-five children in the sites. Poverty is a root cause of suboptimal child nutrition and grandmothers have central roles in child feeding by being key advisors to younger mothers and child caregivers. Furthermore, the study illustrates that timely child immunization, mother's parity and household socioeconomic status are important factors predicting time to recover from stunting within the first five years of life. Finally, it was demonstrated that child post-stunting linear growth was influenced by factors including diseases, age at stunting and mother's parity and age.

Conclusions

Targeting single and young mothers in child health and economic interventions in these areas would contribute to lowering the prevalence of linear growth impairment and reduce adolescent and young mother's vulnerability. Child optimal feeding practices as recommended by international programs may not be successfully implemented in these settings without considering the roles of grandmothers and the quasi-impossibility for young and single mothers to combine child exclusive breastfeeding with their work or schooling. In a context of extreme poverty, policy-makers and program implementers should consider prioritizing addressing the root cause of stunting including economic reinforcement interventions such as cash transfers and access to decent employment and housing.

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1 Introduction

1.1 Problem statement

Malnutrition ranks among the most important factor contributing to child mortality in Africa (1). Nearly 50% of deaths among under-five children in sub-Saharan Africa (SSA) are related to poor nutrition (2, 3). Recent studies indicate that Africa has not made sufficient progress to attain the Millennium Development Goal 4 (MDG 4) which aimed to reduce under-five mortality by two-thirds by 2015 (4). If the current pace is maintained, achievement of the Sustainable Development Goals (SDGs) also might be hindered, in particular SDGs 2 and 3 which respectively aim to end hunger and promote good health and well-being for all at all ages. Eastern Africa has been the region most affected by child malnutrition in Africa. For instance, although child stunting in that region decreased from 46 % in 2000 to 36% in 2017, it remains above the average prevalence in SSA which is 30% (5). Recent estimates show that 45% of pre-school children in Eastern Africa suffer from poor nutrition and related consequences such as growth retardation and stunting (6). Stunting, also known as chronic malnutrition (low length or height-for-age) is a failure of linear growth as a result of several factors including inadequate nutrition over a long period of time (6-8). Stunting is defined by comparing the length/height-for-age z-scores (HAZ), with the World Health Organization (WHO) 2006 standards for children under five years (9).

In Kenya, stunting prevalence among under-five children has decreased from 35% in 2008-09 (10) to 26% in 2014 (11). The corresponding figure for Nairobi, the capital city of Kenya was 17% in 2014 (11). This figure however hides intra-urban disparities. Indeed, the prevalence of child stunting in two Nairobi informal settlements, Korogocho and Viwandani, was reported at 46% in 2015 (12). Notwithstanding this alarming situation in the slums, only a few studies have focused on understanding the determinants of child linear growth failure in this context. They found that a child's attributes at birth (sex and weight) and mother's background characteristics, in particular, education, marital status, health seeking behavior were associated with child stunting in the slums (13, 14). Another study found that household food insecurity is a major cause of child stunting (15).

Although informative, these studies have not integrated immediate causes of child stunting such as child diseases and inadequate food intake; therefore they provide a partial understanding of the problem.

The present study proposes to extend knowledge by taking a more holistic approach to the factors influencing child linear growtrh in these deprived urban settings. This approach attempts to take into account the multifactoral determinants of child growth. For example, research shows that deficiency in

nutrient consumption and infections increases child biological requirements and prevents the body from absorbing the few nutrients consumed, which directly leads to poor nutrional outcomes such as stunting (16). In addition, suboptimal breastfeeding contributes to poor child health outcomes including stunting, deficient cognitive development, and increased morbidity (17-20). Finally, it is known that sociocultural dynamics in developing countries confer important responsibilities and social power to extended family members such as grand-mothers, sisters and husbands, with the capacity to influence decisions on maternal and child health (21, 22). Therefore, it is important to study the influences of this set of factors on child health outcomes in the context of urban informal settlments.

Another aspect is that child stunting is associated with adverse health effects such as delays in motor development and maturity (23-25). However, when the immediate cause of stunting is mitigated, stunted children may experience in the short or long-term an increased growth velocity (26, 27). This physical recovery is referred in the literature as “catch-up growth”, and it is defined as “an accelerated growth following a period of slowed development, particularly as a result of nutrient deprivation” (26, 28).

There is a paucity of data and studies on the incidence of recovery from stunting for under five children in SSA. Evidence from studies shows possible catch-up among stunted children, and the incidence was estimated between 53% in Ethiopia and 75% in South Africa, based on the same definition of catch-up growth as used in this study (29, 30).

Most of the studies on linear catch-up growth focused on the recovery much later in adolescence. Little is known about recovery among children at the age of five years. For instance, severity and duration of the undernutrition period, as well as the stage of development at the commencement of undernutrition are influential factors in catch-up growth (31, 32). The study by Miller et al. (33) about adopted children from Eastern Europe found that younger age, shorter height at adoption and greater caloric intake could predict an accelerated growth in childhood after undernourrishment. In a recent study in urban South Africa, mother’s education and height were associated with recovery from stunting (30). Understanding the determinants of recovery from stunting among under-five children in deprived urban settlements will add to knowledge in this under-researched area.

Investigating the factors associated with child stunting and recovery from stunting in a context of urban informal settlements could be an important contribution to further our understanding of child development in this context and therefore to devise appropriate policies towards reducing socioeconomic inequities among urban dwellers. This study thus aimed to investigate factors associated with child

stunting and recovery from stunting. In particular, the work is conducted in urban informal settlements in Nairobi because the prevalence of stunting is higher in these environments. The rapid growth of urban slums in Kenya and Africa more generally makes this an important area or work.

If the SDGs are to be attained in the context of rapid urbanization in developing countries, being able to understand and mitigate the effect of child stunting in informal settlements is urgent and important. Providing such relevant data to inform policy and programs constitutes a public health priority.

1.2 Research questions and objectives

This study addresses three important questions to fill the gaps in knowledge about stunting in informal settlements in Nairobi.

a) What are the determinants of linear growth among under-five children in two Nairobi informal settlements?
b) In what way are mothers' decisions on child nutrition influenced by other family members?
c) What are the factors associated with recovery from stunting by five years in the two informal settlements?

In line with the above research questions, the study aims to achieve the following objectives:

Obj. 1. Analyze the growth trajectories of under-five children in two informal settlements in Nairobi between 2007 and 2012, and identify the factors associated with child linear growth.
Obj. 2. Explore the practices of family members that may influence child nutritional outcomes, in particular stunting, in two Nairobi informal settlements.
Obj. 3. Determine the incidence of child catch-up growth by five years among stunted children in two Nairobi informal settlements;
Obj. 4. Identify the factors associated with catch-up growth by five years in two Nairobi informal settlements;

2 Literature review

2.1 Definitions

Child malnutrition generally refers to both undernutrition and over-nutrition. It can be defined as a state of altered nutritional status that is associated with increased risk of adverse clinical events such as complications or death (34, 35). In this study, I focus on undernutrition which affects about 13% of the population in developing countries (36). Both undernourishment and undernutrition are terms that have been used and include stunting, wasting, and deficiencies of essential micronutrients such as vitamins and minerals (37). Stunting, which is the focus of this research, is the failure to grow both physically and cognitively and is the result of chronic or recurrent malnutrition (5). Stunting refers to a child who is too

short for his or her age. On the other side, wasting refers to acute malnutrition and is the result of recent rapid weight loss or the failure to gain weight (5). Wasted children are usually too thin for their height.

2.2 The burden of child stunting in sub-Saharan Africa and Kenya: Urban differences

Malnutrition is documented as a predominant cause of child mortality in the world (38). In Sub-Saharan Africa, studies show that nearly 50% of deaths among children under-five are related to malnutrition (2, 3, 7). Eastern Africa (EA) has been the region most affected by child malnutrition, in particular stunting, in Africa. For instance, child stunting in EA reduced only from 46% in 2000 to 36% in 2017, but is still above the SSA prevalence which was 30% in 2017 (5). Recent estimates showed that 45% of preschool children in Eastern Africa suffer from stunting and its consequences such as poor cognitive development and increased child morbidity and mortality (6). In Kenya, stunting prevalence among under-five children declined from 35% in 2008-09 (10) to 26% in 2014 (39). Urban-rural differences were noted during that period with a higher decrease in urban areas (25%) as compared to rural areas (21%). However, this noticeable decrease in urban areas conceals the continuing burden of child malnutrition in Nairobi informal settlements where child stunting reached 60% among children by the age of 15 months between 2007 and 2010 (14).

As in many African cities, Nairobi faces urbanization challenges with rapid increase of the urban population over the last decades. In a context of poor access to formal housing and to basic social services, most of the new urban residents end up squatting in unoccupied spaces, leading to the proliferation of informal settlements within Nairobi (40). The population living in informal settlements within or on the periphery of the city is estimated to be between 60 and 70% of Nairobi's total population (41-43). These settings are mainly characterized by poor living conditions including overcrowding, high poverty levels and fertility rates and poor access to health care services (44). These conditions expose young children to health hazards and a heightened risk of morbidity and mortality (42, 45). Therefore, it is important to advance our understanding of child development conditions, including child linear growth, in a context of urban informal settlements if we want better policies towards reducing socioeconomic inequities among urban dwellers.

2.3 Determinants and consequences of child stunting

Although malnutrition can affect people of all ages, young children are known to be the most vulnerable population, in particular with regards to stunting. Previous research has documented the determinants of child stunting in developing countries (37, 46). These determinants are found at different levels including child, mother, household and the community. For instance, a child's conditions at birth (weight, age, and

colostrum initiation) (47-50) and mothers' demographic and socio-economic background (age, education, poverty level) (14, 17, 50) were listed among the underlying causes of child stunting. Likewise, inadequate child feeding practices and diseases were documented as immediate causes of child stunting (51, 52). Further studies conducted in developing countries demonstrated the relationship between breastfeeding practices and child nutritional status. For instance, short duration of breastfeeding (less than 6 months) and absence of exclusive breastfeeding in the first six months of life, was related to child stunting by the age of five years (53, 54). Finally, food insecurity, climate disasters, and degradation of agro-pastoral resources and low purchasing power of households are known to be associated with stunting (3, 17, 37, 55).

Child stunting is known to have adverse short-term and long-term effects on child health, cognitive development, and survival (56, 57). Likewise, increased child morbidity and mortality, and increased risk of metabolic diseases later in the life course, were reported to be among the consequences of child malnutrition, in particular stunting (56, 58). A UNICEF publication mentioned that a severely stunted child faces a four times higher risk of dying than a normal child (59).

2.4 Breastfeeding and determinants of sub-optimal breastfeeding

World Health Organization (WHO) current recommendations for breastfeeding practices include: i) initiation of breastfeeding for all newborns within the first hour of life; ii) exclusive breastfeeding for the first six months of life; and iii) continued breastfeeding for two years and beyond with nutritionally appropriate and safe complementary foods introduced at the sixth month (38). Exclusive breastfeeding means that the infant receives only breast milk and no other liquids or solids are given – not even water – with the exception of oral rehydration solution, or drops/syrups of vitamins, minerals or medicines (38).

Suboptimal breastfeeding, defined as a failure to meet any of the three WHO breastfeeding recommendations, is widely documented among the prime proximate causes of child malnutrition in the first years of life of children in developing countries.

Optimal breastfeeding practices have innumerable advantages on child health. In a recent publication, Black revealed that "If every child was breastfed within an hour of birth, given only breast milk for their first six months of life, and continued breastfeeding up to the age of two years, about 800,000 child lives would be saved every year" (3). Sub-optimal breastfeeding leads to poor child health outcomes. It is documented as a cause of over a million deaths each year and 10% of the global disease burden in children (60). Findings from a study in Vietnam showed that sub-optimal breastfeeding was associated with high risk of diarrhea and acute respiratory infections (61). In a prospective facility-based study conducted in

Democratic Republic of Congo, the author evidenced mother's lack of breastfeeding knowledge as a key predictor of sub-optimal breastfeeding (62). However, there was little evidence on the predictors of sub-optimal breastfeeding in urban informal settlements of sub-Saharan Africa. A study by Kimani et al. (63), using longitudinal data from informal settlements of Nairobi, examined the predictors of breastfeeding cessation in the first year of life. The findings showed that only 2% of the infants are exclusively breastfed for the first six months in Nairobi informal settlements. Among the reasons of this low exclusive breastfeeding rate, the mother's perception of insufficient breast milk was mainly cited. In addition, mother's marital status, ethnicity and educational level were listed among the factors associated with early cessation of breastfeeding. While the study's key strength lies in its longitudinal nature and its attempt to evidence predictors of suboptimal child breastfeeding, the causality between mother/family-related factors, breastfeeding practices and child nutritional outcomes could not be established as the latter aspect was not assessed.

Breastfeeding patterns have significantly improved in developing countries over the past decades (59). However, they are still far below the recommended levels in the developing world. About 39% of all infants under 6 months in the developing world are exclusively breastfed (3, 59, 64) and less than 60% of infants aged 6 to 9 month continue to be breastfed while also receiving solid, semi-solid or soft foods. In Kenya, exclusive breastfeeding rates reach 60% among children less than 6 months and more than half of children are still breastfeeding at age 20-23 months (39). However, differences persist among urban dwellers with only 2% of the infants in Nairobi informal settlements being exclusively breastfed for the first six months (63).

Child nutritional status can also be viewed from the point of view of household characteristics. Madise et al. (65) investigated child morbidity, feeding variables using DHS data in Malawi. The household poverty status, area of residence and suboptimal breastfeeding were associated with poor child nutritional status. Nevertheless, mother specific variables such as age, marital status or post-partum contraception were omitted in the model, again providing only partial information.

2.5 Child growth trajectories

Child growth trajectories are central to monitoring child health as they provide essential indicators of childhood development. In addition, they can be used to predict health outcomes in adulthood. There are different types of child growth trajectories documented in the literature. Building on the WHO standards for child growth (9), child growth trajectories were classified into three types: standard or normal growth; delayed growth; and rapid growth. Normal growth refers to child weight, height or head size within the

standard WHO child growth references (9). Research suggests that children with normal growth trajectories are more likely to have better health outcomes than those with abnormal growth (24, 56, 66). Abnormal child growth refers to deviations in weight, height or head size and mostly reflects either a growth retardation (delayed growth) when the deviations are below standards or growth acceleration (rapid growth) when the deviations are above standards (9, 67). Rapid growth is associated with health issues later in life such as hypertension and obesity (68, 69), while delayed growth is associated with both short-term and long-term negative effects on child development including poor cognitive, psychosocial, and schooling outcomes (3). Likewise, increased child morbidity and mortality, have been reported among the consequences of child growth failures (2, 24, 56, 70, 71). This study focuses on child linear growth which refers to growth in terms of crude height or height-for-age z-score.

2.6 Recovery from stunting or catch-up growth

Catch-up in childhood linear growth has been a subject of scientific debate over the last few decades. Different definitions and methods have been used in the litterature to estimate catch-up in linear growth. In the earlier studies, absolute height gains over time were referred to as 'catch-up growth' which reflected a decrease in absolute height deficit between the individual child and the mean height for a reference population of healthy children (e.g. WHO child height standards). In most recent studies, catch-up in linear growth was defined based on the changes in height-for-age z-scores as a relative height gain (30, 72, 73). In this study, relative catch-up growth definitions were used based on the changes in height-for-age z-scores over time at individual level to account for the increasing variability in height as children age. In this context, there is need to distinguish 'linear catch-up growth' as mostly used in Pediatrics, and 'recovery from stunting' as described in this research, although there is a thin line between the two definitions and both terms are used interchangeably in the literature and are useful at the population level. A child is classified as having recovered from stunting when there is resumption of a normal growth velocity after the growth-suppressing problem has been resolved (74). In other words, recovery from stunting occurs when there is an improvement in HAZ such that HAZ is above the -2 SD cut-off at some later age (29, 30, 75). On the other side, linear catch-up growth is observed only when the height velocity is above the statistical limit of normality for age (e.g. HAZ is above the -2 SD cut-off), and remains above this limit for a defined period of time (74, 76). Recovery from stunting confers a stricter description within the broader range of relative catch-up growth definitions. We however recognize that clinicians may prefer referring to 'linear catch-up growth' indicating that a child regains lost heights and then continues to grow.

3 Conceptual framework

This study uses an adapted version of the original UNICEF conceptual framework (46) that was modified by Black et al. (37). Child malnutrition is influenced by a number of interrelated factors which are classified into three main groups: immediate factors, underlying factors and basic factors (46).

3.1 Immediate factors

The immediate causes of child malnutrition are inadequate food intake and infectious diseases. Deficiency in nutrient consumption and infection can increase biological requirements and prevent the body from absorbing the few nutrients consumed (16). This interrupts growth.

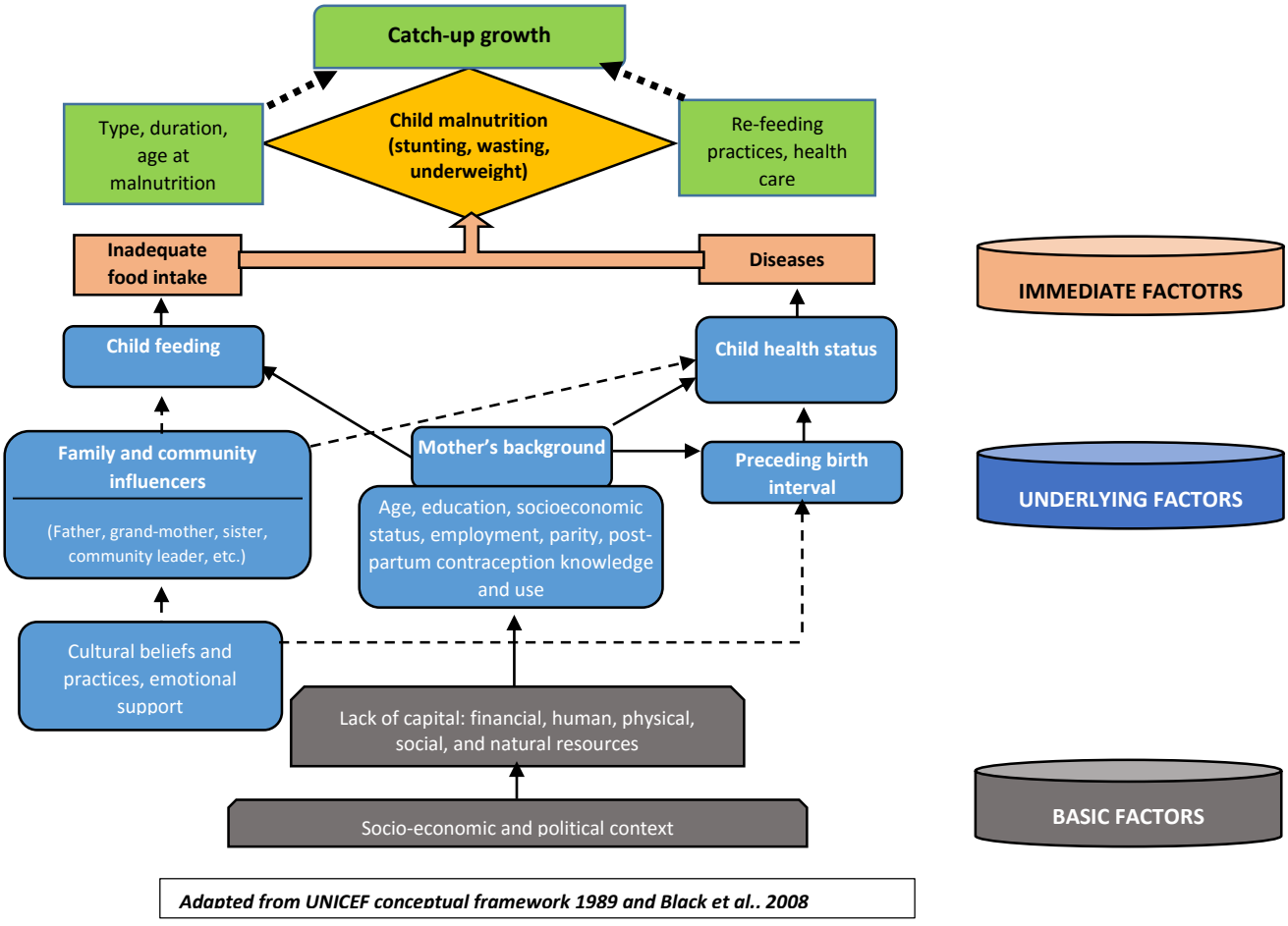

Figure 1. Conceptual framework

3.2 Underlying factors

The original UNICEF model lists household food insecurity, inadequate care and unhealthy household environment and lack of health services as underlying causes of malnutrition. Based on the literature in this study, the conceptual framework has been adapted and now postulates the existence of five sub-groups of factors that significantly influence child nutritional outcomes. These individually and collectively

impact child nutritional status. The five sub-groups include feeding practices, birth intervals, child's health status, mother's characteristics, cultural beliefs and practices. The inclusion of these factors in the conceptual framework was informed by the literature. Poor **feeding practices,** including suboptimal breastfeeding, contribute to deficiency in children's nutrient consumption which reflects an inadequate food intake, as evidenced by several studies (53, 61). Also, research suggests that short **birth intervals** are important factors contributing to child malnutrition and poor maternal health (19, 77). In further studies, other **maternal-related factors** such as age, education and socioeconomic status and **child health factors** (birth order, age and weight at birth, immunization status) were documented among determinants of child malnutrition (14, 17, 50). Finally, **cultural beliefs and practices** reinforced by family and community members were mentioned to have influenced mothers' decisions related to child feeding and other reproductive health issues including pregnancy (21, 22, 78, 79). However, that relationship was missing in the original conceptual framework which is why in this study the framework has been adapted.

In this study, qualitative information aimed to clarify the indirect influences of community and family members on child stunting. These five factors are postulated as the underlying causes of child malnutrition.

The factors influencing **catch-up growth** were explored using two types of information: the characteristics describing the stunting (type, duration, age at stunting) and the external factors which may influence the change in stunting status (re-feeding practices, health care). Other relevant covariates such as sex of the child and conditions at birth were l also included in the analyses.

3.3 Basic factors

Among the basic factors influencing child nutrition, the socioeconomic and political context as well as lack of capital (including financial, human, physical, social, and natural resources) are widely documented. For instance, in a multi-country analysis conducted by Smith and Haddad (80), it was found that increases in per capita national income had accounted for about 50% of the total reduction in undernutrition. In another study by Blaney et al. (81), it was concluded that natural resources, as primary sources of food, significantly contribute to the nutritional status of children in developing countries. Therefore, specific actions towards reducing socioeconomic inequities, sustaining favorable political environments and ensuring equitable access to natural resources at the household level can result in reduced child undernutrition. Because of lack of reliable data, these factors are not studied in this research.

4 Methods

4.1 Study design

This study combined quantitative and qualitative data to provide a better understanding of the factors associated with child stunting and recovery from stunting in a context of urban informal settlements. The quantitative component was a longitudinal survey of children under five, while the qualitative approach consisted of in-depth interviews with caregivers of the children who were selected from the longitudinal survey. Quantitative and qualitative data were analyzed separately but then interpreted in a complementary approach. This approach is considered appropriate as it allows exploring child stunting and catch up growth from different perspectives. Also, it enables triangulation of the different strengths of quantitative methods (large sample size, trends, generalization) with those of qualitative methods (in-depth details explaining why and how decision making influences practice) (82-84).

4.2 Data sources

Quantitative data for the study were sourced from the Maternal and Child Health (MCH) project implemented by the African Population and Health Research Center (APHRC). Secondary analyses were done using longitudinal quantitative data collected between 2007 and 2012 in two informal settlements in Nairobi. I used elements of the data that were not previously fully explored. Then, I collected qualitative data through in-depth interviews (IDIs) to investigate the influence of community and family members on child nutritional outcomes, in particular stunting.

The MCH project was nested within the Nairobi Urban Health and Demographic Surveillance System (NUHDSS) that APHRC has been running since 2002 in Korogocho and Viwandani informal settlements in Nairobi. The NUHDSS records demographic events (births, deaths and migration), pregnancy episodes and outcomes, vaccination coverage every 4 months. In addition, the NUHDSS collects detailed information on household characteristics: household possessions and amenities, and household livelihoods; education, marriage, and employment status. The MCH project recruited cohorts of mother-child pairs from the NUHDSS and followed them up every four months from 2007 to 2012. A mother-child pair was recruited if the child was born in the informal settlement and was 23 months old or younger at the time of recruitment. In addition to the NUHDSS routine data, the MCH project collected data on maternal reproductive health (pregnancy, delivery, antenatal care including mothers' height and weight, postpartum period, pregnancy and contraception) as well as child health (postnatal care, diseases, feeding practices, vaccination and anthropometric measurements).

4.3 Study settings and participants

As in many African cities, Nairobi faces high rates of urbanization standing roughly at 4% annually (85), with a large proportion of the urban population living in informal settlements within or on the periphery of the city, as in Korogocho and Viwandani. These two settlements cover a total population of roughly 80,000 residents and are characterized by poor living conditions including overcrowding, high poverty levels and fertility rates and poor access to health care services (12, 44). They are located approximately ten kilometers from the city center and about seven km from each other. Korogocho has a relatively stable population with more than a quarter of its adult residents born in the slum (44). By contrast, Viwandani has a more transient community which attracts a youthful and highly mobile population seeking job opportunities in the nearby industries (44). Child health interventions in the area are yet to have significant impact due to the near absence of public health facilities in these settlements and high costs of health services (86, 87). These conditions expose young children to health hazards and a heightened risk of morbidity and mortality (42, 45).

For the quantitative component, recruitment into the MCH project was done every six months in a series of 10 cohorts between 2007 and 2012. In this study, I restricted my analysis to cohorts 3 and 4 where the mother-child pair was recruited between 2007 and 2008. These cohorts were chosen as they had the least loss to follow-up over the five-year period. Cohorts 3 and 4 had observation periods of 4.5 and 5 years respectively and had lower annual attrition rates of 12% and 15%, compared to an average 20% loss to follow up in the other cohorts. Additionally, these two cohorts provide the biggest sample sizes and have sufficient observations throughout the five year-period to enable in-depth and statistically valid analyses. Within these two cohorts, mothers of at least one child, and for whom no important information – like the date of birth of the child or their age – is missing or implausible were included in the analyses. The following table provides details of the sample size over the period of observation.

Table 1. Number of observations for each of the two cohorts by survey from 2007 to 2012

Period of data collection	Oct 07 - May 08	May 08 - Aug 08	Sep 08 - Jan 09	Feb 09 - May 09	June 09 - Sep 09	Oct 09 - Jan 10	Feb 10 - Jun 10	Jul 10 - Oct 10	Aug 11 - Jan 12	Feb 12 - June 12	June 12 - Sept 12	Total obs.	Mean number of obs. per child	Most common number of obs. per child (Mode)
Cohort 3	948	739	665	606	551	505	462	411	419	376	304	**5,986**	**6.3**	**11**
Cohort 4	0	969	823	730	640	572	442	391	399	357	297	**5,620**	**5.8**	**10**

The qualitative component targeted households where stunted under-five children were identified from NUHDSS database as well as households with non-stunted children. In each selected household, in-depth

interviews were conducted with the identified child's mother, and grandmother and father, where possible. Households were selected purposively based on information in the NUHDSS and interviewees were identified using Community Health Workers working under APHRC's projects in the study area. In total, 30 in-depth Interviews (IDIs) were conducted in the two sites: 12 with mothers of stunted children, eight with mothers of non-stunted children, six with grand-mothers, and four with fathers.

4.4 Outcomes

The first outcome is child stunting based on length/height-for-age z-scores (HAZ), computed using the World Health Organization (WHO) 2006 standards for children under five years (9). The overall stunting is defined as: HAZ < - 2 standard deviations (SD) from the median of the WHO reference while severe stunting is HAZ < - 3SD from the median of the WHO reference (8, 88). The HAZ was treated as a continuous variable in the multivariable analyses and coded into three ordered categories (severely stunted: HAZ < - 3SD; moderately stunted: - 3SD ≤ HAZ < -2SD; and not stunted: HAZ ≥ - 2SD) in the descriptive analyses.

The second outcome is catch-up in linear growth by five years. I first looked at the time to recover from stunting using event history analysis. In this case, the 'failure event' is recovery from stunting which is defined by an increase in the height-for-age z-score (HAZ) between two time points t_1 and t_2, such that $HAZ(t_2) \geq -2$. Cox regression analysis was done to identify the factors associated with the time to recover from stunting. Second, I used HAZ slope modelling to estimate the change in height-for-age z-score among children who were stunted at any time during the observation period. The difference in HAZ for each stunted child is estimated by fitting a line through the points, starting from the first stunting episode, and using the slope for the individual as the measure of change over time (72).

To avoid biases due to the birth status, children in this study were not treated as a homogenous group. For instance, premature births were excluded when analyzing child catch-up growth as well as twin-births.

4.5 Explanatory variables

Building on the literature on child growth (30, 37, 46, 89, 90), I considered child, maternal and household level factors documented as potential determinants of child linear growth. At the child level, I included individual characteristics such as sex, age, birth weight, place of delivery, immunization status (up to date vs. not up to date), and number of illness symptoms reported over the last two weeks preceding each survey round. At the maternal level, I considered covariates including (age, slum of residence, education, ethnicity, marital status and parity at child's birth). Finally, the household size and socioeconomic status,

estimated using principal component analysis (PCA) based on household assets (91), were included among the potential determinants of child linear growth and recovery from stunting.

The full list of explanatory variables is provided in Table 2 below.

Table 2. List of explanatory variables

Variables
1. Mother's background characteristics Age - Highest education level - Marital status - Ethnic group – Parity - Place of delivery
2. Child specific variables Sex – Age – Weigh at birth - Type of gestation - Child illness symptoms - Child feeding - Exclusive breastfeeding in first 6 months - Immunization status - Child health seeking practices
3. Household level variables Study site - Socioeconomic status - Household size

4.6 Data analysis

At the first step, descriptive statistics were used to analyze growth trajectories of under-five children, and to depict the differences by background characteristics. The descriptive analyses of growth trajectories included comparisons by: study site, child sex, birth weight, and number of illness symptoms. Secondly, panel data multivariable modelling (generalized linear regression model using the GEE method) was used to identify factors associated with child linear growth trajectories (**Paper 1**). Then, I used descriptive analyses to determine the incidence of recovery from stunting among under-five children in the two informal settlements. In the third paper (**Paper 3)**, event history analysis and Cox regression were used to identify the factors associated with time to recover, and then a linear regression model of ΔHAZ on a second degree fractional polynomials in age at first stunting was fitted to identify the factors associated with post-stunting linear growth.

Random effects due to the longitudinal nature of the data (repeated measurements from the same population) were taken into account in the multivariable modelling.

The qualitative analyses (**Paper 2**) explored family-related factors underlying child nutritional outcomes, in particular, stunting and catch-up growth. Specifically, I tried to understand how decisions about child feeding (when and what to give the child) and child health (caring about child health status including

stunting, taking child to health facility, child vaccination) are taken within the family and explored which voice counts the most in these kinds of decisions. These analyses were mainly driven by theoretical concepts on child health and feeding. The qualitative data were transcribed in English and coded in NVIVO software using deductive analysis with the objective of complementing the quantitative findings in order to get a more in-depth view of factors associated with child stunting and catch-up growth by five years.

4.7 Ethical procedures

For this study, several measures were taken to ensure ethical research and respect of the respondents. The data were fully anonymized and confidentiality was guaranteed. Informed consent was given for the data when it was collected in the MCH project which observed all ethical requirements and was approved by the Kenya Medical Research Institute (KEMRI) ethical review board at the time of the survey. In addition, the study was approved by the African Medical and Research Foundation (AMREF) Ethics and Scientific Review Committee in Kenya and the Human Research Ethics Committee (Medical) at the University of Witwatersrand in South Africa. All interviews were conducted in private places and written informed consent was sought from all participants. Confidentially was guaranteed.

5 Results

Key findings from the study are highlighted in this section. The detailed results are already presented and discussed in the papers (Appendices 10.1.1, 10.1.2 and 10.1.3)

5.1 Child growth trajectories in the slums

The first finding in this research was that, regardless of the characteristic of interest, the height-for-age z-scores follow a standard pattern that is unique to developing countries as documented in several studies (9, 92, 93). There is a decline in linear growth from after birth up to about 24 months, followed by regular catch-up to about 5 years, as shown in Figure 2. However, differences were noted in particular by site, sex and birth weight. For instance, children living in Korogocho had better linear growth in their first months of life than those in Viwandani; then from about 8 months, the linear growth became greater for children living in Viwandani. Looking at child sex, linear growth patterns for girls remained above that for boys throughout the period 0 to 5 years. With regards to birth weight, children with low birth weight remained below those with normal birth weight and below those whose birth weight was missing. Finally, differences in linear growth were observed between children who had more than one illness symptoms over the last two weeks preceding the survey round and those who did not.

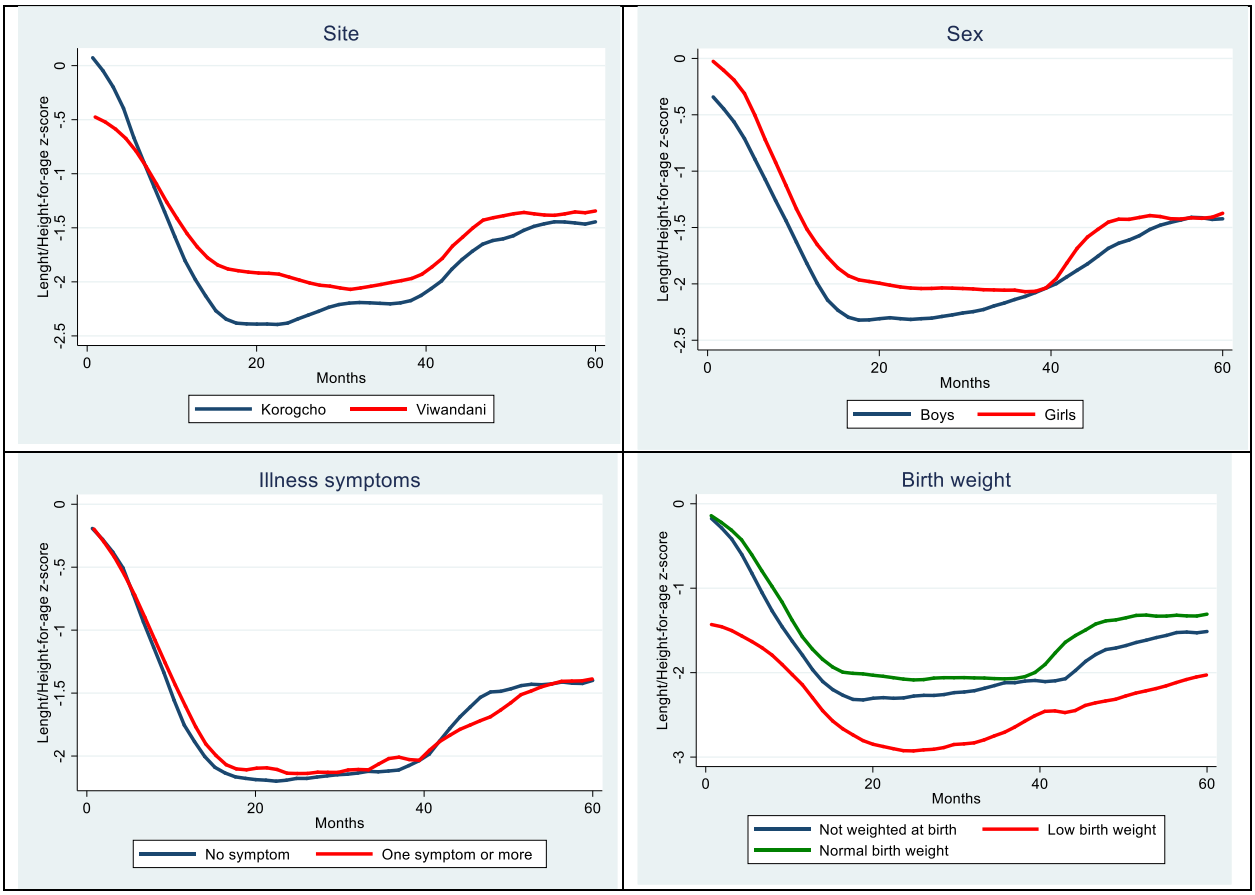

Figure 2. Variation in child height-for-age z-scores for specific characteristics

Additionally, the heights of children were plotted against their age to visualize linear growth patterns from birth to five years (Figure 3). The WHO height references (upper and lower) were used to compare the study population with reference children. The result shows that children in the study areas (either stunted or not stunted) brushed the lower boundary of the WHO height references relative to their age, reflecting persistent failure in linear growth among the under-five population.

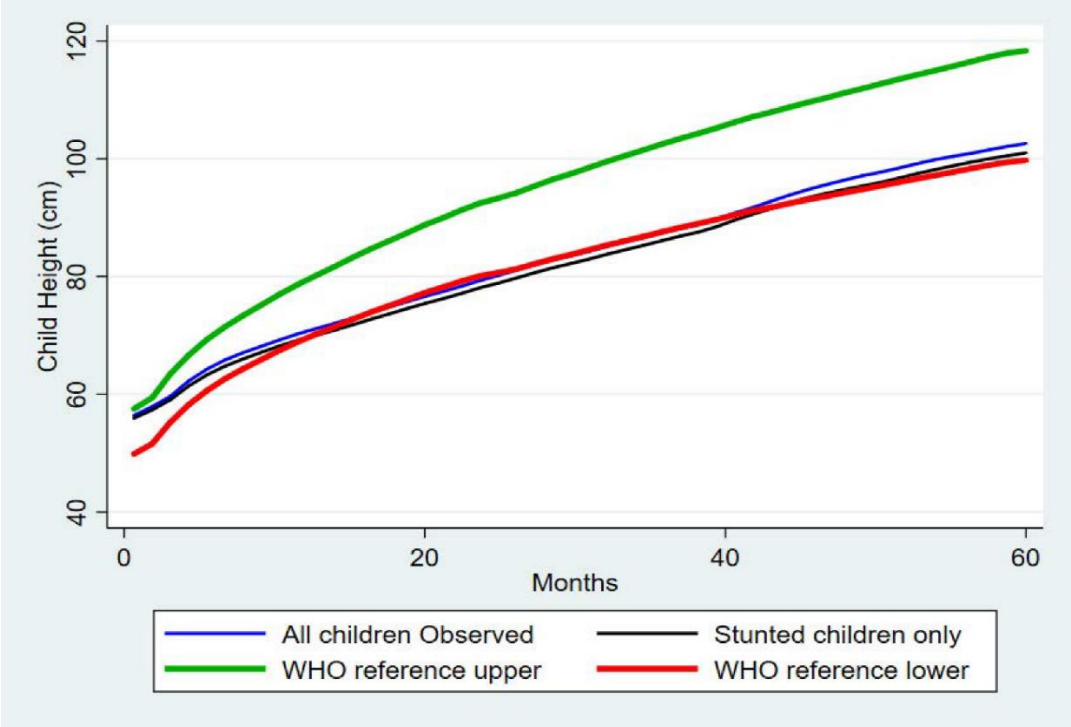

Figure 3. Child length/height (cm) for all children, stunted children only and WHO references by age (months)

5.2 Stunting and factors associated with child linear growth

Another finding is that about 58% of the children were stunted before the age of five years. By study site, a significantly greater proportion of stunted children were found in Korogocho compared to Viwandani, as shown in Figure 4. With regards to sex, there was no significant difference between female and male children.

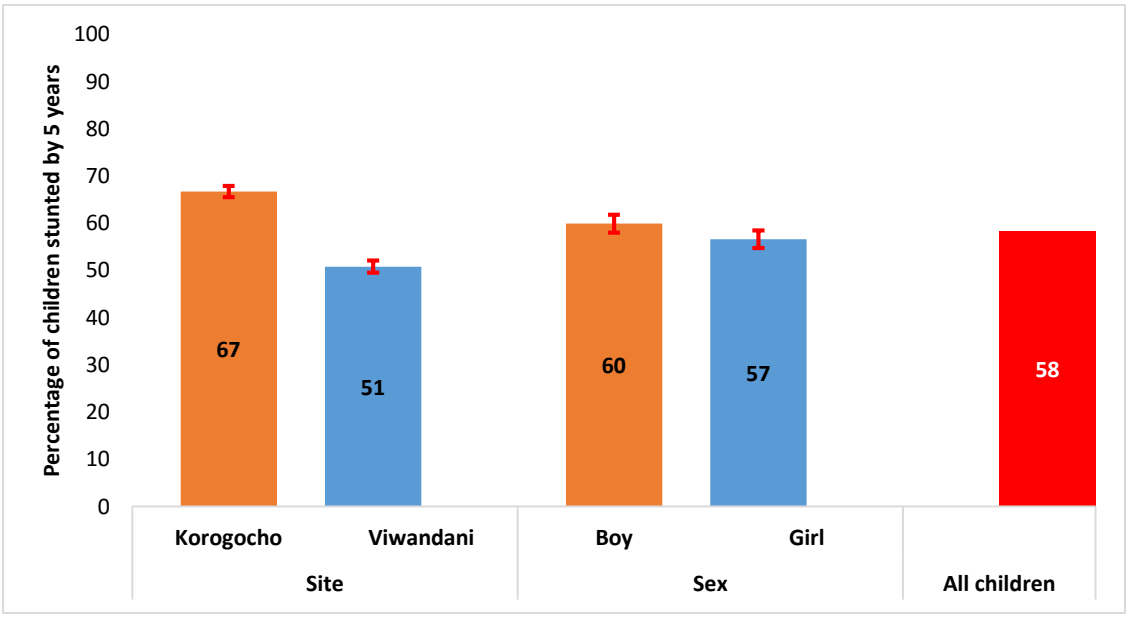

Figure 4. Percentage of children stunted before five years, by site, by sex, and overall

After fitting a generalized linear model on the height-for-age z-scores using the GEE method, factors associated with child linear growth are presented in Table 3. The results show that area of residence, child-related variables (sex of the child, birth weight, exclusive breastfeeding, immunization status), maternal characteristics (mother's age, marital status), and household level factors (economic status, size of household) were significantly associated with child linear growth. Specifically, female children appeared to grow faster than male children. We also noted that low birth weight was associated with slower growth while full immunization status was related to faster growth. In addition, children who were exclusively breastfed in the first six months of life, presented better linear growth outcomes than those who were not. On maternal factors, we noted that children from older mothers (25-34 years) were more likely to grow faster than those from younger mothers (age below 18). Higher education level (secondary or above) of the mother seemed to be positively associated with better growth outcomes, however the association was not statistically significant. Marital status of mothers also influenced child linear growth outcomes. In particular, children from mothers who were formerly married, were less likely to grow faster than those of currently married mothers. Looking at household level factors, the findings show that mother's socioeconomic status was significantly associated with child linear growth. Specifically, children from least poor households were more likely to grow faster than those from the poorest households. We also noted that size of the household influenced child linear growth, with children from larger households (3 members and above) having better linear growth outcomes than those from smaller households (less than 3 members). At site level, we noted that children in Viwandani were more likely to grow faster than those in Korogocho. These results are discussed in Appendix 10.1.1.

Table 3. Coefficients and 95% confidence interval associated with determinants of child linear growth

Covariates	All under-five children		
	Coef.	(95% CI)	Robust Std. Error
Child sex (Ref.=Boy)			
Female	0.33***	(0.19;0.47)	0.072
Site (Ref.=Korogocho)			
Viwandani	0.16†	(0;0.33)	0.084
Place of delivery (Ref.=Health facility)			
Elsewhere	-0.16	(-0.43;0.11)	0.139
Weight at birth (Ref.=Normal)			
Not weighted/Missing	-0.1	(-0.35;0.14)	0.127
Low weight	-0.88***	(-1.32;-0.44)	0.222
Exclusive breastfeeding up to 6 months (Ref.=No)			
Yes	0.92**	(0.28;1.57)	0.328
Full immunization (Ref.=Yes)			
No	-1.3***	(-1.43;-1.18)	0.064
Illness symptoms (Ref.=No symptom)			
One or more	0.09**	(0.03;0.14)	0.029
Mother age group (Ref.=<18)			
18/24	0.23	(-0.1;0.55)	0.166
25/34	0.37*	(0.01;0.73)	0.186
35+	0.28	(-0.19;0.75)	0.241
Ethnicity (Ref.=Kikuyu)			
Luhya	-0.07	(-0.3;0.17)	0.120
Luo	-0.03	(-0.26;0.2)	0.118
Kamba	-0.24†	(-0.47;0)	0.122
Other	-0.16	(-0.39;0.06)	0.114
Mother education (Ref.=Primary and below)			
Secondary+	0.09	(-0.09;0.26)	0.088
Mother marital status (Ref.=Married)			
Formerly married	-0.41***	(-0.64;-0.18)	0.117
Never married	0.12	(-0.16;0.4)	0.145
Mother's parity (Ref.<=1)			
2	0.05	(-0.14;0.24)	0.098
3	-0.08	(-0.33;0.17)	0.127
4	-0.17	(-0.47;0.13)	0.153
5+	-0.1	(-0.46;0.25)	0.181
Household economic status (Ref.=Poorest)			
Least Poor	0.17**	(0.07;0.28)	0.055
Size of household (Ref.<=2)			
3-4	0.47***	(0.22;0.72)	0.126
5+	0.3*	(0.02;0.57)	0.140
_cons	-4.02***	(-4.45;-3.58)	0.220
ln(child_age)	1		(Exposure)

*†p<0.1; *p<0.05; **p<0.01; ***p<0.001*

Another finding was the significant random effects noted at household level. They may be due to the repeated measurements on the same child or other unexplained factors.

5.3 Exclusive breastfeeding as per WHO recommendations is hard to implement in these settings

Exclusive breastfeeding, as recommended by WHO, was explored in the study. The results show that only about 2% of the children were exclusively breasted in their first six months of life. Further, children who were exclusively breastfed as recommended by WHO presented better linear growth outcomes, as reported in section 5.2. Using qualitative interviews, the reasons why exclusive breastfeeding rate was so low in these settings were explored. While most of the respondents recognized the importance of exclusive breastfeeding for a newborn, they unanimously found it hard to sustain up to six months for different reasons. For instance, mothers found it impossible to combine their occupation with exclusive breastfeeding of their child as some were young studying mothers, housemaids in richer areas of Nairobi or food sellers on the streets.

> *I used to breastfeed her, but after one month I had to do my KCSE (Kenya Certificate of Secondary Education). Then I started giving her Nan milk (infant formula).* ***Mother non-stunted child, Korogocho****.*

Some others evoked their baby's reluctance to breastmilk without expanding on the reasons.

> *After three months I started mixing with water, he (the baby) stopped breastfeeding by himself.*
>
> ***Interviewer****: Why did he stop?*
>
> *Just like that, he did not like my milk, and preferred sweet things like juices.* ***Mother stunted child, Viwandani***

However, we also found that some mothers lacked good information about health effects of pregnancy on breastfeeding, and about use of contraception while breastfeeding.

> *When I just realized that I was pregnant (five months after birth), I stopped breastfeeding as suggested by a friend.* ***Mother non-stunted child, Viwandani****.*
>
> *I stopped breastfeeding because I was taking family planning contraceptives. I thought the contraceptives were making him sick.* ***Mother stunted child, Viwandani***

Grandmothers, however, were mostly supportive of exclusive breastfeeding without being clear on the conditions and duration. Some of them reported having advised young mothers to comply with the practice and offered their support to take care of babies when mothers were away.

> *Exclusive breastfeeding is good because it is vital in development in the child's brain. Then the milk of the mother helps to prevent diseases. The mother's milk is always ready, it needs neither boiling nor cooking, and it has no budget.* ***Grand-mother, Korogocho***

5.4 Influence of grandmothers

In order to further understand the random effects noted at household level and to explore the influence of household members on child feeding, I conducted qualitative research in the study areas (See Appendix 10.1.2). The main interest focused on how decisions on child feeding are taken in the two informal settlements and who the main persons involved are. The findings show that mothers are not the only decision-makers on the feeding of their child. Beside health providers and grandmothers were commonly reported to have a key role in that process.

Most of the mothers recognized and valued advice from grandmothers and this was the case for mothers of children who were stunted and not-stunted.

> *When I introduced cow's milk and porridge at six months, my mother is the one who advised me to do that.* ***Mother stunted child, Viwandani***
>
> *My mother used to advise me on the importance of breastfeeding the child for long.* ***Mother non-stunted child, Korogocho.***

However, some grandmothers did not always think their advice was fully considered by younger mothers. Indeed, their comments implied generational shifts in norms and suggested intergenerational conflict between young mothers and grandmothers in this community, as a grandmother reported.

> *These days you can see how they (young mothers) behave…If you talk to them, they would say 'what this old woman can teach me?' I would not be surprised if their children are fed on French fries at night.* ***Grand-mother, Korogocho***

Looking at the roles of fathers in child feeding, the results show that most of the fathers interviewed indicate that their role is limited to that of providing food and they have developed strategies to cope with their expected duties. Their role did not extend to decision making about child feeding.

5.5 Incidence of recovery from stunting-up

The incidence of recovery from stunting was 45% among stunted under-five children in the two settlements. Table 4 shows the percentage of children who were stunted by five years and, among them, the percentage who recovered from stunting (incidence) before five years, according to background

characteristics of the child and mother at the time of recruitment. There were no significant differences noted between the child level characteristics (site, sex, place of birth, weight at birth, immunization status, and illness symptoms in last two weeks) and recovery from stunting. Looking at maternal characteristics, there were significant differences with child recovery. For instance, recovery from stunting was significantly least pronounced for children of younger mothers (41% when mother is below 18 vs. 68% when mother is 35 and above). With regards to mothers' education, there was interestingly no significant difference in the incidence of recovery. At household level, the results show significant difference in recovery from stunting by size of the household. For instance, the incidence of recovery was significantly higher in households with bigger size (3 members or more) than in households with smaller size.

Table 4. Percentage of children who were stunted by five years and, among them, the percentage who recovered from stunting before five years, background characteristics at the time of recruitment

	Stunted children		Recovery from stunting	
	%	N	%	N
All children	**58.3**	**1,816**	**45.3**	**1,059**
Site				
Korogocho	66.7***	854	48.3	570
Viwandani	50.8	962	41.9	489
Sex				
Boy	59.9	926	42.7	555
Girl	56.6	890	48.2	504
Place of delivery				
Health Facility	58.6	1,293	49.8	757
Elsewhere	64.2	523	37.5	336
Child weight at birth				
Not weighted at birth/missing	62.0	642	37.2	398
Low weight (<2500g)	69.6	56	41.0	39
Normal weight (2500-5500)	58.7	1,118	51.7	656
Exclusively breastfed up to six months				
Yes	41.7†	24	60	10
No	60.4	1,792	45.9	1,082
Immunization status				
Up to date	61	1,003	48.9	612
Not up to date	59.2	813	42.4	481
Number of illness symptoms in last two weeks				
No symptoms	60.1	1,038	46	624
One or more symptoms	60.3	778	46.1	469
All mothers	**60.2**	**1,616**	**46.0**	**973**
Age group at child birth				
<18	69.3	114	40.5*	79
18/24	61.2	824	48.4	504
25/34	61.5	574	47.9	353
35+	72.1	104	68	75
Ethnic group				
Kikuyu	60.9***	399	56.8***	243
Luhya	65.6	285	41.7	187
Luo	63.3	327	44	207
Kamba	62.1	338	41.4	210
Other	61.6	267	61.8	164
Highest Education				
Primary or below	64.9***	1,208	49.2	784
Secondary+	55.6	408	48.5	227
Socioeconomic status[m]				
Poorest	68.1***	921	49.4	627
Least Poor	56.5	451	47.8	255
Household size[m]				
<=2	55.2***	87	35.4*	48
3-4	60	773	46.1	464
5+	72.3	512	54.3	370
Marital status at birth[m]				
In union	61.3*	1,365	48.8	837
Formerly married	67.1	88	44.1	59
Never married	71.3	160	54.4	114
Parity at child birth[m]				
1	59.3	582	48.1	345
2	62.1	443	48	275
3	62.5	264	50.9	165
4+	69.2	325	50.7	225

*[m]: Missing values not reported - †p<0.1; *p<0.05; **p<0.01; ***p<0.001*

Table 5. Adjusted hazard ratios from Cox regression model predicting the risk of recovery from stunting

	All stunted children	
Covariates	**Haz. Ratio**	**(95% CI)**
Child sex (Ref.=Boy)		
Female	1.05	(0.7;1.58)
Site (Ref.=Korogocho)		
Viwandani	1.44	(0.86;2.4)
Place of delivery (Ref.=Health facility)		
Elsewhere	1.32	(0.64;2.71)
Weight at birth (Ref.=Normal)		
Not weighted/Missing	0.45**	(0.22;0.92)
Low weight	1.92	(0.75;4.94)
Immunization (Ref.=Up to date)		
Not up to date	0.64*	(0.41;1)
Illness symptoms (Ref.=No symptom)		
One or more	1.10	(0.72;1.68)
Mother age group (Ref.=<18)		
18/24	1.49	(0.6;3.7)
25/34	1.58	(0.57;4.4)
35+	1.88	(0.51;6.97)
Ethnicity (Ref.=Kikuyu)		
Luhya	0.71	(0.31;1.6)
Luo	1.2	(0.6;2.42)
Kamba	1.29	(0.71;2.36)
Other	1.26	(0.66;2.42)
Mother education (Ref.=Primary and below)		
Secondary+	0.84	(0.5;1.41)
Mother marital status (Ref.=Married)		
Formerly married	0.51	(0.18;1.47)
Never married	1.29	(0.6;2.77)
Mother's parity (Ref.<=1)		
2	0.75	(0.44;1.3)
3	0.56	(0.27;1.16)
4+	0.34**	(0.14;0.84)
Household economic status (Ref.=Poorest)		
Least Poor	1.61**	(1.01;2.57)
Size of household (Ref.<=2)		
3-4	0.53	(0.26;1.08)
5+	1.01	(0.47;2.17)

**p<0.1; **p<0.05; ***p<0.01*

5.6 Determinants of recovery from stunting

☞ ***Timely child immunization, mother's parity and household socioeconomic status are important factors predicting the time to recover from stunting within the first five years of life***

Factors associated with the time to recover from stunting are presented in Table 5 from the adjusted Cox regression model. The results show significant associations between four of the covariables (weight at birth, immunization status, mother's parity at child birth, household economic status) and the time to recover from stunting. For instance, children who were not weighted at birth or whose birth weight was not reported, had were less likely to recover earlier (HR=0.45) as compared to those with a normal weight at birth. In addition, children whose immunization status was not up to date were less likely to recover earlier (HR=0.64) than those within on-time immunization. Children whose mothers had higher parity at birth (4 children or more) had a lower chance to recover earlier than those from mothers with lower parity (HR=0.34). At household level, the results show that children from the least poor households were significantly more likely to recover earlier (HR=1.41), compared to children from the poorest households. These findings are discussed in detail in Appendix 10.1.3.

☞ ***Child illness status and age at first stunting, mother's parity and age have a strong influence on child post-stunting linear growth.***

After fitting a linear regression of ΔHAZ on a second degree fractional polynomials in age of the child at first stunting (Table 6), we demonstrated key factors associated with post-stunting linear growth among under-five children. The results show that stunted children who presented illness symptoms over the last two weeks prior to the survey, were less likely to catch-up on linear growth before five years. Also, children of older mothers (35 years above) were more likely to experience post-stunting catch-up in linear growth than those of younger mothers. Another result is higher mother parity at child birth was negatively associated with child post-stunting growth. Finally, the model shows that age at first stunting is an important factor associated with post-stunting catch-up, as children who were older at first stunting were less likely to catch-up by five years.

Table 6. Coefficients and 95% confidence interval from the linear regression of ΔHAZ on a second degree fractional polynomials in age of the child at first stunting

	All stunted children	
Covariables	**Coef.**	**(95% CI)**
Child sex (Ref.=Boy)		
Female	0.002	(-0.01;0.01)
Site (Ref.=Korogocho)		
Viwandani	-0.003	(-0.02;0.01)
Place of delivery (Ref.=Health facility)		
Elsewhere	-0.003	(-0.02;0.02)
Weight at birth (Ref.=Normal)		
Not weighted/Missing	-0.003	(-0.02;0.01)
Low weight	-0.02	(-0.05;0.01)
Immunization (Ref.=Up to date)		
Not up to date	-0.003	(-0.01;0.01)
Illness symptoms (Ref.=No symptom)		
One or more	-0.015**	(-0.03;0)
Mother age group (Ref.=<18)		
18/24	0.004	(-0.02;0.03)
25/34	0.008	(-0.02;0.03)
35+	0.03*	(0;0.06)
Ethnicity (Ref.=Kikuyu)		
Luhya	0.005	(-0.01;0.02)
Luo	-0.005	(-0.02;0.01)
Kamba	-0.003	(-0.02;0.01)
Other	0.01	(-0.01;0.03)
Mother education (Ref.=Primary and below)		
Secondary+	0.004	(-0.01;0.02)
Mother marital status (Ref.=Married)		
Formerly married	-0.015	(-0.03;0.01)
Never married	0.003	(-0.02;0.02)
Mother's parity (Ref.<=1)		
2	-0.016**	(-0.03;0)
3	-0.025**	(-0.04;-0.01)
4	-0.035***	(-0.06;-0.01)
Family economic status (Ref.=Poorest)		
Least Poor	0.004	(-0.01;0.02)
Size of household (Ref.<=2)		
3-4	0.01	(-0.02;0.04)
5+	0.02	(-0.01;0.05)
age_first stunting_1	-0.053**	(-0.11;0)
age_first stunting_2	0**	(0;0)
_cons	0.016	(-0.02;0.05)

**p<0.1; **p<0.05; * **p<0.01*

6 Discussion: From Data Mining to Data Meaning - When Statistics speaks Public Health

Discussing the overall results of this research required stepping back and reviewing the data collectively from all three sub sections. It also required thinking about what the results mean rather than restating the tables in words. This marked a personal transition from a data specialist to a public health specialist; from a person looking for patterns in data to a person looking for evidence based meaning that can improve public health. Reflecting on the meaning of the data required self-reflection.

After my Master's degree in Statistics obtained in 2001, I spent fifteen years of my research career being a data scientist; data mining. This was a game I played and loved. Data Mining is : the process of discovering patterns in large data sets involving methods at the intersection of machine learning, statistics, and database systems (94) or simply the process of digging through data to discover hidden connections and predict outcomes (95, 96). In data mining, to use a soccer analogy, the players are variables ranging from numeric (continuous or discrete), categorical (ordinal or nominal) or sometimes qualitative (text, open-ended). The rules are many and usually depend on the types of analysis and statistical models to fit, whether descriptive, bivariate or multivariable. As the data miner I was the coach in charge of thinking through the strategy; to identify the appropriate model and analyses to run; preparing my players, that is cleaning, recording and creating new variables; and launching the game, that is running and re-running the analyses, changing some parameters here and there, no matter how long it takes- a few minutes, hours, days or sometimes weeks, until an outcome is produced. The outcome was a nice table with a lot of numbers, some called coefficients or ratios, others errors, others confidence intervals, and others … are just there. The game was over and the resultant tables were handed to the Team Leader – job done and on to the next data set.

After 15 years of doing and enjoying this kind of work I realized that not only can those nice tables be much simpler, but importantly that I can make those tables, particularly their quintessence, more useful to my life, to people's life. That's when I started a PhD but not in statistics but rather to develop a skill to give meaning to numbers. This was my PhD journey which I will try to narrate through my PhD research findings highlighted in section 5 – the jump from Data Mining to Data Meaning.

One of my first research findings was related to **child growth trajectories and factors associated with them in the two Nairobi's informal settlements**. In my Data Mining life, I would extensively describe the generalized linear model used focusing on the GEE method, explaining how the method provides consistent parameters and standard error estimates even when I could miss the correct correlation

structure, showing how the link function relates the mean response to the regression equation, and presenting the correlation matrix and parameters. All very good and useful … for sure! But in a Public Health life, I decided to focus on the importance of exclusive breastfeeding up to six months as recommended by the WHO, and timely immunization as key drivers of child linear growth in early ages in the study settings. However, I must highlight the finding that it was almost impossible for most mothers in these settings to implement exclusive breastfeeding as recommended by WHO. Several barriers were identified in particular: difficulty for younger mothers to combine exclusive breastfeeding with their occupation; lack of good information about health effects of pregnancy on breastfeeding, and misconceptions around use of contraception during breastfeeding. The finding is consistent with studies from similar settings which also demonstrate that poor social and professional support, early and single motherhood, poor knowledge, myths and misconceptions, and unintended pregnancies emerged as barriers to exclusive breastfeeding (97)(98). The finding calls for a more inclusive approach for tackling suboptimal breastfeeding in these communities. For instance, initiatives to support mothers to combine breastfeeding and occupations (e.g. studies, work) need to be promoted. One such initiative is human milk banking (99-101).

On the other side, timely immunization during childhood is widely documented as one of the most effective strategies for preventing a number of child diseases and growth impairments (102). It is also known that children who are not or not fully immunized are more likely to have adverse health outcomes in early life (103). This result highlights the need for increased efforts above what is already done, in particular beyond the basic promotional immunization campaigns, to reduce child diseases in these rapidly urbanizing settings.

Furthermore, the finding that children from poorest households were more likely to have adverse linear growth than those from least poor households, to me is very helpful to program implementers and policy-makers in these settings. The result is also consistent with studies in similar settings (13, 15). In contexts of limited resources, any actions towards tackling extreme poverty and targeting the most vulnerable, would be of high impact in these settings.

These findings on child growth trajectories are some of the ones I described in my first paper (Appendix 10.1.1). They should be considered when designing interventions aiming at addressing child health inequities in these settings. These interventions must also take into account the enabling role of women's education (secondary or higher) in ensuring good child health outcomes, including normal linear growth. To me, this was a contribution of a Data Mining person trying to give Meaning to numbers.

Of course, a Data Mining background was essential to be able to connect these coefficients and error estimates to the reality of children's linear growth and children's survival in deprived urban settings like these. And then, while going through these important findings and trying to speak to a Public Health audience, something that the data mining illustrated, remained unclear to me. Random effects were found at household level, what is the meaning of this? What is the relevance of the finding that random effects could influence children's linear growth, their life? In my Data Mining life, I would conclude that there are significant random effects, maybe due to repeated measurements on the same child and also to some other things happening at household level that I could not know. However, my new Public Health lens inspired me to go and talk to household members in order to understand what those significant random effects could be and how it may inform Public Health. That's when I decided to collect qualitative data through in-depth interviews with household members (mothers, fathers, grandmothers) in order to give a Meaning to those random effects.

That was my other jump to a new thinking framework, that of qualitative data analysis. I could not say it was totally new to me as a Data Miner, I have had to deal with open-ended questions leading to huge amount of text variables, which all had to be read, decoded, and categorized to use within a quantitative framework. But that is not qualitative data analysis. Part of my PhD journey was being exposed to a totally new epistemology and learning a new methodology. After going through that process, and using a deductive coding framework, I learnt that **Grandmothers are very influential on household decision-making around child feeding**. That was another key finding from my PhD research. And the random effects were being explained in a way that can be useful. Indeed, the unexplained factors influencing child linear growth as mentioned in section 5.2, reflected the fact that mothers are not the sole decision-makers within the household regarding the feeding of their children. Grandmothers play key advisory roles in addition to being potential child caregivers. Importantly, they seemed supportive of exclusive breastfeeding by young mothers. The result confirms findings in studies from different settings where senior women were central to the social dynamics and decision-making within households and communities (78, 104, 105). My significant random effects were then given a Meaning, something that a Public Health person could easily understand and use to influence health outcomes.

Another interesting result from my qualitative research was that **fathers are described as only providers of food**. They are not expected to be involved in decision-making around child feeding. When I read similar results found in Ethiopia and other African settings (106, 107), I could appreciate the strength of Public Health research in compiling and translating scientific evidence into simpler meanings. It is important to

note that if fathers are not knowledgeable about child feeding, then they may provide food that is not always appropriate to children, thus resulting to sub-optimal child nutrition. Therefore, for effective child health and development, involvement and appropriate knowledge of both parents in the feeding and caring of infants and young children is be essential (108, 109).

The core part of my research was to identify the factors associated with recovery from stunting among under-five children in the two informal settlements. I could have really enjoyed this piece in the Data Mining Game. Playing with the data, fitting the "best" multivariable regression model, narrating its history, describing the equation and parameters, their mathematical framework, …., it would have been hours, days of the Game. I found I enjoyed it nonetheless when, jumping into my Public Health life, I tried to make it meaningful by answering the questions: 1) Which proportion of stunted children have recovered by five years? 2) Why are some recovering faster than others? 3) What are the factors affecting post-stunting linear growth among under-five children in the two informal settlements?

Of course, answering these questions could not be done without a bit of Data Mining, particularly descriptive analyses and statistical modelling – which I did. After running a range of crosstabs, plotting the outcome variables against some covariables (Figure 4 and Table 4), and computing Kaplan-Meier estimates (Figure 2 in Appendix 10.1.3), I arrived at the finding that: **58% of children in the two settlements were stunted before their five years, and among those, 45% have recovered from stunting before five years.** That was my answer to Question 1. Similar patterns of recovery from stunting were found in a longitudinal study from four LMICs where the proportion of stunted children who recovered by five years ranged from 27% in Vietnam to 53% in Ethiopia (29). Also, Adair et al. (110) found that 30% of Filipino children stunted at 2 years recovered by the age of 8.5 years, while in urban South Africa a higher incidence of recovery from stunting (75%) was estimated among under-five children (30). As in this current research, these studies defined catch-up in linear growth in relation to changes in height-for-age z-scores and considered recovery from stunting when HAZ at later age was above minus two SD. Therefore, this study confirms these patterns in a different context of urban informal settlements. I could have also commented on the Kaplan-Meier parameters and the comparison tests. Yes, our beloved chi-squared test, so appreciated in the Game! We also called it Pearson's chi-squared test (111-113). I should confess the power of this test – in the Game – in assessing the goodness of fit between a set of observed values and those expected theoretically (111). In other words, the test was good in closing the debate on whether there was significant difference between two groups or not. I used it to show that there were significant differences on recovery from stunting only by mother's age group, ethnic group and household size. In

Public Health, that could mean that recovery from stunting was least pronounced for children of younger mothers (< 18 years) than those of older mothers (35 years and above); that children of *Kikuyu* mothers recovered mostly by five years; and that the incidence of recovery was significantly higher in bigger households than in smaller households.

However, that was not enough! I had to run the models, adjusted models, ensuring that confounders and other noisy variables are controlled for, to understand why some children were recovering faster than others. In that Game, I would never have missed explaining the parameters and theoretical frameworks of the Cox regression analyses. Nevertheless, in trying to speak Public Health, my answer to Question 2 was that: **child weight at birth, timely immunization, mother's parity, and household economic status were important factors associated with time to recover from stunting.** These findings emphasize the need to reinforce child vaccination interventions in order to prevent child growth failures and reduce child diseases in Nairobi informal settings. This study has reinforced existing knowledge and provided confirmatory evidence in a different setting that child immunization is one of the most effective strategies for preventing a number of child diseases and growth impairments (102). From a Public Health point of view, it is important to highlight that immunization coverage is usually low in informal settlements and that this finding should be used to emphasize the need to pay greater attention to populations living in these settings.

The findings that mother's parity and household socioeconomic status are influential factors of time to recovery from stunting, are not surprising given the context of the sites described in Emina et al. (44) and Fotso et al. (14), and call for sustained promotion of family planning programs and economic reinforcement in these areas.

Answering Question 3, also involved modeling, in particular HAZ slope modeling, and fitting a linear regression of ΔHAZ on a second degree fractional polynomials in age of the child, to identify factors that were significantly associated post-stunting linear growth. After doing that, I was able to translate the results into a Public Health language. Simply to say that: **child illness status and age at first stunting, mother's parity and age have a strong influence on child post-stunting linear growth.** The results could be emphasized as child diseases is one of the main obstacles to linear growth in early childhood. The finding extends that of studies from different settings where acute and chronic illnesses in childhood were highly associated with poor linear growth outcomes in early life (2, 3, 114). Therefore, access to child health services and increased awareness among health professionals and caregivers, would be critical in improving child growth outcomes in informal settlements, again emphasizing that ignoring informal

settlements will prevent countries from achieving the SDGs. Another finding is that maternal factors such as mother's age and parity at child birth are shown to be influential in post-stunting linear growth. The result is in line with the first paper in this PhD research (Appendix 10.1.1) where children of older mothers (35 years and above) demonstrated better linear growth outcomes than those of younger mothers (age below 18 years) (115). Other studies have shown that young mothers living in the two slums are mostly single (116) and lack resources and experience to cater for their child's needs including nutrition and health care (97). Specific maternal and reproductive health interventions targeting young mothers in informal settlements may be needed to reduce adolescent and young mother's vulnerability and improve their children's health outcomes. The need to pay more attention to informal settlements is a recurring theme.

7 Study limitations and further research

Notwithstanding the importance of these findings, I need to highlight a few limitations. For instance, child diseases, illustrated by illness symptoms in this study, was not significantly associated with linear growth trajectories, as reported in number of studies (2, 3, 114). This absence of association doesn't necessarily contradict the effect of diseases on child growth, it may be due to the timing of measurement as the illness symptoms (fever, convulsions, diarrhea, cough, rapid breathing) were reported only over the two weeks preceding each interview. This may have led to underestimation of the effects of illnesses that occurred before.

Similarly, some variables such as mother's height, child gestational age at birth and complementary feeding variables were not included in the model as the information was not consistently collected during the survey. However, I believe ethnicity, child weight at birth and exclusive breastfeeding could be appropriate proxies to capture some of the missed information respectively.

Furthermore, child weight at birth was not found to be a predictor of post-stunting linear growth, as shown in studies from other settings (110, 117). This could be explained by the small sample size that only 3% of the children in the study had low birth weight. Therefore, further studies with bigger sample sizes may be needed to better understand the relationship between low birth weight and post-stunting growth.

In identifying the factors associated with time to recover, use of HAZ slope modelling limits the benefits of the time-varying covariates because some have to be recoded as non-time varying variables, thus potentially losing a bit of information.

On the qualitative component, we did not relate the views of all respondents from the same household. That could have contributed to enriching the narratives and provided a better understanding of child feeding practices and decision-making mechanisms within each household. In addition, some mothers of stunted children did not expressly recognize the status of their children, and provided answers as if their child was never stunted. In such circumstances our probes on re-feeding once stunting was recognized could not be exploited.

Finally, basic determinants of child health, specifically the political context and physical environment that were not directly studied, might have been captured by the effects of household level variables which will be investigated in further study.

8 Conclusions

The importance of normal linear growth in early life in developing countries cannot be over-emphasized as it has profound effects on child health outcomes. In this study, I tried to expand the literature on child linear growth particularly in the context of deprived urban settings. I first looked at the determinants of child linear growth; then I investigated the family influence on decisions around child nutrition; and finally I identified the factors associated with recovery from stunting by five years among under-five children in the two Nairobi's informal settlements.

The findings illustrate important factors that are associated with child linear growth. Among these factors, some are more easily modifiable and there is possibility for policy-makers and program implementers to act on them. For instance, child weight at birth, timely immunization, feeding practices and mothers and fathers knowledge and education should be considered when designing interventions aiming at addressing child health inequities in these settings. Similarly, targeting single and young mothers in child health and economic interventions in these areas would contribute to lowering the prevalence of linear growth impairment and reduce adolescent and young mother's vulnerability.

The study also finds that grandmothers have central roles in child nutrition as they are key advisors to younger mothers and actively contribute to child caregiving. As such, they should be among the targets for child health interventions and should been seen as a potential asset in strategies aiming to reduce child malnutrition in these settings. In addition, optimal feeding practices as recommended by international programs may not be successfully implemented in these settings without considering the roles on grandmothers and the almost total impossibility for young and single mothers to combine child exclusive breastfeeding with their work. Interventions that leverage on grandmothers' willingness to

support young mothers, and those creating possibilities for mothers to continue breastfeeding in their workplaces, through human milk banking and other baby-friendly initiatives must be prioritized. However, it's important to highlight possible difficulties to properly implement human milk banking solutions in slum context due to high costs and lack of appropriate hygiene conditions. There are ongoing studies in these very sites to assess the feasibility and efficiency of such interventions in this context. Another solution would be to give allowances to working mothers that can support fees for a caregiver or nun who would take care of their babies while at work. Providing correct but implementable advice (exclusive breastfeeding) without creating the conditions to make uptake of such advice represents an incomplete Public Health strategy.

Among the other factors, extreme poverty in the informal settlements is at the center. Any intervention omitting to address poverty reduction in these settings is likely to be ineffective. In a context of poor access to formal housing, uncertain daily access to food and to basic social needs, policy-makers and program implementers must prioritize economic reinforcement interventions such as cash transfers and access to decent employment and housing.

A number of interventions have been implemented in Nairobi's informal settlements to reduce child mortality including malnutrition and growth impairments. However, the reasons why significant impact is not yet seen must be answered. I believe some of the answers are humbly described in this research, by showing that in fact interventions are missing important targets such as senior women, are missing the most vulnerable targets such as single and young mothers, are keeping fathers behind the scene of child growth. Lastly, the importance of paying attention to informal settlements cannot be overstated.

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10 Appendices

10.1 Papers

10.1.1 Paper 1

(See attached)

10.1.2 Paper 2

(See attached)

10.1.3 Paper 3

(See attached)

10.1.4 Policy-brief

10.2 Ethical approvals

amref health africa

Amref Health Africa In Kenya

REF: AMREF – ESRC P244/2016 26th July 2016

Cheikh Faye
Africa Population and Health Research Center
Tel: +254 739 217 509
Email: cfaye@aphrc.org

Dear Cheikh Faye,

RESEARCH PROTOCOL: FACTORS ASSOCIATED WITH STUNTING AND CATCH UP GROWTH AMONG UNDER FIVE CHILDREN IN NAIROBI INFORMAL SETTLEMENTS

Thank you for submitting your research protocol to the Amref Ethics and Scientific Review Committee (ESRC).

This is to inform you that the ESRC has approved your protocol. The approval period is from 26th July 2016 to 26th July 2017 and is subject to compliance with the following requirements:

a) Only approved documents (informed consents, study instruments, advertising materials etc) will be used.

b) All changes (amendments, deviations, violations etc) are submitted for review and approval by Amref ESRC before implementation.

c) Death and life threatening problems and severe adverse events (SAEs) or unexpected adverse events whether related or unrelated to the study must be reported to the ESRC immediately.

d) Any changes, anticipated or otherwise that may increase the risks or affect safety or welfare of study participants and others or affect the integrity of the research must be reported to Amref ESRC immediately.

e) Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period (attach a comprehensive progress report to support the renewal).

f) Clearance for export of biological specimen or any form of data must be obtained from Amref ESRC, NACOSTI and Ministry of Health for each batch of shipment/export

g) Submission of an executive summary report within 90 days upon completion of the study. This information will form part of the data base that will be consulted in future when processing related research studies so as to minimize chances of study duplication and/or plagiarism.

Please do not hesitate to contact the ESRC Secretariat (esrc.kenya@amref.org) for any clarification or query.

Yours sincerely,

Prof. Mohamed Karama
Chair, AMREF ESRC

CC: Dr. George Kimathi, WASH Programme Manager, Amref Kenya and Vice Chair Amref ESRC
Samuel Muiiula, Monitoring & Evaluation and Research Manager, Amref Kenya

KENYA MEDICAL RESEARCH INSTITUTE

P.O. Box 54840-00200, NAIROBI, Kenya
Tel (254) (020) 2722541, 2713349, 0722-205931, 0733-400003; Fax: (254) (020) 2720090
E-mail: director@kemri.org nfo@kemri.org Website:www.kemri.org

KEMRI/RES/7/3/1 **May 31, 2012**

TO: DR. ALEX EZEH (PRINCIPAL INVESTIGATOR)
AFRICAN POPULATION AND HEALTH RESEARCH CENTRE,
P. O. BOX 10787-00100,
NAIROBI

Dear Sir,

RE: SSC PROTOCOL No. NON-SSC 271B (*RE-SUBMISSION: REQUEST FOR STUDY RENEWAL):* URBANIZATION, POVERTY AND HEALTH DYNAMICS IN SUB-SAHARAN AFRICA

Reference is made to your letter dated 29th May 2012.

The ERC Secretariat acknowledges receipt of copies of the study dissemination packages to the Urban Nutrition Group in the Ministry of Public Health and Sanitation; World Food Programme; Concern Worldwide and World Congress of Epidemiology.

The Committee determines that the issues raised at the 200th ERC meeting of 17th April 2012 are adequately addressed. Consequently, the study is granted approval for continuation.

Please note that authorization to conduct this study will automatically expire on **January 23, 2013**. If you plan to continue data collection or analysis beyond this date, please submit an application for continuation approval to the ERC Secretariat by **December 12, 2012**.

You are required to submit any proposed changes to this study to the ERC for review and the changes should not be initiated until written approval from the ERC is received. Please note that any unanticipated problems resulting from the conduct of this study should be brought to the attention of the ERC and you should advise the ERC when the study is completed or discontinued.

You may continue with the study.

Sincerely,

DR. CHRISTINE WASUNNA,
ACTING SECRETARY,
KEMRI ETHICS REVIEW COMMITTEE

R14/49 Mr Ceikh Mbacké Faye

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M160453

NAME: (Principal Investigator)	Mr Ceikh Mbackè Faye
DEPARTMENT:	School of Public Health African Population and Health Research Center
PROJECT TITLE:	Stunting and Determinants of Catch-Up Growth among Under-Five Children in Nairobi's Informal Settlements
DATE CONSIDERED:	06/05/2016
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Sharon Fonn
APPROVED BY:	Professor P. Cleaton-Jones, Chairperson, HREC (Medical)
DATE OF APPROVAL:	11/07/2016

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary in Room 10004,10th floor, Senate House/2nd floor Phillip Tobias Building, Parktown, University of the Witwatersrand. I/We fully understand the the conditions under which I am/we are authorised to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated,from the research protocol as approved, I/we undertake to resubmit to the Committee. I **agree to submit a yearly progress report.** The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. In this case, the study was initially review in April and will therefore be due in the month April each year.

Principal Investigator Signature Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

March 31, 2016

Cheikh Mbacké Faye, PhD student
School of Public Health, University of the Witwatersrand
27 St Andrews Road - Parktown 2193 – Johannesburg, South Africa
Tel: +27 11 717-2543
Fax: +27 11 717-2084

Dear Cheikh,

RE: Data Request Approval

I write to confirm that APHRC has approved your request to use the data from its project "Urbanization, Poverty and Health Dynamics - Maternal and Child Health", as part of your PhD dissertation titled "Stunting and determinants of catch-up growth among under-five children in Nairobi's informal settlements. Anonymized versions of the following data files can be accessed:

- UPHD_MCH_Cohort3_anon.dta
- UPHD_MCH_Cohort4_anon.dta

If you need any further assistance, please do not hesitate to let me know.

Yours sincerely,

Dr. Catherine Kyobutungi
Director of Research
African Population and Health Research Centre (APHRC)

10.3 Faculty approvals

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

Private Bag 3 Wits 2050
Fax: 027117172119
Tel: 0271 7172078

Reference: Mrs Sandra Benn
E-mail: sandra.benn@wits.ac.za

24 June 2016
Person No: 1513579
PAG

Mr CM Faye
Aphrc Campus
Corner Manga Close
Kirawa Road
19787
Kenya

Dear Mr Faye

Doctor of Philosophy: Approval of Title

We have pleasure in advising that your proposal entitled *Factors associated with stunting and catch-up growth among under-five children in Nairobi's informal settlements* has been approved. Please note that any amendments to this title have to be endorsed by the Faculty's higher degrees committee and formally approved

Yours sincerely

Mrs Sandra Benn
Faculty Registrar
Faculty of Health Sciences

10.4 Plagiarism report

(attached)

10.5 Data collection tools

(attached)