ASSOCIATION BETWEEN SOCIOECONOMIC STATUS WITH BIRTH OUTCOMES AND INFANT GROWTH IN THE FIRST TWO YEARS OF LIFE. CASE STUDY IN SOUTH AFRICA AND DEMOCRATIC REPUBLIC OF CONGO.

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A THESIS

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Declaration

I, **Christian Bwangandu Ngandu**, declare that this thesis is my own original, unaided work. It is being submitted for the Degree of Doctor of Philosophy at the University of the Witwatersrand, Johannesburg, South Africa. It has not been submitted before for any degree or examination at any other university or institution.

Signature

14th day of October 2020.

Abstract

Background: Lower socioeconomic status has been associated with impaired child growth globally, but there have been limited literature and lack of consensus of the evidence on the relationship between socioeconomic status (SES) factors and infant growth in sub-Saharan Africa (SSA). Therefore, the aim of this thesis was to investigate the relationship between the household and maternal demographic as well as SES factors including maternal education; occupation; income; marital status; and household wealth index (HWI]), and adverse birth outcomes and infant undernutrition from birth until age two years in SSA.

Methods: One theoretical and two empirical studies were conducted to achieve the aim of this thesis. Firstly, a systematic review, following the PRISMA guidelines, combined the existing evidence on the association between SES factors and birth outcomes, including low birth weight (LBW), preterm birth (PTB), small for gestational age (SGA), and growth outcomes including stunting, wasting and underweight in children younger than 24 months in SSA countries. Secondly, in a cross-sectional comparative study, the associations between SES factors and birth outcomes in the Democratic Republic of Congo (DRC) and South Africa (SA) were compared in newborns at birth (ranged from 0 to 2 days). Thirdly, a cross-sectional analysis, drawing data from a longitudinal study which is referred to as the Soweto Baby WASH, investigated the associations between SES factors and undernutrition from 0 to 12 months in infants born and living in Soweto in SA.

Results: Overall, the thesis highlighted that maternal education and household wealth, as major SES factors, were associated with nutritional status in children at birth and during the first two years of life. Findings were threefold: Firstly, in the systematic review, a lack of consensus on the definition of 'SES factors' made comparison and generalisability of the evidence challenging. However, lower HWI, maternal unemployment, and low maternal education were consistently shown to be SES predictors of adverse birth outcomes (LBW, SGA), and infant undernutrition (stunting, wasting, and underweight) in SSA. Secondly, the local/regional context matters when assessing the association between SES factors and infant growth. Living in SA as compared to the DRC was associated with reduced odds of a newborn to be LBW, PTB or SGA, which reflects country-specific differences in maternal and household resources as well as social position (education access, housing, marriage). Being married in the DRC was associated with decreased likelihood of having LBW and PTB newborn whilst South African mothers with secondary level of education and above experienced lower risk of having a SGA

newborn. Thirdly, living in a wealthier household was associated with higher weight-for-height Z-scores and associated with lower height-for-age Z-scores at twelve months. However, living in a poor household with mother who had a secondary level of education and higher was associated with greater linear growth and lower weight gain at twelve months in SA. Maternal income, occupation and marital status were not significantly associated with infant growth in Soweto, in, SA.

Discussion: Maternal level of education, marital status, and household wealth were associated with growth and nutritional status from birth to two years of age in SSA with country disparities. These disparities were based on the level of socioeconomic development across different countries in SSA. In addition, maternal biological and country factors were strong predictors of infant growth and nutritional outcomes as they underpin individual and household capabilities. In wealthier households, infants gain weight compared to their height in the nutrition transition context like in South Africa.

Conclusion: Social policies should protect single women who are socially and economically deprived before, during, and after pregnancy to improve maternal and child health and nutrition, and to optimize their intergenerational influences.

Keywords: Socioeconomic status, birth outcomes, infant growth, undernutrition, sub-Sahara Africa, the Democratic Republic of Congo, South Africa.

Dedication

This study is dedicated to all children in sub-Saharan Africa, who are grappling with undernutrition and low birth weights.

Acknowledgements

This work is the fruit of a long journey for which I am thankful to Almighty God, the Supreme Being, for the materialization of such great achievement.

I acknowledge Prof Shane Anthony Norris for his incessant encouragement and invaluable support throughout the period of this study. His intellectual insights and experience have been of great benefit to me, and I can confidently say he is indeed an excellent mentor. I also acknowledge Dr Rihlat Said-Mohamed who patiently supported me during the course of this study and was available to guide me. She has been very willing to accompany us in our quest for scientific truth, and she was very patient. May she receive the expression of our gratitude.

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I acknowledge the Wits Medical School librarians who always responded positively to my requests for literature search. Your availability and timely responses have not gone unnoticed.

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To the children, women and all the volunteers who participated in this research, I say thank you. I am certain that you have contributed to the promotion of the well-being and nutritional status of children in Africa and around the world.

To all the others that I cannot mention here but contributed to the success of this long-awaited accomplishment, I say thank you.

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List of abbreviations

APA : Appropriate gestational age

BMI : Body mass index

CHBAH : Chris Hani Baragwanath Academic Hospital

DHS : Demographic Health Surveys

DPHRU : Developmental Pathways for Research Health Unit

DRC : Democratic Republic of Congo

EBF : Exclusive breastfeeding

ENT : Epidemiological nutritional transition

GA : Gestational age

GHI : Global hunger index

GWG : Gestational weight gain per week

HAZ : Height-for-age z-score

HIC : High income country

HREC : Human Research Ethics Committee

HWI : Household wealth index

IUGR : Intra-uterine growth retardation

LBW : Low birth weight

LGA : Large for gestational age

LMIC(s) : Low-income country(ies) and middle-income country(ies)

MIC : middle income country

MICS : Multi-indicators country surveys

NCD : Non-communicable disease

NIDS : National Income Dynamic Surveys

PTB : Preterm birth

RAs : Research assistants

SA : South Africa

SDG(s) : Sustainable Development Goal(s)

SES : Socioeconomic status

SGA : Small for gestational age

SSA : sub-Sahara Africa

UCH : Universal coverage health

UN : United Nations

UNICEF : United International Children Emergency and Funds

WASH : Water, sanitation and Hygiene

WAZ : Weight-for-age z-score

WHO : World Health Organization

WHZ : Weight-for-height z-score

Presentation of the thesis, conferences and publications

Presentation of the thesis

This thesis has been sub-divided as the following in the **Figure 1**

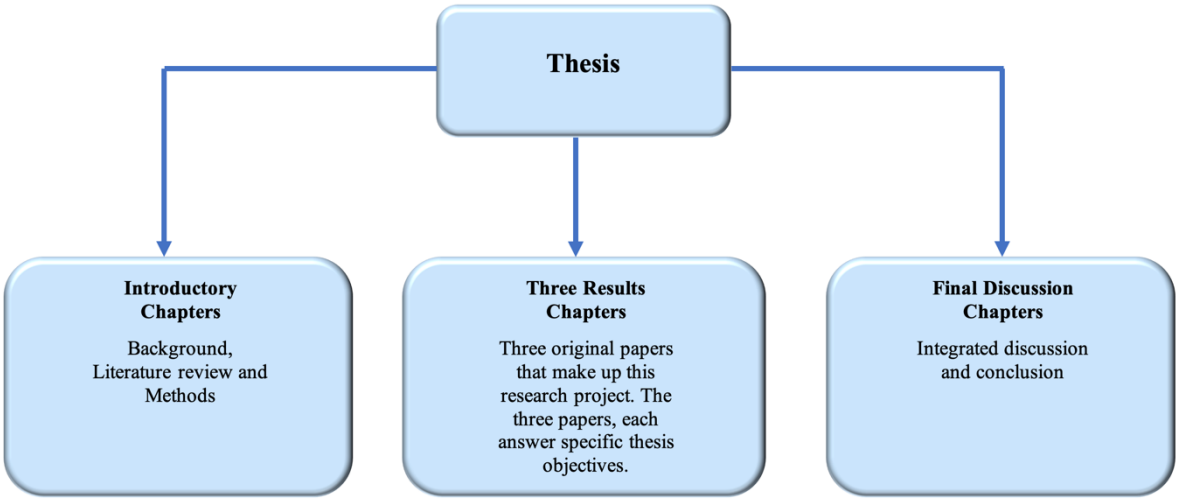

Figure 1 Graphical view of the thesis structure.

Conference proceedings:

Table 1 shows the conferences that were attended during the period of study:

Table 1: List of conferences

Date	Conference Title/Place	Presentation title
15-18 October 2017	The 10th anniversary world congress on Developmental origins of Health and Diseases (DOHaD). Rotterdam, Netherlands.	Oral presentation: The association between household socioeconomic status, maternal sociodemographic characteristics and adverse birth and infant growth outcomes in sub-Saharan Africa: a systematic review
03-06 December 2017	The 3rd International Conference on Global food security. Cape town, South Africa.	Poster presentation: The association between household socioeconomic status, maternal sociodemographic characteristics and adverse birth and infant growth outcomes in sub-Saharan Africa: a systematic review.
18 October 2019	Great grow summer on stunting, Johannesburg, South Africa	Poster: The association between household socioeconomic status, maternal sociodemographic characteristics and adverse birth and infant growth outcomes in sub-Saharan Africa: a systematic review
23 October 2019	The 2019, University of the Witwatersrand- School of clinical Medicine (SOCM) Research day, Johannesburg, South Africa	Oral presentation: The association between household socioeconomic status, maternal sociodemographic characteristics and adverse birth and infant growth outcomes in sub-Saharan Africa: a systematic review.

Publications

PhD Paper 1: Ngandu CB, Momberg D, Magan A, Chola L, Norris SA, Said-Mohamed R. The association between household socioeconomic status, maternal socio-demographic characteristics and adverse birth and infant growth outcomes in sub-Saharan Africa: a systematic review. Journal of Developmental Origins of Health and Disease. 2019:1-18. (Published)

PhD Paper 2: Ngandu CB, Momberg D, Magan A, Norris SA, Said-Mohamed R. Association between household and maternal socioeconomic factors with birth outcomes in the Democratic Republic of Congo and South Africa: a comparative study. Maternal and Child Health Journal. 2020. 1-7. (under review)

PhD Paper 3: Ngandu CB, Maposa I, Momberg D, Magan A, Norris SA, Said-Mohamed R. Association between maternal and household socioeconomic factors and infant growth: the Soweto Baby WASH study (South Africa). Public Health Nutrition. 2020. (under review)

Role of student on the above papers: Study design and conceptualization; developing data collection tools; data collection; data analysis and interpretation; drafting the manuscripts.

Other published papers during PhD study

Momberg DJ, **Ngandu CB**, Voth-Gaeddert LE, Cardoso Ribeiro K, May J, Norris SA, et al. Water, sanitation and hygiene (WASH) in sub-Saharan Africa and associations with undernutrition, and governance in children under five years of age: a systematic review. Journal of Developmental Origins of Health and Disease. 2020. 1-28.

Nieuwoudt SJ, **Ngandu CB**, Manderson L, Norris SA. Exclusive breastfeeding policy, practice and influences in South Africa, 1980 to 2018: A mixed-methods systematic review. PLOS ONE. 2019;14(10): e0224029.

Voth-Gaeddert LE, Jonah C, Momberg D, **Ngandu CB**, Said-Mohamed R, Oerther DB, May J. Assessment of environmental exposure factors on child diarrhea and systemic inflammation in the Eastern Cape. Water Research. 2020;169:115244.

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Preface

This thesis is a long scientific journey, reflecting numerous opportunities, challenges, and support that fostered my understanding of my PhD objectives. After my studies in immuno-haemato-transfusion and epidemiology, I was interested in research and epidemiology on health problems for young children who were affected by anaemia and malnutrition, particularly in sub-Saharan Africa. Thus, malnutrition in childhood has been the scientific focus and the scientific motivation for this research.

My main challenge during the PhD journey was language barrier: I come from the DRC, a French speaking country. French has always been the language of instruction in school, beginning from my primary school to higher levels of education; I also pursued my master's degree from a French speaking country. Pursuing PhD studies in English was one of the uphill tasks that I was determined to confront. I remember during my first year of PhD studies, joining English classes at the University of the Witwatersrand in South Africa. I was not only learning how to structure sentences in English, but also putting what I learnt into practice – by structuring my study objectives and goals in English. I thank my supervision team, which included a French speaking supervisor who facilitated communication with my other supervisor, who also patiently took their time to understand me, and to improve the work. Today, I am glad to have completed my PhD in English. I have also presented my work in different public platforms and drafted manuscripts in English. I hope this background contributes to motivating other students who are determined to conduct studies in foreign languages

Relevance of the PhD topic

Early child nutritional status is a predictor of disabilities, high morbidity and mortality as well as cardiometabolic diseases. Early child nutritional status is also a predictor of poor child schooling, low job opportunities, low country development and poverty. However, poverty and low socioeconomic status of mothers and households are associated with and impact on child nutritional status. Apart from the biological, food insecurity and dietary factors not covered in this study, socioeconomic factors (maternal education, maternal income, maternal occupation and household wealth) and socio-demographic factors (marital status) have been studied in their relationship with nutritional status of children at birth and during the first two years of life in sub-Saharan Africa (SSA), which is considered as a poor setting. The relevance of this research is hinged on the fact that this study focused particularly on early growth which refers to the first 1000 days (from conception to two years of life). This period is critical for predicting the health and nutrition of individuals as well as populations, on the life cycle. The role played by demographic and socioeconomic (SES) factors on the nutritional status of children under two years of age are not widely documented, particularly, in SSA. Even when the data and evidence do exist, there is a lack of consensus. In addition, the association between SES factors and child nutritional status, especially during 0 to 5 years of age is very critical; for example, the age of two years is quite relevant because it is the age of essential interventions that are vital and determining for the lives of children and even adults. Therefore, the findings reported in this thesis will inform policy makers in decision making, particularly on how to protect and promote maternal and child health and growth in SSA.

Overarching research question

The UNICEF's undernutrition framework reported the role of socioeconomic factors on child growth and nutritional status. Following the paradigm of the Developmental Origins of Health and Diseases, are socioeconomic factors in the closest social structure associated to poor nutritional status of children under two years of age in sub-Saharan Africa? The question of the role of maternal and household demographic and socioeconomic factors on infant growth at a specific age of all opportunities remains open. This question provided the platform for the fundamental question of this present study.

Structure of the thesis

The thesis is organised into three parts which, when considered in chapters, is divided into seven.

Part 1: This part is made up of introductory chapters (Chapters 1,2, and 3). **Chapter 1** provides the background on infant undernutrition in low-income countries and middle-income countries (LMICs), adverse birth outcomes and infant undernutrition, conceptual framework used, and problem statement. **Chapter 2** provides literature review and highlights the gaps identified. The chapter provides a rationale for the study, thesis aims, objectives and hypotheses. **Chapter 3** describes the methods used for the purpose of this study.

Part 2: This part encompasses the three PhD papers emanating from this PhD thesis (Chapters 4, 5, and 6). Each paper addresses a specific objective for the thesis. **Chapter 4** provides a systematic review on household and maternal socioeconomic factors on birth outcomes and infant undernutrition in SSA. **Chapter 5** presents the investigation of the association between SES factors with birth outcomes comparing two SSA countries – South Africa and the Democratic Republic of Congo. **Chapter 6** presents the investigation of the association between SES factors with infant growth using a longitudinal cohort which was analysed at three different time points (one, six and twelve months) cross-sectionally.

Part 3: This part, which is made up of **Chapter 7**, presents the integrated narrative and discussion on the cross-cutting themes of this whole thesis**.** First, the chapter introduces a summary of key findings in a table, then discusses the methodology, conceptual framework used and identified gaps. Policy and research implications, recommendations, study limitations and conclusions are also presented in this last part of the thesis.

PART 1: INTRODUCTORY CHAPTERS

CHAPTER 1: BACKGROUND

1.1 Infant undernutrition and growth in low-income countries and middle-income countries

1.1.1 Infant undernutrition and physical growth

This thesis falls under the Developmental Origins of Health and Diseases (DOHaD) paradigm which was developed more than five decades ago (1). The paradigm suggests that environmental factors may trigger early life developmental plasticity and modify the risk of non-communicable disease later in life (1). While following this theory, this thesis addresses ongoing questions regarding the environmental factors that have an effect on infant growth and undernutrition, with a particular focus on socioeconomic and demographic factors while taking into consideration biological factors in the model(1).

Child growth is an indicator of the nutritional status of individuals, as well as the broader population health (2). Infant undernutrition refers to deficiency in macronutrients (carbohydrates, fats, and proteins) which goes with micronutrients disorders (3). As shown in the **Figure 2**, maternal undernutrition may result in foetal growth faltering, adverse birth outcomes, impaired physical growth and development in infancy, childhood, adolescence and cardiometabolic disorders later in adulthood (**Figure 2**) (3-5). Also, a study has reported a correlation of birth weight to maternal undernutrition, foetal growth, and the duration of pregnancy (6). Impaired foetal growth has been assessed using the following indicators: low birth weight (LBW), preterm birth (PTB) and small for gestational age (SGA). Undernutrition during childhood has been assessed using indicators of impaired growth, including stunting (height-for-age below the WHO growth standards); wasting (weight-for-height below the WHO growth standards); and underweight (weight-for-age below the WHO growth standards) (7). While *stunting* is referred to as a sign of chronic undernutrition and is the hardest to curb due to its intergenerational influence, *wasting* is explained as a sign of acute undernutrition, and *underweigh*t is a sign of overall undernutrition (8).

The impact of undernutrition on vulnerable mother-child pairs is also significant in terms of morbidity (e.g. infection, diarrhoea, kidney failure); disability (e.g. hearing disability, mental disability); as well as mortality (e.g. 45% of death in children under five years due to undernutrition globally), making undernutrition a strong indicator for population global health, as well as economic growth and development (9, 10).

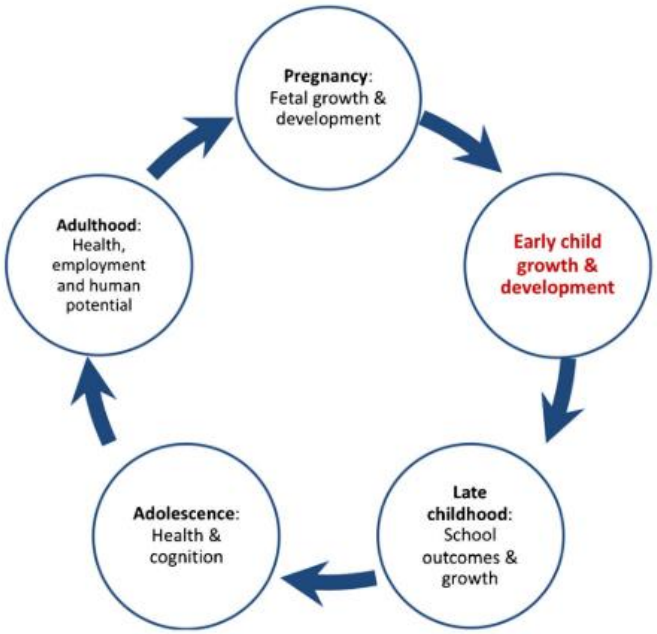


Figure 2: The cycle of child growth and development (3).

1.1.2 The first 1000 days: A critical window for undernutrition and infant growth

This thesis focused on the "first 1000 days" which is also referred to as the "window of opportunity" (11). This 'window' is the period from conception up to two years of age when growth faltering prevalently occurs, and nutrition interventions for mothers as well as infants may be more efficient with greater impact throughout the lifespan (1, 3, 7, 9, 12).

Cusick and colleagues (13) emphasized the role of healthy nutrition which was explained as the golden opportunity of the first 1000 days of life because, appropriate nutrition during that period of developmental plasticity entails optimal brain maturation before three years of age. Hence, the "window of opportunity" is essential for foetus as well as infants' growth and development (13). Wells and colleagues (14) suggested that during the window of opportunity, foetal and infant growth respond mostly to stimuli from the mother (maternal capital being embodied in her height, weight, and other metabolic functions) rather than that from immediate environmental factors. These hypotheses are based on the life history theory which defines a framework of the life-time among which organisms are born, grow and mature, survive, reproduce, and die (15, 16).

The question of child growth and development during the first thousand days, using life history theory, raises important considerations in the context of undernutrition concerning the physiological allocation of metabolic energy between competing demands such as physical

body growth and brain growth and their short- and long-term implications on health and disease (15). Undernutrition during the "window of opportunity" may have short and long-term negative impact on growth, development, and on health during childhood and adulthood (9). Furthermore, three decades ago, the thrifty phenotype hypothesis has suggested an association between maternal malnutrition, poor fetal growth and infant malnutrition as the origins of non-communicable diseases (diabetes type 2, metabolic syndrome and cardiovascular diseases such as hypertension) in adulthood (17). Postnatal insulin resistance was the most common mechanism to explain that theory, while genetic and environmental (epigenetic) factors were the subject of much debate (17).

1.1.3 Global epidemiology of birth outcomes and infant undernutrition

Undernutrition persists as a public health problem in the world affecting all ages, and in particular, children under five years of age, adolescents and women (3, 12). The 2011 UNICEF Global Nutrition Report indicated that, worldwide, more than 311 million children (prevalence rate of 32%) under five years of age were affected by undernutrition. Globally, undernutrition has been the cause of death of more than four million children under the age of one, more than 45% of deaths of children under five years of age (U5), and the majority of U5 deaths were younger than the first month of life (18).

1.1.3.1 Epidemiology of birth outcomes: low birth weight, preterm birth and small-for-gestational age

Globally, low birth weight was found to be responsible for 60 to 80% of newborn deaths (19). In 2015, UNICEF reported that, worldwide, 14.6 % (20.5 million) of newborns were LBW, and that 96.5% of these were in LMICs (**Figure 3**). (20, 21). The trends of large numbers and prevalence of LBW seem to decrease globally; however, the number in Africa is still high (5.7 million, 13.7%) and continues increasing even though it remains below the world average (**Figure 4**) (20).

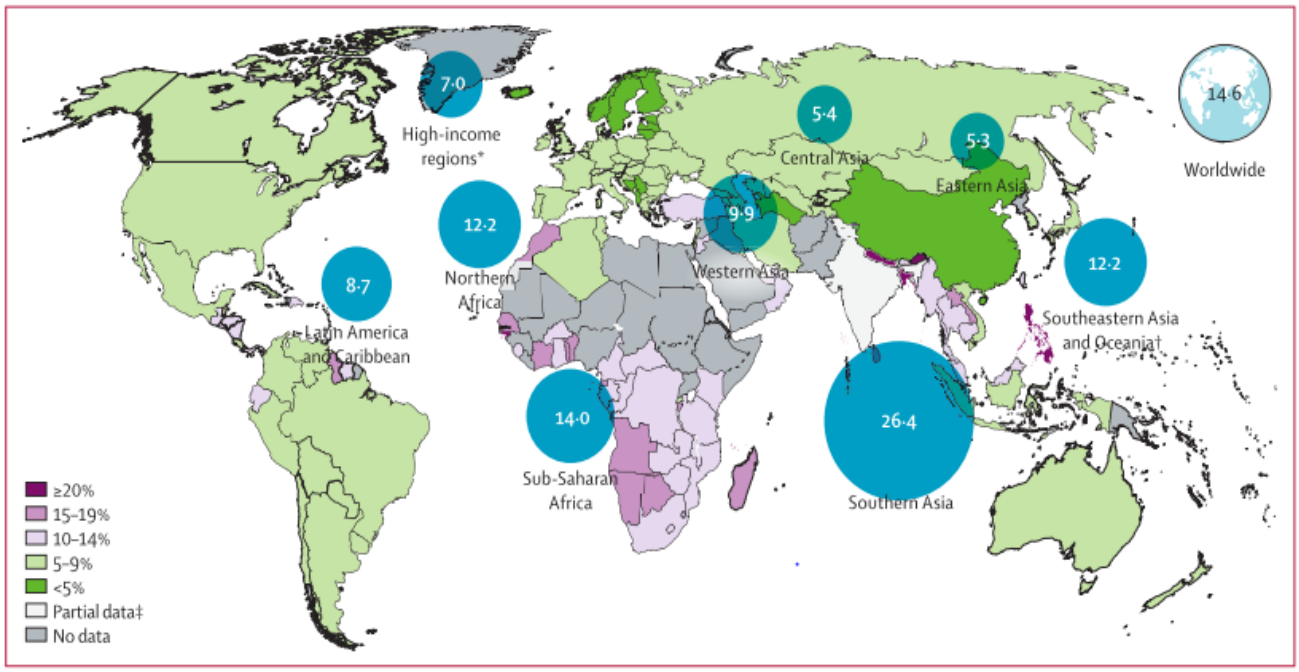
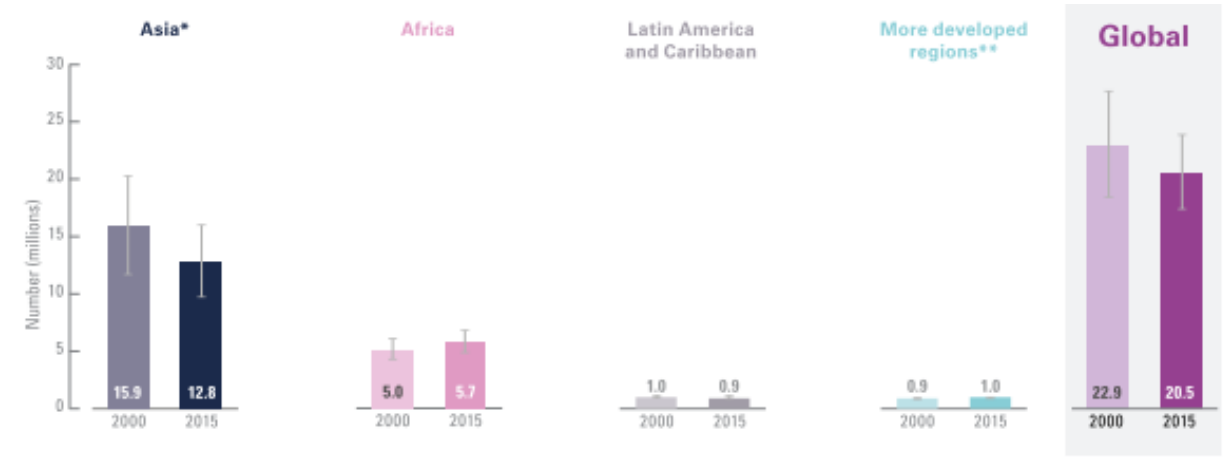


Figure 3:The prevalence of LBW in 2015 (19)

a)



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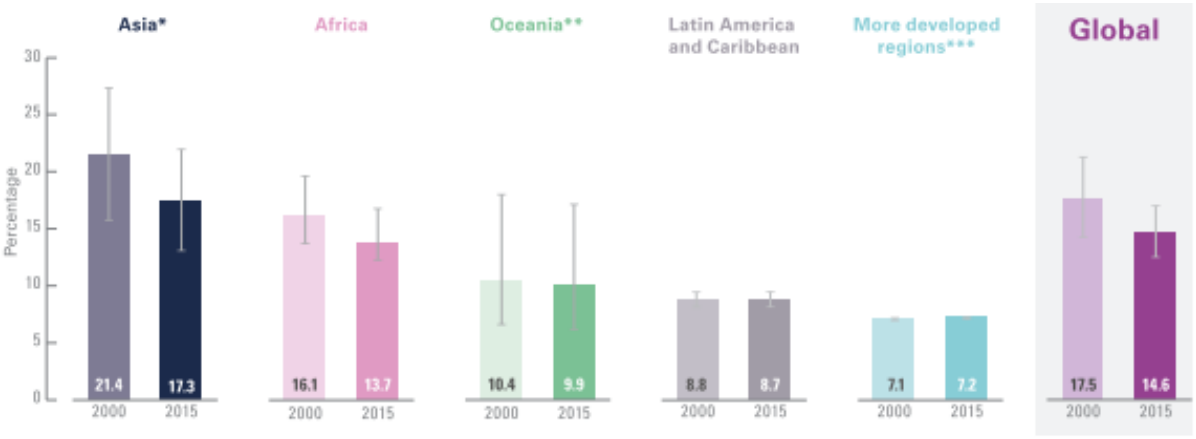

Figure 4 a, b: Numbers (a) and prevalence (b) of low birth weight in the world by continent and by region (20)

From the **Figure 3**, the Sub-Saharan Africa region had the second highest LBW rate (14.0%) after Southern Asia (26.4%)(20). In analysing data from 148 countries, Blencowe et al. (21) revealed that the annual reduction of the prevalence of LBW was estimated 1.09% in SSA in comparison to 1.23% globally between the year 2000 and 2015. In 2010, four SSA countries, including the DRC, featured on the top ten highest number/prevalence in poor birth outcomes (**Table 2**). **Table 2** shows the top ten countries in all birth outcomes in LMICs.

Table 2: The top ten LMICs countries out of 138 LMICs in numbers of neonate born LBW, PTB and SGA in 2010 (19)

Countries	Live births in 2010 (million)	Neonatal mortality rates (%)	LBW births (million)	PTB births (million)	Term-SGA births (million)	Preterm-SGA birth (million)	Number of SGA births (million)	SGA prevalence (%)
India	27.0	33.1	7.5072	3.5191	12.0000	0.7846	12.8000	46.9
Pakistan	4.7	36.1	1.2328	0.7481	2.0613	0.1668	2.2281	47
Nigeria	6.3	40.2	0.7409	0.7736	1.3795	0.1242	1.5038	23.7
Bangladesh	3.0	27.5	0.6561	0.4241	1.1085	0.0946	1.2030	39.6
China	17.0	9.4	0.3984	1.1723	0.8107	0.2614	1.0721	6.5
Indonesia	4.4	15.9	0.4853	0.6757	0.8916	0.1507	1.0423	23.8
Ethiopia	2.6	32.4	0.5304	0.2634	0.7957	0.4230	0.8380	32.1
Philippines	2.3	12.6	0.4595	0.3489	0.7089	0.7780	0.7867	33.6
The Democratic Republic of Congo	2.9	47.4	0.2758	0.3414	0.5746	0.5480	0.6295	21.9
Sudan	1.4	31.5	0.4386	0.1883	0.5650	0.0302	0.5952	41.7

However, these numbers need to be interpreted with caution, because a multi-country study based on the Demographic Health Surveys (DHS) and Multiple Indicator Cluster Surveys reported that 58% of babies born in LMICs had not been weighed at birth and the highest global rates were found in South Asia (74%) and SSA (65%) (22). Also, in the 2018 UNICEF

report, 39.7million babies, globally, were not weighed with half of these (51.7%; 21.5 million) in Africa in 2015 (23). Although the rate of not weighted newborns improved from 74 % in 1990 to 62% in 2000 globally, there has not been much progress in SSA (22). The rate of unweighted newborns increases with the level of poverty of countries and regions in relation with inadequate policies and lack of resources (**Table 3**) (20). **Table 3** shows prevalence of unweighted newborns in the countries of interest for this thesis, being the Democratic Republic of Congo and South Africa.

Table 3: Birth weight country coverage in 2018(20).

Level of development/Places	**Prevalence of unweighted newborns (%)**	**Years of study**	**Sources**
Low income	52.6	2014	World Bank
- Democratic Republic of Congo	23.9	2013-2014	DHS
Lower-middle income	37.9	2014	World Bank
Upper-middle income	4.3	2014	World Bank
- South Africa	18.3	2014	HMIS
High income	2.6	2014	World Bank

DHS: Demographic Health Surveys; HMIS: Health Management Information System

Furthermore, in 2016, 10% of newborns worldwide (15 million) were born preterm with 60% of them being in SSA and South Asia (24). One million of these babies born prematurely died before their first birthday (20). In 2010, globally, 32.4 million newborns were born SGA and 27% of these newborns were in low- and middle-income countries. The highest prevalence of SGA occurred in SSA and South Asia either 25.5% and 27% of worldwide prevalence of SGA newborns (**Table 4**) (4).

Table 4: Prevalence of PTB and SGA in 138 LMICs in 2010 (25).

No.	Regions	Births in 2010 (million)	Prevalence			
			PTB	SGA	Term-SGA	PTB-SGA
			(CI, 95%)	(CI, 95%)	(CI, 95%)	(CI, 95%)
1	Total world	120.4613	11.3 (8.6-14.7)	27.0 (24.1-30.5)	24.7 (21.7-28.1)	2.3 (1.7-2.9)
2	South Asia	38.753	13.3 (10.1-16.8)	44.5 (40.0-49.7)	41.5 (37.4-46.9)	2.9 (2.1-3.8)
3	Sub-Saharan Africa	32.0855	12.3 (9.5-15.8)	25.5 (21.7-28.8)	23.5 (19.9-26.7)	2.0 (1.4-2.8)
4	East Asia	17.49	7.2 (5.4-9.0)	7.0 (9.42-11.6)	5.3 (2.7-10.1)	1.7 (1.1-2.1)
5	Southeast Asia	10.9834	13.6 (9.3-18.6)	24.3 (19.5-30.2)	21.2 (16.7-27.1)	3.0 (2.0-4.3)
6	Latin America and Caribbean	10.8445	8.6 (7.0-12.0)	12.5 (9.4-16.3)	10.7 (7.7-14.4)	1.8 (1.4-2.5)
7	North Africa	3.543	7.3 (4.8-10.9)	9.6 (6.8-13.2)	8.5 (5.7-11.9)	1.2 (0.7-1.9)
8	West Asia	1.8553	10.1 (6.9-14.3)	21.8 (17.6-27.2)	19.6 (15.4-25.3)	2.2 (1.5-3.2)
9	Caucasus and Central Asia	1.643	9.2 (6.1-13.0)	15.0 (10.6-21.4)	12.9 (8.5-19.2)	2.1 (1.3-2.9)
10	Oceania	0.2631	7.4 (4.5-15.6)	21 916.2-27.4)	19.4 (14.6-25.3)	1.6 (1.0-3.5)

A study in 14 low-income and eight middle-income countries found that 18 million babies had LBW, 59% of whom were born SGA and 41% were born preterm (**Figure 5**; **Table 4**: Prevalence of PTB and SGA in 138 LMICs in 2010) (4).

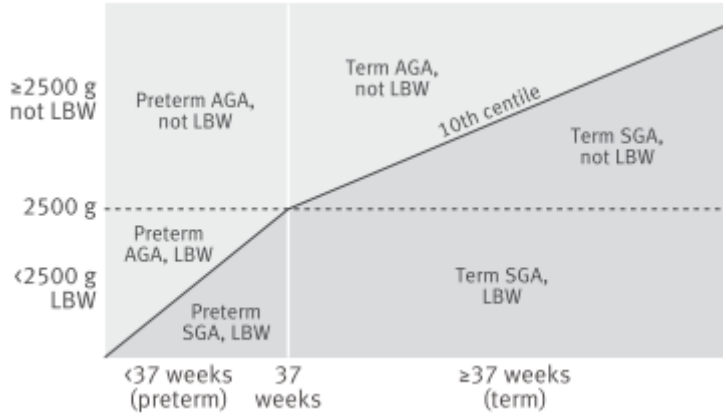

Figure 5: Combinations of exposure categories of preterm birth (PTB), small for gestational age (SGA), and low birth weight (LBW, 2500g). AGA=appropriate for gestational age (26)

Of the 32.4 million SGA births, the majority occurred in South Asia (16.2 million) and SSA (7.5 million) (25). Among all LBW globally, 2.8 million combined PTB and SGA (27). The majority of SGA births (90%) occurred at term.

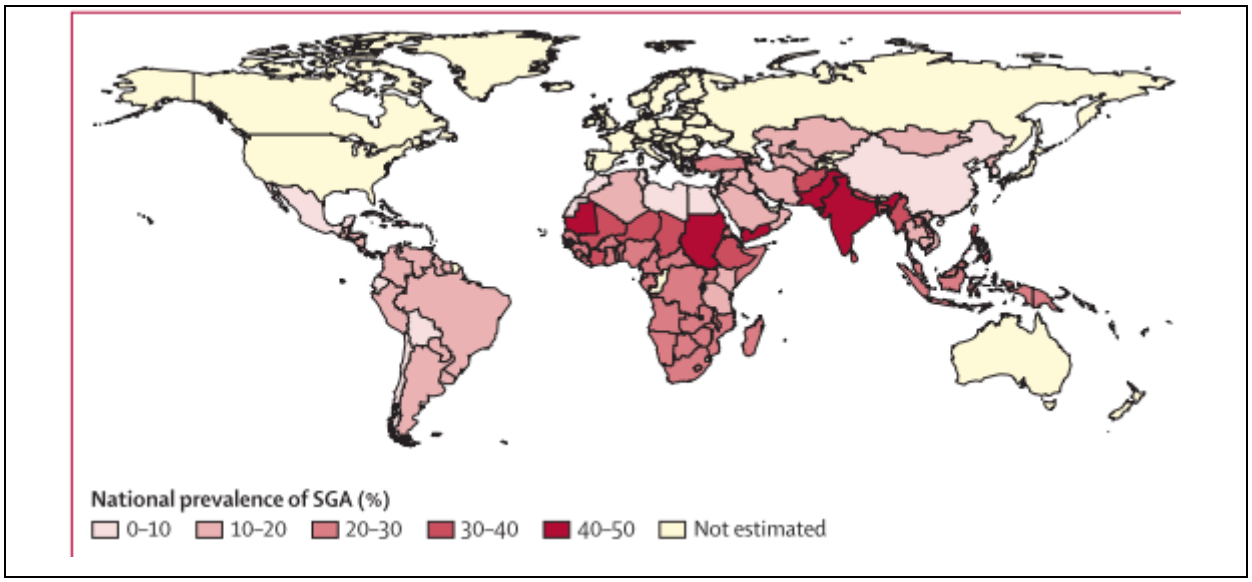

Figure 6: World map showing the prevalence of SGA in 138 LMICs in 2010. Ranges of SGA prevalence estimates between 10 to 50% for LMICs (28)

1.1.3.2 Epidemiology of infant undernutrition: stunting, wasting, and underweight

Although there seems to be no data on undernutrition in children younger than two years of age, the epidemiological data on undernutrition in children under five years of age is greatly documented in the world and in SSA region. In a meta-analysis of the prevalence of undernutrition in sub-Saharan African countries based on the DHS, 45.6% of children under five years of age had poor nutritional status (29). in 2016, Africa had the second largest prevalence of undernutrition in children under five years of age in the world (31.6%) (30). The SSA region had 91% of African undernourished children under five years of age while the absolute number of affected children continues to rise (30). Between 2000 and 2018, undernutrition prevalence (all forms) decreased consistently globally and in SSA countries, however, Africa was the only region where the number of stunted children under five years of age increased from 50.3 million to 58.8 million (23). In **Figure 7** and **Figure 8** , 21.9% (149 million) of children under five years of age were stunted and 7.3% (49 million) were wasted in 2018 in the world (23).

Figure 7 and **Figure 8** show that stunting was predominant in the east African region; wasting was predominant in west African region; central Africa has a very high prevalence of all forms of undernutrition; and the south African region had the lowest prevalence(23). The multi-dimensional character of undernutrition was described in a study in Ethiopia where there was a relationship between underweight with either stunting or wasting but, no relationship between wasting and stunting (31).).

Table 5, sub-Sahara African region was labelled as medium and very high level of wasting and stunting prevalence respectively. The south African region holds the lowest score of undernutrition compared to other regions in SSA.

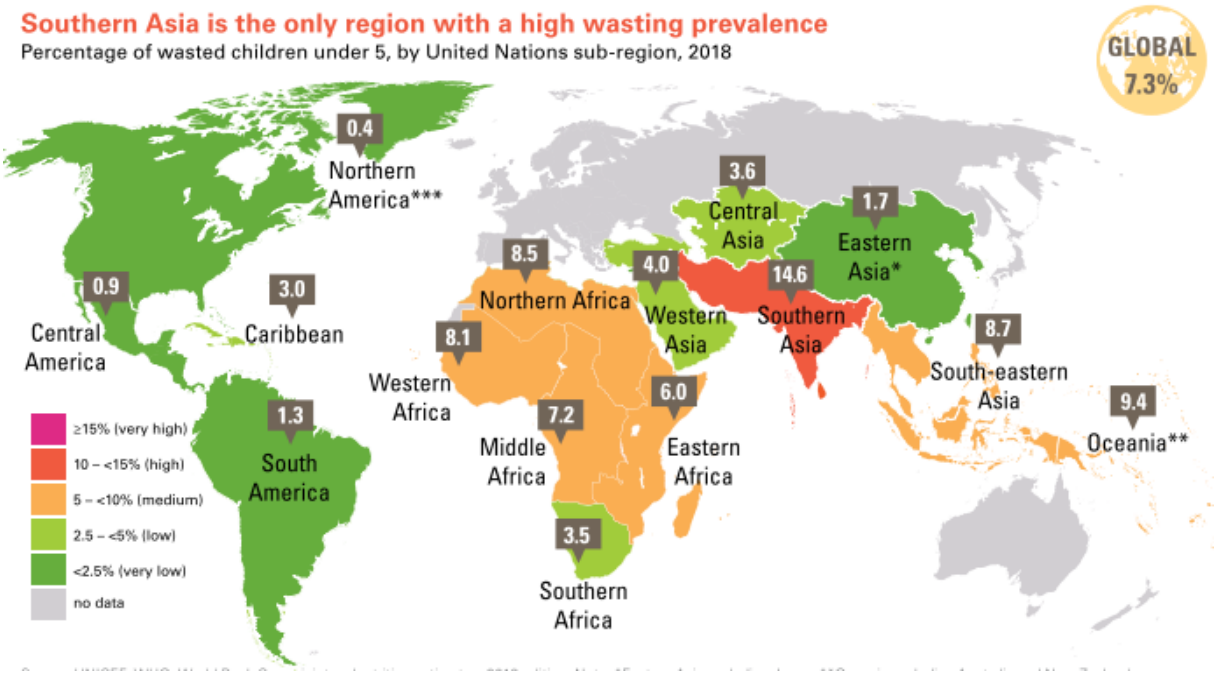

Figure 7: The prevalence of wasted children under 5 years of age in the United Nations sub-regions 2018 (23)

All SSA regions have prevalence of stunting in children under five years of age above the world average (23). The east African region (35.2% of children of under 5 years of age, 24.0 million) and the central African region (32.1% of children of under 5 years of age, 18.5 million) hold the highest worldwide prevalence of stunting (**Figure 8**; **Table 5**) (23).

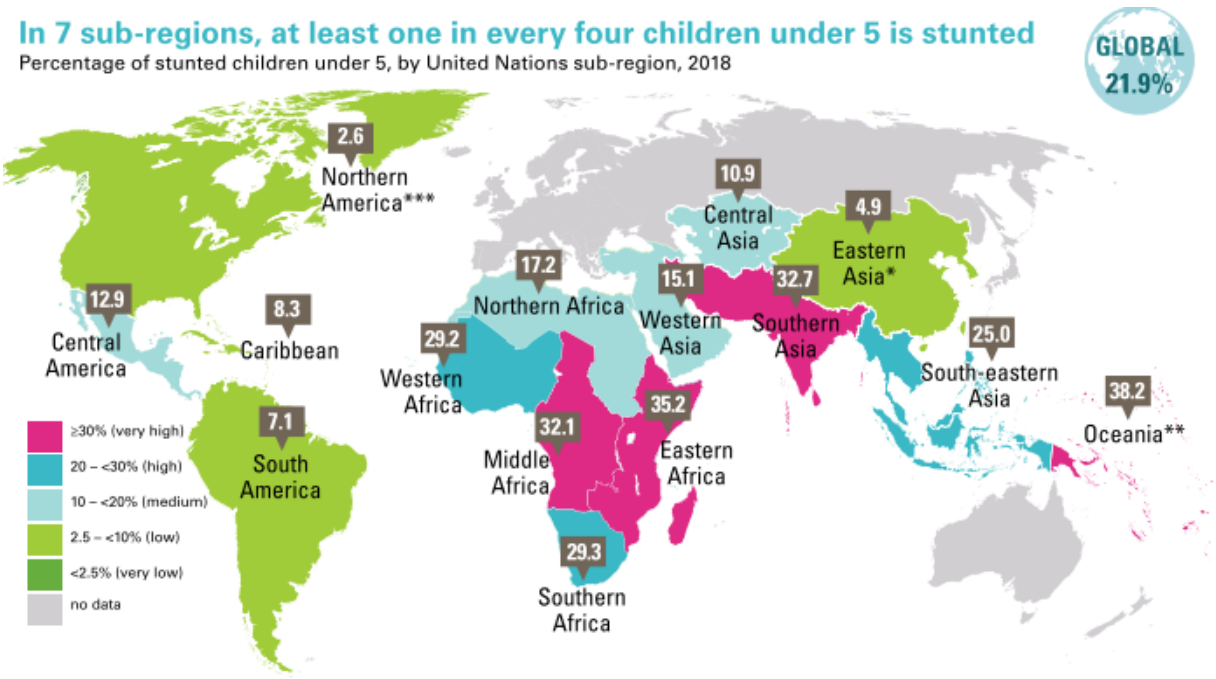

Figure 8: The prevalence of stunted children under 5 years of age in the United Nations sub-regions 2018 (23).

The prevalence of wasted children was estimated at 7.3% (48.5 million) for wasting in the world and 7.6% in SSA in 2018. The distribution of wasting in SSA region showed disparities. The western Africa region (8.1%, 14 million) and the central Africa region (7.2%, 5.1 million) held the highest prevalence of wasting in children under five years of age and above the world average (**Figure 7**; **Table 5**).

Table 5: Prevalence and thresholds of stunting and wasting in children under 5 years of age (U5) by United Nations regions (23).

Regions/country	**Wasting in U5**		**Stunting U5**	
	Prevalence (%)	Levels	Prevalence (%)	Levels
World	7.3	Medium	21.9	High
Sub-Sahara Africa	6.9	Medium	33.1	Very high
Western Africa	8.1	Medium	29.2	High
Middle-Africa	7.2	Medium	32.1	Very high
Eastern Africa	6	Medium	35.2	Very high
Southern Africa	3.5	Low	29.3	High

Note: Wasting thresholds includes ≥15% (very high); 10-14% (high); 5-9% (medium); 2-5% (low); <2.5% (very low). Stunting thresholds includes ≥30% (very high); 20-<30% (high); 10-<20% (medium); 2-10% (low); <2.5% (very low).

1.1.4 Double and triple burden of malnutrition

It is now evident that the SSA region is experiencing a double burden of malnutrition which is a co-existence of undernutrition and concomitant increase in the rate of overnutrition (overweight or obesity), or diet-related non-communicable diseases in households, countries and during the life-course (23, 32-34, 35). Recently in 2019, the UNICEF reported a triple burden of nutrition in Africa which was defined as the double burden of malnutrition together with hidden hunger related to mineral and vitamin deficiencies with lack of appetite in children and women (23, 36). The term ‘’malnutrition’’ encompasses undernutrition (manifested through stunting, wasting and underweight), overnutrition (manifested through obesity or overweight) and deficiencies in micronutrients (or hidden hunger, deficiencies in minerals such as iron, zinc and calcium and, vitamins) (37). Overnutrition refers to overconsumption of nutrients above the physiological needs which may increase the risks for non-communicable diseases (such as cardiovascular diseases, diabetes, or cancers) and is responsible for two-third of worldwide burden of chronic non-communicable diseases (38). According to the WHO, overweight refers to weight-for height above plus two standard deviations from the median of the WHO Child Growth Standards and obesity is defined as weight-for height above plus three standard deviations from the median of the WHO Child Growth Standards (7). In 2016, 155 million children under five years of age were stunted, 51 million were wasted while the number of overweight or obese children younger than five years increased and reached 45 million in 2017 in the world (36). A total of 340 million of children under five years of age suffered from hidden hunger and 243.2 million (71.5%) were concerned in Africa in 2016 (36). The numbers of overweight in children under five years of age continues to increase globally from 30.1 million in 2000 to 40.1 million 2018 (from 4.9 % of prevalence in 2000 to 5.9 % in 2018) and in SSA region from 5.1 million in 2000 to 6.1 million in 2018 although the prevalence in SSA decreased from 4.4% in 2000 to 3.5% in 2018 (23). Globally, 340 million of children under five years of age were affected by hidden hunger and 243.2 million (71.5%) were concerned in Africa in 2016 (36). In 2018, overweight and obesity affected 9.5 million (4.9%) in African children and 5.8 million (3.3%) in SSA (23). The shift in diet and lifestyle with subsequently

the coexistence of undernutrition, overnutrition and hidden hunger places SSA in both the nutrition transition and the triple burden of malnutrition (23, 36).

1.2 Factors and consequences associated with adverse birth outcomes and infant undernutrition

1.2.1 Causes of adverse birth outcomes and infant undernutrition

The mechanistic pathways to LBW are unclear, but maternal factors, foetal factors or placental factors may contribute to intra-uterine growth retardation (IUGR) resulting in PTB and/or SGA. The common pathway is restricted uterine-placenta blood flow with inadequate foetal nutrition that restricts foetal growth (39). Maternal biological factors associated with IUGR include genetic and epigenetic factors, lower maternal age, morbidity (hypertension, the human immunodeficiency virus (HIV), malaria, anaemia, pre/eclampsia), gynaecological traumatism, obstetrical factors (pregnancy complications such as placental abruption, cervical insufficiency), parity, short interbirth period, maternal malnutrition resulting in unhealthy maternal anthropometry (height, weight), and inadequate prenatal health care (39). Foetal factors of IUGR are multiple pregnancy, prematurity and placental factors include chorioamnionitis and funiculitis (39). Factors which were found to be associated with PTB are maternal pre-conception lower body weight, prior preterm birth, multiple births, infection, incompetent cervix, tumours, multiple pregnancy, and placental abruption (39, 40). In addition to maternal and foetal biological factors, non-biological factors such as lower socioeconomic (SES) factor, lower level of maternal education, poor mental health (stress, domestic violence), prenatal substance use (tobacco, smoking, narcotics), poverty, and ethnicity (41), have been associated with LBW and PTB (40, 42).

The UNICEF conceptual frameworks have defined three categories of causes of infant undernutrition: intermediate, underlying and basic causes (4, 35). According to this framework, infant undernutrition results from poor dietary intake and/or repeated diseases while SES factors and political context are the basic cause of infant undernutrition. Poor health care for mothers and children (antenatal and postnatal care), poor access to clean drinking water and improved sanitation are underlying causes. Among intermediate causes of infant undernutrition, poor feeding practice (e.g. breastfeeding and complementary food) and frequency of infectious disease are determinant.

1.2.2 Consequences of adverse birth outcomes and infant undernutrition

Low birth weight has immediate consequences in early childhood (stunting, irreversible brain injuries and disabilities, lower intellectual quotient, childhood morbidity and death) (9). Furthermore, according to finding emanating from the DOHaD field, low birth weight associated to poor linear growth under 2 years of age were associated with poor schooling (less than secondary level of education) and chronic diseases such hypertension, diabetes type 2, and obesity in the multi-country cohorts study in LMICs (43). Preterm birth, as leading cause of mortality before the fifth child anniversary (one million of preterm births die yearly), is responsible for developmental disabilities (vision, hearing, mental disorder, cerebral palsy), respiratory and digestive disorders, and intracranial haemorrhage (39). Neonatal deaths are caused mainly by preterm birth (28%), infection (26%), asphyxia (23%) and tetanus (7%), particularly in SSA where expensive newborn care is unaffordable (44). The leading causes of mortality among children under 5 years of age were associated to undernutrition and were due to respiratory tract diseases such as pneumonia (15%), PTB (12%), diarrhoea (10%), congenital disorders (9%) and infectious diseases (45%) in the world (45). Early infections concomitant to undernutrition result in high child mortality estimated at 5.4 million of death among children under 5 years of age in 2017 (45). In term of long-term consequences, infant undernutrition has been associated with poor income earning (in 2007, 22% of income reduction yearly in adulthood) and poor country development due to less productivity (7, 46). The distant consequences of maternal and infant undernutrition are poor human capital (47, 48), disadvantaged social capital (49), weak economic growth (50, 51), poverty and poor development of countries (9).

1.3 Conceptual framework of infant undernutrition

The conceptual framework of the thesis was built by combining the relevant element of the existing conceptual frameworks that are presented in the section below. It was unclear that a conceptual framework linking household and maternal SES factors to infant undernutrition does exist.

1.3.1 Ecological model for human development

The Bronfenbrenner's ecological systems theory (52, 53) explains the development of the child based on his/her relationship with the social structures in which he/she lives in and the changes in the relationship between the child with his environment (**Figure 9**). This environment includes the individual context, maternal characteristics (microsystem), household socioeconomic status (macrosystem) and eventual changes in the family (chronosystem) (53, 54).

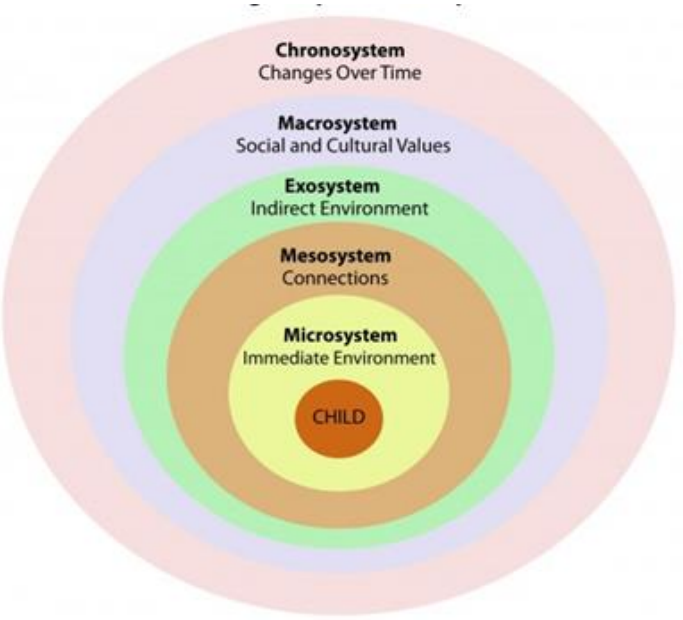

Figure 9: Representation of Bronfenbrenner's ecological theory (54).

The family structure, including the household and maternal factors, was of interest in this thesis because it is the closest social structure that influences infant health and nutritional status. Maternal socioeconomic status influences infant health and nutrition, particularly in disadvantaged regions such as SSA. In the SSA context, mothers were shown to play a critical role in human development and countries economic development as shown in **Figure 10**. However, sub-Saharan African countries have the lowest performance for female education and literacy combined with inadequate nutrition and health (55).

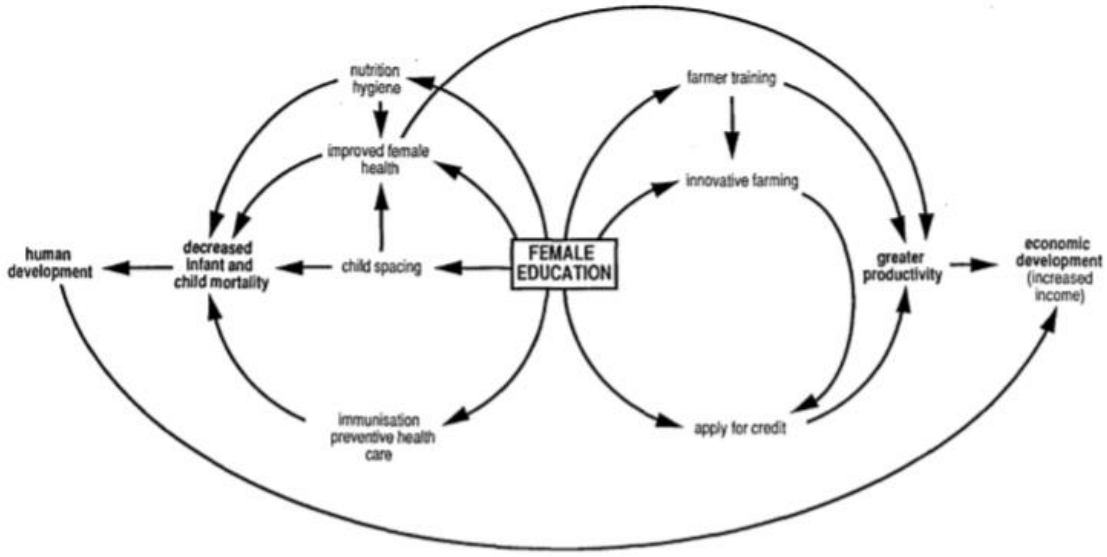

Figure 10: The link between female education, human development and economic development (55).

1.3.2 The UNICEF Conceptual frameworks of childhood undernutrition

The conceptual framework of this research was partly derived from the UNICEF conceptual framework of maternal and children undernutrition which highlighted the relationship between SES factors with birth outcomes and infant undernutrition.

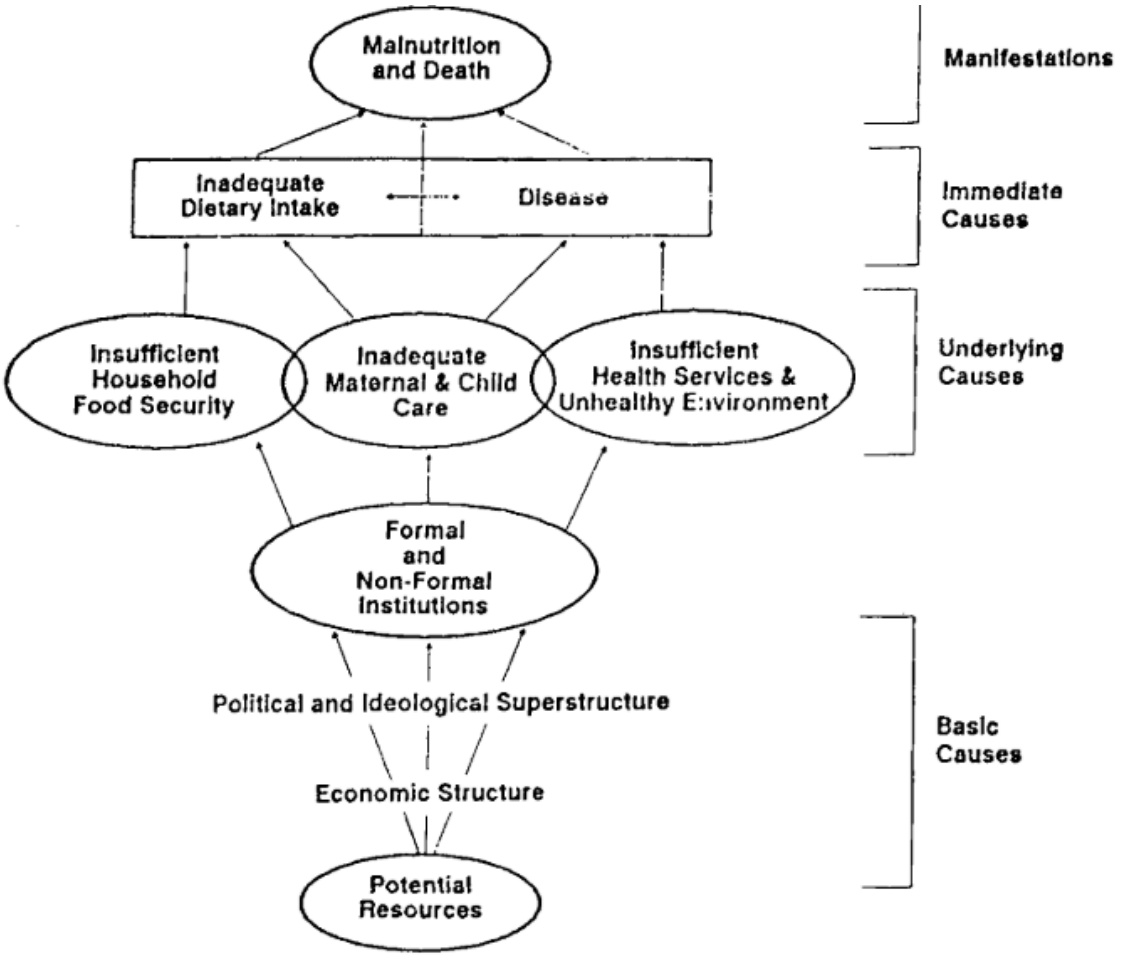

Figure 11: Causes of malnutrition and deaths. This was the first UNICEF conceptual framework on undernutrition (56).

The first framework drawn in 1991 (**Figure 11**) was related to infant undernutrition and mortality whilst the second, published later in 2013 (**Figure 12**), put together maternal and child malnutrition, correlatively. The first conceptual framework of malnutrition and mortality

identified the causes of malnutrition without showing explicitly the short-term, long term and intergenerational consequences, which were added with the 2013 conceptual framework (57). All UNICEF frameworks on undernutrition emphasized that SES factors were a basic cause of undernutrition.

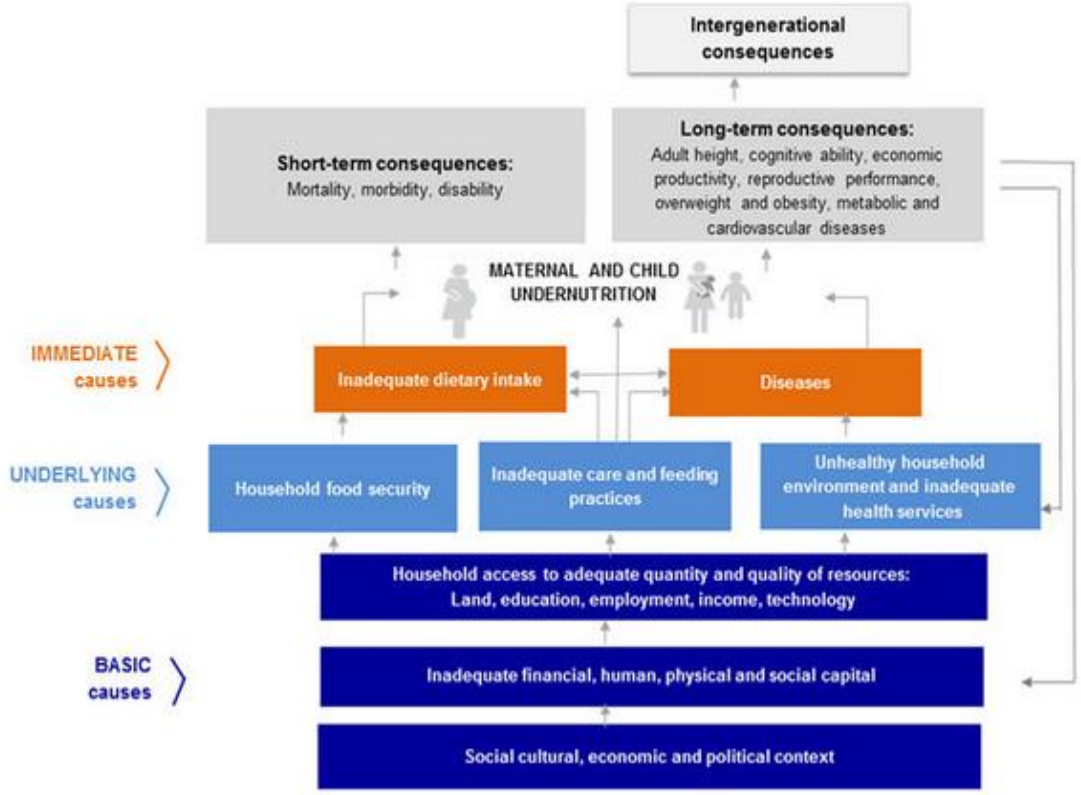

Figure 12: The UNICEF conceptual framework of maternal and child undernutrition (4).

1.3.3 The conceptual frameworks of the causes of adverse birth outcomes and infant undernutrition

Wedderburn and colleagues (5), in the context of the prevention of mother-to-child transmission (PMTCT), proposed a conceptual framework (**Figure 13**) highlighting the pathways between adverse growth and neurodevelopment, with HIV exposure in LMICs. This conceptual framework came up to highlight the role of SES factors on birth outcomes and infant growth mediating by maternal infection, water, sanitation and hygiene (WASH) and maternal lifestyle (consumption of substances during pregnancy) (5). Education level, income, and occupation were interrelated dimensions of individuals' socioeconomic status in this framework although

their respective relationships to adverse birth outcomes are indirect and unclear factors compared to HIV/anti-retroviral therapy exposures which are direct factors (5).

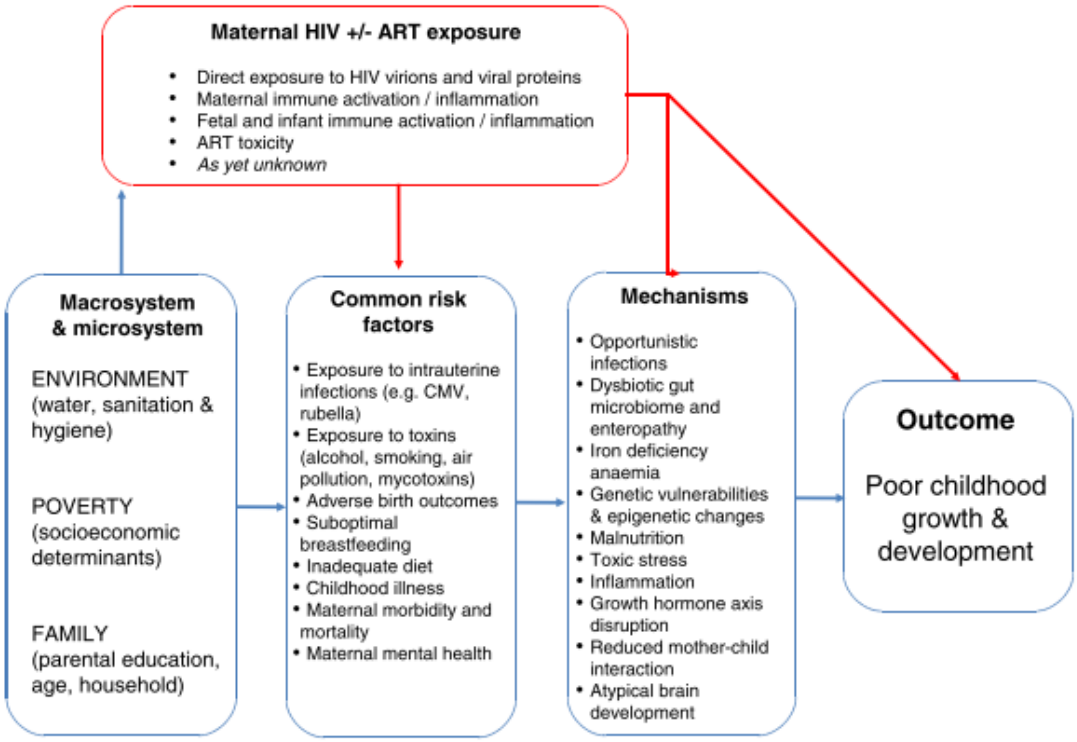

Figure 13: Conceptual framework for the hypothesised pathways through which HIV and ART exposure affect child growth and development. Red lines demarcated HIV-specific pathways; blue lines represent general pathways; ART: antiretroviral therapy (5).

The framework proposed by Fraser and collaborators (58) showed the pathways linking maternal nutrition and birth outcomes throughout women reproductive cycle which includes four periods (pregnancy, delivery, lactation and preconception period), and that these pathways are modulated by socioeconomic factors which accumulate already before pregnancy and over the reproductive cycle (58).

Stewart and collaborators (59) developed the conceptual model showed in **Figure 14**. In this model, they described the context, causes and consequences of stunting and growth in childhood. Political and socioeconomic context (e.g. policies, household expenditures or income), performances of health care and health system, social and cultural aspects, food system

and environmental conditions such access to water, sanitation and hygiene (WASH) were the global context for poor linear child growth and development. Then, the consequences of stunting were categorized as short-term or long-term consequences. In the Stewards model, socioeconomic factors were described as contextual to the community and society, while the level of education and knowledge of the caregiver were factors at the family level.

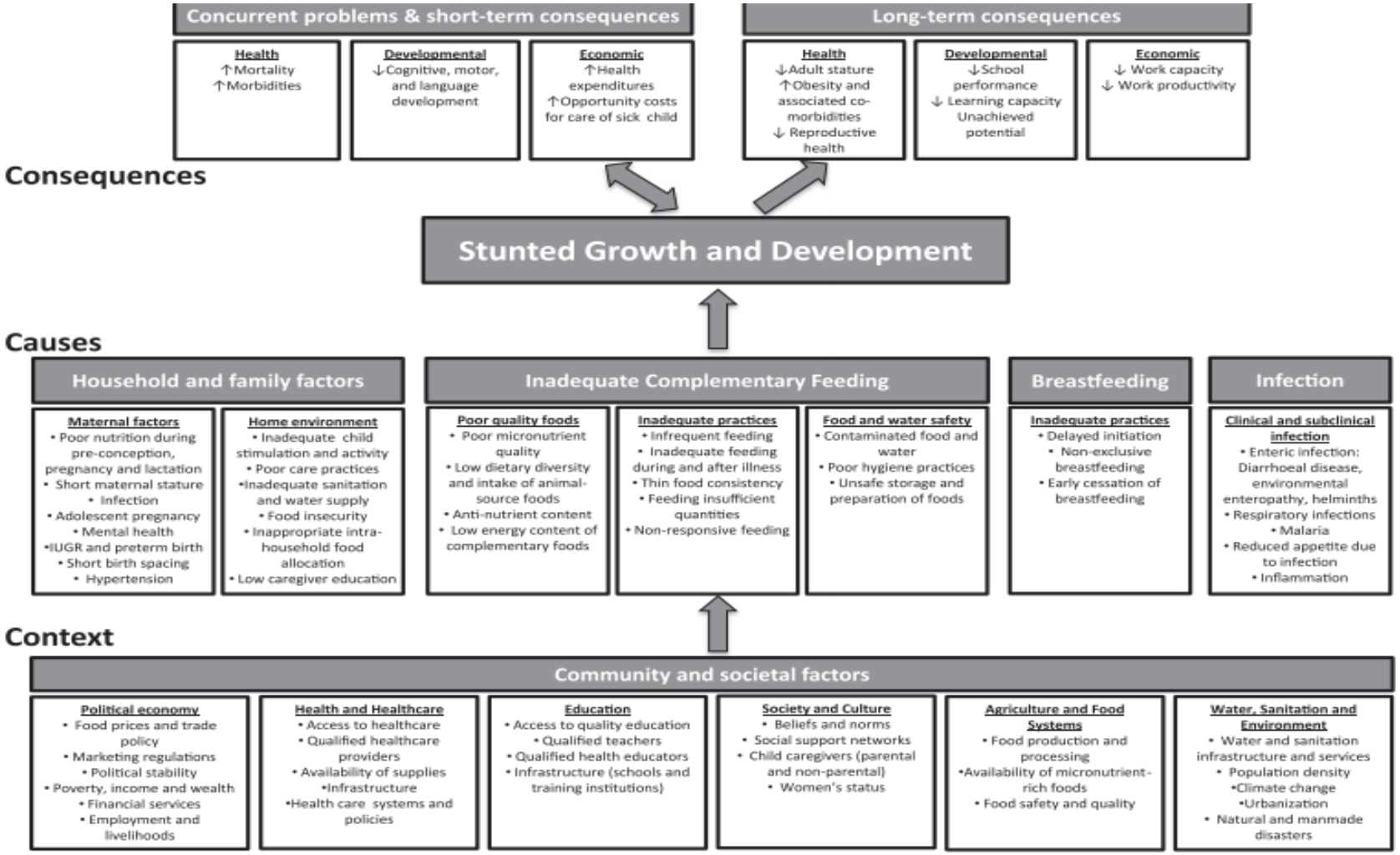

Figure 14: WHO conceptual framework of childhood stunting: context, causes, consequences, with an emphasis on complementary feeding (59)

The advantage of the conceptual frameworks presented above is that they highlight the relationship between ecological factors and early poor growth during the window of opportunity in various specific contexts (e.g. global death, HIV infection). Undernutrition and impaired physical growth in children younger than two years of age have been shown to be determined by many factors in the frame of the ecological social model, some of which are context-specific with differences and predominance of certain pathways linking the different factors. For instance, the understanding of the specific pathway linking household as well as maternal sociodemographic, and SES factors with undernutrition and growth faltering, has received little attention in comparison to the biological factors, particularly in the diverse SSA contexts as I will demonstrate in this thesis. This thesis subscribed to the effort to fill in this gap while building its conceptual framework from existing conceptual models.

1.4 Problem statement

1.4.1 Millennium and Sustainable Development Goals: targets, achievements and challenges for infant undernutrition in sub-Saharan Africa

1.4.1.1 Sustainable development goals and infant undernutrition

The Millennium Development Goals (MDGs) and the Sustainable Development Goals (SDGs) were set up respectively in 2000 and 2012, with goals pertaining to the improvement of food security and nutrition (60). Nutrition is a core element of the SDGs because of two main reasons: 1) nutrition improvement may be transduced over generations and across life course, 2) nutrition targets are more likely to impact the completion of other SDGs (61). Therefore, the Global Nutrition Targets (GNT) were set and consist of tackling 8 SDG nutrition indicators and related conditions, including: LBW; stunting in children under 5 years; wasting; overweight; exclusive breastfeeding; adult obesity; adult diabetes; and women at reproductive age with anaemia (61). Improving population nutritional status contributes to the achievements of the SDG 2 (achieve zero hunger) and SDG 3 (ensure healthy lives and promote well-being for all at all ages), the improvement of the gross domestic product (GDP), education and health (60). Undernutrition has economic cost by affecting the access to basic social resources (education and health), reducing the productivity of individuals and populations, reducing the GDP, and economic growth (61). Therefore, since 2012, the United Nations World Health Assembly has decided that 2016-2025 should be the decade of actions against malnutrition. Three strategic documents were drafted including the ‘Global actions plan to prevent non-communicable diseases by 2013-2020’; the ‘Global strategy for women, children and adolescents between

2016-2030'; and the 'Agenda for SDGs to 2030' (23). In the below table, the progress of three GNT related to this study are shown (**Table 6**).

1.4.1.2 Progress on the Sustainable Development Goals in sub-Sahara Africa

The progress in reducing the prevalence of GNT indicators has become significant since the world put malnutrition as one of the focus for the achievement of the SDG 2 and the SDG 3. However, the prevalence of undernutrition remains seriously elevated. In 2018, slight progress was realised at achieving the 2025 GNT on the global prevalence of LBW, stunting, and wasting for children under 5 years of age (**Table 6**) (30).

Table 6: Progress on three Global Nutrition Targets: low birth weight, wasting and stunting (30).

Global nutrition indicators	Baselines, Year	Actual progress, year	SDGs targets, Year	Progress
Low birth weight	15% (2008-2012)	14.6% (2015)	10% (2025)	Light reduction
Stunting in children 5 years old	165.2 million (2012)	149.0 million (2018)	100 million (2025)	Light reduction
Wasting in children 5 years old	7.9 % (2012)	7.5 % (2017)	< 5 % (2025)	Negligible reduction

Although the trend in absolute estimates of undernutrition (stunting, wasting, and underweight) is increasing, the prevalence of severe forms of malnutrition is declining over time due to the effectiveness of efforts to prevent and treat undernutrition globally and within countries (**Figure 15**) (62).

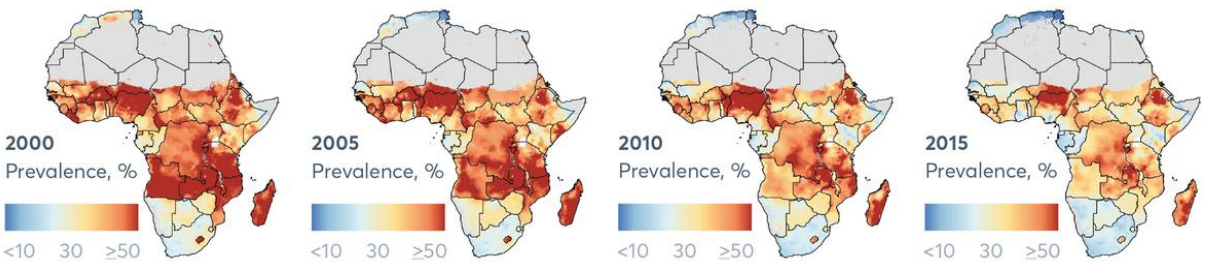

Figure 15: Prevalence of moderate and severe stunting between 2000 to 2015 (62).

Despite a reduction in the number of undernourished people from 945 million (14.5%) to 821 million (10.9%) between the year 2005 and 2017 in the world, there was an increase in the number of undernourished persons from 195 million (20.7%) to 237 million (23.2%) in the SSA region (63). The number of stunted children under five years of age decreased from 252.5 million (39.2%) to 149.0 million (21.9%) in the world between 1990 to 2018. The target for the prevalence of stunting in children under five years is 100 million by 2025 and 83 million by 2030 in the world. However, Africa was the only region in the world with the increased number of stunted children younger than five years old (from 50.3 million to 58.5 million) between 2000 to 2018 whilst the prevalence of stunting decreased from 34.0% to 30.0%, due to, perhaps, increasing demographic growth. In the SSA region, the prevalence of stunting in children under five years of age went from 43.0% (in 2000) to 33.3% (in 2018).

In conclusion, the vast majority of the eight GNT are declining, while overweight is showing an increase. However, the trend of numbers and the prevalence remain high despite the worldwide and country efforts. In keeping with this high prevalence, the SDG targets are at risk of not being met overall because, despite slight progress in child undernutrition trends, the magnitude of malnutrition remains alarming and persists in SSA countries.

1.4.2 Persistence of the burden of infant undernutrition in sub-Saharan Africa

Globally, the prevalence of adverse birth outcomes and infant undernutrition have remained high for about four decades (64). Trends over 15 years have shown increasing numbers of LBW and infant undernutrition in SSA (35). Corroborating the DOHaD paradigm and the Intergenerational Influence Hypothesis (IIH), the perpetuation of the cycle of triple burden of malnutrition, draw the pathway between maternal body size, birth weight, and early infant growth; this expands over generations (65).

In a review, Martorell et al. (66) emphasized that there is an intergenerational influence of poor growth and development across generations. Varela-Silva and colleagues (65) found that having shorter mother (<150 centimetres) and a birth weight <3000gr were associated with stunting in Mexican children of 4 to 6 years of age. Although many efforts are constantly made to reduce the burden of malnutrition, these efforts are slowed down by the supposed “intergenerational cycle of malnutrition”(**Figure 16**) (32, 33, 37, 67).

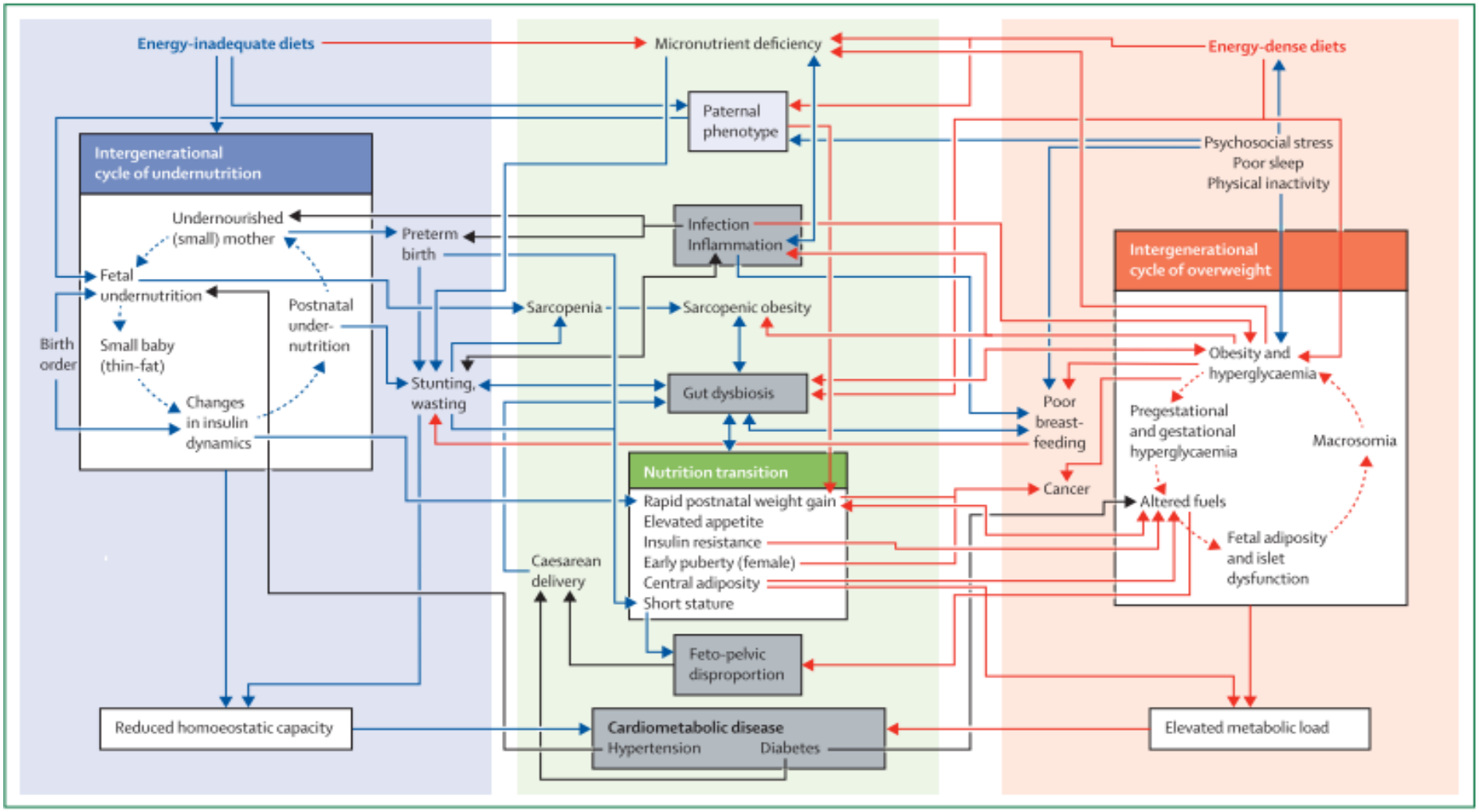

Figure 16: The intergenerational cycles of malnutrition. Interactions between the intergenerational cycle of undernutrition and overnutrition, the triple burden of malnutrition and the nutrition transition (33).

Studies have also shown that the intergenerational cycle of malnutrition is interconnected with the nutrition transition (65). Maternal undernutrition before and during pregnancy exposes the foetus to the risk of intrauterine growth retardation (4, 58). The resulted LBW newborn has higher risk of having impaired growth during the first two years of life, childhood, adolescence, which will also lead to short adult stature, depending on food intake and other environmental factors (water, sanitation, hygiene, health status) (9, 68). Several studies have found that household poor environment, particularly in LMICs, was associated with both transgenerational persistence of malnutrition and triple burden of malnutrition (32-34, 69). In addition, low birth weight babies have higher risks for cardiometabolic diseases, such as hypertension, in adulthood (9, 68). Women with hypertension are more likely to have LBW children in LMIC and the transgenerational cycle of undernutrition is thus brought full circle (9, 70). It is now recognised that only effective nutrition interventions, conducted preferably in pre-pregnancy at adolescence period, could break the intergenerational cycle of undernutrition (71).

Intergenerational determinants of undernutrition includes genetic and epigenetic factors which may perpetuate physiological effects of undernutrition through several generations despite efforts to reduce the problem (72, 73). For instance, the development of metagenomic analyses has allowed to find that undernutrition was associated with changes in the microbiome (catalogue of human microbes and their genes), impaired development of intestinal microbiota (specific microbes in a gut) and related functional troubles (intestinal inflammation, malabsorption of nutrients) (74). Regarding epigenetic mechanisms, prenatal and neonatal phenotype modifications resulting from undernutrition are associated with the histones methylation and, therefore, with the transgenerational modification of the genes expression (72, 73). Genetic and epigenetic alterations associated with undernutrition have been associated with high risk of impaired growth and development, and cardiometabolic diseases in adulthood (73, 75).

Epigenetics changes may also be driven by environmental factors of infant undernutrition and impaired growth, outlined in the UNICEF conceptual framework (**Figure 12**), which are persistent in SSA and may perpetuate the burden of malnutrition through the intergenerational cycle of undernutrition (35, 37). One of the factors that has proven to be critical is socioeconomic status of the household and mothers, which is intimately linked with countries' economic and political context. In sub-Saharan Africa, the alleviation of poverty has been the most challenging factor in the effort of reducing maternal and infant undernutrition.

1.4.3 Poverty and infant undernutrition in sub-Saharan Africa

Poverty and poor social as well as economic position are associated with maternal undernutrition, which is a predictor of impaired foetal and infant growth (2, 44, 67). Poor infant growth impacts negatively on the country's economic growth and development (50), while poverty, in turn, provides a framework for the establishment of undernutrition which mainly affects young children, adolescents and women of childbearing age (9, 76). Studies conducted in LMICs have reported that infant impaired growth and development was positively associated with poor economic growth of countries and poverty of households (50, 51, 77, 78). Low birth weight has been found to commonly affect disadvantaged individuals and households in LMIC and in humanitarian settings (79). Therefore, the relationships between poverty of the country, poor socioeconomic status of households and infant undernutrition have been established (4, 9) with LBW, having been shown to be a predictor of stunting, particularly in regions with low socioeconomic status (4). Several other studies have emphasised negative effects of poor socioeconomic status (poor education, low income, unemployment) on infant growth and health in LMICs (15, 35, 76, 80, 81, 82).

Table 7 shows SSA, the region of our focus in this study, having the highest rates of poverty in the world (with 41.4% of Africa population living with up to $US 1.9 per day in 2015) and high rates of food insecurity (83), poor level of education and unemployment (6% of total unemployment). Although the rate of extreme poverty dropped between 2002 and 2015 (25.5% to 10.0%), Africa experienced higher social inequity compared to other continents of the world (84).

Table 7: Socioeconomic indicators and prevalence is sub-Sahara region (84).

Socioeconomic indicators	World	Sub-Saharan Region	Note
Primary completion rates	85.6 % (2018)	68.8% (2018)	
Secondary school enrolment (net)	66.3 % (2018)	36.0% (2019)	This indicator has been increasing over 10 years in the world.
Tertiary school enrolment (gross)	38.0 % (2018)	9.0 % (2019)	
Total unemployment	4.9 % (2019)	6.1 % (2019)	This indicator has been decreasing since 2009.
Labour force total	3.489 billion (2019)	428.228.202 (2019)	

Within the SSA region, countries vary in culture, epidemiology, socioeconomic, and environmental factors, which are commonly associated with high rates of nutritional status. The root of undernutrition in children living in SSA has been associated with the persistent poor economic development, while for instance in South Asia, acute forms of undernutrition were rather associated with food insecurity and the burden of diseases in a context of high demographic growth (12). Moreover, the prevalence of infant undernutrition varies between SSA regions and countries, probably due to differences in social and economic landscapes (85). The level of development in countries within SSA ranges from low income countries to middle-income countries. For instance, South Africa (SA) and the Democratic Republic of Congo (DRC) have disparities in their level of socioeconomic development (middle-income vs. low-income respectively), epidemiological transition (differences in the prevalence of undernutrition/overnutrition and other diseases such as HIV, malaria, and non-communicable diseases), and politics (the DRC has been experiencing political instability and war for the last 20 years). In the 2019 WHO report, the prevalence of LBW declined from 12.4% (269.600) to 10.8% (354.400) in the DRC, and from 15.0% (166.900) to 14.2% (167.100) in SA between 2000 and 2015 (86). The prevalence of both LBW and PTB was estimated at 14.4% in South Africa in 2018 (87). In 2013, the South African National Health and Nutrition Examination Survey (SANHANES-1) reported that in children under 5 years of age in SA, the prevalence of stunting, underweight and wasting were 21.5%, 5.2% and 2.6%, respectively (88), whilst the

DRC DHS reported a prevalence of 43% for stunting, 23% for underweight, and 8 % for wasting (89).

Whilst the influence of maternal and child biological factors (such as growth and morbidity) on child nutritional status at birth and during the first two years of life have been widely studied, the influences of non-biological factors such as SES (wealth, education, income, employment, and marital status) remain less explored or mainly explored as covariates. The pathway linking SES and health may involve two mechanisms. Socioeconomic factors could determine directly individual health considering that better maternal income enables access to better health care and food (90). Another mechanism (**Figure 17**) postulated that socioeconomic status could also be associated with the intermediate characteristics such as age, sex, ethnicity, household density, water quality, waste management, housing quality; these characteristics impact directly on individual health (90). Although we know that SES factors related to environmental and maternal factors may directly and sustainably influence child nutritional status during the life course (91), little is known about the role that SES factors play on infant growth and undernutrition, particularly within SSA. That is the reason this study was specifically and methodologically designed to explore the role of SES as the main exposure to undernutrition instead of being a covariate.

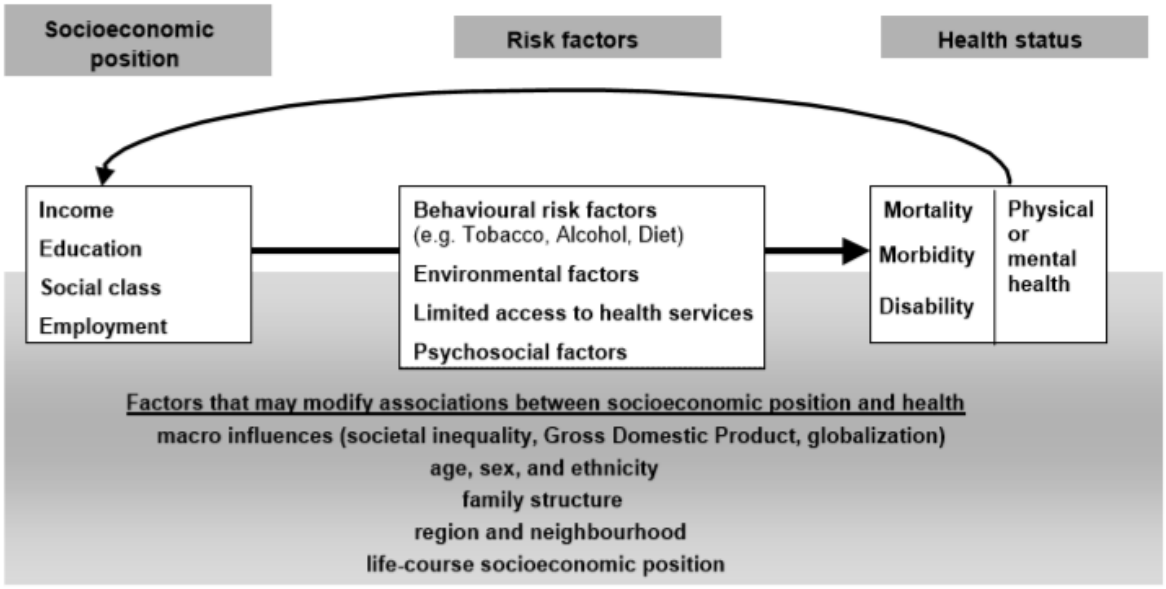

Figure 17: Socioeconomic factors and risk of pathways to health (90)

Moreover, most studies have investigated the association between SES and birth outcomes and undernutrition in children under five years of age as a group. However, the effects of

undernutrition seem to appear from pregnancy and during the first two years of life. In addition, within SSA, it is common for women to change houses during pregnancy and in post-natal period; this new living environment with various social structures may imply potential changes in SES context for women and their newborn (90).

1.4.4 Other global contexts

Globally and in sub-Sahara Africa, high rates of infant undernutrition are associated to socioeconomic disparities in other contexts including climate change (92, 93), demographic growth (84), famine (94) as well as hunger (94, 95), epidemiological transition (96), and nutrition transition (97). Theses contexts are important although they are not at focus in this thesis.

Therefore, this study investigated the role of household and maternal SES as well as sociodemographic factors, and child growth during the first 1000 days in two sub-Saharan African countries: SA and the DRC. These countries present different levels of economic development and their epidemiological transition and nutrition transition context.

CHAPTER 2: LITERATURE REVIEW

The main aim of this section is to review extant literature on the association between household and maternal SES as well as child growth and nutritional status. This section includes a brief history and definitions of SES as well as demographic factors in health sciences, and the review of extant literature on the association between SES and main outcomes (birth outcomes and infant undernutrition).

2.1 A brief history of socioeconomic status in health sciences

Historically, socioeconomic factors were measured in African American immigrants through individual components (e.g. education) rather than as composite factors (e.g. scores made up of the components combination) (52). Socioeconomic factors were analysed as multidimensional factors such as education, income, and occupation in order to get a comprehensive view of the position of individuals, families, and groups in a socioecological structure based on social values (52). Socioeconomic factors were also used as synonym of race or ethnicity in studies about immigrants in America (98). Two opposing schools of thought on the definition of SES factors existed and focused on social position (related to economic position) and social status (related to prestige) in relation to access to basic and social resources like health care (52).

In 1988, Coleman et al. (99) and Bradley et al. (52) introduced the theory of capital, which allows one to attain either social position or prestige and which comprises three forms: human capital (non-material resources), financial capital (material resources) and social capital (network, connections). In general terms, capital allows individuals to access basic services through a stratified social structure. Specifically, financial capital is measured by occupation rather than by income, which is an unreliable and volatile indicator of SES in LMICs (52, 100). The concept ‘wealth’ has been introduced by Smith et al. (101) as it better represents financial capital compared to income. Although the combination of education, income and occupation is common, it requires an entire process for measurement even if there is no consensus on how to measure these indicators individually, or how best to combine them.

2.2 Definitions of demographic and socioeconomic status

Demographic characteristics of individuals refer to the characteristics of individuals according to their distribution (e.g. rurality), their composition (e.g. gender), or their structure (e.g. age). On the other hand, socioeconomic status (SES) is a complex concept with several definitions,

and it is assessed through different scales (102). Socio-demographic factors involve social and demographic variables such as marital status and living arrangement. According to the WHO, SES refers to an economic or sociological position of individuals or groups in the hierarchical society based on education, income and occupation. Robert and colleagues (52) defined SES as social class (position), status (prestige) or capital (resources, assets) which characterizes an individual or a group and their access to basic social resources. The capital could be material (owned assets) or non-material including human capital (education, employment, workforce, wellness, health care access, and healthy environment) (103), social capital (social connections) or financial capital (income, occupation, wealth) (104). While income refers to flow of money in the household, wealth represents the resources that may be numbered at any time point (100). Another definition was proposed by the American Association of Psychology (AAP), which explains socioeconomic status as how individuals or groups of individuals access basic social services, their occupation, health, education or wealth and place of residence. Due to the variety of SES definitions, many scores have been used to assess SES factors for individuals (e.g. a mother) or groups of individuals (country, region, family, household) (52, 100). Socioeconomic status has been quantified through compositional factors (e.g. education, occupation, or income) or contextual factors (the creation of aggregated indices or scores including the literacy, housing, assets, access to safe water and improved toilets) (105). Social factors provide the prestige or position of individuals or group of individuals within the social structure with an impact on the access to basic social services such as health and education (52, 100, 105, 106).

Household wealth indicators include characteristics of housing materials (floor, wall, roof), assets, household size, as well as access to basic social facilities or services (water, toilets, health facilities, education) (106). Household wealth is important when assessing the accumulation of income or assets and measuring the social position of individuals in the social structure (individuals, community, region, country) (77, 78, 105).

2.3 Relation between socioeconomic status with birth outcomes and infant undernutrition

2.3.1 A conceptual framework of the association between SES factors with birth outcomes and infant undernutrition

The nutritional status of the child from birth until 2 years of age has been associated with the socioeconomic status of the mother and the household in which she lives. Child, maternal and household factors may play a role on infant undernutrition, and these relationships are related to other environmental factors, such as the location (local, regional and national) and the health system.

For investigating the association between SES factors and infant undernutrition in this study, a conceptual model (**Figure 18**) was developed and adapted from extant literature as well as conceptual frameworks. At the individual level, there are maternal demographic and SES factors, biological factors, and behavioural factors (lifestyle etc.). Maternal socioeconomic and demographic factors include maternal level of education, income level, occupation and marital status. Maternal biological factors include maternal nutritional status, age, weight, height, morbidity, mode of delivery, and parity whilst some of the non-biological factors were infant feeding practices (exclusive breastfeeding) and lifestyle during pregnancy (substance use). Infant factors include gender, gestational age at birth, birth weight and postnatal morbidity. At the household level, factors such as the wealth accumulated by the household, the size of the household, the place of residence, the relationship between the child and the caretaker and the environment (household density, water, sanitation and hygiene) are considered. This conceptual framework suggests that the household structure may impact maternal biology and non-biological factors, which in turn influences child outcomes (weight and height).

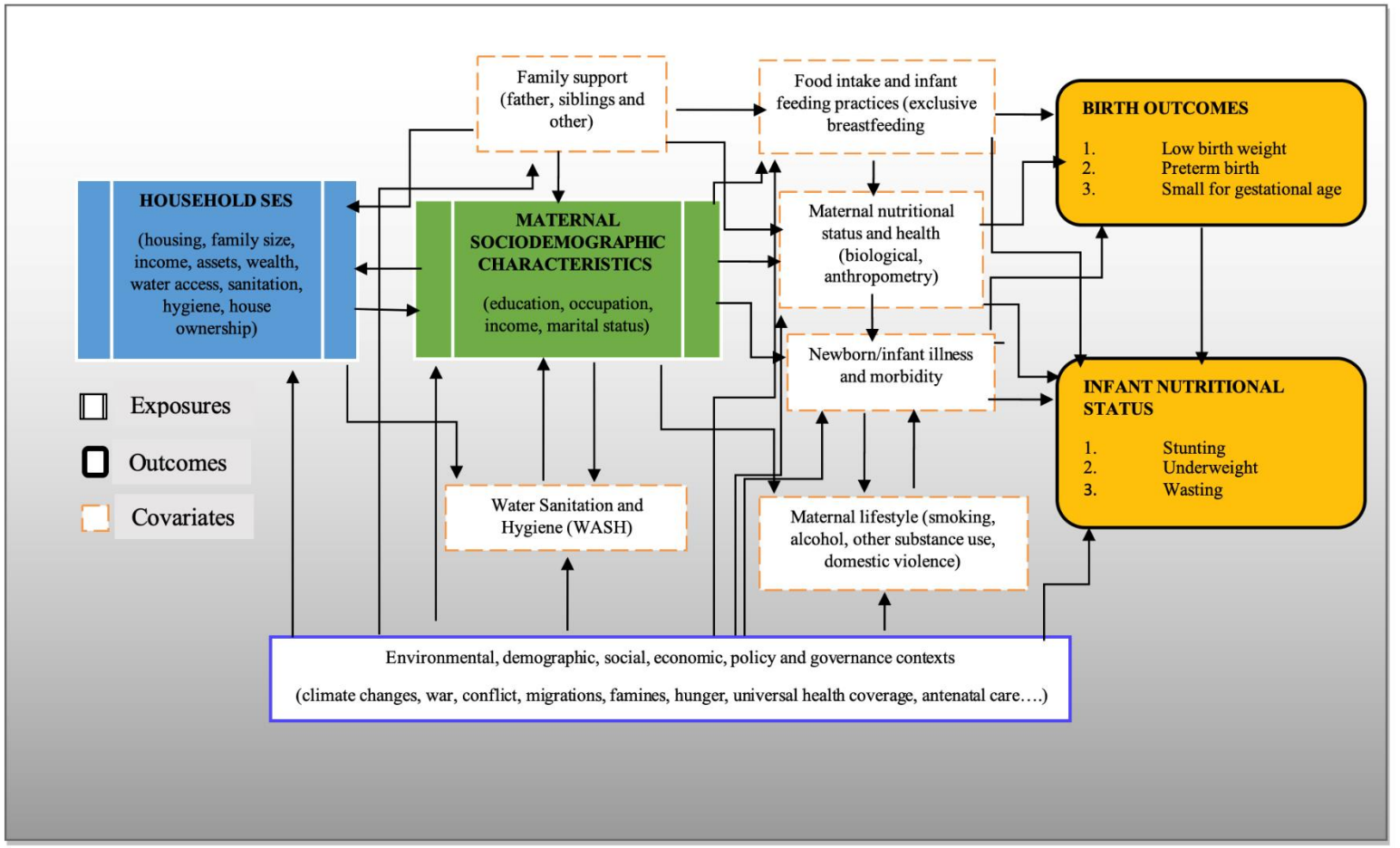

Figure 18: Integrated conceptual framework on the association between SES factors and infant undernutrition.

2.3.2 Demographic and socioeconomic factors and infant undernutrition

Recent reviews have found that lower maternal education was associated with poor child nutritional status in SSA countries (107) and in Latin America (108), and with SGA, PTB and LBW in high-income countries (109, 110). Another meta-analysis in high-income countries (America and Europe) found that maternal marital status (married vs single or cohabiting) was associated with an increased risk of adverse birth outcomes (111). Luo et al. (112, 113) emphasized that amongst SES factors, maternal high education was the most protective against adverse birth outcome. In addition, Aguayo and colleagues found that poor household wealth and poor sanitation were associated with LBW and stunting in infants of 6 to 23 months of age in India (114). In persistent poor SES conditions, maternal undernutrition (during preconception and pregnancy periods) has been correlated with high gestational weight gain and low birth weight (115). However, the association between SES factors, as the main exposure variable, with birth outcomes and infant growth is not sufficiently described in SSA region. Moreover, there is no review that synthesizes the evidence for this association.

2.3.3 Other maternal and child factors associated with undernutrition

Other non-SES factors play a role in infant nutritional status; these are hereafter categorised as child factors, maternal factors, and household factors.

2.3.3.1 Child sex and age

Child sex and age have been associated with infant growth and undernutrition (116). Gestational age was found to be positively associated with birth weight and male infants were found to be more likely to be LBW and stunted compared to female children (72, 114). Male infants were more affected by undernutrition compared to females (9). To illustrate the age factor, a multi-country cohort study by Victora and collaborators in 2012 reported that the prevalence of stunting was 10% at birth, 20% between birth to 6 months, 20 % between 6 to 24 months and 50% between 2 to 3 years of age (18).

2.3.3.2 Maternal biology and biometry

Maternal age, maternal anthropometric (height, weight, middle upper arm circumference, skinfold thickness, body mass index [BMI, defined as the weight in kilograms divided in the square of height of mother in metres and expressed in kg/m^2]), and maternal nutrition are amongst the biological factors associated with infant growth and infant nutritional status (114). Maternal age has been strongly associated with infant growth from birth onwards. In a review in SSA, adolescent mothers (<18 years old) were more likely to have LBW and PTB neonates

and to a lesser extent an SGA child (117). Similarly, in four LMIC African countries (Benin, Gabon, Mozambique, and Tanzania), adolescent mothers (<16 years old) were also found to be more likely to have LBW and PTB newborns (118). Maternal anthropometric characteristics have been found to be the predictors of their children's nutritional status (119). Preconception BMI and the total gestational weight gain (GWG, defined as the amount of maternal weight gained from the conception to delivery) were negatively associated to birth outcomes (72). Being overweight lowered the risk of having a PTB and wasting child in Bangladesh (120). Conversely, underweight women were more likely to have stunted and wasted children (121).

In the current nutrition and epidemiological transition in SSA, several studies investigated the association between maternal nutrition on child growth and development from birth until the age of 2 (5, 122). Fat and sugar consumption during pregnancy were associated with an increased risk of higher GWG and a lower risk of poor birth weight (123, 124). Supplementation in mineral, micronutrient and vegetable intake seemed to be very healthy for mother and the child before and after pregnancy (58). Healthy food intake and physical activity during pregnancy are important for maternal and child health as well as nutrition, because they were associated with better child survival rate (9, 58, 123, 124).

2.3.3.3 Prenatal care, parity, type of delivery, infant feeding practices

Prenatal health care is very important for preventing maternal and child undernutrition, diagnosing early risk conditions for adverse birth outcomes, as well as maternal and child survival threat later. Low number of prenatal visits (less than 4) and maternal prenatal morbidity (HIV, malaria) have been associated with high risk of having a LBW newborn (125). Also, the quality as much as the quantity of prenatal care contributes considerably to better pregnancy outcomes (125). Maternal parity has been inconsistently associated with birth outcomes. Studies have found that high parity was associated with low risk of having a PTB newborn, while others studies found the contrary because of confounding factors such as low maternal age, poor SES factors and poor quality of prenatal health care (126). Another important factor for fetal, newborn and infant health as well as nutritional status is feeding practices. Food/diet brings essential nutrients that mothers and children need for their metabolism. The double burden of malnutrition in children was associated with high risk of caesarean delivery in Indian women (120). In Brazil in 2006, there were a linear relationship between caesarean delivery and SES factors; however, those associations were not significant after adjusting for confounding factors (127).

2.3.3.4 Lifestyle factors: maternal prenatal smoking and alcohol use

Maternal lifestyle such as prenatal substance use is associated with birth outcomes (5, 20). Globally, alcohol came second to hypertension as the leading cause of LBW between 1990 to 2010 in 21 regions of the world (128). Alcohol consumption and smoking (tobacco) were associated with SGA newborns in Nigerian Demographic Health Surveys (129). In SA, which has one of the highest prevalence of smoking in Africa, the effects of smoking in women living in the farming regions (130) and prenatal alcohol use were associated with LBW newborns (128, 131). However, little is known about the effects of maternal substance abuse on growth during infancy (132).

2.3.3.5 Maternal diseases and illness (infections and non-communicable diseases)

. Maternal HIV infection poses greater risk for impaired foetal growth and/or premature birth (133) which are a pathway for infant undernutrition (4). The progress made by the Prevention Mother To Child Transmission (PMTCT) programs across countries increases the number of HIV exposed uninfected infants, who mostly have LBW or were born prematurely. Studies have shown that infection or co-infections with HIV (5, 134) or with Cytomegalovirus (135) threatened household socioeconomic environment, quality of family life and child care leading to impaired growth in uninfected newborns in Zimbabwe and SA (136). Studies have shown that there is a higher risk of LBW, SGA and PTB in HIV newborns compared to HIV exposures uninfected newborns (5, 134). Non-communicable diseases in adulthood such as hypertension, diabetes and heart diseases, are associated with foetus impaired growth with subsequently LBW and stunting (137).

2.4 Rationale and justification

Developmental origins theory has demonstrated environmental factors of poor growth on the foetus, newborn and early childhood in sub-Saharan African countries (1). Several studies have shown an association between SES factors and birth as well as child growth outcomes in HIC (9, 21, 35, 51, 52, 76, 77, 85, 137, 138, 139, 140). Hence, this thesis is motivated by many reasons. Firstly, undernutrition remains a significant public health issue, especially in SSA, which has been associated with socioeconomic inequalities (141). Thus, the SDGs were set to decrease levels of poverty (SDG 1); end hunger (including reducing stunting, wasting and underweight) (SDG 2); improve health (SDG 3); and reduce the level of inequality (SDG 10). Secondly, infant growth during the first 1000 days of life is critical because it predicts health and nutritional status throughout an individual's life course and in subsequent generations. It

thus influences the well-being of populations and the development of countries. The third reason is that, countries in SSA differ in their level of socioeconomic development, epidemiological situation, and political context. These varying levels may influence household SES and maternal socio-demographic characteristics differently, and subsequently infant undernutrition.

However, there is a lack of longitudinal studies which characterise the effect of changes in socio-demographic maternal characteristics and household SES factors on birth and infant growth and nutritional status in the first 1000 days of life. Furthermore, little is known about the association between SES factors and infant growth outcomes (birth outcomes and infant undernutrition) in the sub-Saharan African region, particularly for the DRC and SA, which are representatives of two different levels of development (low-income country and middle-income country). In addition, there is no consensus on how to combine SES indicators, as well as how to differentiate between maternal socio-demographic characteristics and household SES. There is also no consensus on which indicators best assess maternal and household SES, and how changes in maternal socio-demographic characteristics and household SES between 0 to 2 years of life could affect infant nutritional status and growth. Furthermore, despite our understanding that there is an association between maternal socio-demographic characteristics and household SES and child nutritional status, little is known about the magnitude, direction and strength of these associations in infants of different age groups and living in different social and economic contexts in the SSA region, such as the DRC and SA.

Therefore, the fundamental question of this thesis is: what is the association between the maternal socio-demographic factors and household SES with adverse birth outcomes and infant undernutrition in SSA? This question was sub-divided into three sub-questions:

1. What are the associations between household and maternal socioeconomic factors and demographic factors with birth outcomes and infant undernutrition between 0 to 2 years of age in sub-Saharan African region?
2. Are there any differences in the associations between household and maternal socioeconomic factors and demographic factors with birth outcomes in the DRC compared to SA, two SSA countries varying in term of level of socioeconomic development and nutrition epidemiology?

3. Are there any associations between household and maternal socioeconomic and demographic factors with infant growth (HAZ, WHZ and WAZ) in the first year of age in South Africa?

2.5 Aim of the thesis

The overall aim of this thesis was to investigate the association between household SES factors, maternal socio-demographic characteristics with birth outcomes (LBW, PTB, and SGA), and infant growth and undernutrition in the first two years of life (0-24 months) in SSA by comparing the DRC and SA.

2.6 Objectives and hypotheses

To achieve the overall aim, the following scientific objectives were defined:

2.6.1 Objective and hypothesis 1

To review the association between maternal socio-demographic characteristics and household SES with birth outcomes and infant undernutrition under two years of age in SSA countries. In order to respond to the objective 1, a systematic review of the literature was conducted to gather evidence on the associations between SES factors, at household and maternal levels, with birth outcomes and infant undernutrition in sub-Saharan African countries.

To achieve the objective 1, two hypotheses were formulated and tested:

1. Null hypothesis 1 ($H_0 1$): there were associations between household and maternal socioeconomic and demographic factors with birth outcomes and infant growth in SSA.
2. Alternate hypothesis 1 ($H_1 1$): there are no associations between household and maternal socioeconomic factors and demographic factors with birth outcomes and infant growth in SSA.

2.6.2 Objective and hypothesis 2

To compare the association between maternal socio-demographic characteristics and household SES during pregnancy with PTB, LBW, and SGA in the DRC and SA. To achieve the objective 2, a study compared the association between household and maternal SES factors with birth outcomes in the DRC and in SA, two countries with a different level of economic development.

To achieve the objective 2, two hypotheses were formulated and tested:

1. Null hypothesis 2 ($H_0$2): Associations between household and maternal socioeconomic factors and demographic factors with birth outcomes were the same in the DRC and in SA.
2. Alternate hypothesis 2 ($H_1$2): Associations between household and maternal socioeconomic factors and demographic factors with birth outcomes were different between the DRC and SA.

2.6.3 Objective and hypothesis 3

To assess the relationship between maternal socio-demographic characteristics and household SES with infant growth between birth to one year of age in SA.

Two hypotheses were formulated and tested in order to achieve this objective:

1. Null hypothesis 3 ($H_0$3): there were associations between household and maternal socioeconomic factors and demographic factors with infant growth during the first year of life in infant living in SA.
2. Alternate hypothesis 3 ($H_1$3): there were not any associations between household and maternal socioeconomic factors and demographic factors with infant growth during the first year of life in infant living in SA.

CHAPTER 3: METHODOLOGY

3.1 Summary of Methodology

Table 8 summarises the methods used for the purpose of this thesis in order to achieve its three specific scientific objectives. Each objective is briefly described before they are detailed in the results chapters.

Table 8: Summary of methods by objective

Objective 1: To review the association between maternal socio-demographic characteristics and household SES with birth outcomes and infant undernutrition under 2 years of age in sub-Sahara African countries.		
Research question	**Hypothesis**	**Methods**
What are the associations between household socioeconomic status and maternal socio-demographic determinants with foetal and infant growth until age 2 years in 46 SSA countries?	There are associations between household and maternal socioeconomic and demographic factors with birth outcomes and infant growth in SSA.	This systematic review followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines. The protocol was registered on International Prospective Register of Systematic Review (PROSPERO). Three databases were used: PubMed, Scopus and ScienceDirect. The process included: searching of articles, screening of articles, inclusion of articles, quality appraisal, data extraction, summary, synthesis. Quality appraisal of primary articles was performed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) tool. Data were extracted including adjusted odds ratios. The process included two independent reviewers with a third when there was disagreement between the first two.

Objective 2: To compare the association between maternal socio-demographic characteristics and household SES during pregnancy with PTB, LBW and SGA in the DRC and SA		
Research Question	**Hypothesis**	**Methods**
Are there any differences in the associations between household and maternal socioeconomic factors and demographic factors with birth outcomes in the DRC compared to SA, two SSA countries varying in term of level of socioeconomic development and nutrition epidemiology?	Associations between household and maternal socioeconomic factors and demographic factors with birth outcomes were comparable in the DRC and in SA.	The study design was cross-sectional on the association between SES factors and birth outcomes (LBW, PTB, SGA) in the DRC and in SA. Data were collected from mother and newborn pairs in 4 hospitals in the DRC and in one hospital in SA. Inclusion criteria were alive mother-newborn pairs, mothers at least 18 years old, singleton newborn, no physical or mental abnormality for the newborn. This study used structured questionnaires and anthropometric characteristics to collect SES information (maternal education, marital status, type of house walls) and measurements of mother and newborn anthropometric measurements were done. The newborn outcomes were LBW, PTB and SGA. Variables for adjustment (covariables) were collected, including child sex, maternal parity, type of delivery, gestational age, maternal age, maternal height and maternal weight from the first prenatal visit and at delivery, maternal morbidity (malaria, high blood pressure, anaemia, tuberculosis, HIV). Descriptive analyses by country and by sex were done. Unadjusted and adjusted logistic regression analyses were performed for each outcome, each country, and pooled.

Objective 3: To assess the relationship between maternal socio-demographic characteristics and household SES with infant undernutrition (stunting, wasting and underweight) between birth to one year of age in SA.		
Research question	**Hypothesis**	**Methods**
Does the association between household and maternal socioeconomic and demographic factors with infant undernutrition change in the first year of age in South Africa?	The associations between household and maternal socioeconomic factors and demographic factors with infant undernutrition did not change during the first year of life in infant living in SA.	This is a prospective cohort study on the association between sociodemographic and household socioeconomic and infant growth (HAZ, WHZ and WAZ) in Soweto in SA. Data were collected between January 2018 to March 2019. Participants were mother and newborn pairs, recruited according to eligibility criteria. Maternal SES variables (maternal occupation, maternal education, marital status, maternal income, household wealth index) and household variables (assets, house ownership, household size and characteristics of house) were collected using structured questionnaires. The SES information was collected at 1, 6 and 12 months postnatally. Descriptive statistics were done at baseline then at 6, and 12 months. Test of hypothesis (t-test, chi square) and analyses (simple and multiple linear regression analysis). The regression diagnostic has been done to test the fitting models.

3.2 Study Settings and Designs

Three study designs were used to gain insight into the association between household and maternal SES and demographic factors with birth outcomes and infant undernutrition in SSA.

To address objective 1, a systematic review was conducted in 46 sub-Saharan African countries. A comparative cross-sectional study between the DRC and SA was led to address objective 2, and a cross-sectional data nested in a prospective longitudinal study to address objective 3 in SA.

3.3 Objective 1: to review the association between maternal socio-demographic characteristics and household SES with birth outcomes and infant undernutrition under two years of age in SSA countries

A systematic review was conducted to assess the evidence on the association between SES factors (at household and maternal levels) with birth outcomes and infant undernutrition in SSA. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines were followed (142).

3.3.1 Protocol drafting and registration

The protocol of the review was registered on the international database of Prospective registered Systematic Review in health and social care PROSPERO. The PRISMA guidelines allowed us to identify, screen, select and include primary articles (143, 144). All articles written between 1990-2018, investigating the association between the socioeconomic factors of households and mothers with birth outcomes (low birth weight, small for gestational age, preterm birth) and undernutrition (stunting, wasting and underweight) of children aged between 0-24 months of life in SSA were included.

3.3.2 Search of primary articles

The search strategy included three electronic databases (Pubmed, Scopus and Science Direct) which were used to search for publications using all combinations of keywords (socioeconomic status, socioeconomic inequality, socioeconomic position, household assets, household wealth, maternal education, maternal income, maternal occupation, low birth weight, small for gestational age, preterm birth, stunting, wasting, underweight, undernutrition, infant, Africa and the name of the 46 sub-Saharan African countries).

3.3.3 Information source and eligibility criteria

All publications and citations resulting from the search were imported into Endnote version X7.0.1 as reference manager. A few authors were contacted for either additional information or for articles that were not available online. After removing duplicate references resulting from

the search, the following eligibility criteria were used to include the studies relevant for the systematic review: all studies in French or English published between 1990 and June 2018, assessing the relationship between SES and the outcomes of interest in SSA countries.

3.3.4 Study selection

The search and selection of studies for inclusion were performed separately by Christian Bwangandu Ngandu (CBN) and Douglas Momberg (DM), and conflicts were resolved by Rihlat Said-Mohamed (RSM). Full text articles were retrieved and the quality of each selected study was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach (145, 146). Each study was evaluated and graded as high, moderate, low or very low quality.

3.3.5 Data items

Relevant data were retrieved from studies and recorded in Microsoft Excel version 10. Exposure variables included the indicators used to evaluate household SES and maternal socio-demographic characteristics such as maternal education, income, occupation (type of job), marital status, household wealth. The following outcomes were extracted: stunting, wasting, underweight in children younger than two years as well as SGA, LBW, and PTB. The relevant statistics (adjusted odds ratio [OR], risk ratio [RR] and their confidence intervals [CIs]) on the association between maternal socio-demographic characteristics and household SES with stunting, wasting, underweight, LBW, SGA, PTB were extracted from each article.

3.3.6 Risk of bias

This study was limited by the fact that only studies in English and French were included.

3.3.7 Quality appraisal

The GRADE tool was used to approach the quality of primary articles between and within them (143, 145-148). The judgement of the quality of evidence shows the confidence that the effect estimates and evidence contain and its extent (strength) (148). This process encompasses steps, criteria for grading, and the assignation of the grade to the evidence (148). After assessing the quality of each outcome with criteria across primary articles, the judgement on the quality of outcomes was built and the quality of evidence done between articles. Some of criteria increase the rate (large effect size, existence of dose-response, confounders are likely to minimize the effect) whilst others lower the rate (study limitations, imprecision, inconsistency, indirectness

of the results, and publication bias) (145, 146). The process for assigning a score and value to the quality of evidence is shown in **Table 9.** The GRADE assessment provided the quality of evidences to allow for drafting guidelines based on evidence (149). The criteria for rating the quality of primary studies are shown in **Figure 19** and **Table 9**. The details of the summary, synthesis and interpretation method have been presented in chapter four.

Table 9: The grading process using GRADE tool, adapted from Atkins and co-workers (148)

Domains for scoring	Criteria	Score	Value
Type of study designs	Interventional studies (Randomized trials)	High	
	Observational studies	Low	
	Other types of studies	very low	
Decrease score or value	Limitation of the study or risk of bias	Serious	-1
		very serious	-2
	Inconsistency		-1
	Indirectness	High	-2
		Low	-1
	Imprecision		1
	Risk of reporting bias		1
Increase score or value	strong effect size estimate and significant with no plausible confounder	<0.5 and >2	+1
	very strong evidence and significant with no threats to the validity of evidence	<0.2 and >5	+2
	Dose response		+2
	Plausible factors that can negatively confound the evidence		+1

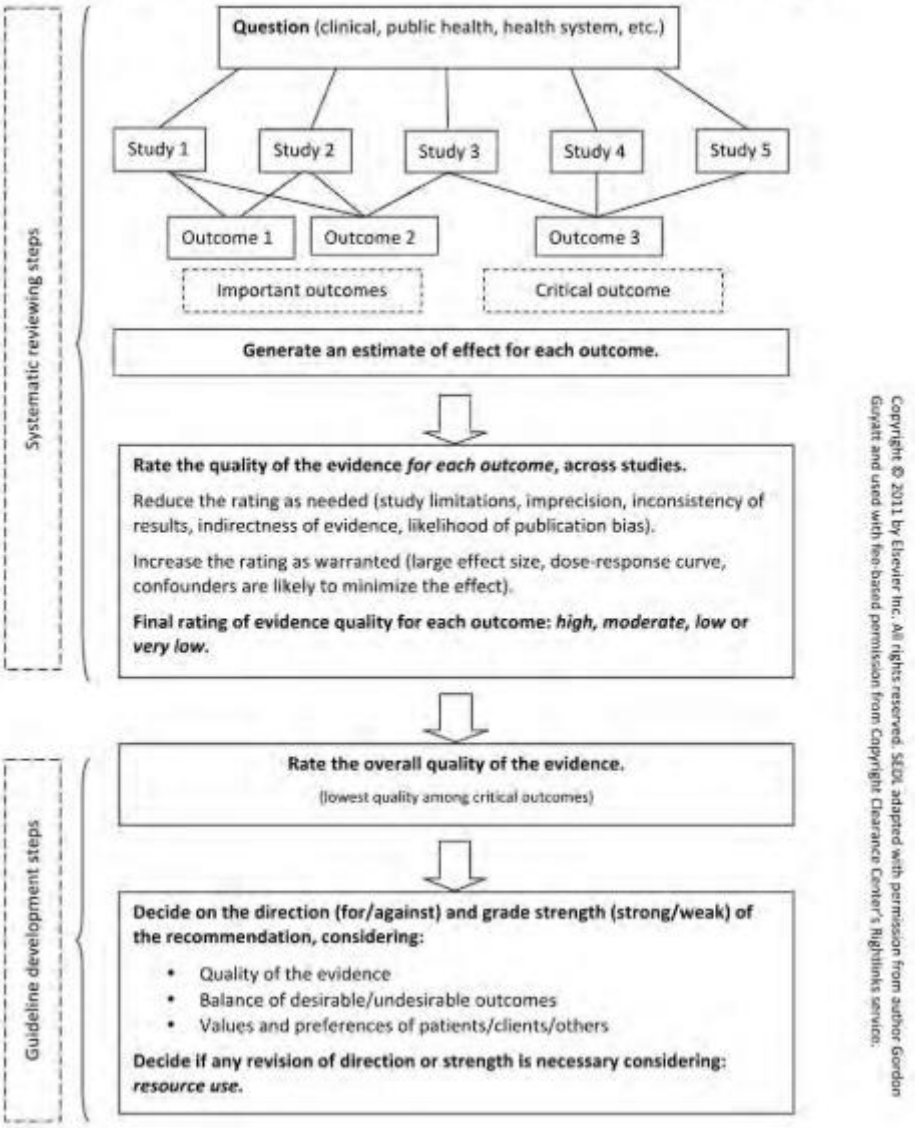

Figure 19: The GRADE process modified from Guyatt and collaborators (146)

3.3.8 Summary, synthesis and data analysis

Primary studies were summarized and synthesized. Effect size estimates (adjusted odds ratio or relative risk) were extracted from selected articles.

3.4 Objective 2: to compare the association between maternal socio-demographic characteristics and household SES during pregnancy with PTB, lbw and SGA in the DRC and SA

3.4.1 Study design and setting

A cross-sectional study compared the associations between SES factors with birth outcomes in Kasai Central in the DRC and in Soweto in SA. The DRC is a central African country, with an

area of 2 345 000 Km^2 and a population of approximately 86 790 567 inhabitants. The DRC has 26 provinces, with Kasai central province, being where the study was conducted, and 22 health districts (**Figure 20**) (84, 89). The current study was conducted in 4 health districts among which three were rural (Bunkonde, Mikalayi and Tshikula) and one was urban (Kananga). The Kasai central province has faced armed conflicts with high migration, famine, hunger and the highest rate of undernutrition in the DRC (84).

South Africa, which is a southern African country, has an area of 1 221 037 Km^2, 58 558 270 inhabitants and 10 provinces (**Figure 20**). Gauteng, located centrally within SA, is one of its 10 provinces (84) with 6 health districts (88). Soweto, an area in Johannesburg metro council district within Gauteng, had 1.3 million inhabitants in 2008 (150).

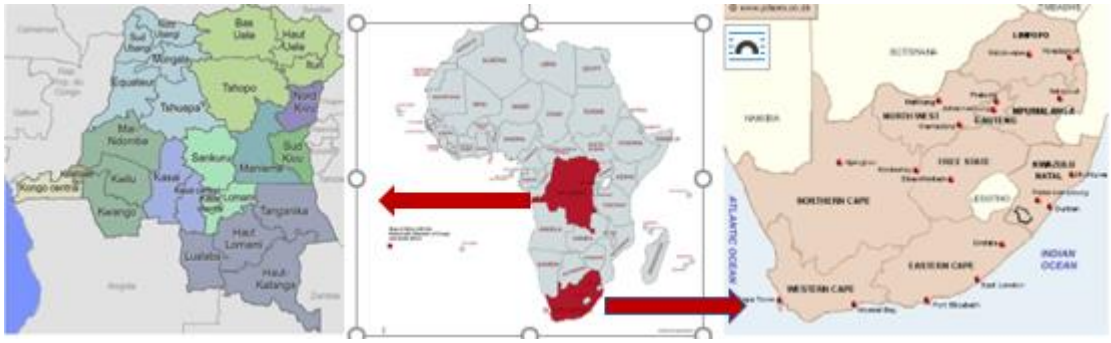

Figure 20: Map of the Democratic Republic of Congo and the South Africa. Adapted from(84, 151)

In SA, data for secondary analyses were collected from a large pregnancy cohort study (Soweto First 1000-Day Research Project or S1000) led from 2013 until 2016. The recruitment of mothers and their newborns was done at the Chris Hani Baragwanath Academic Hospital (CHBAH) in Soweto, Johannesburg, South Africa.

There were several reasons for choosing the DRC and SA for comparison. Firstly, the sub-Saharan African region comprises low-income countries (LIC) and middle-income countries (MIC). Thus, comparing the DRC which is a LIC with a lower human development index (HDI) (0.37) and a weaker gross domestic product (GDP) per capita ($US 808)), and SA which is a MIC with a medium HDI (0.41) and $US 12,215 per capita GDP) (84), depicts a representation of varying contexts within SSA. These two countries allow better representation of the socioeconomic status and level of development in the SSA region. Secondly, the epidemiologic profile of the nutritional status of children is disparate with high rates of infant undernutrition

(at birth or later in infancy) in the DRC and low rates in SA (23). Finally, the two countries have differences in governance, existence of conflicts and war, the extent of famine, climate, language and health epidemiology.

3.4.2 Population, participants and sample size

Population and participants

In the DRC, participants were selected from the following 4 maternity hospitals: Kananga provincial Hospital, Tshikula General Hospital, Bunkonde General Hospital and Mikalayi General Hospital. The DRC DHS reported that 84% of deliveries occurred in hospitals in Kasai central province in 2013 (89). Only mothers who were at least 18 years of age, and who had given birth to a live singleton at the selected hospital whose gestational age at delivery was at least 28 weeks of pregnancy were included in the research project. The exclusion criteria were mother-newborn pairs where death of either the mother or child or both occurred at delivery, birth before 28 gestational weeks, and multiple births. Authorization was obtained from the directors of each hospital. Thereafter, informed consent was obtained from mothers who met the eligibility criteria. In SA, the eligibility criteria included mothers who resided in Soweto, who were at least 18 years old, at least 18 weeks pregnant at recruitment, non-epileptic, non-diabetic, and had a singleton. Data collection for S1000 research project took place at six time points during pregnancy (<14 weeks; 14–18 weeks; 19–23 weeks; 24–28 weeks; 29–33 weeks and 34–38 weeks).

3.4.3 Data source and collection

In the DRC, household socioeconomic and maternal socio-demographic data were collected from mothers using an interviewer-administrated questionnaire (see **appendix 7)**. Questionnaires included items on demographic, socioeconomic information of the household, the mother, and newborn. Data were collected at a single time point up to 72 hours after delivery by trained nurses. Birth weight (kilogram) was measured to the nearest 100 grams using a calibrated infant scale. The stadiometer (Holtain, UK) and digital scale for adults were used by the same trained nurses to measure maternal height (centimetre) and weight (kilogram) up to 72 hours after delivery.

South African data were nested from the Soweto 1000-days project and used for secondary data analysis. Maternal variables consisted in maternal demographic and socioeconomic data were collected by trained researchers using interviewer-administered questionnaires at the first

pregnancy visit (<14 weeks gestational age) to delivery. Data on maternal education, marital status, house walls type were collected. Anthropometry data included maternal data and newborn data. Neonate anthropometry was assessed using an infant-meter (for length) and a scale (for weight) by trained research assistants. Maternal height and weight were measured to the nearest 50 centimetres and 100 grams, respectively.

3.4.4 Variables of the study

The variables of the study included SES factors, birth outcomes and covariates (newborn, maternal and country variables). As exposures, household socioeconomic status and maternal socio-demographic characteristics variables included maternal education (the highest level of education attained); maternal occupation; type of house walls (type of material used for wall construction); maternal marital status; and characteristics of household wealth (106, 152). The type of house walls materials within which participants resided was used as a proxy for social position and household wealth instead of the household wealth index (HWI), which is a composite index of the inventory of assets owned by the household, individuals or groups, in chapter 5 in particular. The HWI could not be used to compare the DRC and SA due to the vast contrast in economic development between the two countries, precluding the differences in the assets owned by participants of the two countries (153, 154). The outcomes variables were LBW, PTB or SGA at birth. Covariables included newborn (sex); maternal (gestational age at the first prenatal visit); parity; mode of delivery; gestational weight gain; smoking, alcohol use; morbidity (during the pregnancy); and country of residence.

3.4.5 Statistical analysis

Skewness and kurtosis tests were performed to identify the type of the distribution. All exposures data were either numerical or transformed into categorical variables (ordinal or nominal) while LBW, PTB and SGA were binary (yes/no). Descriptive statistics were performed for each variable by sex and by country. The level of significance was set at $p \leq 0.05$ at 95% of confidence interval with $\alpha = 0.05$. Birth outcomes (LBW, PTB, and SGA) were expressed as binary variables and SGA were defined according to the Intergrowth-21st Global Foetal and Newborn Growth Standards (155, 156). These outcomes were derived from birth weight or gestational age at delivery: LBW (< 2.5 kilograms of birth weight), PTB (< 37 weeks of pregnancy) and small for gestational age (< 10th percentile of the INTERGROWTH 21st curve).

Multivariable logistic regressions analyses were used to assess the associations between household socioeconomic status and maternal socio-demographic characteristics with birth outcomes. Potential confounding factors (infant as well as maternal factors) were adjusted for the regression models.

3.5 Objective 3: to assess the relationship between maternal socio-demographic characteristics and household SES with infant growth between birth to one year of age in SA

The longitudinal study was part of a larger project titled *"Interaction between nutrition, infection, household environment and care practices on growth and development in infants between birth and one year of age"* with Dr Rihlat Said-Mohamed as the Principal Investigator and was commonly known as the 'Soweto Baby WASH' (Ethics Clearance: M170753).

3.5.1 Study design and setting

A prospective longitudinal study was led on the associations between SES factors and infant undernutrition (stunting, wasting, underweight) during the first year of life in Soweto in SA. Participants were recruited at the Chris Hani Baragwanath Academic Hospital (CHBAH) and the follow up at the participants' homes in Soweto or at the Developmental Pathways for Health Research Unit (DPHRU) in CHBAH from 22 January 2018 until 26 March 2019.

3.5.2 Population, sample size and eligibility criteria

The population for this study was women and their children aged 0-12 months. Mothers who were at least 18 years old with their newborns (less than two days old) were recruited into the study. Other eligibility criteria were delivery at the CHBAH, living in Soweto for 12 months following delivery, negative HIV/AIDS status, birth up to two days before, single newborn with normal weight (2500grams to 4000grams) and without any illness, physical abnormality, as well as mental or congenital disorders. Newborns with birth weight less than 2500grams or born before 37 weeks of pregnancy or multiple newborns were excluded.

3.5.3 Recruitment of mother-newborn pairs

Mother-newborn pairs were recruited into the study. To manage the bias due to loss to follow up or incomplete data for participants, 28% attrition was implemented in recruitment and the adjustment for covariates was used to mitigate the selection bias potential effects (157). One hundred fifty-five mother-newborn pairs were recruited for the study.

3.5.4 Participant follow up

The follow-up of the participants was carried out at their homes or at DPHRU. To minimize the loss of participants, the following were done: field visits involving participants, at least two phone calls before the visit and one 'thank-you' call after the visit, impromptu visits for non-regular participants.

Socioeconomic and demographic factors, WASH and infant feeding practices data were collected at 1, 3, 6, 9 and 12 months. Anthropometric data were collected once every week for the first 6 months and once every 2 weeks for the subsequent 6 months. At 6 and 12 months, the interviews and anthropometric measurements of the child participants were carried out at DPHRU in CHBAH.

3.5.5 Variables of the study and measures

Exposures: Socioeconomic variables

Socioeconomic variables were maternal education (the highest level of education attained), maternal occupation (type of job), maternal income, maternal legal marital status and household wealth characteristics which included assets, house ownership, WASH (access to safe drinking water, improved sanitation), and housing material (floor, roof and walls).

Socioeconomic information was collected from mothers using an interviewer-administrated questionnaire (**appendix 7, appendix 8**). The SES questionnaire was based on existing and validated questionnaires such as the Demographic Health Survey (DHS) (158), National Income Dynamic Survey questionnaire (NIDS) (159) and SA Living Conditions Survey (LCS) (160).

The outcomes: Infant growth and undernutrition variables

Three forms of infant undernutrition were included in this study: stunting or chronic form (height-for-age Z-scores below minus two standard deviations [-2 SD] from the median of the standard population); wasting or acute form (weight-for-height Z-scores below minus two standard deviations [-2 SD] from the median of the standard population); and underweight or both acute and chronic forms (weight-for-age Z-score below minus 2 SD of the WHO standards population) among children from birth up to their first birthday (3).

Other variables

Other characteristics which were found to be associated with the outcomes of interest in the literature and in the conceptual framework of this thesis were measured (**Figure 1**) (4, 29, 76, 107, 161, 162). Variables that were considered as possible confounders were child factors including sex, age, illness (such as fever and diarrhoea), feeding practices (exclusive breastfeeding); maternal factors (maternal age, maternal BMI, morbidities); and household factors (household size, number of room for sleeping in the house). .

3.5.6 Statistical analysis

Data were collected and extracted with the Redcap software, at birth and 1 month (as baseline data) and at 6 months and 12 months. After cleaning the dataset by managing duplicates, outliers and missing data, a merged dataset was constituted including data at 1, 6 and 12 months. For statistical analyses, observations were included when they had the outcomes of interest which were height-for-age Z-scores (HAZ), weight-for-age Z-scores (WAZ) and weight-for-height Z-scores (WHZ) (161). Infant growth was deduced from Z-scores based on the growth standard to determine the infant nutritional status. Descriptive statistics of variables were done. Infant growth indices were expressed as continuous variables (HAZ, WHZ and WAZ). Multiple linear regression models were used to assess the associations between household socioeconomic status and maternal socio-demographic characteristics and infant undernutrition during 1 year of the study. Confounders factors were infant characteristics, maternal factors and household factors. Diagnostic regression was performed to assess the fitted model. The level of significance was set at $p =< 0.05$ with 95% confidence intervals and $\alpha = 0.05$.

3.6 Software

Software were used to manage the data of this research. The systematic review used the Review manager (Review manager version 5.3) to manage all steps of the review (163). Endnote version 9 was used from the outset to the end of the research to store and to manage the references. Redcap was used for the longitudinal study to capture, code and store data. Excel version 8 was used in the cross-sectional and longitudinal studies to manage data, and Stata version 13 (http://www.ats.ucla.edu/stat/stata/) was used for data management and statistical analyses. The WHO Anthro plus software (164) was used to generate Z-scores for height-for-age, weight-for-age, weight-for-height.

3.7 Ethics

Before consent was sought from prospective participants (mothers for themselves and assent for their newborns), ethical clearance for the research protocol was obtained from the Human Research Ethics Committee (HREC) (Medical) from the University of the Witwatersrand. The approval of the protocol was given under the Developmental Pathways for Health Research Unit (DPHRU) (Clearance: M170955) (**appendix 2, 3 and 4**). Based on the fact that this research comprised three complementary studies, ethical clearance was obtained for each component that required approval. The systematic review which was completed did not require ethical clearance. The cross-sectional study was ethically approved at three different committees: the DRC ethics approval was given by the Centre National d'Ethique (Clearance number: 046/CNES/BN/PNMF/2016) and permission was obtained from the four hospitals where data were collected (**appendix 5, 6**). The SA S1000-days project, as secondary analysis, obtained ethical clearances (M120524 and M130905) which were given by the Human Research Ethics Committee (HREC) (Medical) of the University of the Witwatersrand in South Africa (**appendix 7**). The longitudinal study obtained approval (Clearance: M170753) from the HREC (Medical) of the University of the Witwatersrand in South Africa (**appendix 2**), and permission was obtained from the Chris Hani Baragwanath Academic Hospital as well as from the Head of Department of Paediatrics (**appendix 3 and appendix 4**).

PART 2: RESULTS CHAPTERS

CHAPTER 4: PHD PAPER 1

Title: The association between household socioeconomic status, maternal socio-demographic characteristics and adverse birth and infant growth outcomes in sub-Saharan Africa: a systematic review.

Authors: Christian Bwangandu Ngandu, Douglas Momberg, Lumbwe Chola, Ansuyah Magan, Shane Anthony Norris, Rihlat Said-Mohamed.

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4.1 Introduction

Undernutrition in infants under two years of age remains a major public health issue, particularly in low and middle-income countries (LMICs) (82, 165). The 2011 UNICEF Global Nutrition Report indicated that more than 311 million children (32% of all children) under five years of age were undernourished. Globally, more than four million children died within a year of their birth due to inadequate nutrition.(81) In addition, poor infant nutrition has been shown to be responsible for more than 40% of deaths in children younger than five years, particularly during their first month of life (82). The adverse effects of infant undernutrition include physical disabilities (15), poor school attendance (82), diabetes (82), hypertension and cardiovascular disease (166), which may affect the subsequent generation (82, 167). Therefore, undernutrition may have negative long-term consequences for a country's economic growth and development (81).

Sixty percent of all undernutrition occurs in sub-Saharan Africa (SSA) and South Asia (81). The impact of undernutrition on child growth and development starts in-utero. Maternal undernutrition has been associated with poor foetal growth (82, 168, 169) which may result in low birth weight (LBW, weight at birth less than 2500 grams) (82), small-for-gestational age (SGA, newborns weighing less than the 10th percentile of a sex-specific reference population) and preterm birth (PTB, children born before 37 gestational weeks) (81, 170). In 2016, UNICEF reported that 15% (20 million) of newborns worldwide had LBW and 10% (15 million) PTB (81). In 2010, 32.4 million newborns worldwide were SGA (170). The prevalence of SGA was 27% in LMICs, with SSA having one of the highest prevalence (155, 170, 171). Studies in LMICs have shown that LBW, SGA and PTB are predictors of infant undernutrition in children below the age of two years (172-174). Undernourished infants may present with underweight

(weight-for-age less than -2 SD of the median of the WHO growth standards) or wasting (weight-for-height less than -2 SD of the median of the WHO growth standards) which are sometimes combined with a third form of undernutrition, stunting (height-for-age less than -2 SD of the median of the WHO growth standards) (81, 82). Globally among children under five years of age in 2011, 25.9% were stunted, 15.7% were underweight and 8% were wasted (7). In 2016, Africa had the second largest prevalence (31.6%) of undernutrition in children under five years of age in the world and the absolute number of affected children is continuing to increase (175).

To formulate strategies to prevent and reduce maternal and infant undernutrition in SSA, a major public health concern in the region, it is critical to understand the contextual factors associated with LBW, PTB, SGA, stunting, wasting and underweight. The period between conception and two years of age, the first thousand days, has been shown to be an opportune time for interventions such as immunization, deworming, nutrient supplementation, (vitamin A, iodine) which optimize child growth and development (76). However, the prevalence of undernutrition varies between SSA countries, probably due to different factors including socioeconomic (SES), cultural and political landscapes (81). The UNICEF causal framework for maternal and child undernutrition, the first version of which was described in 1990, has clearly outlined that infant undernutrition is associated with basic, underlying and immediate factors (57, 81). In addition, in the UNICEF framework, maternal demographic characteristics and socioeconomic factors have been identified as basic causes of undernutrition (81). Empirical studies in LMICs have reported associations between household and maternal demographic characteristics and SES factors with stunting in preschool children (between two and five years of age) (176). Maternal education (177), maternal occupation (178), household poverty (168, 179) and marital status (180) have been shown to be associated with adverse birth outcomes and child undernutrition (82). However, most studies in SSA report those associations in children under five years of age as a group, overshadowing evidence during the first thousand days period. In addition, the directions of the associations between the various SES factors and infant undernutrition are not consistent throughout the studies in SSA. Therefore, we undertook a systematic review of the literature to summarize the findings on the associations between maternal demographics and household SES factors and LBW, PTB, SGA, stunting, wasting and underweight in children under two years of age in SSA.

4.2 Methods

4.2.1 Protocol and registration

This systematic review followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines (143, 181). The protocol was registered under the International prospective register of systematic reviews (PROSPERO, https://www.crd.york.ac.uk/prospero/#myprospero, number CRD42018076828).

4.2.2 Eligibility criteria

We considered studies published between 1990 and June 2018, which investigated the associations between maternal socio-demographic characteristics and household SES factors with birth outcomes and nutritional status of children under two years of age, in 46 SSA.

Search method

Three electronic databases (PubMed, Scopus, and ScienceDirect) were searched for references between 1990 to June 2018. We used combination of keywords as search strategy in selected databases (**Table 10**).

Table 10: Supplementary sheet on the search strategy

Low birth weight	**"infant, low birth weight"[MeSH Terms] OR ("infant"[All Fields] AND "low"[All Fields] AND "birth"[All Fields] AND "weight"[All Fields]) OR "low birth weight infant"[All Fields] OR ("low"[All Fields] AND "birth"[All Fields] AND "weight"[All Fields]) OR "low birth weight"[All Fields]**
Preterm birth	"premature birth"[MeSH Terms] OR ("premature"[All Fields] AND "birth"[All Fields]) OR "premature birth"[All Fields] OR ("preterm"[All Fields] AND "birth"[All Fields]) OR "preterm birth"[All Fields]
Small for gestational age	"Small"[Journal] OR "small"[All Fields]"gestational age"[MeSH Terms] OR ("gestational"[All Fields] AND "age"[All Fields]) OR "gestational age"[All Fields]
Stunting	"growth disorders"[MeSH Terms] OR ("growth"[All Fields] AND "disorders"[All Fields]) OR "growth disorders"[All Fields] OR "stunting"[All Fields]
Wasting	"cachexia"[MeSH Terms] OR "cachexia"[All Fields] OR "wasting"[All Fields]

Underweight	"thinness"[MeSH Terms] OR "thinness"[All Fields] OR "underweight"[All Fields]
Undernutrition	"malnutrition"[MeSH Terms] OR "malnutrition"[All Fields] OR "undernutrition"[All Fields]
free full text[sb]	"loattrfree full text"[sb]
full text[sb]	"loattrfull text"[sb]

Combination of keywords:

The combination took into account to the country, the socioeconomic exposure, and the outcome of interest (birth and infant growth outcomes).

1. **Setting:**

Angola OR Benin OR Botswana OR Burkina Faso OR Burundi OR Cameroon OR Cape Verde OR Central African OR Republic Chad OR Comoros OR Congo OR Democratic Republic of Congo OR Zaire OR Côte d'Ivoire OR Djibouti OR Equatorial Guinea OR Eritrea OR Ethiopia OR Gabon OR The Gambia OR Ghana OR Guinea OR Guinea-Bissau OR Kenya OR Lesotho OR Liberia OR Madagascar OR Malawi OR Mali OR Mauritania OR Mauritius OR Mozambique OR Namibia OR Niger OR Nigeria OR Réunion OR Rwanda OR Sao Tome and Principe OR Sao Tome OR Senegal OR Seychelles OR Sierra Leone OR Somalia OR South Africa OR Sudan OR Swaziland OR Tanzania OR Togo OR Uganda OR Western Sahara OR Zambia OR Zimbabwe OR sub Saharan Africa OR Eastern Africa OR Southern Africa OR Central Africa OR Austral Africa OR Western Africa.

2. **Socioeconomic factors**:

Household ownership OR Household assets OR Housing OR Wealth index OR Socioeconomic status OR Socioeconomic position OR Socioeconomic inequality OR Income OR Education OR Marital status OR Occupation OR Employment.

3. **Outcomes**:

Low birth weight OR Preterm birth OR Small for gestational age OR Stunting OR Stunted OR Wasting OR Wasted OR Underweight OR Undernutrition OR Malnutrition.

4.2.3 Data sources

Studies included in this review were obtained from three databases: PubMed, ScienceDirect and Scopus. For studies that were not sourced through these databases, we contacted the corresponding authors to request a copy of the original publication.

4.2.4 Search strategy and study selection

The following combination of category of keywords were used to search for eligible studies: Maternal demographic characteristics and household SE factors (maternal education, maternal occupation, maternal marital status, maternal income, household wealth) AND birth outcomes and child undernutrition (low birth weight or small for gestational age or preterm birth or stunting or wasting or underweight or undernutrition) AND 46 SSA countries. We sequentially screened titles, abstracts and the full text to identify studies that matched our inclusion and exclusion criteria. The study search and selection were performed separately by two co-authors (CBN, DM) and conflicts resolved by a third co-author (RSM).

4.2.5 Data

4.2.5.1 Maternal socio-demographic characteristics and household socioeconomic factors

In accordance with the UNICEF conceptual framework (81), we considered the following maternal socio-demographic characteristics and household SES factors: maternal education, maternal occupation, maternal income, maternal marital status, household wealth. Maternal education was measured as educational milestones, qualifications attained or literacy level (182). In LMICs, repeating school years is considered the most appropriate measure for education level of individuals (182). Maternal marital status referred to the civil status of each mother in relation to the marriage laws in the country under consideration (183). Maternal income and maternal occupation in LMICs are more difficult to measure because of the presence of an informal economy, self-employment and seasonal activity. Similarly, occupation was measured by informal employment and domestic work (182). Household wealth index (HWI) was based on ownership of a range of durable assets, household measures of SES characteristics, or access to basic services such as health or education (182).

4.2.5.2 Birth outcomes

The following birth outcomes were considered: LBW, SGA and PTB. Preterm birth or prematurity was defined as a baby born before 37 completed gestational weeks or 259 days of

pregnancy (170, 184). Low birth weight was defined as birth weight less than 2500 grams regardless of gestational age (81). Newborns classified as SGA were defined as those whose birth weight was below the tenth percentile when compared to the 1991 US national reference population (6) or the WHO standard curve (170, 185).

4.2.5.3 Undernutrition in children between birth and two years of age

The following categories of undernutrition were considered: stunting, wasting and underweight. Stunting was defined as children with length/height-for-age (LAZ or HAZ) adjusted for sex, less than minus two standard deviations (-2SD) of the median of the WHO growth standard curve (186). Wasting and underweight were defined as weight-for-height (WHZ) and weight-for-age (WAZ) less than -2SD of the median of the WHO growth standard curve, respectively (186).

4.2.5.4 Synthesis of results

We extracted the following data from each study included in this systematic review: author names, year of publication, study aims, country, study design, study setting, participant's age, study sample size, SES factors, growth outcomes and quality of evidence.

4.2.6 Data collection process and summary measures

Data were extracted separately by two co-authors (CBN and DM) and conflicts were resolved by a third co-author (RSM). Data extraction was done independently by the first and second authors. Odds ratios (OR) and/or adjusted odds ratios (aOR), relative risk and/or adjusted relative risk (aRR), related confidence intervals (CI) were extracted for each association of interest.

4.2.7 Quality appraisal and risk of bias for primary studies

The quality of the studies included in this systematic review was assessed using the GRADE approach by two independent co-authors (CBN, DM) with involvement of a third co-author (RSM) when there was no consensus. Consensus was reached by two co-authors for 5 (45.4%) studies (187-191) (**Table 11**). Eight parameters were used to score the quality of each study: study design, risk of bias, inconsistency, indirectness, imprecision, publication bias, magnitude of effect, confounding and dose-response (145). The quality of the studies was graded as follows: high (4 points), moderate (3 points), low (1 point), and very low (0 points).

Table 11: Supplementary table on quality appraisal of selected studies by GRADE

No.	Included studies	Type of design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Strength	Plausible confounders	Dose response	Quality of evidence		
											First author	Agreement by two authors	Reasons
1	Assefa N et al 2012(9)	Case control study	Serious	Consistent. Same positive direction and positive magnitude for the estimate of the association of Mat. Education, WI and Low birth weight.	Indirect. Conclusion did not proceed from sample size to population (pregnant women) on the SES and LBW.	Precise. Sample size of 956 and CI of 95% were used in the study to appreciate the estimation of effect of outcomes.	Unclear	Strong. Magnitude (AOR=2.1, p=0.01).	Absent. Confounders have been searched and adjusted for both exposure that we were investigating in the study.	Present. The magnitude of AOR increases with increasing of Wealth index in the direction to poor category.	Very low	Moderate	Not bias of publication, Precise (the sample size is sufficient), strength of evidence upgrades with aOR (+1 point).
2	Engebretsen MS et al., 2008(10)	Cross sectional Survey	Unclear	Consistent. There is same negative direction of effect size for all household wealth index on Z- score mean of LAZ and WAZ.	Direct. Data come from Uganda Demographic Survey??? Population and outcomes broadly generalizable.	Precise. Large sample (723) to increase the precision.	Suspected. Marital status and twin variables are not analyzed or reported in the final model.	Weak. Effect size less than 1 for adjusted effect size estimates.	Present. Having sibling may modify the effect of the association between wealth and LAZ adjusted by child gender and age.	Present. Larger effect size for mean of LAZ and WAZ with great level of poverty.	High	High	A Relative lower risk of bias increases the quality.
3	Ickes SB et al., 2015(11)	Cross sectional	Serious	Inconsistent. Lack of agreement for the socioeconomic and demographic factors associated to undernutrition forms.	Direct. The inference was done in the study (participants and outcomes).	Precise. Broad sample size (1897) and small CI of 95% .	Unclear	Weak. At least one effect size is inferior to 2 and the other ones are no significant.	Absent. No confounders. Confounders haven't been searched.	Undetected. The magnitude of the OR cannot be analyzed when variables are exclusively binary.	Very Low	Moderate	Consistent (consistent for wasting and underweight), not bias of publication.
4	Mamabolo R et al., 2004(12)		unclear	Inconsistent. Lack of agreement: various directions for	Direct. Population broadly generalizable.	Not precise. Narrow sample size (219) decreases the precision.	Undetected. All outcomes were analysed and reported.	Weak. Various effect size: around 3 for occupation with	Present. Confounders factors may be present and could reduce the effects size	Present. Paradoxal outcomes that poor SES (education, occupation) and	Very low	Low	Inconsistent effect size for WAZ (no agreement on WAZ). Total

				the effect size estimates.				wasting, ≤ 1 for other exposures (education and marital status).	estimates for stunting, wasting and undernutrition (No adjustment).	demographic (being single) protect against stunting, wasting and underweight. Except? Wasting which is predicted by No working for the mother.			score wrongly calculated:
5	Medhin G et al., 2010(20)	Cohort study	Serious	Inconsistent. Lack of agreement. Poverty index has two directions in the same study depending on crude and adjusted effect size estimate.	Direct. Data come from Butajiri DSS. Population and outcomes broadly generalizable.	Precise. Large sample (1065) to increase the precision.	Undetected. All outcomes were analysed and reported.	Weak. Effect size (OR) around 1 for adjusted effect size estimates.	Present. Confounders factors may be present and could reduce the effects size estimates for poverty on underweight and/or stunting.	Undetected. There is no enough levels of exposure (SES) and any judgement could be made on the effects on the outcomes.	Low	Moderate	Inconsistent (lack of agreement on the effect of poverty index on WAZ and LAZ) =-1
6	Muhihi, S et al. 2016(14)	RCT	No serious	Inconsistent. Maternal education and household wealth index have no dose response, sparse directions on the effect of outcomes (either for SGA or PTB as well).	Direct. The wide sample size admitted us to consider that the inference from participants to population is easier (One way).	Precise. The sample size is broad and CI of 95%.		Weak. The magnitude of associations was less than 2 and sometimes not significant.	Absent. They were minimized by adjustment by covariates on the estimates effect of PTB and SGA.	Undetected. Lack of agreement for dose response for the association of Maternal education and wealth index with SGA, PTB in rural and urban area.	High	High	
7	Ndirangu J et al., 2012(15)	Cohort study	Serious	Consistency. Positive direction and positive magnitude for Relative risk for maternal education in association with SGA/PTB.	Directness. The inference was done according SES and adverse birth outcomes (PTB, SGA and LBW).	Precision. Broad sample size of 2368 and small CI of 95% were used in the study to appreciate the estimation of the effect of outcomes.	Unclear	Weak. Not significant (Small adjusted RR around 1 and not significant).	Present. No confounders. Confounders haven't been searched for Maternal education - SGA/PTB.	Present. Dose response. The magnitude of the RR for the estimate effect increases with 3 levels of maternal education (No, Primary, Secondary and tertiary.	Moderat e	Moderate	

				Both were not significant.									
8	Ukwani et al., 2003	Cross sectional study	Serious	Consistent. Protective role of HWI on infant nutritional status	Direct. Conclusion proceed from sample size to population (worker mothers) in the effect of mother's work on infant nutritional status.	Imprecise. Sample size of 1338 with lack of the CI in the study.	Unclear	Weak. Magnitude (aOR=0.57, p≤0.01).	Absent. Confounders have been searched and adjusted for few factors in the study.	Absent. The magnitude of AOR was not modified with infant nutritional changes.	Very low	High	Not bias of publication, Precise (the sample size is enough), strength of evidence upgrades with aOR (+1 point).
9	Wamani H et al., 2004(18)	Cross sectional survey	No serious	Consistent. There is same positive direction of effect size for all SES variables.	Direct. Data come from Uganda Demographic Survey??? Population and outcomes broadly generalizable.	Precise. Large sample (720) to increase the precision.	Suspected. Marital status and twin variables are not analysed or reported in the final model.	Strong. Effect size more than 1 and significant.	Present. Maternal education was adjusted by child sex and age but not with all covariates.	Present. There is an increment in maternal education is likely to have a positive influence on child growth.	High	High	
10	Wamani H et al., 2005(17)	Cross sectional Survey	No serious	Consistent. There is same positive direction of effect size for Maternal education on stunting.	Direct. Data come from Uganda Demographic Survey Population and outcomes broadly generalizable.	Precise. Large sample (698) to increase the precision.	Suspected. Marital status and twin variables are not analysed or reported in the final model.	Strong. Effect size more than 1 and significant for mothers who did not completed primary school and above.	Absent. Maternal education was adjusted by child sex and age, having latrine, child not de-wormed, child not who had not received food in 24h and fever in 2 last week.	Present. There is an increment in maternal education is likely to have a positive influence on child growth.	High	High	
11	Watson-Jones D et al., 2007(19)	Cohort study	Serious	Consistent. Positive direction and positive magnitude	Indirect. Two problems for directness:1) no inference	Precise. Sample size of 1536 and small CI of 95% were	Unclear	Weak. (Small adjusted odds ratio less than 1	Present. Plausible confounders. Confounders have been	Present. The magnitude of the Adjusted Odds ratio for the estimate	Very low	Moderate	Not publication bias, Indirect (-1), a OR around 0.2

				for the estimate effect of the association of Maternal occupation with Preterm birth and Low birth weight.	from participants to population, 2) the Benzathine injection intervention was different than routines one.	used in the study to appreciate the estimation of the effect of outcomes.		for all the estimate of effect).	searched and adjusted for both exposure that we were investigating in the study.	effect increases with the level of kind of occupation (skilled occupation, manual occupation).			(the study design was to scale the result to all tested). pregnant population for syphilis) and effect size (≥0.2).

Risk of bias

The risk of bias was identified using the GRADE approach (145, 146). Studies were evaluated on three domains: recruitment of the participants (two criteria on randomization), conduction of the study (one criterion on blinding) and the reporting of the study outcomes (two criteria). For each study, each criterion was rated as either high, low or unclear. Studies were then categorised as being either high risk (low rate in 3 or more characteristics), moderate risk (low rate in 2 characteristics), low risk or very low risk (low rate in less than 2 characteristics).

4.2.8 Quantitative analysis

A meta-analysis was not conducted in this systematic review as the number of included studies was small and the definitions of SES factors varied across studies.

4.3 Results

4.3.1 Description of studies

The processes of search, selection, inclusion and exclusion of relevant studies for this systematic review, are presented in **Figure 21**.. We identified 2031 studies from the databases. After removing duplicate studies (1141 articles), titles and abstracts of 890 studies were screened and 148 studies were retained for full text screening. The reasons for exclusion were as follows: duplicated study, publications before 1990, studies conducted in countries outside of SSA, no SES factors included in the study, no outcomes of interest included in the study, conference papers, editorials, newsletters, comments, notes. We included eleven studies in this systematic review (**Figure 21**; **Table 12)**.

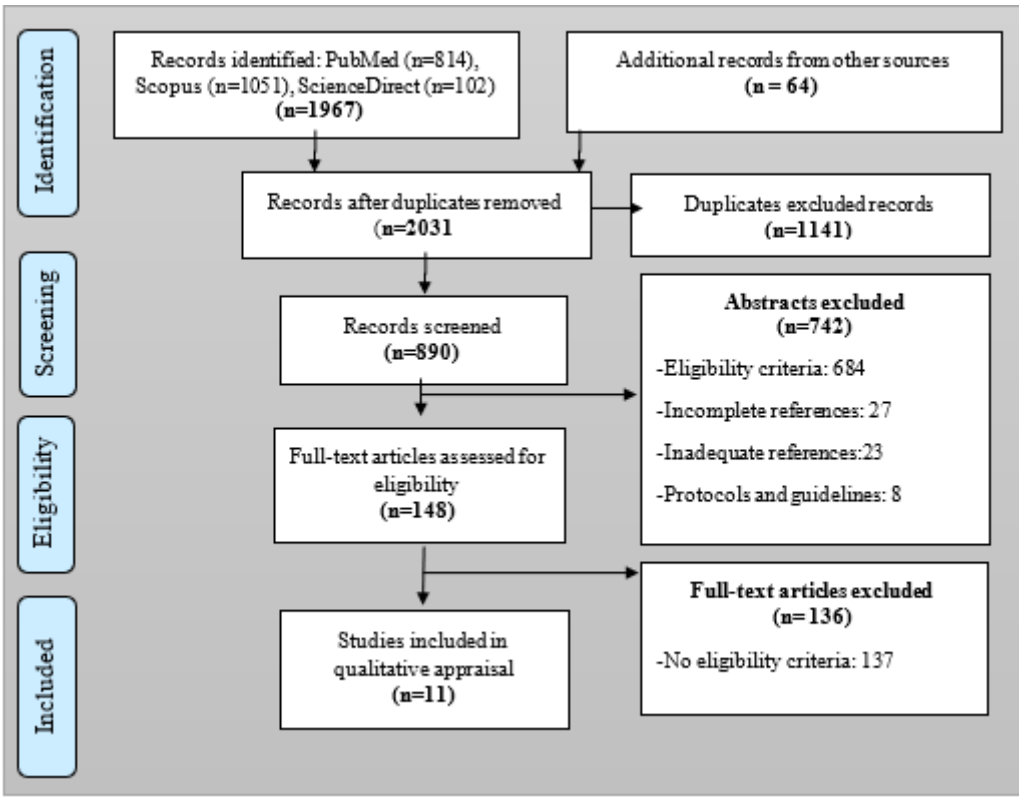

Figure 21: Flow diagram on the association between demographic, socioeconomic factors with birth and infant growth outcomes**.**

Table 12: Characteristics and summary of studies included in the systematic review

First author, year (reference)	Aim	Study Design	Country	Setting	Participants age	Sample size	Demographic and Socioeconomic factors	Outcomes	Quality of evidences
Assefa N, 2012 (187)	To measure the incidence and determinants of LBW in a rural population in Ethiopia	Cohort study	Ethiopia	Urban and Rural	0-28 days	956	Maternal education, Household wealth index, Maternal income	LBW	Moderate
Engebretsen MS et al. 2008 (192)	To describe current infant growth patterns and their association with feeding practices in Uganda	Cross-sectional study	Uganda	Rural and Urban	0-11 months	723	Household wealth index, Maternal marital status, Maternal occupation, Maternal education	Stunting Wasting	High
Ickes SB, 2015 (188)	To assess maternal sociodemographic factors that may constrain women's caring capabilities and child nutrition in Uganda	Cross-sectional study	Uganda	National	0-23 months	1897	Maternal occupation, Maternal marital status, Maternal education, Household wealth index	Stunting Wasting Underweight	Moderate
Mamabolo RL et al.2004 (193)	To evaluate feeding practices and growth patterns in the central region of Limpopo in SA	Cohort study	South Africa	Semi-rural	0-12 months	276	Maternal marital status, Maternal occupation, Maternal education	Stunting Wasting Underweight	Low
Medhin G et al., 2010(189)	To assess the predictors of short and intermediate term infant health and nutritional outcomes in Ethiopia	Cohort	Ethiopia	Rural	0-12 months	1065	Maternal marital status, Maternal occupation, Maternal education	Underweight Stunting Wasting	Moderate
Muhihi A et al. 2016 (194)	To determine risk factors of PTB and SGA in 19629 newborns in Tanzania	Cross-sectional	Tanzania	Urban and rural	0-28 days	19269	Maternal education, Household wealth Index	Term-AGA, SGA, PTB, SGA-PTB	High

Ndirangu J. et al. 2012 (190)	To determine the associations between SGA, PTB, maternal HIV status and infant mortality in South Africa	Cohort	South Africa	Rural	0-24 months	2368	Maternal education	SGA PTB	Moderate
Ukwuani FA et al., 2003 (195)	To examine the relationship between women's work and infant and child nutritional status in Nigeria	Cross-sectional	Nigeria	National	0-12 months (sub-group of 0-59 months)	1338	Marital status Maternal occupation, Maternal education, Household wealth index	Stunting, wasting	High
Wamani H et al., 2004 (196)	To examine the association between four socioeconomic indicators (maternal and paternal education, household asset index and land ownership) and stunting in Uganda	Cross–sectional	Uganda	Rural	0-24 months	720	Maternal education, Household wealth index	Stunting	High
Wamani H et al., 2006 (197)	To assess the determinants of poor anthropometric status in infants and young children in Uganda	Cross–sectional	Uganda	Rural	0-23 months	698	Maternal education	Stunting Wasting Underweight	High
Watson-Jones D. et al, 2007 (191)	To determine risk factors for poor birth outcomes and their relative contribution on the outcomes in Tanzania	Cohort	Tanzania	Rural	0-28 days	1536	Maternal occupation	PTB, LBW	Moderate

AGA: Appropriate gestational age; HIV: Human immune-deficiency virus; LBW: low birth weight; PTB: Preterm birth; SGA: Small for gestational age; SA: South Africa.

Table 12 presents the characteristics of each study. All included studies were observational and comprised five cohort studies (187, 189, 191, 193) and six cross-sectional surveys (188, 192, 194-197). There were five (45.4%) high quality studies (192, 194-197), five of moderate quality (187-191) and one low-quality study (193).

Although the studies covered the four regions of SSA, they were conducted in only five countries: four in Uganda (188, 192, 196, 197), two each in South Africa (190, 193), Ethiopia (187, 189) and Tanzania (191, 194), and one study in Nigeria (195). Most of the studies were conducted exclusively in rural areas (189-191, 193, 196, 197), five were conducted in both rural and urban areas (187, 188, 192, 194, 195), and two were national surveys (188, 195).

Only four studies focused on the birth outcomes of interest (187, 191, 194, 198), while seven studies focused on undernutrition from birth to two years of age (188, 189, 192, 193, 195-197). The distribution of studies per outcome of interest was as follows: three for LBW (187, 191, 194), four for PTB (190, 191, 194, 198), two for SGA (190, 194), seven for stunting (188, 189, 192, 193, 195-197), seven for wasting (188, 189, 192, 193, 195, 197) and four for underweight (188, 189, 193, 197).

Maternal socio-demographic characteristics and household SES factors investigated in the studies were: maternal education in eleven studies (187-189, 191-198), maternal occupation in five studies (188, 191-193, 199), maternal marital status in five studies (188, 189, 192, 193, 195) and maternal or HWI in five studies (188, 189, 192, 195, 196). Maternal education was defined as illiterate or not (187, 188), educated or not (188, 196), student or not (193), formal or not formal (194), and the level of education (i.e. none, primary and secondary education level) (190, 193-195). Maternal occupation was measured as follows: staying at home *vs*. not staying home (187), working in a skilled job *vs* .unskilled work such as farming (191), working *vs.* not working (188, 195), being a housewife *vs* not being a housewife (193). Ukwani and collaborators (195) defined occupation in combination with other variables such as mother earning a cash payment and taking her child with her to work. Maternal marital status was defined as follows: polygamous *vs*. non-polygamous marriage (189, 195), or married/living with a partner *vs*. divorced/widowed/not living together (188), or married vs non married (192). Lastly, HWI was categorised into three classes (better off, middle or poor) (187) or five quintiles (188, 192, 194, 197). In some studies, the HWI compared mothers using a 60% cut off for the HWI (188) or a poverty index from 1 to 12 (189).

4.3.2 Associations between maternal socio-demographic characteristic, household socioeconomic factors and birth outcomes

Table 13: Association between demographic and socioeconomic factors with LBW, PTB and SGA

Outcomes	Demographic and socioeconomic factors	Studies	Demographic and socioeconomic Variables	Effect size	Effect size estimates (Coefficient and CI)	Factors that variables were adjusted for
Low birth weight	Maternal education	Assefa N et al., 2012	Illiterate (Ref: literate)	OR	1.2 (0.8-1.82)	Maternal age, residence, parity, MUAC, fertility desire, ANC, violence in pregnancy, access to health facility, involvement of the husband.
			Illiterate (Ref: literate)	aOR	0.9 (0.58-1.46)	
			Illiterate (Ref: literate)	aOR	0.9 (0.6-1.47)	
	Household wealth index	Assefa N et al., 2012	Poor (Ref: better off)	OR	2.1 (1.46-2.98)	Maternal age, residence, parity, MUAC, fertility desire, ANC, violence in pregnancy, access to health facility, involvement of the husband
			Middle (Ref: Better off)		1.3 (0.93-1.92)	
			Poor (Ref: better off)	aOR	1.9 (1.29-2.68)	
			Middle (Ref: Better off)		1.2 (1.29-2.68)	
			Poor (Ref: better off)	aOR	2.1 (1.42-3.05)	
			Middle (Ref: Better off)		1.0 (0.96-2.10)	
	Maternal occupation	Assefa N et al., 2012	Staying at home (Ref: having employment)	OR	1.8	Maternal age, residence, parity, MUAC, fertility desire, ANC, violence in pregnancy, access to health facility, involvement of the husband
		Watson-Jones D et al., 2008	Skilled work (Ref: staying at home)	aOR	0.28 (0.1-0.9)	Benzathine penicillin- G treatment, maternal age, ethnicity, maternal sexual debut, smoker mother, maternal anthropometry, gravidity, past stillbirth, child sex, maternal illness, placental malaria
			Manual/Farmer work (Ref: staying at home)	aOR	0.45 (0.2-0.9)	

Small Gestational for age	Maternal education	Muhihi A et al. 2016	No formal schooling (Ref: completed primary)	aRR	0.88 (0.76-1.02)	Paternal education, maternal anthropometry, maternal age, parity, starting ANC in the 3rd trimester, birth order, child sex
			Some primary (Ref: completed primary)	aRR	1.01 (0.88-1.15)	
			Secondary plus (Ref: completed primary)	aRR	0.87 (0.77-0.98)	
		Ndirangu J et al., 2012	Some primary (Ref: no education)	RR	1.05 (0.58-1.93)	Child sex, residence, WASH, delivery place, parity, maternal age, maternal anthropometry, HIV status, infant mortality
			Secondary and tertiary (Ref: no education)	RR	1.08 (0.60-1.94)	
	Maternal occupation	Watson-Jones D et al., 2008	Skilled work (Ref: staying at home)	OR	0.19 (0.1-1.5)	Benzathine penicillin G treatment, maternal age, ethnicity, maternal sexual debut, smoker, maternal anthropometry, gravidity, past stillbirth, child sex, maternal illness, placental malaria
			Manual/Farmer work (Ref: staying at home)	OR	0.5 (0.2-1.4)	
			Maternal occupation (Ref: no occupation)	OR	1.94	
	Household wealth index	Muhihi A et al. 2016	Q1 or poorest (Ref: Q5 or richest)	aRR (urban)	1.26 (1.00-1.60)	Paternal education, maternal anthropometry, maternal age, parity, starting ANC in the 3rd trimester, birth order, child sex
			Q2 (Ref: Q5)	aRR (urban)	1.34 (1.08-1.67)	
			Q3 (Ref: Q5)	aRR (urban)	1.18 (0.94-1.49)	
			Q4 (Ref: Q5)	aRR (urban)	1.15 (0.93-1.42)	

			Q1 or poorest (Ref: Q5 or richest)	aRR (rural)	1 (0.90-1.12)	Paternal education, maternal anthropometry, maternal age, parity, starting ANC in the 3rd trimester, birth order, child sex
			Q2 (Ref: Q5)	aRR (rural)	0.95 (0.86-1.06)	
			Q3 (Ref: Q5)	aRR (rural)	1 (0.90-1.11)	
			Q4 (Ref: Q5)	aRR (rural)	0.95 (0.86-1.05)	
Preterm birth	Maternal education	Muhihi A et al. 2016	No formal schooling (Ref: completed primary)	aRR	1.03 (0.91-1.17)	Paternal education, maternal anthropometry, maternal age, parity, starting ANC in the 3rd trimester, birth order, child sex
			Some primary (Ref: completed primary)	aRR	1.11 (0.98-1.26)	
			Secondary plus (Ref: completed primary)	aRR	0.95 (0.84-1.07)	
		Ndirangu J et al., 2012	Some primary (Ref: no education)	aRR	1.74 (0.76-3.97)	Child sex, residence, WASH, delivery place, parity, maternal age, maternal anthropometry, HIV status, infant mortality
			Secondary and tertiary (Ref: no education)	aRR	1.72 (0.77-3.85)	
	Maternal occupation	Watson-Jones D et al., 2008	Skilled work (Ref: staying at home)	OR	0.43 (0.2-1.0)	Benzathine Penicillin G treatment, maternal age, ethnicity, maternal sexual debut, smoker, maternal anthropometry, gravidity, past stillbirth, child sex, maternal illness, placental malaria
			Manual/Farmer work (Ref: staying at home)	OR	0.84 (0.5-1.4)	
			Maternal occupation (Ref: no occupation)	OR	2.95	

	Household wealth index	Muhihi A et al. 2016	Q1 or poorest (Ref: Q5 or richest)	aRR (urban)	1.21 (1.001.46)	Paternal education, maternal anthropometry, Maternal age, Parity, starting ANC in the 3rd trimester, birth order, child sex
			Q2 (Ref: Q5)	aRR	1.10 (0.92-1.32)	
			Q3 (Ref: Q5)	(urban)	1.08 (0.89-1.31)	
			Q4 (Ref: Q5)	aRR	1.08 (0.90-1.29)	
			Q1 or poorest (Ref: Q5 or richest)	aRR (rural)	1.49 (1.32-1.68)	Paternal education, maternal anthropometry, maternal age, parity, starting ANC in the 3rd trimester, birth order, child sex
			Q2 (Ref: Q5)	aRR	1.39 (1.24-1.56)	
			Q3 (Ref: Q5)	(rural)	1.13 (1.00-1.28)	
			Q4 (Ref: Q5)	aRR	1.23 (1.09-1.37)	

Abbreviations: A: Activity, aRR: adjusted relative risk; C: Cash, AC: Activity with cash, ANC: Antenatal care, AWC: Activity with no cash, AOR: Adjusted odds ratio, MUAC: Middle upper arm circumference, OR: Odds ratios, RR: Relative risk; WASH: Water sanitation hygiene; Q (1,2,3,4,5): Quintile (1,2,3,4,5); WC: Work with child, WI: Wealth index, US: United states of America.

In **Table 13**, three studies, maternal level of education was not associated with LBW and PTB (187, 190, 194). However, when cut offs for PTB and SGA were 37th week and 3rd percentile, respectively. Muhihi et al. (194) found that having a mother with no formal schooling was associated with simultaneous PTB and SGA compared to having a mother who completed formal schooling. In another study, a maternal education higher than secondary level reduced the odds of SGA by 13% after adjusting for maternal age, residence, parity, maternal height, and infant male sex (194).

There was no significant association between maternal occupation and either SGA or PTB (191). Stay-at-home mothers had 80% greater odds of having a LBW child compared to those who were working (187). Another study (191) found that, the odds of having LBW were lower by 72% for those mothers who had skilled work compared to only 55% for those mothers who had unskilled work after adjusting for maternal characteristics (age, anthropometry, fertility desire, parity), paternal support, geographical location (residence), behavioural characteristics (physical violence) and health (access to the antenatal care services).

Household wealth index was not significantly associated with SGA in one study (194). However, the poorest households had 21% and 49% greater risk of PTB than affluent households in urban and rural settings, respectively (194). Another study showed that the poorest households had 110% greater odds of having a LBW child than the richest households after adjusting for maternal mid-upper arm circumference (MUAC), antenatal care (ANC) attendance, violence during pregnancy, and access to a health facility (187).

4.3.3 Associations between maternal demographic characteristics, household socioeconomic factors and stunting

Table 14: The associations between demographic and socioeconomic factors with infant growth outcomes (stunting, wasting and underweight)

Outcomes	Demographic and SES determinant	Studies	SES factors	Effect size	Estimate effect size (value, confidence interval or p-value)	Adjusted variables for
Stunting	Maternal education	Ukwuani FA et al., 2003	Primary (Ref: None)	aOR	0.94 (p□0.1)	Father education, father occupation, religion, child feeding duration, maternal age, sex, birth order, ANC, place delivery, residence, immunization, child illness, WASH
			Secondary and above (Ref: None)	aOR	1.06 (p□0.10)	
		Wamani H et al., 2004	None (Ref: above primary)	aOR	2.1 (1.1-3.9)	Child age and sex
			Stopped in primary (Ref: above primary)	aOR	2.1 (1.2-3.8)	
			Completed primary (Ref: above primary)	aOR r	1.0 (0.5-2.0)	
			No educated mother (Ref: educated above primary)	aOR	2,5	Child age, child sex, father education
			Literate in 2011 (Ref: illiterate)	OR	0.84 (0.62-1.14)	
			Literate in 2006 (Ref: illiterate)	OR	0.77 (0.58-1.00)	
			Educated mother (Ref: no educated) in 2006	OR	0.72 (0.53-0.99)	
			Maternal educated in 2006 (Ref: illiterate)	OR	0.43 (0.28-0.66)	

		Mamabolo RL et al., 2004 (22)	Primary (Ref: secondary)	aOR	0.438 (0.139-1.382)	Feeding practices, child sex, maternal age at birth, parity
			Student (Ref: no student)	aOR	1.044 (0.523-2.084)	
		Engebretsen IMS et al., 2008	Completed lower secondary and more (Ref: full primary and less)	OR	0.78 (052-1.18)	Child sex, child age, country wealth, residence, owning land, maternal age, father education, demography, birth weight
	Maternal occupation	Ukwuani FA et al., 2004	A/NC/WC (Ref: NA)	aOR	0.97 (p□0.10)	Father education, father occupation, religion, child feeding duration, maternal age, sex, birth order, ANC, place delivery, residence, immunization, child illness, WASH
			A/C/WC (Ref: NA)	aOR	0.98 (p□0.10)	
			A/NC/NWC (Ref: NA)	aOR	0.66 (p□0.10)	
			A/C/NWC (Ref: NA)	aOR	0.88 (p□0.10)	
		Ickes SB et al., 2015	Employed in 2006 (Ref: Not employed)	aOR	1.01 (0.61-1.68)	Child age, child sex, decision making in family, maternal age at birth, violence, having travelled away from home or not, feeding practices, access to health facility
			Employed in 2011 (Ref: Not employed)	aOR	1.54 (1.05-2.25)	Child age, child sex, decision making in family, maternal age at birth, violence, having travelled away from home or not, feeding practices, access to health facility
		Mamabolo RL et al., 2004	Not being a housewife (Ref: being a housewife)	OR	1.254 (0.518-3.033)	
			Not working (Ref: working)	OR	0.519 (0.178-1.508)	

		Engebretsen IMS et al., 2008	Has a job (Ref: Doesn't have a job)	aOR	0.63 (0.37-1.)	Child sex, Child age, Country wealth, residence, owning land, maternal age, father education, demography, birth weight
	Maternal marital status	Mamabolo RL et al., 2004	Single (Ref: Married)	OR	0.749 (0.354-1.583)	Feeding practices, child sex, mother age at birth, parity
		Medhin G et al., 2010	Polygamous marriage at 6 months of the study (Ref: Not polygamous marriage)	aOR	1.06 (0.64-1.74)	Maternal characteristics (religion, ethnicity, age, MUAC), age of husband, father education, WASH, poverty, traditional surgical practices
		Medhin G et al., 2011	Polygamous marriage at 12 months of the study (Ref: Not polygamous marriage)	aOR	1.19 (0.76-1.87)	
		Ukwuani FA et al., 2003	Two wives polygynous (Ref: one wife)	aOR	1. 2 (p□0.10)	Father education, father occupation, religion, child feeding duration, maternal age, sex, birth order, ANC, place delivery, residence, immunization, child illness, WASH
			Three wives polygynous (Ref: one wife)	aOR	1.37 (p□0.10)	
		Engebretsen IMS et al., 2008	Formal marriage (Ref: Traditional)	aOR	1.09 (0.58-2.08)	Child sex, child age, country wealth, residence, owning land, maternal age, father education, demography, birth weight
			Single, separated, divorced, widowed (Ref: Traditional)	aOR	1.91 (0.99-3.66)	
		Ickes SB et al., 2015	Married or living with partner in 2006 (Ref: single/separated/divorced/divorced)	aOR	1.10 (0.73-1.67)	Child age, child sex, decision making in family, maternal age at birth, violence, having travelled away from home or not, feeding practices, access to health facility

		Ickes SB et al., 2015	Married or living with partner in 2011 (Ref: single/separated/divorced/divorced)	aOR	0.82 (0.54-1.25)	Child age, child sex, decision making in family, maternal age at birth, violence, having travelled away from home or not, feeding practices, access to health facility.
	household wealth	Ukwuani FA et al., 2003	Medium (Ref: Low)	aOR	0.78 (p□0.10)	Father education, father occupation, religion, child feeding duration, maternal age, sex, birth order, ANC, place delivery, residence, Immunization, child illness, WASH,
			High (Ref: Low)	aOR	0.61 (p□0.10)	
		Wamani H et al., 2004	Q1 or poorest (Ref: 5 acres or more)	OR	2.1 (1.2-3.7)	Mother education, father education, child sex male, child age between 18-23 months.
			Q2 (Ref: 5 acres or more)	OR	1.7 (0.9-2.9)	
			Q3 (Ref: 5 acres or more)	OR	1.3 (0.8-2.5)	
			Q4 (Ref: 5 acres or more)	OR	1.1 (0.6-2.0)	
		Wamani H et al., 2004	None (Ref: 5 acres or more)	aOR	0.9 (0.5-1.8)	Child age, child sex, father education, father education
			1 acre or less (Ref: 5 acres or more)	aOR	0.9 (0.6-1.6)	
			2 acres or less (Ref: 5 acres or more)	aOR	1.2 (0.7-2.1)	
			3 or 4 acres or less (Ref: 5 acres or more)	aOR	1.0 (0.6-1.8)	
			Poorest (Ref: Least poor)	OR	2.1	
		Medhin G et al., 2010	Poverty index at 6 months (Range from 0 to11)	aOR	0.94 (0.83-1.06)	Maternal characteristics (religion, ethnicity, age, MUAC), Age of husband, father education, WASH, poverty, traditional surgical practices.
			Poverty index at 12 months (Range from 0 to11)	aOR	0.98 (088-1.09)	
		Engebretsen IMS et al., 2008	Mid 40% (Ref: Top 20%)	aOR	1.65 (0.74-3.68)	Child sex, child age, country wealth, residence, owning land, maternal age,

			Lowest 40% (Ref: Top 20%)	aOR	3.50 (1.57-7.78)	father education, demography, birth weight
		Engebretsen IMS et al., 2008	Mid 40% (Ref: Top 20%)	aOR	1.71 (0.87-3.36)	Child sex, child age, country wealth, residence, owning land, maternal age, father education, demography, birth weight
			Lowest 40% (Ref: Top 20%)	aOR	3.10 (0.56-6.15)	
		Engebretsen IMS et al., 2008	Mid 40% (Ref: Top 20%)	aOR	1.30 (0.62-2.73)	Child sex, child age, country wealth, residence, owning land, maternal age, father education, demography, birth weight
			Lowest 40% (Ref: Top 20%)	aOR	2.7 (1.39-5.28)	
		Ickes SB et al., 2015	Maternal WI upper 60% in2006 (Ref: Less 60%)	aOR	0.82 (0.62-1.06)	Child sex, child age, country wealth, residence, owning land, maternal age, father education, demography, birth weight
			Maternal WI upper 60% in 2011 (Ref: Less 60%)	aOR	1.17 (0.87-1.58)	
		Engebretsen IMS et al., 2008	Owning land (Ref: no owing land)	aOR	1.45 (0.86-2.45)	Child sex, child age, country wealth, residence, owning land, maternal age, father education, demography, birth weight
Wasting	Maternal education	Ukwuani FA et al., 2003	Primary (Ref: None)	aOR	1.08 (p□0.10)	Father education, father occupation, religion, child feeding duration, maternal age, sex, birth order, ANC, place delivery, residence, Immunization, child illness, WASH,
			Secondary and above (Ref: None)	aOR	0.86 (p□0.10)	

		Engebretsen IMS et al., 2008	completed lower secondary and more (Ref: Full primary and less)	OR	0.90 (0.42-1.95)	Child sex, child age, country wealth, residence, owning land, maternal age, father education, demography, birth weight
		Ickes SB et al., 2015	Literate in 2011(Ref: illiterate)	aOR	0.87 (0.54-1.41)	Child age, child sex, decision making in family, maternal age at birth, violence, having travelled away from home or not, feeding practices, access to health facility
			Literate in 2011 (Ref: illiterate)	aOR	0.87 (0.59-1.29)	
			Educated in 2006 (Ref: Not educated)	aOR	0.74 (0.47-1.15)	
			Educated in 2011 (Ref: illiterate)	aOR	0.58 (0.31-1.11)	
		Mamabolo RL et al., 2004	Primary (Ref: secondary)	OR	0.699 (0.141-3.461)	
			Student (Ref: no student)	OR	1.404 (0.508-3.880)	
	Maternal occupation	Ukwuani FA et al., 2003	Activity/No cash/Work with Child (Ref: No Activity)	aOR	0.96 (p□0.10)	Father education, father occupation, religion, child feeding duration, maternal age, sex, birth order, ANC, place delivery, residence, Immunization, child illness, WASH
			Activity/Cash/Work with Child (Ref: No Activity)		1.17 (p□0.10)	
			Activity/No Cash/No Working with Child (Ref: NA)	aOR	1.87 (p□0.05)	
			Activity/Child/No Working with Child (Ref: No Activity)	aOR	1.48 (p□0.10)	
		Engebretsen IMS et al., 2008	Has a job (Ref: Doesn't have a job)	OR	0.50 (0.14-1.76)	Child sex, Child age, Country wealth, residence, Owning land, Maternal age, Father education, demography, birth weight,
		Ickes SB et al., 2015	Employed in 2006 (Ref: Not employed)	aOR	1.86 (0.76-4.55)	Child age, child sex, decision making in family, maternal age at birth, violence, having travelled away from

			Employed in 2011 (Ref: Not employed)	aOR	0.57 (0.34-0.95)	home or not, feeding practices, access to health facility
		Mamabolo RL et al., 2004	Not working (Ref: working)	aOR	2.943 (0.916-9.455)	
	Maternal marital status	Engebretsen IMS et al., 2008	Formal marriage (Ref: Traditional)	OR	0.87 (0.25-2.94)	
			Single, separated, divorced, widowed (Ref: Traditional)	OR	0.33 (0.04-2.60)	
		Ukwuani FA et al., 2003	Two wives (Ref: One wife)	OR	1.26 (p□0.10)	
			Three wives (Ref: One wife)	OR	1.01 (p□0.10)	
		Ickes SB et al., 2015	Married or living with partner in 2006 (Ref: single/separated/divorced/divorced)	aOR	0.97 (0.55-1.71)	Child age, child sex, decision making in family, maternal age at birth, violence, having travelled away from home or not, feeding practices, access to health facility
			Married or living with partner in 2011 (Ref: single/separated/divorced/divorced)	aOR	1.64 (0.72-3.72)	
		Mamabolo RL et al., 2004	Single (Ref: Married)	OR	0.444 (0.121-1.629)	
		Engebretsen IMS et al., 2008	Mid 40% (Ref: Top 20%)	aOR	1.76 (0.54-5.70)	Child sex, Child age, Country wealth, residence, Owning land, Maternal age, Father education, demography, birth weight,
			Lowest 40% (Ref: Top 20%)		1.51 (0.48-4.71)	
			Owning land (Ref: Do not own land)	aOR	1.06 (0.40-2.81)	

		Ickes SB et al., 2015	Maternal WI upper 60% in 2006 (Ref: less 60%)	aOR	1.00 (0.68-1.49)	Child age, child sex, decision making in family, maternal age at birth, violence, having travelled away from home or not, feeding practices, access to health facility
			Maternal WI upper 60% in 2011 (Ref: less 60%)	aOR	0.80 (0.50-1.29)	
		Ukwuani FA et al., 2003	Medium	aOR	0.82 (p□0.10)	
			High	aOR	1.02 (p□0.10)	
Underweight	Maternal education	Mamabolo RL et al., 2004	Primary (Ref: Secondary)	OR	0.244 (0.066-0.903)	Feeding practices, child sex, mother age at birth, parity.
			No student (Ref: Student)		3.199 (1.111-9.208)	
		Ickes SB et al., 2015	Literate in 2011 (Ref: Illiterate)	aOR	0.76 (0.53-1.10)	Child age, child sex, decision making in family, maternal age at birth, violence, having travelled away from home or not, feeding practices, access to health facility
			Literate in 2006 (Ref: Illiterate)	aOR	0.60 (0.43-0.82)	
			Educated in 2006 (Ref: no educated)	aOR	0.65 (0.45-0.94)	
			Educated in 2011 (Ref: illiterate)	aOR	0.49 (0.30-0.81)	
	Maternal marital status	Mamabolo RL et al., 2004	Single (Ref: Married)	OR	0.660 (0.203-2.150)	Feeding practices, child sex, Mother age at birth, Parity.
		Medhin G et al., 2010	Polygamous marriage at 6 months (Ref: Not polygamous)	aOR	0.89 (0.52-1.54)	Maternal characteristics (religion, ethnicity, age, MUAC), Other characteristics in the household (Age of husband, father education, WASH), Poverty, traditional surgical practices.
			Polygamous marriage at 12 months (Ref: Not polygamous marriage)	aOR	0.77 (0.45-1.33)	
		Ickes SB et al., 2015	Married or living with partner in 2006 (Ref: single/separated/divorced/)	aOR	1.6 (0.93-2.73)	Child age, child sex, decision making in family, maternal age at birth, violence, having travelled away from

			Married or living with partner in 2011 (Ref: single/separated/divorced/)	aOR	1.20 (0.68-2.12)	home or not, feeding practices, access to health facility
	Maternal occupation	Ickes SB et al., 2014	Maternal employment in 2006 (Ref: no employment)	aOR	1.85 (0.91-3.77)	Child age, child sex, decision making in family, maternal age at birth, violence, having travelled away from home or not, feeding practices, access to health facility
			Maternal employment in 2011 (Ref: no employment)	aOR	1.14 (0.72-1.79)	
		Mamabolo RL et al., 2004	Not being a housewife (Ref: Being a housewife)	OR	0.614 (0.131-2.874)	
			Not working (Ref: working)	OR	0.341 (0.043-2.715)	
	Household wealth index	Ickes SB et al., 2015	Maternal WI upper 60% in 2006 (Ref: less 60%)	aOR	0.76 (0.55-1.04)	Child age, child sex, decision making in family, maternal age at birth, violence, having travelled away from home or not, feeding practices, access to health facility
			Maternal WI upper 60% in 2011(Ref: less 60%)	aOR	0.79 (0.54-1.14)	
		Medhin G et al., 2010	Poverty index at 12 months (Range from 0 to 11)	aOR	0.85 (0.74-0.97)	Maternal age, maternal anthropometry, maternal marital status, autonomy scale, Maternal obstetric complication, substance use (Khat or alcohol), residence, number of children, father age, WASH, social support
			Poverty index at 6 months (Range from 0 to 11)	aOR	0.97 (0.85-1.11)	

A: Activity, C: Cash, AC: Activity with cash, ANC: Activity with no cash, OR: Odds ratio, aOR: Adjusted odds ratio, MUAC: Middle upper arm circumference; NA: Not active; NC: No cash; NWC: No work with child; Q (1,2,3,4,5): Quintile; WC: Work with child, WASH: Wash, sanitation and Hygiene; WI: Wealth index, US: United States of America

In **Table 14**, several studies found that maternal marital status was not significantly associated with stunting (188, 189, 193, 195). The relationship between maternal level of education and stunting was not consistent across the studies reviewed. Having a mother with either no education or schooling up to primary school level was associated with 110% greater odds of stunting compared to having a mother who had been educated beyond primary school level (196). Ickes et al. (188) found that educated mothers had 57% lower odds of having stunted infants but there was no significant association between maternal literacy and infant stunting. Two studies did not find an association between maternal education and stunting (192, 195).

Ickes et al. (188) found that having a mother with an occupation was positively associated with 54% greater odds of stunting. The association between occupation and stunting was adjusted for child age, breastfeeding, maternal religion, maternal age, maternal education, marital status, decision maker in the family, domestic violence, maternal exposure to media, mothers travelling during pregnancy, delivering in a health facility, water sanitation and hygiene, and HWI (188, 195). However, Engebresten et al. (192) did not find any association between maternal occupation and risk of stunting. Studies have defined household wealth using wealth index (terciles (195), quintiles (188, 192, 196, 197), or cut offs which varied between studies), land ownership (192, 196, 197), poverty index (173). Wamani et al. (196) and Engebresten et al. (192) found that the lowest HWIs were associated with higher odds of stunting (192, 197), whilst other studies reported no significant association between HWI and infant stunting (188, 189, 195).

4.3.4 Association between maternal socio-demographic characteristic, household socioeconomic factors and wasting (Table 3)

Maternal occupation was associated with 43% lower odds of wasting in the study by Ickes et al. (188); however, in the study by Ukwani et al. (195), mothers who were not remunerated in cash and did not take their child to work had 87% greater odds of having a wasted child. Two other studies found no association between maternal occupation and wasting (192, 193). In two of the studies reviewed there was no significant association between the HWI and wasting (188, 192). Engebertsen et al. (192), Ickes et al. (188), and Ukwani et al. (195) did not find any significant association between wasting and maternal level of education or marital status (188, 192, 195).

4.3.5 Associations between maternal socio-demographic characteristic, household socioeconomic factors and underweight (Table 3)

The odds of having an underweight child was 40% lower for literate mothers vs illiterate mothers (188); 35% lower for educated mothers vs non-educated mothers (188); 76% lower for mothers who had completed primary school vs those who had completed secondary school.

4.4 Discussion

This review has identified a lack of research in SSA (only 11 studies for 46 countries), a region with one of the highest prevalence of child undernutrition, and the role of maternal and household socioeconomic determinants of impaired growth and development during the first thousand days. Furthermore, we highlighted interesting methodological challenges when assessing maternal or household socioeconomic characteristics as well as important empirical findings pertaining to sub-Saharan African context. Methodologically, although the definitions of LBW, SGA, PTB, stunting, wasting and underweight were standard, studies used varying definitions of SES factors that made comparison and generalisability of their results challenging. However, overall, lower HWI, maternal unemployment, and low maternal education were shown to be important SES predictors of adverse birth outcomes (LBW, SGA) and infant undernutrition (stunting, wasting, and underweight) in SSA.

Women's socioeconomic implications on infant health and nutrition are specific in SSA compared to other regions of the world. Women are the key actor for human development and economic development of countries. Sub-Saharan African countries have the poorest performances for female education and literacy with subsequently poor hygiene, nutrition and health for all their family (55). For instance, the rate of non-education and even unemployment generally affects more women and girls in SSA with consequences of poor access to health services and a high risk of undernutrition for themselves and their infants (55, 200).

4.4.1 Socioeconomic factors and adverse birth outcomes

Evidence gathered in this systematic review have shown that PTB is associated with lower maternal occupation and lower HWI (191, 194). While the risk for a newborn to be SGA was associated with a lower level of maternal education in one out of two studies reviewed (194), LBW was predicted by living in a household with a lower HWI (187, 194). In addition, having a mother with an occupation, and therefore a source of income, was associated with lower risk of LBW. In a review of studies in 22 LMICs, Vogel and collaborators (191, 201) found that less educated mothers had and increased risk of having a newborn that was PTB. However, in a recent study in Kenya, Wagura and collaborators (139) found that maternal level of education

had no significant association with PTB but was significantly associated with previous PTB. Furthermore, in Brazil, Zambonato and collaborators (202) found an association between SGA in Brazilian newborns and a lower family income, similar to the study conducted in Tanzania in this review (194). Similarly, in Japan, mothers living in prefectures with higher socioeconomic inequality (measured by the Gini coefficient) had 24% greater risk of having a SGA newborn (203). In addition, lower parental education and household income was associated with SGA (203). The protective effect of maternal education, occupation and aggregated SES indices against LBW has been shown in previous studies in other LMICs (South Africa (172), Pakistan (204), Vietnam (205), and Bangladesh (206)), as well as in a meta-analysis of studies conducted in middle and high income countries (108). In this systematic review, we did not find any study which investigated the association between maternal marital status and birth outcomes.

4.4.2 Socioeconomic factors and infant undernutrition between birth and two years of age

Most studies included in this review reported that higher level of maternal education was protective against stunting and underweight whilst maternal occupation and low HWI increased the risks for a child to be stunted (188, 192, 196, 197). The evidence was not consistent for underweight; studies found positive and negative associations with maternal education (173, 188, 193). While some studies found that maternal occupation reduced the risks of wasting, others have shown the contrary (188, 195). No study found an association between marital status and stunting (188, 189, 192, 193, 195) or wasting (188, 192, 193, 195), and the association between marital status and underweight had not been explored.

A review on malnutrition over 15 years in LMICs showed that higher maternal/caregivers' level of education and greater HWI reduced the odds of stunting during infancy (35). In a pooled analysis of five cohort studies including South Africa (168), results showed that low maternal education, low maternal income, low social class (measured by paternal occupation), and low paternal education were predictors of stunting at two years of age. However, SES factors (maternal education, maternal income, paternal occupation, paternal education) had less influence on stunting than biological factors (birth weight, maternal height), particularly in South Africa (168). Similarly, a study in Ivory Coast found that having an educated mother was protective against stunting in three year old children (207).

In Bangladesh, Raihan and collaborators (208) found that low SES (assets, maternal and household income, maternal education) increased the risk of wasting in children younger than

five years of age. They also found that water sanitation and hygiene characteristics (e.g. use of soap, use of hygienic latrine, safe drinking water), often used as a composite of household wealth index and/or as a risk factor of infectious disease, mediated the association between SES factors and wasting (208).

The outcomes of this review align with existing findings in children aged between 6 and 23 months in Myanmar (209) and in children under three years of age in Vietnam (178) which reported that children of working mothers had a higher risk of being stunted. Also in Vietnam (178), maternal occupation was a predictor of all forms of undernutrition (stunting, wasting and underweight), whereas maternal education and income were not. In contrast, Ukwani and collaborators (195) found that in Nigeria maternal occupation was protective against wasting suggesting that working women have an income that allows for provision of food and better care, and that mothers breastfeed for longer than their non-working peers.

4.4.3 Maternal and household SES factors during the first 1000 days

At the country level, a review of 121 surveys in 36 LMICs (51) found that a 5% increase in per capita gross domestic product (GDP) decreased the risk of undernutrition in children aged between 0 to 35 months, but this association did not occur in the poorest households, suggesting that poverty and socioeconomic inequalities are both vehicles of infant undernutrition. The first thousand days, the period between conception and two years after birth, has been acknowledged as a critical period for child growth and development and for adult health outcomes (4, 12). Evidence from this review highlight that low maternal and household SES are more likely to have a negative effect on growth and development during that period (210).

The socioeconomic environment is both a contributory factor to and a consequence of infant undernutrition (211). Maternal and household lower socioeconomic status is an underlying factor of household food insecurity, and therefore of maternal and child health and undernutrition (212). Children living in households with low SES were found to consume more carbohydrates and less protein and less fat with subsequent undernutrition (213). Educated mothers have greater knowledge, better job opportunities, higher income, a healthy lifestyle, and access to health care, all of which impact infant growth and nutritional status (105, 108). Although the level of education of the general population is improving in SSA countries, education of females is still lower than that of males (214). McGovern and collaborators (50), in their systematic review on stunting and economic growth, concluded that education of

women is a cost-effective investment which reduces poor infant growth and translates into greater future opportunities for children.

One study included in this review found that maternal occupation had a detrimental effect on child growth (105). Having a job may generate an income for mothers and their households, but it can limit the time spent with their newborn. Whilst having an occupation provides an income that enables greater access to health care, working mothers are not always available to breastfeed their children or to access health care when necessary (105). Lack of support systems (social support, maternity leave, etc.) may jeopardize mothers' possibilities to provide optimal care for their children (including exclusive breastfeeding), thereby exposing children to the risks associated with early weaning, introduction of solid food and infectious diseases (15). In this review, we did not find any studies conducted in SSA on the association between maternal marital status and infant undernutrition. Having a partner (married or concubine) may have a positive effect on maternal and child health through the widest network of social support, and additional income that this situation may provide; however, domestic violence may offset those benefits (215).

Based on the studies included in this review, socioeconomic factors were generally assessed as contextual variables (household wealth index) and/or as compositional measurements (education, income, occupation) (105). In addition, we highlighted that across studies, contextual and compositional SES factors were defined using different characteristics (105). The lack of standardization and harmonization of SES measures may explain discrepancies observed between the studies included in this review. For example, whereas a study showed that higher maternal education level was associated with lower risk of stunting (196), the same study found no association between maternal literacy and stunting (196). It may be that either the influence of education is different depending on the social and economic contexts, or that having a higher level of education, which is indicative of the knowledge acquired, is more important than maternal literacy, which reflects a skill. Wamani and collaborators (197) found that in rural Uganda having a secondary education level was the critical threshold at which maternal level of education was protective against stunting. The use of a variety of SES indicators may also limit comparisons within and between countries, and therefore, the identification of critical maternal and household factors to target in national or regional intervention programs which aim to promote foetal and infant optimal growth.

The majority of studies reviewed did not specifically focus on the assessment of the association between SES factors and birth outcomes or infant undernutrition. Possibly, the choice of SES indices might have been dictated by the main objective of the study. Therefore, another source of discrepancies between studies could be the covariates in the multivariate analyses. The UNICEF causal framework (81) has established that several immediate, underlying and basic causes play a role in infant undernutrition. Various combination of causal factors were taken into account across the articles reviewed here, including: infant gender (207, 212), infant feeding practices (35, 209), maternal age (207), maternal anthropometric characteristics (207), maternal morbidity (urinary tract infection, hypertensive disorders, malaria, HIV, infection, gestational diabetes, pre-eclampsia, pregnancy induced hypertension, antepartum haemorrhage, pre-labour rupture of membranes, placental bleeding) (201), maternal obstetrical history (parity, previous PTB, gestation number) (201, 202, 216), access and usage of antenatal care services, household food insecurity (207, 212), household size, level of urbanization (35, 212).

Limitations

This review has some limitations. Firstly, studies were selected using English keywords; given the linguistic diversity in the SSA region, studies written in only other languages may have been missed. Secondly, the various definitions and measurement of SES and the inability to retrieve some key data from publications did not allow us to undertake a meta-analysis. Thirdly, one (9%) study (193) was rated low because of lack of randomization in recruitment, no blinding in the conduction of the study, lack of adjustment for any variable and no confidence intervals in the results (145, 146). Finally, the accuracy of gestational age may vary across studies depending on the method of assessment. These limitations could lead to a low power of the data included (quality and quantity) in the review.

4.5 Conclusion

In conclusion, despite the paucity of studies which have explored the relationship between maternal and household SES and LBW, PTB, SGA, stunting, wasting and underweight in SSA, results from this review emphasize the negative long-term effects of poor maternal and household SES on child growth during the first thousand days. More research, including using a qualitative approach, has to be undertaken to improve our understanding of contextual SES factors that are associated with undernutrition during the first thousand days in the different SSA countries. Furthermore, early intervention from pre-pregnancy through infancy may prevent undernutrition during the first two years of life and any irreversible damages caused by

undernutrition during infancy. Finally, promoting maternal education and female employment as well as alleviating female poverty and inequality are key interventions to favour optimal maternal and child health.

CHAPTER 5: PHD PAPER 2

Title: Association between household and maternal socioeconomic factors with birth outcomes in the Democratic Republic of Congo and South Africa: a comparative study

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5.1 Introduction

Poverty is associated with maternal undernutrition, adverse birth outcomes and poor human capital (9). Low birth weight (LBW), small for gestational age (SGA), and preterm birth (PTB) have been shown to be strong predictors of high morbidity and mortality during infancy, and have increased risk for chronic diseases in adulthood (21). Birth outcomes reflect disparities in sociological and economic categories of individuals or groups (85). The UNICEF conceptual framework of maternal and child undernutrition identified poor maternal and household socioeconomic factors (SES) as critical determinants of birth outcomes (82).

Birthweight (BW) is the first postnatal measurement indicating newborn growth and nutritional status, whilst LBW has been used as an indicator of impaired intra-uterine growth (86). Maternal undernutrition contributes to LBW (58), whilst other maternal factors such as age (217), diet (218), anthropometric indicators (82), infection (9) and chronic conditions (e.g. hypertension, diabetes) (9), obstetrical conditions and parity (219), lifestyle (smoking and alcohol use) (217, 220) and access to prenatal health care (221) predict BW. Birth weight is closely related to gestational age at birth, which also has been associated with maternal mental and physical health during pregnancy, and foetal distress (9).

The association between SES factors and birth outcomes has been widely documented in high-income countries (110, 217) contrasting with SSA where the prevalence of newborns with LBW, PTB and SGA is amongst the highest worldwide at 14.6% (20.5 million) (222), 10.6% (14.84 million), (85) and 19.3% (23.3 million) (155), respectively. Studies in SSA are scarce and poor birth outcomes have been associated with poor maternal education, unemployment, and household economic deprivation, as highlighted in a recent systematic review (223). Women with a high level of education are more likely to have better job opportunities and an income than their counterparts with a lower educational level, thus enabling easier and informed

access to health information and health care for themselves and their children (108). The role of marital status in birth outcomes has not yet been investigated in SSA (223).

However, it is important to consider that the SSA region comprises low-income (e.g. the DRC) and middle-income (e.g. South Africa) countries with different social, cultural and political contexts. In 2018, the DRC had a lower human development index (HDI) (0.37) and a weaker gross domestic product (GDP) per capita ($US 808) than SA which had a medium HDI (0.41) and $US 12,215 per capita GDP (224). The poverty level in the DRC was higher than that of SA with the percentage of the population living on less than US$ 1.90 per day being 73% and 18.8% , respectively (224). However, social inequality, measured by the Gini coefficient was higher in SA (63%) than in the DRC (42.1%) (224). The aim of this study was, therefore, to assess and compare the associations between household and maternal demographic and SES factors, and adverse birth outcomes (LBW, PTB and SGA) in two socioeconomically contrasting countries in SSA namely, SA and the DRC.

5.2 Methods

5.2.1 Study design and setting

This study included mother and newborn pairs living in rural and urban areas of the DRC and an urban area of SA. In the DRC, a cross-sectional study was conducted in Kasai central province, in which six out of the 26 health districts are urban. Data were collected from one urban hospital (Kananga Provincial hospital) and three rural hospitals (Mikalayi, Bunkonde, Tshikula).

For a secondary analysis of cross-sectional data which were collected as part of the Soweto First 1000 Days cohort (S1000) study undertaken at the Chris Hani Baragwanath Academic Hospital (CHBAH) in Soweto, Johannesburg. The S1000 study investigated the associations between maternal factors with foetal and newborn nutritional status and explored the levers of maternal and child health within the first 1000 days of life in Soweto, which is an urban-poor area in South Africa (225).

5.2.2 Ethics approval

The DRC study was approved by the Centre National d'Éthique of the DRC (clearance number: 046/CNES/BN/PNMF/2016). The S1000 study was approved by the Human Research Ethics Committee (Medical) of the University of the Witwatersrand, South Africa (clearance numbers: M120524 and M130905). Written informed consent was obtained from mothers in both studies.

5.2.3 Participants

In the DRC, a two-stage cluster sampling was used. We first selected 4 districts out of 26 in the province in proportion to the number of rural and urban health districts within the province. Mother-newborn pairs were recruited in 4 selected hospitals between August 2016 and January 2017. In each hospital, we included post-partum mothers (72 hours after delivery) with their healthy, singleton child, born after 28 weeks of pregnancy.

In SA, mothers and newborns were recruited at the CHBAH between 2013 and 2016. Eligibility criteria included healthy pregnant women older than 18 years, with a singleton newborn, residing in Soweto (226). Follow up data were collected at participants' homes at 6 time points: before 14 weeks, 15-19 weeks, 20-23 weeks, 24-28 weeks, 29-33 weeks and 34-38 weeks (225).

5.2.4 Variables

5.2.4.1 Exposures: household and maternal demographic and socioeconomic factors

Data on maternal education, maternal marital status and the type of house walls within which mothers lived were collected using interviewer-administered questionnaires adapted from the Demographic Health Survey questionnaires (227). Maternal education was the level of education completed by the time of delivery. Maternal education was aggregated into two categories for analyses: none plus primary education vs. secondary education and above. Maternal marital status was defined as the legal marital status (single, married, widowed, divorced) and then aggregated into two categories: married vs. unmarried. The type of house walls was categorised as: walls constructed using durable materials (bare bricks, cement block, plaster finished) vs. walls constructed using non-durable materials (plastic, cardboard, mud, corrugated iron/zinc).

5.2.4.2 Birth outcomes

Birth weight was measured using digital scales (Salter in the DRC; Seca 376 in SA) to the nearest 100 g with babies wearing no clothes(226). The scales were calibrated daily to ensure the reliability and accuracy of the measurements. Gestational age at birth was measured in weeks of pregnancy between the last menstrual period (LMP) and the date of delivery in the DRC and by dating ultrasound (Philip HD-9, the United States of America) in SA(226). Classification of newborns was as follows: LBW (BW <2500 g), SGA (BW <10th percentile of the INTERGROWTH 21st standard curve), and PTB (birth before 37 gestational weeks) (85, 86, 155).

5.2.4.3 Covariates

Newborn factors were the child sex (male or female) and birth weight. Maternal factors included age, height and weight according to the WHO guidelines (228). Maternal weight (kilogram) and height (centimetre) were measured using a digital scale to the nearest 100 grams and an adult stadiometer, respectively (226). Interviewer-administered questionnaires were used in the DRC and in SA to obtain data on gestational age at the first prenatal visit (in weeks of pregnancy), gestational weight gain per week (GWG) (in kilograms per week of pregnancy) and parity (number of previous deliveries), maternal morbidity during pregnancy (including high blood pressure, malaria, anaemia, tuberculosis), smoking status (yes or no) and prenatal alcohol consumption (yes or no). Maternal morbidity was categorised as a binary score (disease vs no disease).

5.2.5 Study sample size

In the DRC, 256 mother-newborn pairs were included in the study after calculating to detect a 10% difference from the baseline LBW prevalence found in the literature (229) with 80% of power ($\alpha < 0.05$ significance). Low birth weight was used for sample size calculation because it includes PTB and SGA (229). In SA, data of 828 mother-newborn pairs were included in the secondary analyses.

5.2.6 Statistical analyses

For each variable, a descriptive analysis was done according to sex. Summary statistics included proportions, means and standard deviation, or median and range (**Error! Reference source not found.**). Skewness and Kurtosis tests were performed to identify the type of distribution for each variable. Differences by sex and by country were assessed using a Pearson's chi squared test, or an independent t-test. Multivariable logistic regression analyses and modelling were done to identify factors associated with birth outcomes (**Table 16)**. Maternal weight at first prenatal visit was excluded from multivariable regression models due to collinearity with maternal weight at delivery (variation inflation factors, r=0.96). Maternal smoking was excluded from the analyses due to its small rate (<10%) in the DRC.

For each model setting, associations between household and maternal sociodemographic and SES factors with birth outcomes were assessed. Model 1 (M1) investigated the association between SES factors (maternal education, maternal marital status and type of house walls) and birth outcomes adjusted for newborn sex. In the Model 2 (M2), M1 was adjusted for maternal characteristics (maternal height, maternal age, type of delivery, gestational age at first prenatal

visit, GWG, maternal weight at delivery, maternal morbidity score and maternal lifestyle). In Model 3 (M3), M2 was adjusted for the country. Finally, multivariable logistic regression models were performed by pooling the DRC and SA data. This last model consisted of two models adjusted for the country. The significance level was set as $p \leq 0.05$ with 95% confidence intervals. Stata version 13 (StataCorp LP, College station, TX, the United States of America) was used for data management and analyses.

5.3 Results

Table 15: Comparative characteristics of the participants in the Democratic Republic of Congo and in South Africa

Socioeconomic factors		The Democratic Republic of Congo (N=256)							South Africa(N=828)							The DRC vs SA (p)
		Male (n=187)		Female (n=69)		p	Total		Male (n=429)		Female (n=397)		p	Total		
		N	%	N	%		N	%	n	%	n	%		n	%	
Maternal education	None + Primary	92	50.5	44	65.7	**0.03**	136	54.6	8	1.9	9	2.3	0.68	17	2.1	**<0.01**
	Secondary+ tertiary	90	49.5	23	34.3		113	45.4	421	98.1	388	97.7		809	97.9	
Maternal marital status	Unmarried (Single/widowed/divorced)	9	4.9	4	6.0	0.75	13	5.2	252	58.7	263	66.3	**0.03**	515	62.3	**<0.01**
	Married	173	95.1	63	94.0		236	94.8	177	41.3	134	33.7		311	37.7	
Type of house	Non-durable materials	130	72.2	60	89.5	**<0.01**	190	76.9	51	13.8	43	12.6	0.63	94	13.2	**<0.01**
	Durable materials	50	27.8	7	10.5		57	23.1	318	86.2	298	87.4		616	96.8	
Birth Outcomes																
Birthweight (Mean, SD)	Kilogram	162	3.2 (0.5)	60	3.1 (0.4)	0.90	222	3.20 (0.3)	404	3.0 (0.6)	385	2.9 (0.6)	**0.05**	789	2.97(0 .56)	**<0.01**
GA at delivery (Mean, SD)	Weeks of pregnancy	168	37.0 (3.5)	67	36.2 (3.5)	0.12	235	36.6 (0.3)	415	38.0 (2.5)	397	38.2 (2.3)	**0.05**	826	38.1 (2.5)	**<0.01**
LBW (%)	Yes	20	12.4	5	8.8	0.40	222	11.3	63	15.6	72	18.7	0.25	789	17.1	**0.03**
PTB (%)	Yes	49	29.2	28	41.8	0.06	235	32.8	69	16.6	60	15.1	0.56	812	15.9	**<0.01**
SGA (%)	Yes	20	13.3	23	10.1	0.08	211	10.1	69	17.1	90	23.4	**0.03**	789	20.2	**<0.01**
Maternal and Newborn Characteristics																
Parity (Median, range)	Number of deliveries	172	3.9 (2-7)	64	3.7 (2-5)	0.95	236	3.0 (0-10)	429	2 (0-7)	397	2 (0-9)	0.99	826	2.0 (0-5)	**<0.01**
Delivery (%)	C-section	19	10.8	6	9.1	0.70	25	10.3	170	41.0	170	42.8	0.59	340	41.9	**<0.01**
	Vaginal	157	89.2	60	90.9		217	89.70	245	59.0	227	57.2		472	58.1	**<0.01**
Maternal age at delivery (Mean, SD)	Years	187	27.8 (7.9)	69	26.5 (6.5)	0.57	256	27.5 (0.5)	429	29.5 (5.8)	397	30.2 (6.0)	0.76	826	29.8 (5.9)	**0.57**
Maternal height (Mean, SD)	Centimetre	185	161.1 (7.5)	68	160.6 (7.6)	0.57	253	160.9 (7.3)	429	158.8 (6.7)	397	158.7 (6.8)	0.62	826	158.8 (6.7)	**<0.01**
GA at the first prenatal visit (Mean, SD)	Weeks of pregnancy	169	18.3 (5.9)	67	16.4 (5.2)	0.12	236	17.8 (0.4)	429	12.4 (2.4)	397	12.4 (2.6)	0.95	826	99.8	**<0.01**

Duration between first prenatal visit and delivery (Mean, SD)	Weeks of pregnancy	165	18.6 (6.1)	67	19.8 (5.9)	0.40	232	18.9 (6.1)	415	25.6 (3.4)	397	25.8 (3.5)	0.36	812	25.0(6 .1)	**<0.01**
Maternal weight at the first prenatal visit (Mean, SD)	Kilogram	170	58.2 (7.2)	65	56.1 (6.2)	0.45	235	57.6 (7.0)	429	70.8 (15.0)	397	71.9 (17.3)	0.99	826	71.3 (16.2)	**<0.01**
Maternal weight at delivery (Mean, SD)	Kilogram	176	62.5 (7.7)	66	60.8 (6.2)	0.45	242	61.8 (0.5)	428	78.8 (14.9)	397	79.7 (16.8)	0.99	825	79.2 (15.8)	**<0.01**
Gestational weight gain per week (Mean, SD)	Kilogram per week	160	0.3 (0.7)	66	0.4 (0.8)	0.20	226	241 (24)	429	0.3 (0.3)	397	0.3 (0.2)	0.98	826	290 (27)	**0.01**
Smoking (%)	Yes	11	6.1	5	7.8	0.64	16	6.6	34	8.6	37	8.6	0.96	71	8.6	**<0.01**
Alcohol use (%)	Yes	49	30.1	22	37.9	0.27	71	32.1	44	12.4	34	10.2	0.37	78	11.3	**<0.01**
Morbidity score (Score)	No morbidity	26	13.9	15	21.7	0.10	41	16.0	139	32.4	139	35.0	0.43	278	33.7	**<0.01**
	Morbidity or co-morbidity	161	86.1	54	78.3		215	84.0	290	67.6	258	65.0		548	66.3	

GA: gestational age: LBW: low birth weight; PTB: preterm birth; SGA: small for gestational age; SD: standard deviation; p= p-value;

Significant values $p < 0.05$ highlighted in bold

Table 16: Multivariable logistic regression analyses of the SES factors and birth outcomes (LBW, PTB, and SGA) in the pooled dataset from the Democratic Republic of Congo and South Africa

		LBW			PTB			SGA		
		M1, n=855, OR (95% CI)	M2, n=817, OR (95% CI)	M3, n=817, OR (95% CI)	M1, n=926, OR (95% CI)	M2, n=850, OR (95% CI)	M3, n=850, OR (95% CI)	M1, n=882, OR (95% CI)	M2, n=817, OR (95% CI)	M3, n=817, OR (95% CI)
SES Factors										
Maternal education	None +Primary	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Secondary + tertiary	1.22 (0.62 - 2.38)	2.13 (0.82 - 5.50)	0.74 (0.27 - 1.99)	0.96 (0.58 - 1.57)	3.16 *** (1.60 - 6.27)	2.21 ** (1.07 - 4.59)	0.85 (0.45 - 1.62)	1.01 (0.50 - 2.03)	0.77 (0.36 - 1.65)
Maternal marital status	Unmarried (Single/widowed/divorced)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Married	0.71 * (0.47 - 1.06)	0.55 ** (0.34 - 0.91)	0.75 (0.45 - 1.24)	1.05 (0.73 - 1.51)	0.62 ** (0.39 - 0.98)	0.81 (0.50 - 1.32)	0.83 (0.57 - 1.22)	0.87 (0.58 - 1.29)	0.99 (0.66 - 1.50)
Type of house walls	Non- durable materials	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Durable materials	1.00 (0.61 - 1.65)	1.26 (0.66 - 2.41)	1.07 (0.55 - 2.06)	0.48 *** (0.32 - 0.72)	0.74 (0.44 - 1.24)	0.61 * (0.36 - 1.04)	1.66 * (0.99 - 2.78)	1.92 ** (1.10 - 3.36)	1.48 (0.83 - 2.62)
Maternal and Newborns Characteristics										
Child sex	Male	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Female	1.16 (0.79 - 1.68)	1.19 (0.76 -1.87)	1.11 (0.71 - 1.74)	1.04 (0.74 - 1.45)	1.36 (0.91 - 2.06)	1.32 (0.87 - 1.99)	1.35 * (0.95 - 1.93)	1.22 (0.77 - 1.07)	1.33 (0.92 - 1.93)
Parity	Number of deliveries		0.89 (0.76 - 1.04)	1.19 ** (1.03 – 1.37)		1.16 ** (1.04 – 1.30)	1.12 * (0.99 – 1.26)		0.87 ** (0.76 – 0.99)	0.92 (0.80 – 1.07)
Type of delivery	C-section		Ref	Ref		Ref	Ref		Ref	Ref
	vaginal		1.46 * (0.95 -2.24)	1.26 (0.76 - 2.07)		1.77 ** (1.11 - 2.82)	1.97 *** (1.22 - 3.15)		0.98 (0.66 - 1.45)	0.98 (0.66 – 1.47)
Maternal age at delivery	Years		1.05 ** (1.01 - 1.09)	1.02 (0.99 - 1.06)		1.02 (0.98 - 1.05)	1.01 (0.98 - 1.05)		1.02 (0.99 - 1.05)	1.02 (0.99 - 1.05)
Maternal Height	Centimetre		0.99 (0.96 – 1.02)	1.01 (0.97 - 1.05)		1.01 (0.98 - 1.04)	1.02 (0.99 - 1.06)		0.96 (0.93 - 0.99)	0.97 ** (0.94 - 0.99)
GA at the first prenatal visit	Weeks of pregnancy		0.63 *** (0.57 - 0.70)	0.65 *** (0.59 - 0.73)		0.95 ** (0.90 – 0.99)	0.93 ** (0.89 – 0.98)		1.14 *** (1.04 -1.26)	1.14 ** (1.03 - 1.26)

Duration between first prenatal visit and delivery	Weeks of pregnancy		0.63 *** (0.58 - 0.69)	0.61 *** (0.56 - 0.67)		0.76 *** (0.71 - 0.79)	0.72 *** (0.68 - 0.77)		1.13 *** (1.04 - 1.23)	1.11 ** (1.01 - 1.21)
Maternal weight at delivery	Kilogram		0.98 ** (0.96 - 0.99)	0.97 *** (0.95 - 0.99)		0.99 (0.98 - 1.01)	0.99 * (0.97 - 1.00)		0.97 *** (0.96 - 0.99)	0.97 *** (0.95 - 0.98)
Gestational weight gain per week	Kilogram per week		0.55 (0.17 - 1.73)	0.48 (0.15 - 1.52)		0.23 *** (0.08 - 0.65)	0.21 *** (0.07 - 0.61)		1.01 (0.95 – 1.07)	0.94 (0.54 - 1.65)
Alcohol use	Yes		0.79 (0.44 – 1.43)	0.89 (0.49 – 1.62)		0.49 ** (0.27 - 0.91)	0.59 (0.32 - 1.11)		1.21 (0.71 – 12.07)	1.35 (0.78 – 2.32)
Morbidity score	No morbidity		Ref	Ref		Ref	Ref		Ref	Ref
	Morbidity or co-morbidity		0.53 ** (0.34 - 0.85)	0.55 ** (0.34 - 0.89)		0.89 (0.57 - 1.40)	0.94 (0.60 - 1.49)		0.82 (0.55 - 1.22)	0.87 (0.58 - 1.29)
Country										
	The DRC			Ref			Ref			Ref
	SA			16.1 *** (4.81 - 53.88)			3.72 *** (1.51 - 9.15)			2.44 ** (1.00 - 5.94)

*: 0.05<p≤0.1, **: 0.01<p≤0.05, ***: p≤0.01; M1= SES factors + child sex, M2= M1 + Newborn and maternal characteristics, M3= M2 + country; OR = Odds Ratio; the DRC= the Democratic Republic of Congo, GA: gestational age; SA= South Africa

A total of 1084 mothers and newborns were included in the study (the DRC: 256; SA: 828) (**Error! Reference source not found.**). In comparison to SA women, a greater number of the DRC women had a lower level of education (SA: 2.1%; the DRC: 54.6%), were married (SA: 37.7%; the DRC: 94.8%) and were living in houses constructed of non-durable materials (SA: 13.2%; the DRC: 76.9%). The rates of LBW and SGA were lower in the DRC (LBW: 11.3%; SGA: 10.1%) than in SA (LBW: 17.1%; SGA: 20.2%). The rate of PTB in the DRC (32.8%) was almost double that of SA (15.9%). Child sex-differences were found for maternal education, type of house in the DRC, and marital status in SA. Except for maternal age at delivery, household, maternal, newborn and lifestyle characteristics differed significantly between the DRC and SA. The DRC women were taller, had higher parity and later first prenatal visit, weighed less at delivery, smoked less and consumed more alcohol during pregnancy, compared to SA women. However, in both countries, the majority of women presented with morbidity conditions during pregnancy (the DRC: 78%; SA: 66.3%) and most women had a vaginal delivery (the DRC: 89.7%; SA: 58.1%).

Bivariate analyses of the separate dataset (**supplementary table 1; pages 291-292**) showed that maternal education and type of house were not associated with birth outcomes in the DRC. The odds of LBW decreased by 9% for every kilogram increase in maternal weight at first prenatal visit and by 63% for morbidity during pregnancy. The odds of PTB decreased by 72% for married women and by 7% for every week of delay in the first prenatal visit but increased 2.3-fold with smoking during pregnancy. The odds of SGA decreased 7% with every centimetre increase in maternal height but increased by 12% with every week of delay in the first prenatal visit.

Regression analyses adjusted for newborn and maternal characteristics were performed per country **(supplementary table 2; page 293-294**. After adjusting for newborn and maternal characteristics, being married was associated with 83% and 79% decreased odds of LBW and PTB, respectively. Having a secondary level of education or higher decreased the odds of SGA by 86%. In SA, no significant association between household and maternal demographic and SES factors with birth outcomes were found in the bivariate analyses nor in the regression analyses adjusted for newborn and maternal characteristics.

In bivariate analyses of the pooled dataset (**supplementary tables 3, pages 295-296**), a kilogram increase in maternal weight at first prenatal visit and a kilogram increase in GWG were associated with a 2% and 87% decrease in the odds of LBW, respectively. The odds of LBW increased by 3%, 27% and 57% with a one-year increase in maternal age, a unit increase in parity and having a

vaginal delivery, respectively. For every centimetre increase in maternal height, for every kilogram increase in maternal weight at delivery, the odds of SGA decreased by 4% and 3%, respectively. For every kilogram increase in GWG, the odds of having PTB decreased by 63%. For every unit increase in parity and vaginal delivery there was a 20% and 74% increase in the odds of PTB, respectively. Maternal education was associated with PTB, marital status with LBW and SGA, and type of house walls with PTB and SGA.

In the pooled analyses adjusted for newborn and maternal characteristics, and country (**Table 16**), maternal education, marital status and type of house walls were associated with birth outcomes. Having higher than secondary level of education increased the odds of PTB 2.2-fold. Being legally married decreased the odds of LBW and PTB by 45% and 38%, respectively. Living in a house with durable walls decreased the odds of PTB by 39% but increased that of SGA by 92%. After adjusting for country, the odds for women with secondary level of education and above with PTB increased 2.21-fold. Maternal height, gestational age at the first prenatal visit, maternal weight at delivery and GWG confounded the association between SES with LBW. Parity, vaginal delivery, maternal weight at delivery confounded the association between SES and PTB. Child sex, parity, maternal weight at the first prenatal visit and at delivery confounded the association between SES with SGA. Gestational age at the first prenatal visit confounded the association between SES and LBW, PTB and SGA.

5.4 Discussion

5.4.1 Main findings

It is clear from the findings of this study that local/regional context matters when assessing the association between maternal and household socioeconomic, as well as household factors and birth outcomes in sub-Saharan Africa. Living in SA as compared to the DRC was associated with reduced odds of a newborn with LBW, PTB or SGA, which reflects country-specific maternal and household resources and social position differences (education access, housing, marriage). In the DRC, being married decreased the likelihood of having LBW and PTB children while in SA being a mother with secondary level of education and above was associated with lower risks of having a SGA newborn. Furthermore, findings from the pooled analyses support that maternal education is a critical determinant of birth outcomes across SSA countries.

5.4.2 Maternal education, maternal marital status and type of house walls, and birth outcomes

To our knowledge, this study is among few that explore the association between marital status and birth outcomes in SSA. Whilst support from biological fathers may contribute to greater household income allowing access to health care and food security, which benefit maternal and child health (230), it has been shown that these positive family influences may be mitigated by factors such as domestic violence (231) or changing partners between two births, and thus, increased the risk of having LBW and PTB newborn in Norwegian women with more than 14 years of education (232). Collectively, these above studies emphasize that cross-country comparisons of associations between marital status and birth outcomes must be interpreted with caution, considering the social structure, performance and quality of pre- and post-natal health care as well as the cultural contexts specific to each country. We used the type of house wall material within which participants resided as a proxy for social position and household wealth, better social position (i.e. living in a house with durable walls) decreased the risk for PTB but increased that of SGA in the pooled dataset.

Our findings also corroborate those of others which found that a lower level of maternal education was associated with LBW in SSA countries (223) and in Latin America (108), and with SGA, PTB and LBW in high-income countries (109). In the United Kingdom, a poor level of maternal education and unemployment was associated with a higher risk of SGA, which was greater in single compared to married women (110). We found that maternal education had the strongest association with birth outcomes compared to other SES factors. This is consistent with findings from a previous review which found that maternal education rather than maternal income was associated with birth outcomes in high income countries (233), while health systems (with/without universal health care coverage), locality and income (113) contrast with the LMICs context.

The effects of social factors on prematurity have been inconsistently shown in high income countries such as in Canada and Europe in the past three decades; while a recent review in sub-Saharan Africa demonstrated a protective role of maternal education from offspring prematurity. The protective role of maternal education from offspring preterm birth is well documented irrespectively of contextual settings. In contrast, economic factors, access to and quality of health care, obstetrical care in particular (such caesarean section and inductive labour), and maternal

lifestyle may mediate the positive effects on offspring prematurity of higher maternal education level (234).

5.4.3 Other maternal and child factors with birth outcomes

In our study, maternal and newborn biological factors (child sex, parity, maternal age at delivery, maternal height, gestational age at first prenatal visit, GWG and maternal morbidity during pregnancy) were associated with the birth outcomes of interest independently of demographic and SES factors. Maternal height, parity, weight pre-pregnancy, and GWG were negatively associated with having a LBW, PTB or SGA newborn, reflecting the importance of maternal nutritional status during preconception and pregnancy periods. Gestational weight gain has been associated with dietary intake and physical activity in SA women (225). In the S1000, previous analyses have shown that mothers consuming an energy dense diet (sugar and fat foods) during pregnancy were more likely to have greater GWG while maternal traditional diet (beans, legumes, traditional meats and porridge) was associated with adequate GWG (225). A review conducted in London showed that maternal nutritional status and quality of maternal dietary intake in the life course affected the strong association between SES factors with LBW and PTB; maternal nutrition was rather correlated to the quality of diet in the poorest populations in comparison to their richest counterparts (58). A meta-analysis in high-income countries showed that a higher GWG was associated with increased risks of PTB (115) however, two recent reviews (in Peru, Korea, China, Japan, Italy, Denmark and USA) found that women with a higher total GWG (above Institute of Medicine's guidelines) had a lower risk of having a LBW, SGA or PTB newborn(235).

Quite interestingly, we found that maternal morbidity during pregnancy was protective against LBW. This may be attributed to women who are aware of their health conditions being more likely to have their health monitored more closely throughout pregnancy (236). Earlier first prenatal visits played a confounding role in the association between maternal marital status and PTB in our findings. Prenatal alcohol use played a confounding role in our study. Prenatal alcohol exposure was associated with early behavioural birth outcomes (mental disorders) rather than LBW outcomes in China (220). In contrast, fewer prenatal visits (no visit or <5 visits) was associated with 5.4-fold and 9.1-fold increased odds of LBW and PTB, respectively, after adjusting for

maternal level of education, younger maternal age, smoking and alcohol use in a study in Finland (237).

Our findings show that the effect sizes of maternal biological factors on birth outcomes were larger than those of socioeconomic factors, which is in keeping with other studies that have suggested using maternal undernutrition as a marker of poor birth outcomes (9, 58) regardless of the type of delivery (123).

Limitations

The estimate of gestational age using LMP may be less accurate (sensitivity and predictive value) than the ultrasound method in the first trimester compared to the last trimester (238). Inadequate housing may contribute to poorer child health and nutritional status (239). Other related SES and environmental factors such as water, sanitation and hygiene, should also be investigated in future studies to disentangle their role on birth outcomes.

Implications

Social policies should protect single women socially and economically before, during and after pregnancy to improve birth outcomes and to optimize their intergenerational influences. More context-specific mixed-methods studies in SSA that focus on effectiveness of policies and intervention programs in the field to disentangle the role of proximal factors (maternal and paternal biological factors, maternal and household sociodemographic and socioeconomic factors) from the role of distal country factors (governance, health policy and system) is needed.

5.5. Conclusion

There is difference between SA and the DRC with respect to the associations between household and maternal SES and birth outcomes. Maternal education and marital status were associated with birth outcomes in SSA while, maternal biological and country factors (socioeconomic development, governance and health systems) underpin individual and household capabilities. These are all potential levers to affect positive pregnancy outcomes and address the SDGs.

CHAPTER 6: PHD PAPER 3

Title: Associations between maternal and household socioeconomic factors and infant growth: the Soweto Baby Wash study (South Africa).

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6.1 Introduction

Infant undernutrition is a major public health issue which is encountered more frequently in socioeconomically deprived individuals and households, and has been associated with an increase in the risk for cardiometabolic diseases and poor human capital (9, 211, 240). Infant growth is a manifestation of infant nutritional status and is shaped by early stimulations in the ecological structures (e.g. maternal, household) during the first 1000 days of life, from conception to two years of life (14). The pattern of human growth, during infancy, is plastic and determined by many factors (environmental, household, maternal, genetics) which may vary in the course of the first 1000 days of life, and can be inherited throughout successive generations (14). Infant undernutrition is defined as growth faltering manifests and includes stunting (height-for-age Z-scores below minus two standard deviations (-2SD) of the mean of the WHO standards population), wasting (weight-for-height Z-scores below -2SD of the mean of the WHO standards population) and underweight (weight-for-age Z-scores below -2SD of the mean of the WHO standards population) (3, 7).

In the UNICEF conceptual framework of maternal and children undernutrition, three categories of causes were reported: basic, underlying and immediate causes (7) reflecting pathways linking maternal undernutrition, impaired foetal growth and infant undernutrition (9, 14, 72, 241). Maternal undernutrition status has been described as a consequence of inadequate food or dietary intake, illness, mental stress and non-medical factors such as socioeconomic factors. Maternal undernutrition (a risk factor for low birth weight), low birth weight, inappropriate feeding practices during infancy and inadequate access to Water, Sanitation and Hygiene (WASH) facilities were found to be the most frequent predictors of stunting in children under two years of age (114). In line with the intergenerational effects hypothesis, maternal age, gestational age and birth weight are predictors of the nutritional status in childhood in low income settings (65). Low birth weight has been associated with stunting in Kenyan, Indonesian (242), and Nepalese children (243) under 2 years of age. Furthermore, women who exclusively breastfed for 6 months and those who

breastfed for less than 2 years were more likely to have children under 2 years of child age with stunting in Ethiopia (244).

Causes of maternal and child undernutrition are interrelated, and socioeconomic factors are amongst the basic causes of infant growth earlier in the life course according to the UNICEF conceptual framework (7). Socioeconomic factors are a multifaceted and have no consensual approach. Socioeconomic factors are defined as prestige, wealth, or position of individuals and groups of individuals in the social structure and their capacity to access to basic resources such as health (proxied by growth) and education (52, 105, 245). Coleman and colleagues in their study (99) linked SES factors to the capital which encompasses financial capital (material resources like income, assets, housing), human capital (non-material resources like education), and social capital (social networks, family connectivity) (52). Education, occupation and income are commonly included as contextual SES measures although they are intertwined and highly correlated (52, 102, 105, 246). They are not interchangeable, each of them shows a specific dimension of the individuals or groups in the society. Education (often defined as number of years or level of schooling completed) is sustainable and easier to collect in comparison to occupation, or income variables that is called a '*volatile SES*' indicator because since 30% standard deviation change in household incomes was recorded between 1970 and 2008 due to the financial crisis and recession in the world (247). Household wealth index (HWI), a composite SES measurement, is an accumulation of income flow in the house and may reflect the SES position (100, 105). Marital status, as a socio-demographic factor at maternal level, has been found to be associated with child growth (140).

Socioeconomic factors have been associated with infant undernutrition in different settings in the world. In sub-Saharan African (SSA) countries, a recent systematic review emphasized that poor maternal and household SES indicators (e.g. maternal education, maternal occupation, household wealth) were associated with adverse birth outcomes such as low birth weight and infant undernutrition (248). In SSA, between 2001 and 2014, socioeconomic inequalities in undernutrition among children younger than 3 years were stratified by wealth (21% gradient between the richest and the poorest mothers), and by education (31% gradient between the highest educated and the educated mothers) (249). Maternal lower level of education and lower household wealth index (HWI) were associated with infant stunting. In Kenya, living in a poor household

was found to be associated with stunting and wasting in infants of 0 to 23 months of age in 2018 (250). Studies also reported the association between marital status and both maternal and child undernutrition in Uganda (251). Other indicators of low socioeconomic status, such as WASH, were found to be predictive of undernutrition (208). In a Bangladeshi study, 60% of the relationships between SES factors and child undernutrition were mediated by mothers and their children's access to unsafe water, unimproved toilets and poor sanitation (208). Studies do not use all the SES indices at the same time, which would help representing different dimension of SES and identifying and disentangling their independent contributions to undernutrition at different period during the first thousand days (pregnancy period and infancy). For instance, while maternal occupation, defined as primary means for earning an income (252), has been associated with lower risk of poor birth outcomes (preterm birth) in SSA (248), its associations with underweight and wasting during infancy were inconsistent (52, 100).

Undernutrition in infancy remains a serious public health problem in South Africa (SA) and has been associated with socioeconomic factors (240). In 2015, 56% (30.4 million) of SA adult population were living in poverty (240). Ohonda and colleagues found that most caregivers were child mothers and that their level of education was an important determinant of infant growth and health (253). In the 2016 South African Demographic Health Survey, most of women 15-49 years old (89%) had achieved the primary level of education, 28.7% of women completed the secondary level of education, 47% were employed, and 7% of women for age-group 25-49 years were married (254). This survey also reported that 32% of mothers exclusively breastfed their infants, and 80% of children were breastfeeding at 6-8 months of age (254). In 2016, 27.4% of South African children under five years of age were stunted, 3% were wasted and 6% were underweight (254). The top five provinces with highest rates of stunting in under five years of age were: Gauteng (34% where Soweto is), Free State (34%), KwaZulu Natal (29%), North West (27%) and Eastern Cape (25%) (254). Most of the stunted children lived in the poorest two quintiles households (36% and 29%, respectively) (254). Mothers of stunted children were more likely to have a lower level of education and experience poverty (254).

Only a few studies have investigated the effects of SES factors on infant nutritional status in SSA, including in South Africa. Therefore, the aim of this study was to investigate the independent

associations between maternal demographic characteristics and household socioeconomic factors and infant growth during the first year of life in Soweto.

6.2 Methods

6.2.1 Study design

This study used data collected as part of a longitudinal prospective study called "*Interactions between nutrition, infection, household environment and care practices on growth and development in infants between birth and one year of age"*, colloquially named the Soweto Baby WASH Study. The study was conducted from 22nd of January 2018 until 24th of March 2019.

6.2.2 Study setting

Recruitment of mother-newborn pairs took place at the Chris Hani Baragwanath Academic Hospital (CHBAH), in South Africa. In the Soweto Baby WASH Study, infant growth was followed at every 36 time points (at birth, every week in the first semester then fortnight in the second semester). A total of five time points of follow-up were made for SES interviews including three visits at the participants' home in Soweto (at 1, 6 and 9 postnatal months) and two visits at the Developmental Pathways for Health Research Unit (DPHRU) (at 6 and 12 months). This study focussed on cross-sectional data at three-time points 1, 6 and 12 months.

6.2.3 Participants

The inclusion criteria were mother-newborn pairs up to 48 hours after delivery, singleton birth, residing in Soweto for the 12 months following birth, birth weight between 2500 and 4000 grams, and gestational age at birth between 37 and 41 weeks of pregnancy. Newborns with any clinical abnormality (functional or malformation), mothers with positive HIV/AIDS status and multiple newborns were excluded from the study.

6.2.4 Data source, measurement and quality

Socioeconomic data were collected by interviews using a structured SES questionnaire including maternal and household socioeconomic status, and maternal socio-demographic factors. The SES questionnaire consisted of open and closed questions and was derived from the Demographic Health Surveys (DHS) (227) and South African National Income Dynamics Study (NIDS) (159). The SES questionnaire included maternal information (education, marital status, income,

occupation) and household characteristics (size, characteristic of houses, assets, energy access, income). Interviews were administrated by trained research assistants (RAs) at 1, 6, 9 and 12 months. Only data obtained at 1, 6, 12 months were analysed in this study.

Additional questionnaires, validated and adapted for this context, were administered at the same time point to assess the access and use of water, sanitation and hygiene (WASH) (255); breastfeeding weaning practices (BWP) (256), and morbidity illness and assessment questionnaire (257).

Anthropometric measurements were done for mothers and newborns/infants. Gestational age at birth was retrieved in weeks of pregnancy from the maternity case record. Birth weight and infant weight and length were measured, using an infant scale to the nearest 50 grams (Seca 376, Hamburg, Germany), and an infantometer to the nearest 0.5 centimetres (Seca 416, UK). Infants were weighed in a supine position on the scale, naked or with light clothes and no shoes. Maternal eight and height were measured on women with slight clothes without shoes (258). Weight was measured to the nearest 50 grams while the height to the nearest 0.5 centimetres (Seca 416, Hamburg, Germany) (258) using an adult electronic scale and a stadiometer (Holtain, UK), respectively (258). Measurements were assessed by two different RAs and the third measurement was assessed when the minimum allowable difference (MAD) was exceeded (258). The MAD of weight and height were 50 grams and 1 centimetre, respectively (258). The infant scale was calibrated daily, and the infantometer was calibrated every week.

6.2.5 Variables of the study

6.2.5.1 Infant growth and undernutrition: HAZ, WHZ and WAZ

Infant growth outcomes were derived from weight, length, and age of infants, Z-scores were calculated using the WHO Anthro plus software and include height-for-age Z-scores or HAZ, weight-for -height Z-scores or WHZ and weight-for-age Z-scores or WAZ at each time point. Infant stunting or chronic undernutrition was defined as height-for-age Z-scores below minus two standard deviations (-2SD) of the median of the WHO standards population, wasting or acute form of undernutrition as weight-for-height Z-scores below -2SD of the median of the WHO standards population and, underweight or both acute and chronic forms was defined as weight-for-age Z-

scores -2SD of the WHO standard population (254, 258, 259). Infant growth outcomes (HAZ, WHZ and WAZ) were calculate using the WHO Anthro plus software (164).

6.2.5.2 Socioeconomic factors

The main SES exposures were maternal education, maternal occupation, maternal income, marital status and household wealth status. Maternal education was collected as the highest level of education completed by the child's mother at the time of the study. Maternal education was therefore categorised as none, no formal, primary, secondary (12 grades) or tertiary level (college and university level). The level of education was then aggregated into two main categories. Category 1 included mothers with no education, no formal education and primary school (grades 0 to 8). Category 2 included mothers with secondary level (grade 9 to 12) and tertiary level of education (colleges or university). Maternal occupation referred to the type of main employment three months before the interview and was aggregated as employed or unemployed. Maternal income (the average monthly amount earned) was aggregated as a range of either less South African Rand (ZAR)-900, ZAR-900 to ZAR-3600 and above ZAR-3600. Marital status was defined as the legal maternal marital status (single, widowed, married, divorced or partnership with lobola/dowry) that were aggregated into two categories: living with partner/husband (legal married, marriage with lobola/dowry or cohabitation) vs. living alone (single, widowed, divorced, separated). The HWI, was defined as the ownership of durable assets (electricity, bicycle, motorcycle or bike, fridge, microwave, washing machine, landline telephone, camera, cell phone, television, video machine or digital versatile disc (DVD) player, media network (MNet) or digital satellite television (DStv) or satellite, agricultural land, farm animals, computer or lap top and internet access), housing characteristics (shack, flat or cottage, house, room or garage, residence, hostel, RDP or government housing), house ownership and access to basic services (access to safe water, access to improved sanitation and improved hygiene conditions) (153, 260). The DHS commonly use this wealth index to evaluate inequality in health (260).

6.2.5.3 Covariates

Infant factors (age, sex, infant fever and infant diarrhoea two weeks before the interview), maternal factors (age, BMI, exclusive breastfeeding practice), and household factors (household crowd ratio) were considered as potential confounders. Infant age and sex referred to the number of

months of life at the visit time and the gender of infant, respectively. Infant illness was reported by mother and referred to fever and diarrhoea (loose and liquid stools more than 3 times daily) two weeks before the interview. At maternal level, body mass index was calculated by weight (in kilogram) divided by height (in metre) (7). Exclusive breastfeeding referred to infant who received breastmilk without water or any liquid neither solid, excepted drug and syrup (7). At the household level, social network (relation between the child and the person who looks after the child), household size (number of family relatives in the household) and household crowd ratio (ratio between household size and number of rooms to sleep in the house) were included.

6.2.6 Study size

Trained RAs used eligibility criteria to screen and include participants in the study. **Figure 22** indicates that a total of 1289 mothers and their newborns were screened, and 156 were enrolled in the Soweto Baby WASH study at the CHBAH maternity. The remaining 1133 participants were excluded following the exclusion criteria: maternal HIV status and other co-morbidity (32%), mother not residing in Soweto (25.4%), inappropriate term of pregnancy (prematurity or delivery at < 37 weeks of pregnancy: 9.7% post-maturity or delivery at > 41 weeks of pregnancy: 1.3%, inappropriate birth weight either <2500 grams or >4000 grams (7%), refusal (6.7%), mother less than 18 years old (5%), multiple births (1.7%), incomplete screening and other reasons (2.2%). Participants follow-up was done for 96, 79 and 80 mothers-infant pairs at 1, 6months and 12 months, respectively. Children were included in the analyses when they had data for all the outcomes of interest (HAZ, WHZ and WAZ) at 1, 6 months and 12 months.

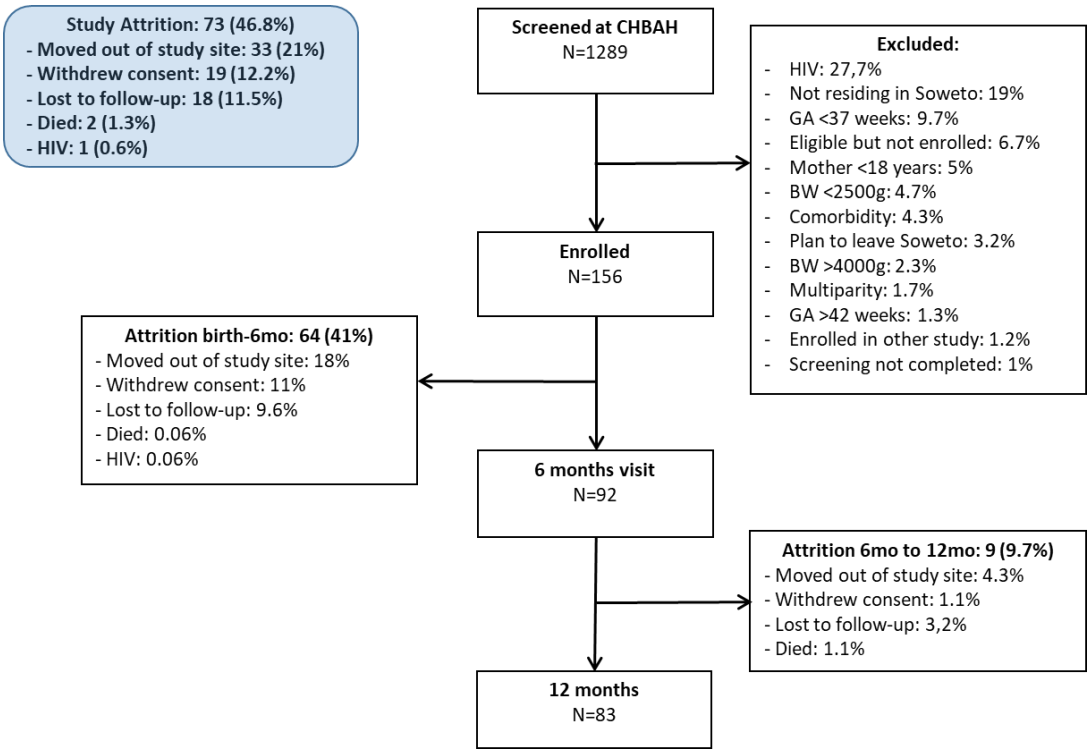

Figure 22: Flow diagram of the Soweto Baby Wash study. HIV: Human immune-deficiency virus; GA: gestational age; BW: birth weight, CHBAH: Chris Hani Academic Baragwanath Hospital.

6.2.7 Bias

High rates of loss of participants due to follow up were limited by strategies including two phone calls before each visit, visits to participants who missed multiple appointments (261). Follow-up visits could minimize loss of participants (262); schedules for participant visits were followed, assessed and updated daily, weekly and monthly.

6.2.8 Statistical analyses

Household wealth index (HWI), which assigns individuals in a relative wealth scale, was built using principal component analysis (PCA) (100). The HWI variable included four following items: household durable assets, housing characteristics, house ownership and access to basic services (100, 260). Household components were weighted by a score, and was standardized and centralized (100). Household wealth was categorized according to the richest category and the poorest category with an equal number of participants in each category.

Descriptive statistics of all the variables were performed at 1, 6 and 12 months and were summarized by proportion, mean and standard deviation, and median and range where appropriate. Hierarchical regression models were done to investigate the association between household SES and maternal socio-demographic factors and HAZ, WHZ and WAZ (261). Three models were built. Model 1 included the main SES variables (maternal education, maternal occupation, income, household wealth index and maternal marital status) and infant growth outcomes (HAZ, WHZ or WAZ). The second model adjusted model 1 for infant factors (birth weight and gestational age at birth). The third model adjusted model 2 for maternal (maternal age, maternal height) and for household factors (household crowd ratio). Infant age and sex were not included in these models as infant growth outcomes are sex and age adjusted. In addition, maternal body mass index was not included in the models as it is highly correlated with maternal height. Other variables (resumed to back to work, infant exclusive breastfeeding, living situation in the marriage) were excluded from the modelling because of the small sample size for some of their categories. As SES variables are not interchangeable and complex, the clustering approach is sensitive to merge similarity within SES data points, whilst distance between SES clusters can be measured. Hierarchical cluster analyses for socioeconomic factors were defined as the organisation of SES variables (maternal education, occupation, income, marital status, household wealth index) in groups based on data sets dissimilarity or similarity. Interactions analyses within maternal sociodemographic characteristics and household SES factors were performed. Regression coefficients were calculated with 95% confidence intervals and the significance level defined at $p<0.05$. Data were collected and stored in Redcap (263), and Stata (version 16) was used for analysis.

6.2.9 Ethics

This study was approved by the Human Research Ethics Committee (HREC) (Medical) at the University of the Witwatersrand (Clearance numbers: M107955 and M170753). The study's researchers were trained on ethical considerations; they informed participants and obtained their written consent before recruitment into the study.

6.3 Results

Table 17: Characteristics of participants in Soweto

Variables	1 month (n=102)	6 months (n=81)	12 months (n=73)
Socioeconomic and demographic factors			
Maternal education (number, percentage)			
None + no formal + primary (Grade 0-8)	68 (71.6)	61 (77.2)	59 (80.8)
Secondary (Grade 8-12) + Tertiary	27 (28.4)	18 (22.8)	14 (19.2)
Maternal occupation (number, percentage)			
Not working	54 (66.7)	55 (70.5)	28 (53.9)
Working	27 (33.3)	23 (29.5)	24 (46.1)
Maternal income ranges (number, percentage)			
< ZAR900	21 (22.1)	11 (14.5)	8 (11.3)
ZAR900 - ZAR3600	29 (30.5)	32 (42.1)	26 (36.6)
≥ ZAR3600	45 (47.4)	33 (43.4)	37 (52.1)
Household wealth index (number, percentage)			
Poorest	46 (50)	34 (50.8)	31 (50.8)
Richest	46 (50)	32 (49.2)	30 (49.2)
Maternal marital status (number, percentage)			
Living with partner (married or cohabitation)	18 (18.8)	21 (27.3)	15 (21.1)
Living alone (single, divorced, widowed, cohabitation)	78 (81.2)	56 (72.7)	56 (78.9)
Infant factors (number, percentage)			
Infant sex (number, percentage)			
Male	53 (52.0)	39 (52.7)	39 (58.2)
Female	49 (48.0)	35 (47.3)	28 (41.8)
Infant age (median, range)			
Birth weight (mean, SD) Weight in kilograms	3.05 (0.35)	-	-
Infant illness (number, percentage)			
Fever (number, percentage)			
No	54 (96.4)	68 (93.2)	68 (91.9)
Yes	2 (3.6)	5 (6.8)	6 (8.1)

Diarrhoea (number, percentage)			
No	54 (98.2)	66 (91.7)	64 (87.7)
Yes	1 (1.8)	6 (8.3)	9 (12.3)
Infant undernutrition and growth (mean, SD)			
Height- for-age Z-score	-0.79 (0.89)	-0.73 (0.96)	-0.68 (0.89)
Weight- for-age Z-score	-0.49 (0.77)	-0.11 (1.09)	-0.18 (1.04)
Weight-for-height Z-score	0.06 (0.96)	0.53 (1.15)	0.21 (1.14)
Stunting (number, percentage)			
No	51 (89.5)	71 (89.9)	64 (88.9)
Yes	6 (10.5)	8 (10.1)	8 (11.1)
Wasting (number, percentage)			
No	57 (96.5)	77 (97.5)	71 (97.3)
Yes	2 (3.5)	2 (2.5)	2 (2.7)
Underweight (number, percentage)			
No	55 (96.5)	77 (97.5)	70 (97.2)
Yes	2 (3.5)	2 (2.5)	2 (2.8)
Maternal and household factors			
Maternal age at delivery (Mean, SD)			
Average age in years	27.5 (5.9)	27.9 (0.6)	28.7 (6.4)
Maternal weight (Mean, SD)			
Average weight in kilograms	71.1 (12.9)	74.3 (16.4)	74.0 (17.7)
Maternal height (Mean, SD)			
Average height in centimetre	157.8 (6.9)	157.8 (7.0)	158.0 (7.0)
Maternal BMI (Mean, SD)			
Average BMI in kg per m2	27.5 (4.9)	29.9 (6.1)	29.9 (6.6)
BMI in kg per m2 (<24.9)	22 (38.6)	16 (21.6)	14 (21.2)
BMI in kg per m2 (>24.9 and plus)	35 (61.4)	58 (78.4)	52 (78.8)
Infant feeding practices (number, percentage)			
Exclusive Breastfeeding (EBF)	3 (2.5)	0 (0.0)	0 (0.0)
No EBF	115 (97.5)	118 (100.0)	73 (100.0)
Caregiver (number, percentage)			
Mother	3 (4.62)	17 (22.7)	27 (37.0)
Other (creche, father, sibling, uncle or ant, neighbour)	62 (95.4)	58 (77.3)	46 (63.0)

Resumed to work (number, percentage)			
No	5 (35.7)	5 (35.7)	7 (58.3)
Yes	9 (64.3)	9 (64.3)	5 (41.7)
Household crowd ratio (mean, SD)	2.8 (1.5)	2.4 (1.1)	2.7 (1.2)

Notes: p-values significance was labelled as ***for p-value=<0.01; **for p-value= between 0.01-0.05; * for p-value= between 0.05-0.1. HAZ: Height-for-age Z-scores, WHZ: Weight-for-height Z-scores; WAZ: Weight-for-age Z-scores; SD: Standard deviation, ZAR: South Africa rand, the currency for South Africa.

Socioeconomic and demographic factors

The sample sizes, at 1, 6 and 12 months, were 102, 81 and 73 participants, respectively (**Table 17**). At 1 month, results showed higher proportions of mothers with lower level of education, who are unemployed, with poor income, and unmarried. The principal component analysis (PCA) was developed to generate HWI at 1 month, 6 months, and 12 months. At 1 month, the first component had an eigenvalue of 3.98 (2.60-5.36) and accounted for 73.8% of the variance. At 6 months, the eigenvalue of the first component was 3.90 (2.75-4.99) accounting for 68.8% of the total variability. At 12 months, the first principal component was 3.91 (2.50-5.32) and accounted for 69.2% of the variance. The most frequent assets in the households (frequency >96%) were electricity, fridge, cell phone and television, motorbike (frequency <4%) was rare in the households. The loadings of factors scores indicated the principal component that should be considered as high SES (positive loadings) or low SES (negative loadings) (264). Hence, having a cell phone was considered as poor SES whilst agricultural land was considered as rich SES in the study. Household wealth indices were similar between the three time points.

Table 18: Simple regression analyses of the association between SES factors with HAZ, WHZ and WAZ in Soweto

Variables	HAZ			WHZ			WAZ		
	1 month Coefficient (95%; CI)	6 months Coefficient (95%; CI)	12 months Coefficient (95%; CI)	1 month Coefficient (95%; CI)	6 months Coefficient (95%; CI)	12 months Coefficient (95%; CI)	1 month Coefficient (95%; CI)	6 months Coefficient (95%; CI)	12 months Coefficient (95%; CI)
Socioeconomic and demographic factors	N= 102			N=81			N=73		
Maternal education									
None+ no formal + primary (Grade 0-8)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Secondary (Grade 8-12) + Tertiary (over grade 12)	0.06 (-0.23 - 0.35)	-0.06 (-0.33 - 0.21)	0.05 (-0.50 - 0.59)	-0.16 (-0.49 - 0.18)	-0.22 (-0.64 - 0.20)	0.08 (-0.54 - 0.70)	-0.03 (-0.30 - 0.24)	-0.20 (-0.56 - 0.17)	0.39 (-0.28 - 1.07)
Maternal occupation									
Working woman	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Not working woman	0.26 (-0.33 - 0.86)	-0.05 (-0.49 -0.48)	1.20 (0.26 - 5.51)	0.29 (-0.30 - 0.88)	-0.19 (-0.77 -0.39)	-0.08 (-0.64 - 0.49)	0.40 (-0.13 - 0.93)	-0.17 (-0.73 - 0.38)	-0.34 (-0.85 - 0.18)
Maternal income ranges									
less ZAR900	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
ZAR900 - ZAR3600	-0.09 (-0.56 - 0.37)	0.25 (-0.42 - 0.91)	0.08 (-0.64 - 0.80)	0.44* (-0.08 - 0.96)	0.22 (-0.58 - 1.02)	-0.04 (-0.96 - 0.89)	0.19 (-0.25 - 0.63)	0.30 (-0.47 - 1.07)	0.01 (-0.82 - 0.85)
More than ZAR3600	-0.03 (-0.46 - 0.39)	0.15 (-0.52 - 0.81)	-0.25 (-0.94 - 0.45)	0.20 (-0.28 - 0.68)	0.02 (-0.77 - 0.82)	-0.26 (-1.15 - 0.62)	0.11 (-0.30 - 0.51)	0.09 (-0.67 - 0.86)	-0.37 (-1.18 - 0.44)
Maternal marital status									
Living with partner (married or cohabitation)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Living alone (single, divorced, widowed, cohabitation)	-0.01 (-0.14 - 0.13)	0.51* (-0.06 - 1.09)	-0.15 (-0.76 - 0.46)	0.35 (-0.22 - 0.93)	0.40 (-0.29 - 1.10)	0.68* (-0.04 - 1.41)	0.24 (-0.24 - 0.73)	059* (-0.06 - 1.25)	0.33 (-0.38 - 1.03)
Household wealth index (HWI)									
Poorest (50%)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Richest (50%)	-0.03 (-0.38 - 0.32)	-0.32 (-0.73 - 0.10)	-0.65*** (- 1.05- -0.24)	-0.05 0.44 - 0.34)	0.32 (-0.22 - 0.86)	0.14 (-0.41 - 0.68)	-0.07 (-0.40 - 0.25)	0.05 (-0.46 - 0.55)	-0.21 (-0.72 - 0.31)
Infant factors									

Birth weight (grams)	1.60*** (1.29 - 1.91)	0.94*** (0.38 - 1.50)	0.93*** (0.35 - 1.51)	1.56 *** (1.18 - 1.93)	0.78*** (0.08 - 1.47)	1.07*** (0.33 - 1.81)	2.15*** (2.09 - 2.21)	1.19 *** (0.57 - 1.81)	1.17*** (0.50 - 1.85)
Maternal and household factors									
Gestational age at delivery (weeks of pregnancy)	0.25 *** (0.14 - 0.36)	0.02 (-0.15 - 0.20)	0.04 (-0.13 - 0.20)	0.03 (-0.10 - 0.15)	-0.02 (-0.23 - 0.20)	-0.09 (-0.30 - 0.12)	0.22*** (0.12 - 0.32)	0.01 (-0.19 - 0.21)	-0.07 (-0.26 - 0.13)
Maternal age at delivery (Mean, SD)	0.00 (-0.02 -0.02)	0.01 (-0.03 - 0.05)	-0.01 (-0.04 - 0.03)	0.02 * (-0.00 - 0.05)	0.01 (-0.04 - 0.05)	0.03 (-0.16 - 0.97)	0.02 (-0.01 - 0.04)	0.01 (-0.03 - 0.06)	0.02 (-0.02 - 0.06)
Maternal height (meter)	0.01 (-0.02 - 0.03)	0.04** (0.01 - 0.07)	4.94*** (2.10 - 7.77)	0.004 (-0.02 - 0.03)	0.01 (-0.03 - 0.05)	4.45** (0.61 - 8.30)	0.01 (-0.02 - 0.03)	0.03* (-0.003-0.057)	5.7*** (2.26 - 9.10)
Household crowd ratio	-0.16* (-0.32 - 0.01)	0.05 (-0.25 - 0.35)	0.001 (-0.21 - 0.21)	0.02 (-0.15 - 0.19)	0.19 (-0.15 - 0.52)	0.15 (-0.07 - 0.37)	0.11 (-0.26 - 0.04)	0.18 (-0.13 - 0.49)	0.15 (-0.06 - 0.36)

Notes: p-values significance was labelled as ***for p-value≤0.01; **for p-value≤0.05; * for p-value≤0.1. CI: Confidence interval. HAZ: Height-for-age Z-scores, WHZ: Weight-for-height Z-scores; WAZ: Weight-for-age Z-scores; SD: Standard deviation, ZAR: South Africa rand, South African currency

Infant factors

The mean birth weight was 3.05 [Standard deviation (SD): 0.3] kilograms (**Table 18**). The proportion of infants who had experienced fever and diarrhoea was less than 10%. Diarrhoea was more frequent at 6 months and 12 months compared to fever. The proportion of stunting, wasting, and underweight remained similar at each time point. However, the proportion of stunted infants was higher compared to wasting and underweight at each time point. The proportion of stunting, wasting and underweight were estimated respectively between 10.5 to 11.1%, 3.5 to 2.7% and 3.5 to 2.8% between 1 month and 12 months.

Maternal and household factors

The mean of maternal age, weight and height were 27.7 (SD: 6.1) years, 71.1 (SD: 12.9) kilograms and 157.8 (SD: 6.9) centimetres at 1 month, 27.9 (SD: 5.9) years, 74.3 (SD: 16.4) kilograms and 157.8 (SD: 14.0) centimetres at 6 months and 28.7 (SD: 6.0) years, 74.0 (SD: 17.7) kilograms and 158.0 (SD: 0.1) centimetres at 12 months. Most mothers were overweight or obese at 1 month (61.4%), 6 months (78.4%) and 12 months (78.8%). Majority of infants were not looked after by their mothers and were not breastfed. The household crowd was more than 2 persons per room

Association between socioeconomic and demographic factors and HAZ, WHZ and WAZ

Table 18, presents the univariate analyses of the associations between growth outcomes and SES and infant, maternal and household factors at each time points. At 1 month, HAZ, WHZ and WAZ were positive associated with birth weight and HAZ and WAZ with gestational age. Weight-height-Z-scores was positively associated with income range ZAR900 -ZAR3600. At 6 months, HAZ was positively associated with birth weight and maternal height. Weight-for-age Z-scores was positively associated with birth weight. At 12 months, HAZ was positively associated with HWI. Weight-for-height Z-scores was positively associated with birth weight. Weight-for-age Z-scores was positively associated with birth weight and maternal height.

Table 19: Multivariable linear regression analyses of the association between SES factors with HAZ in Soweto

Variables	HAZ at 1 month			HAZ at 6 months			HAZ at 12 months		
	Model 1 Coefficient (95%; CI)	Model 2 Coefficient (95%; CI)	Model 3 Coefficient (95%; CI)	Model 1 Coefficient (95%; CI)	Model 2 Coefficient (95%; CI)	Model 3 Coefficient (95%; CI)	Model 1 Coefficient (95%; CI)	Model 2 Coefficient (95%; CI)	Model 3 Coefficient (95%; CI)
Demographic and SES exposures	102			81			73		
Maternal education (level of education)	34	28	22	61	68	35	68	66	47
None+ no formal + primary (Grade 0-8)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Secondary (Grade 8-12) + Tertiary (over grade 12)	-0.21 (-0.97-0.54)	-0.06 (-0.66-0.45)	-0.07 (-0.93 - 0.78)	-0.001 (-0.66 -0.66)	-0.01 (-0.57-0.55)	-0.17 (-0.80 - 0.46)	0.19 (-0.35 - 0.73)	0.09 (-0.42 - 0.60)	-0.06 (-0.63 - 0.1)
Maternal occupation									
Employed	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Unemployed	0.29 (-0.46 -1.06)	-0.22 (-0.91-0.47)	-0.37 (-1.46-0.73)	0.14 ('-0.51-0.79)	0.01 (-0.46 -0.48)	0.47 (-0.21 - 1.16)	-0.17 (-0.70 - 0.36)	-0.12 (-0.61 - 0.37)	0.16 (-0.41 - 0.72)
Maternal income ranges (amount range)									
less ZAR900	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
less ZAR900-ZAR3600	-0.29 (-1.27 -0.68)	0.31 (-0.47-1.10)	0.32 (-0.79 - 1.44)	0.37 (-0.54-1.29)	-0.21 (-1.04 - 0.62)	0.08 (-1.14 - 0.98)	-0.03 (-0.74 -0.69)	0.06 (-0.65 - 0.77)	-0.35 (-1.17 -0.47)
ZAR3600 and plus	0.01 (-0.87- 0.88)	0.30 (-0.43-1.04)	0.37 (-0.73-1.47)	0.42 (-0.53 1.37)	-0.05 (-0.89 - 0.80)	-0.12 (-1.12 - 0.88)	-0.24 (-1.01 - 0.53)	-0.11 (-0.87 -0.65)	-0.49 (-1.35 -0.36)
Maternal marital status									
Living with partner (married or cohabitation)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Living alone (single, divorced, widowed, cohabitation)	-0.32 (-1.17 -0.53)	-0.61* (-1.34-0.12)	-0.70 (-1.79-0.39)	0.03 (-0.57-0.62)	-0.12 (-0.62 - 0.39)	0.17 (-0.53 - 0.86)	0.26 (-0.28 - 0.80)	0.09 (-0.43 - 0.61)	0.13 (-0.47 - 0.74)
Household wealth index (HWI)									
Poorest (50%)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Richest (50%)	0.21 (-0.51-0.92)	0.27 (-0.32-0.87)	0.08 (-0.90 -1.06)	-0.50* (-1.07-0.07)	-0.34 (-0.86 - 0.17)	-0.64* (-1.37-0.09)	-0.65*** (-1.07--0.23)	-0.61*** (-1.00--0.22)	-0.68*** (-0.16 - -0.21)
Infant factors									
Birth weight (grams)		1.64*** (0.99 - 2.29)	1.87*** (0.76 -2.98)		0.57*** (0.33 - 0.80)	0.54*** (0.18 - 0.88)		0.30*** (0.13 - 0.47)	0.52*** (0.31 - 0.73)
Gestational age (weeks of pregnancy)		0.14 (-0.09-0.36)	-0.02 (-0.42-0.38)		0.04 (-0.14-0.23)	0.18 (-0.11 - 0.46)		0.05 (-0.11 -0.21)	0.06 (-0.09 -0.21)
Maternal and household factors									
Maternal age at delivery (Mean, SD)			0.08 (-0.06 - 0.22)			0.002 (-0.05 - 0.05)			-0.01 (-0.05 - 0.02)

Maternal height (kg)			-0.02 (-0.10- 0.07)			-0.01* (-0.06 - 0.04)			0.12 (-0.02 - 0.04)
Household crowd ratio (mean, SD)			-0.11 (-0.50 - 0.28)			-0.07 (-0.39 - 0.25)			-0.20** (-0.40--0.01)

Table 19 show that when infants live in a rich household, the mean of HAZ significantly decreased by 0.64 and 0.68 at 6 and 12 months respectively when adjusted for infant, maternal and household factors. The coefficient of this association between HWI and HAZ was higher at 6 months compared to 12 months. Maternal education, income, occupation and marital status were not significantly associated with HAZ at any time point

Variables	HAZ at 1 month			HAZ at 6 months			HAZ at 12 months		
	Model 1 Coefficient (95%; CI)	Model 2 Coefficient (95%; CI)	Model 3 Coefficient (95%; CI)	Model 1 Coefficient (95%; CI)	Model 2 Coefficient (95%; CI)	Model 3 Coefficient (95%; CI)	Model 1 Coefficient (95%; CI)	Model 2 Coefficient (95%; CI)	Model 3 Coefficient (95%; CI)
Demographic and SES exposures	102			81			73		
Maternal education (level of education)	34	28	22	61	68	35	68	66	47
None+ no formal + primary (Grade 0-8)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Secondary (Grade 8-12) + Tertiary (over grade 12)	-0.21 (-0.97-0.54)	-0.06 (-0.66-0.45)	-0.07 (-0.93 - 0.78)	-0.001 (-0.66 -0.66)	-0.01 (-0.57-0.55)	-0.17 (-0.80 - 0.46)	0.19 (-0.35 - 0.73)	0.09 (-0.42 - 0.60)	-0.06 (-0.63 - 0.1)
Maternal occupation									
Employed	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Unemployed	0.29 (-0.46 -1.06)	-0.22 (-0.91-0.47)	-0.37 (-1.46-0.73)	0.14 ('-0.51-0.79)	0.01 (-0.46 -0.48)	0.47 (-0.21 - 1.16)	-0.17 (-0.70 - 0.36)	-0.12 (-0.61 - 0.37)	0.16 (-0.41 - 0.72)
Maternal income ranges (amount range)									
less ZAR900	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
less ZAR900-ZAR3600	-0.29 (-1.27 -0.68)	0.31 (-0.47-1.10)	0.32 (-0.79 - 1.44)	0.37 (-0.54-1.29)	-0.21 (-1.04 - 0.62)	0.08 (-1.14 - 0.98)	-0.03 (-0.74 -0.69)	0.06 (-0.65 - 0.77)	-0.35 (-1.17 -0.47)
ZAR3600 and plus	0.01 (-0.87- 0.88)	0.30 (-0.43-1.04)	0.37 (-0.73-1.47)	0.42 (-0.53 1.37)	-0.05 (-0.89 - 0.80)	-0.12 (-1.12 - 0.88)	-0.24 (-1.01 - 0.53)	-0.11 (-0.87 -0.65)	-0.49 (-1.35 -0.36)
Maternal marital status									
Living with partner (married or cohabitation)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Living alone (single, divorced, widowed, cohabitation)	-0.32 (-1.17 -0.53)	-0.61* (-1.34-0.12)	-0.70 (-1.79-0.39)	0.03 (-0.57-0.62)	-0.12 (-0.62 - 0.39)	0.17 (-0.53 - 0.86)	0.26 (-0.28 - 0.80)	0.09 (-0.43 - 0.61)	0.13 (-0.47 - 0.74)
Household wealth index (HWI)									
Poorest (50%)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Richest (50%)	0.21 (-0.51-0.92)	0.27 (-0.32-0.87)	0.08 (-0.90 -1.06)	-0.50* (-1.07-0.07)	-0.34 (-0.86 - 0.17)	-0.64* (-1.37-0.09)	-0.65*** (-1.07--0.23)	-0.61*** (-1.00--0.22)	-0.68*** (-0.16 - -0.21)
Infant factors									
Birth weight (grams)		1.64*** (0.99 - 2.29)	1.87*** (0.76 -2.98)		0.57*** (0.33 - 0.80)	0.54*** (0.18 - 0.88)		0.30*** (0.13 - 0.47)	0.52*** (0.31 - 0.73)
Gestational age (weeks of pregnancy)		0.14 (-0.09-0.36)	-0.02 (-0.42-0.38)		0.04 (-0.14-0.23)	0.18 (-0.11 - 0.46)		0.05 (-0.11 -0.21)	0.06 (-0.09 -0.21)
Maternal and household factors									
Maternal age at delivery (Mean, SD)			0.08 (-0.06 - 0.22)			0.002 (-0.05 - 0.05)			-0.01 (-0.05 - 0.02)

Maternal height (kg)			-0.02 (-0.10- 0.07)			-0.01* (-0.06 - 0.04)			0.12 (-0.02 - 0.04)
Household crowd ratio (mean, SD)			-0.11 (-0.50 - 0.28)			-0.07 (-0.39 - 0.25)			-0.20** (-0.40--0.01)

Notes: p-values significance was labelled as ***for p-value≤0.01; **for p-value≤0.05; * for p-value≤0.1. CI: Confidence interval. HAZ: Height-for-age Z-scores, WHZ: Weight-for-height Z-scores; WAZ: Weight-for-age Z-scores; SD: Standard deviation, ZAR: South Africa rand, South African currency.

Table 20: Multivariable linear regression analyses of the association between SES factors with WHZ in Soweto

	WHZ at 1 months			WHZ at 6 months			WHZ at 12 months		
	Model 1 Coefficient (95%; CI)	**Model 2 Coefficient (95%; CI)**	**Model 3 Coefficient (95%; CI)**	**Model 1 Coefficient (95%; CI)**	**Model 2 Coefficient (95%; CI)**	**Model 3 Coefficient (95%; CI)**	**Model 1 Coefficient (95%; CI)**	**Model 2 Coefficient (95%; CI)**	**Model 3 Coefficient (95%; CI)**
Main SES exposures									
Maternal education (level of education)	61	33	22	70	68	41	68	66	47
None+ no formal + primary (Grade 0-8)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Secondary (Grade 8-12) + Tertiary (over grade 12)	0.14 (-0.60 - 0.87)	0.09 (-0.57 - 0.75)	0.22 (-1.00 - 1.44)	0.12 (-0.651 - 0.76)	0.12 (-0.31 - 0.55)	0.29 (-0.27 - 0.85)	0.36 (-0.37 -1.08)	0.01 (-0.23 - 0.26)	-'0.01 (-0.32 - 0.30)
Maternal occupation									
Working woman	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Not working woman	0.06 (-0.66 - 0.78)	-0.05 (-0.74 -0.64)	0.31 (-1.26 - 1.87)	-0.06 (-0.76 - 0.65)	-0.20 (-0.63 -0.24)	-0.36 (-0.97 - 0.26)	0.06 (-0.65 - 0.78)	0.16 (-0.08 - 0.39)	0.05 (-0.26 - 0.36)
Maternal income ranges (amount range)									
less ZAR900	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
less ZAR900-ZAR3600	0.42 (-0.59 -1.44)	-0.02 (-0.87 - 0.91)	-0.34 (-1.93 - 1.25)	-0.08 (-0.98 - 0.82)	-0.21 (-0.77 - 0.36)	-0.17 (-0.05 - 0.70)	-0.15 (-1.10 - 0.80)	0.16 (-0.18 - 0.50)	0.09 (-0.37 - 0.54)
ZAR3600 and plus	0.37 (-0.68 - 1.42)	0.05 (-0.72 - 0.82)	-0.48* (-2.06 - 1.09)	-0.35 (-1.28 - 0.57)	-0.16 (-0.74 - 0.42)	0.12 (-0.66 - 0.91)	-0.62 (-1.64 - 0.40)	0.01 (-0.36 - 0.38)	-0.03 (-0.49 - 0.44)
Maternal marital status									
Living with partner (married or cohabitation)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Living alone (single, divorced, widowed, cohabitation)	0.52 (-1.14 - 1.17)	0.07 (-0.68 - 0.82)	0.96 (-0.60 -2.51)	0.31 (-0.35 - 0.97)	0.10 (-0.29 - 0.50)	-0.03 (-0.66 - 0.60)	-0.58 (-0.13 - 1.30)	-0.04 (-0.29 - 0.21)	-0.06 (-0.39 - 0.26)
Household wealth index (HWI)									
Poorest (50%)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Richest (50%)	-0.03 (-0.67 - 0.60)	0.16 (-0.49 - 0.81)	-0.08 (-1.47 - 1.32)	0.43 (-0.17 - 1.04)	0.38** (0.01 - 0.75)	0.32 (-0.27 - 0.91)	0.79 (-0.48 - 0.64)	0.31*** (0.12 - 0.49)	0.28** (0.01 - 0.54)

Infant factors									
Birth weight (grams)		1.73*** (0.88 - 2.58)	1.53** (0.09 - 2.97)		0.91*** (0.74 - 1.09)	0.87*** (0.58 - 1.15)		0.92*** (0.84 - 1.01)	0.88*** (0.75 - 1.01)
Gestational age (weeks of pregnancy)		-0.22 (-0.48 - 0.05)	-0.10 (-0.59 -0.40)		-0.01 (-0.15 - 0.13)	-0.10 (-0.37 -0.17)		-0.04 (-0.12 - 0.03)	-0.04 (-0.14 - 0.05)
Maternal and household factors									
Maternal age at delivery (Mean, SD)			-0.06 (-020 - 0.08)			0.01 (-0.04 - 0.05)			0.01 (-0.01 - 0.04)
Maternal height (kg)			0.02 (-0.10 - 0.14)			-0.02 (-0.06 - 0.03)			0.60 (-1.67 - 2.86)
Household crowd ratio (mean, SD)			0.09 (-0.47 - 0.65)			0.03 (-0.31 - 0.25)			0.04 (-0.07 - 0.14)

Notes: p-values significance was labelled as ***for p-value≤0.01; **for p-value≤0.05; * for p-value≤0.1. CI: Confidence interval. HAZ: Height-for-age Z-scores, WHZ: Weight-for-height Z-scores; WAZ: Weight-for-age Z-scores; SD: Standard deviation, ZAR: South Africa rand, South African currency

Table 21: Multivariable linear regression analyses of the association between SES factors with WAZ in Soweto									
Variables	WAZ at 1 months			WAZ at 6 months			WAZ at 12 months		
	Model 1 Coefficient (95%; CI)	**Model 2 Coefficient (95%; CI)**	**Model 3 Coefficient (95%; CI)**	**Model 1 Coefficient (95%; CI)**	**Model 2 Coefficient (95%; CI)**	**Model 3 Coefficient (95%; CI)**	**Model 1 Coefficient (95%; CI)**	**Model 2 Coefficient (95%; CI)**	**Model 3 Coefficient (95%; CI)**
Main SES exposures									
Maternal education (level of education)	70	33	22	34	68	41	68	66	66
None+ no formal + primary (Grade 0-8)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Secondary (Grade 8-12) + Tertiary (over grade 12)	0.27 (-1.03 - 0.48)	0.001 (-0.12 - 0.13)	0.04 (-0.13 - 0.21)	0.00* (-0166 - 0.66)	0.06 (-0.19 - 0.31)	0.13 (-0.18 - 0.45)	0.35 (-0.32 - 1.02)	-0.03 (-0.21 - 0.26)	-0.06 (-0.32 - 0.20)
Maternal occupation									
Working woman	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Not working woman	0.37 (-0.39 - 1.13)	-0.01 (-0.14 - 0.12)	-0.18* (-0.40 - 0.03)	0.85 (-0.58 - 0.75)	-0.06 (-0.32 - 0.19)	-0.04 (-0.38 - 0.30)	-0.07 (-0.72 - 0.58)	0.04 (-0.18 - 0.27)	0.11 (-0.15 - 0.37)
Maternal income ranges (amount range)									
less ZAR900	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
less ZAR900-ZAR3600	-0.14 (-1.11 - 0.82)	0.05 (-0.11 - 0.22)	0.11 (-0.11 - 0.34)	-0.13 (-0.71 -0.98)	-0.09 (-0.42 - 0.25)	-0.06 (-0.55 - 0.42)	-0.12 (-0.99-0.76)	0.17 (-0.16 - 0.49)	0.08 (-0.46 - 0.29)
ZAR3600 and plus	0.23 (-0.65 - 1.10)	0.05 (-0.09 - 0.19)	0.09 (-0.13 - 0.31)	0.03 (-0.89 - 0.84)	0.09 (-0.25 - 0.43)	0.11 (-0.33 -0.55)	-0.57 (-1.52-0.38)	0.02 (-0.37 - 0.32)	-0.24 (-0.64 - 0.15)
Maternal marital status									
Living with partner (married or cohabitation)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Living alone (single, divorced, widowed, cohabitation)	-0.35 (-1.20 - 0.50)	-0.06 (-0.20 -0.08)	0.04 (-0.18 - 0.26)	0.35 (0.26 - 0.97)	0.15 (-0.09 - 0.38)	0.17 (-0.18 - 0.52)	0.54 (-0.13 - 1.20)	-0.02 (-0.25 - 0.22)	0.002 (-0.27 - 0.28)
Household wealth index (HWI)									
Poorest (50%)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Richest (50%)	0.18 (-0.53 - 0.89)	0.03 (-0.09 - 015)	0.03 (-0.23 - 0.16)	0.08 (-0.49 - 0.65)	-0.01 (-0.23 - 0.21)	-0.14 (-0.47 - 0.19)	-0.24 (-0.77 - 0.28)	0.05 (-0.23 - 0.13)	-0.11 (-0.33 - 0.11)
Infant factors									
Birth weight (kilograms)		2.21*** (2.04 - 2.37)	2.17*** (1.97 - 2.37)		0.98*** (0. 88 -1.08)	0.99*** (0.84 - 1.16)		0.85*** (0.77 - 0.93)	0.82*** (0.70 - 0.93)

Gestational age (weeks of pregnancy)		0.01 (-0.04 - 0.6)	0.02 (-0.05 - 0.09)		0.03 (-0.05 - 0.12)	0.02 (-0.14-0.17)		-0.01 (-0.08 - 0.64)	-0.02 (-0.10 -0.06)
Maternal and household factors									
Maternal age at delivery (Mean, SD)			-0.001 (-0.02 - 0.02)			0.003 (-0.02-0.03)			0.01 (-0.01 - 0.02)
Maternal height (centimetre)			0.003 (-0.01 - 0.02)			-0.002 (-0.02 - 0.03)			1.30 (-0.60 - 3.20)
Household crowd ratio (mean, SD)			-0.07* (-0.14 - 0.01)			-0.12 (-0.27-0.04)			-0.07 (-0.15 - 0.2)

Notes: p-values significance was labelled as ***for p-value≤0.01; **for p-value≤0.05; * for p-value≤0.1. CI: Confidence interval. HAZ: Height-for-age Z-scores, WHZ: Weight-for-height Z-scores; WAZ: Weight-for-age Z-scores; SD: Standard deviation, ZAR: South Africa rand, South African currency

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Table 19 show that when infants live in a rich household, the mean of HAZ significantly decreased by 0.64 and 0.68 at 6 and 12 months respectively when adjusted for infant, maternal and household factors. The coefficient of this association between HWI and HAZ was higher at 6 months compared to 12 months. Maternal education, income, occupation and marital status were not significantly associated with HAZ at any time point.

Table 20: Multivariable linear regression analyses of the association between SES factors with WHZ in Soweto With regards to the WHZ (

Table 20), the multivariate analyses show that at 1 month, when the infant lives in a household with estimated income above ZAR-3600, the mean of WHZ marginally increased by 0.48 when adjusted for infant, maternal and household factors. When the infant lives in a rich household, the mean of WHZ significantly increased by 0.28 at 12 months when adjusted for infant, maternal and

household factors. Maternal education, occupation and marital status were not significantly associated with WHZ at any time point.

Maternal education, income, occupation and marital status, and household wealth index were not significantly associated with WAZ during the first year of life (**Table 21**). Negative and marginal associations were found between WAZ and having an unemployed mother and the household crowd ratio (**Table 21**).

The cluster analyses described three categories: HWI with maternal education (first cluster), maternal occupation with income (second cluster) and maternal marital status (third cluster). Interactions were found between sociodemographic factors and SES factors (data no shown), and showed the beta coefficients of model 3 for SES factors and the interactions between SES factors which were significantly associated with growth outcomes. At 6 months, infants living in poorer household with mothers with a higher level of education (secondary (Grade 8-12) + tertiary) were more likely to have a lower WHZ (-1.39; 95% CI: -2.58 - -0.20) but a higher HAZ (1.19; 95% CI: 0.01 – 2.37) compared to infants in poorer households but with mothers with a lower education. However, at 12 months, infants living in poorer households with mothers with a higher education were more likely to have higher WHZ (0.72; 95% CI: 0.18 – 1.25) compared to children in poorer households but with mothers with a lower education.

6.4 Discussion

Main results

In agreement with the recent systematic review on the associations between SES factors and infant growth outcomes in SSA (248), this study found that the household wealth index was consistently associated with infant growth. However, in this study, we found that living in a rich household (higher HWI) was negatively associated with infant linear growth (HAZ) at 12 months; but it was positively associated with WHZ at 12 months, and no associations were found with WAZ. There were no associations between maternal education, occupation, income and marital status with infant growth outcomes (HAZ, WHZ and WAZ). As expected, birth weight and maternal height

were strongly associated with infant growth. There was an association between HAZ and the household crowd ratio at 12 months particularly.

Our findings suggest that in better off household children are more likely to gain in weight but experience poor linear growth in height in the first year of life. In the sub-Sahara African context, weight gain rather than gain in height in the first year of life has been shown to be associated with household poverty conditions (9, 265). These results reflect the reality of undernutrition in the context of the nutrition transition, which describes the transition from an healthy diet rich in micronutrients to an excessive consumption of sugar and fat, and the persistence of undernutrition (162, 169, 266) resulting in the double/triple burden of malnutrition in poor households as well as in countries in transition (97). Therefore, the rapid nutrition transition experienced in South Africa may partly explain these results together with the lower rates of exclusive breastfeeding (9, 97, 267). In South Africa, despite nutrition programs promoting exclusive breastfeeding during the first six months postnatally, early cessation of exclusive breastfeeding and introduction of inadequate complementary food have been observed (268). In the pooled analyses of data from longitudinal cohorts in five low- and middle- income countries experiencing rapid nutrition transition (Brazil, India, South Africa, Philippines, Guatemala), there was evidence of rapid gain weight of the infant due to accumulation of fat (central adiposity) resulting in high risk of non-communicable diseases in adulthood (9). Further analyses of the Soweto Baby WASH data will explore the association between SES and infant body composition from birth through one year of age.

In this study we used SES contextual variables (the environment that influences infant growth such as household wealth index) and compositional variable (defined as personal or interpersonal characteristics of individuals such as maternal education, occupation and income) to assess their respective and independent relationships with infant growth. We found that in this context, household wealth index was the only SES proxy variable associated with infant growth. This is consistent with results from 146 surveys in 39 low- and middle-income countries which reported an increase of the composite anthropometric index factor in children under three years of age (CAIF, meaning being either stunted, or wasted and underweighted) with the poverty level (estimated by education level and wealth index expressed in quartiles) (249). Household wealth was measured by ownership of durable assets and was built over a fairly long period of time,

including before the conception of the index child and is therefore a long term and reliable determinant of maternal health and infant growth prior to pregnancy, during pregnancy and after birth. This is consistent with recent epidemiological findings showing that infant growth is dependent on maternal health from the pre-pregnancy period (269). Using the wealth index to assess household and maternal wealth may yield significant results in the identification of socioeconomically vulnerable households and the planning of programs to improve child growth.

Results from a recent systematic review found that high HWI and high level of maternal education were associated with low risk of stunting whilst being a working mother was inconsistently associated with infant undernutrition at birth and during infancy (due to the unavailability of working mothers) (248). However, in this study, the association between compositional SES variables (maternal education, occupation, and income) and infant growth were either marginal or not significant. In the Birth-to-Twenty prospective cohort study in Soweto, which started thirty years ago, it was found that high HWI was protective against stunting at two years of age for males and high level of maternal education was protective against stunting only in female infants (270). The rate of mothers with a primary level of education have increased since birth to twenty study which was conducted thirty years ago (271). The majority of women in this study were living alone and unemployed, and their infants were mainly taken care of by relatives and other formal structures (contrary to the Birth-to-Twenty prospective cohort study) (253), as women possibly seek for economic resources (272). In the context of low- and middle-income countries, household wealth measured as the accumulation of income flow remains a volatile and fluctuating proxy of household and maternal SES, especially in the context of other income flows such as debts and support received from family members, which are difficult to quantify (100). For women of this study who were employed, they tend to have to get back to work early (mostly before the first postnatal month) because of their types of work being mostly informal (without a formal maternity leave). In the South African context, these maternal socioeconomic factors explain why they were not able to practice optimal breastfeeding, with high risk of unhealthy and no-nutritious diet/food introduced before the first birthday (268).

This study also emphasized the intergenerational effect and the associations between maternal nutrition and health and infant growth from birth to 1 year. This study supports that birth weight and maternal weight are associated with weight gain and growth in length in the first year of life

(65). Corroborating the Developmental Origins of Health and Disease paradigm (1), these findings confirm the importance of maternal size and health prior to pregnancy and during pregnancy on infant growth and nutritional status in the first 1000 days as found in multi-country studies (9, 211) in Nepal (243) and in SSA. Studies have found that socioeconomic factors exert further and cumulative effects to maternal biological factors on infant growth. Maternal height and number of years of maternal education were negatively associated with HAZ in infants under two years of age (273). In a South African study in Paarl, Budree and colleagues (240) found that SES factors (HWI quartile including a score of education, income, employment and assets) and maternal height were the main drivers of infant growth. These findings illustrate two theories linking the notions of capital, particularly human capital, and human health. These observations are in line with Coleman's SES stratification which indicated that SES factors are correlated with maternal capital (e.g. material asset ownership) (99), human capital (e.g. knowledge, education, skills, health) (99) and social capital (e.g. parenting function) (99, 152). Grossman (274) explained the relations between the components of human capital whereby improved knowledge and skills enables maternal employment resulting in improved income flow into the household, and better health care options for infants and other family members in the household. Thus, SES factors embedded in the wider concept of capital determine access to basic resources, which in turn influence health across the household ecosystem, including infant growth and nutritional status (99).

Limitations

The HWI is considered as the most reliable SES factor compared to income, occupation and education, but it remains a sensitive topic in vulnerable populations (100, 153). In this study, we identified that the collection of assets information was sometimes challenged when mothers were interviewed out of their houses (e.g. at in-law families or other houses where they spent the whole day). However, the HWI allowed for this as it has various constructs with many interpretations related to the study setting and local culture (105). In this study, the HWI is constructed based on available assets, house ownership, and type of house as well as water, sanitation and hygiene (WASH) variables (275). However, clustering and truncation phenomenon have been reported to challenge the computation of the PCA based on assets (100). Truncation refers to how households

may be deduced over small categories of HWI challenging the distinction between HWI categories (100); it refers to the issues of allocation of households in the HWI categories (100).

The small sample size of this study did not allow to measure the gradient of SES (inequality in infant growth) positions in undernutrition as suggested by Wagstaff et al. (276). Due to the unavailability of working mothers, the SES interviews were challenging and sometimes not feasible, even with a relative who was acting as caregiver. To overcome this issue, interviews were made by phone call with mothers with later confirmation of information provided at the next visit. Household wealth index was calculated based on questionnaires like as DHS where assets were selected based on their availability at the moment of the survey (277). Therefore, we mixed DHS and NIDS questionnaires to increase the range of assets covered in the questionnaire.

6.5 Conclusion

The household wealth index is a relevant and reliable correlate of infant growth and nutritional status in low-income country and middle- income countries experiencing the nutrition transition as in South Africa. In South Africa, our findings suggest that social and economic policies may increase their impact on infant growth and nutritional status by alleviating poverty at the household level and by improving and reinforcing existing social support (the access to) and economic resources (employment, social grants) from pregnancy to two postnatal years. Maternity leave duration policy should be revisited to allow low SES mothers maximise optimal feeding practices and the overall care of their infant.

PART 3 (CHAPTER 7): INTEGRATED DISCUSSION

7.1 Summary table

Within this section, a summary of the findings from this research is given based on the specific objectives of each study. The **Table 22** presents the summary by clearly showing the key outcomes, which are related as well as complementary. Hereafter, these results are discussed in detail.

Table 22: Tables of the overall results of the thesis

Objectives	Key results
Objective 1: **To review the evidence on the association between household SES and maternal socio-demographic characteristics with birth and infant undernutrition outcomes in 46 SSA countries.**	1. It was confirmed that there is paucity of the evidence on the association between household and maternal SES factors and poor infant growth in early life in SSA. 2. Contrasting SES definitions (definition, measures) across studies is challenging a meta-analysis on the relationship between household and maternal SES factors and infant growth. 3. Maternal education, occupation and household wealth were the main SES factors associated with birth outcomes and infant growth in SSA. 4. Role of maternal occupation on infant growth was inconsistent. 5. Maternal marital status was not associated with infant growth in SSA
Objective 2: **To compare the association between maternal socio-demographic characteristics and household SES during pregnancy with PTB, LBW and SGA in the DRC and SA.**	1. Local/regional context matters when assessing the association between maternal and household socioeconomic and household factors and birth outcomes in SSA. 2. In pooled analyses of both countries (the DRC and SA), data support that maternal education is a critical determinant of birth outcomes across sub-Saharan African countries. 3. Maternal education, housing and marital status are the main factors associated with birth outcomes in the DRC and SA.

Objective 3: **To assess the relationship between maternal socio-demographic characteristics and household SES with infant undernutrition (stunting, wasting and underweight) between birth to one year of age in SA.**	1. Living in a wealthier household is associated with a decrease in HAZ and an increase in WHZ at 12 months of age. 2. Maternal marital status, occupation, income and education were not associated with infant growth during the first year of life. 3. Employed mothers resume work early and unemployed mothers may have to look for means of survival, leaving their children with family members (grandmothers, siblings) or at a kindergarten. Infant care may be altered (EBF, health and emotional care), exposing the child to early malnutrition

7.2 Emerging Themes

7.2.1 Methodology Theme:

The combination of different methodological approaches (review, observational studies) in different settings and countries resulted in new perspectives. This research used a complementary approach to bring forward an original empirical evidence. There are several methodological advantages that emerged from the research. The systematic review approach was relevant to consolidate the evidence that emerged from prior research, identify the bias, and increase the consensus on rigorous evidence (robust and sensitive quality of evidence) compared to single primary studies. In this research, the systematic review was the first to be published in the field of household and maternal SES factors in growth during the first 1000 days in SSA. In the systematic review, the quality of primary articles was equally distributed as high and low quality. The next steps were empirical. The original studies gave the opportunity to increase the number of evidences on the topic as these were shown to be scarce in the systematic review. These data were collected in two countries that have different levels of development which has provided an overview of the impact of different levels of socio-demographic and SES factors on infant growth.

Variables measuring household wealth have presented complex challenges in the DRC, SA and in the systematic review. These variables are based on durable assets in the household and many other household characteristics that reflect the accumulation of income at the household level. However, household assets do not have the same meaning or economic value for different individuals, communities, countries, or regions; or the same interpretation between two periods in

the same place. Hence, the methodological approach of this thesis was to bring wealth, together with other proxies of SES factors (such as maternal demographic factors) in the same analyses, to provide a broader perceptive on the respective roles of different SES dimensions on infant growth. This thesis demonstrated that it is feasible and of benefit to better capture all the dimensions of SES factors and their constructs.

However, the combination of methodological approaches may have some issues. Despite its high quality, the approach chosen was challenged by its resources-consuming nature (time and other resources) due to the duration of the review and the inclusion of two different countries. The cross-sectional studies did not allow any causality analyses. Another issue was the lack of representativeness in the empirical studies by being hospital-based for recruitment of participants which did not allow any generalization or extrapolation of the evidences (from hospital-based study to population/community-based study).

From this research findings, new perspectives should be considered for addressing the concern of the construct of SES indices when dealing with different contextual settings. Firstly, socioeconomic variables have been defined differently, they are known to be difficult to collect and to generate, and they were measured differently, so that their quantitative combination to a composite index was impractical and difficult to interpret, and findings between studies were difficult to compare. It was, therefore, difficult to conduct a meta-analysis for the systematic review and to produce an overall effect size of the association between SES factors and infant growth in SSA. For example, the possession of electricity was common in the households of Soweto in South Africa while it was less frequent and a discriminant factor of wealth in Bunkonde (a rural area in the DRC) where households often use candles and power generators for few rich households when there is lack of electricity. For future perspectives, for example, the number of days of power outage per period (month, quarter) could be a measure of the wealth of households in the DRC. Another difficulty is that household wealth based on available assets is difficult to measure and homogenise in contexts where the assets are lacking in the house. The explanation was that some houses which constitute of only one bedroom were empty with no assets available, and that the asset-based measure of the household wealth became a matter of concern especially when comparing the DRC and SA. Finally, another methodological limitation was financial

resources which did not allow for improvement in the statistical power of the cross-sectional studies (sample size).

This current research with a series of studies found an association between SES and infant growth but the interrelation between demographic and SES components should be of interest as well. From this research project, it was found that education (schooling) is a greater investment that shapes the human capital. Education is correlated to economic factors (assets, income), social support (family, relationship status, support from government), as well as social vulnerability (crowded, marital status). Therefore, SES indices should be based on the aforementioned domains that emerged from this research. The critical next step relates to investigating the interactions between SES factors for better understanding of the weight of these interactions on infant growth in the first thousand days.

7.2.2 Empirical Themes

7.2.2.1 The double burden of malnutrition in transition and poverty contexts:

Infant undernutrition has to be understood as part of double burden of malnutrition context and as an interrelated factor with poverty. Poverty has been associated with changes in food intake (through more sugar, more fat and less vegetable), repetitive inflammation and behaviour changes (sedentary lifestyle and less physical activity) resulting in the persistence of the double/triple burden of malnutrition (undernutrition, overnutrition and micronutrient deficiencies) with serious long-term effects in individuals, in households and in the course of life (extant literature reviewed in the Chapter 2 of this thesis). Also, maternal nutrition (under- and over-) is a critical factor for the double burden of malnutrition in the first 1000 days. Maternal undernutrition is associated with poor birth outcomes and poor linear growth in infancy within nutrition transition contexts. Further, infant undernutrition is associated to maternal overweight (or obesity) with related effects such as maternal metabolic diseases (triiodothyronine, dyslipidaemia, low glycate haemoglobin, high blood pressure). Through the first 1000 days in transition contexts (nutrition, epidemiological, demographic) and poverty, infants may develop early undernutrition followed by overweight, insulin-resistance, and diabetes.

Ongoing changes in eating and lifestyle habits are linked to socioeconomic factors that determine the direction and capacity of the response according to available resources. The rapid global nutrition transition is related to socioeconomic status which clusters at different ecological levels including maternal level; household deprivation level; and country specificity level. Worth noting is that, socioeconomic factors are interconnected and contribute to the persistence of the double/triple burden of malnutrition as well as their short- and long-term effects in SSA. It appears that education, occupation and household wealth interact with each other, and determine the specific context of poverty which marks the path to malnutrition for those mostly at risk, namely: children under two and women of childbearing age. This sheds light on the dire need to involve three ecological levels of stakeholders (maternal, household and country) who work together to reduce exposure to the double burden of malnutrition.

The interactions of SES factors with each other and with biological factors are also evident in the context of nutrition transition. The SES factors interact with biological factors (infections), food safety and dietary changes, as well as the mobility of individuals. The dynamic changes of SES factors in nutrition maintain and perpetuate the double burden of malnutrition in the life course, as well as a variability in nutritional status during an individual's life course. Education, however, exerts an influence on job, income, positive information on health and household position. Therefore, the weight of maternal education on the effects of nutrition transition is primordial. Education as an investment may impact on health, growth and diet changes, as well as the wealth of the household.

In the **Figure 23**, the interrelated demographic and SES factors are shown. Maternal education being a basic SES factor is connected to occupation which should generate an income and the household wealth. There is also a relationship between marital status and maternal education. All factors play a role in infant undernutrition. Furthermore, this figure also shows the interconnexions between chronic and acute form of undernutrition. This means that malnutrition does not have a unique manifestation during the life course and may vary depending on environmental and individuals' factors. Manifestations of undernutrition are sequential in the trajectory of the individual's life according to the factors that they are exposed to, including the SES factors.

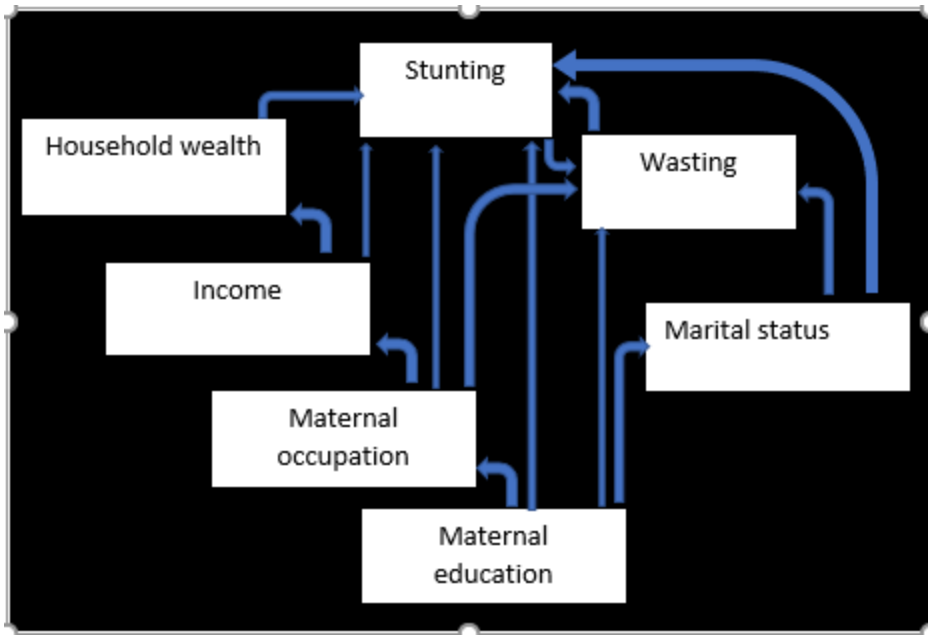


Figure 23: Interactions between socio-demographic and socioeconomic factors and infant growth

7.2.2.2 Timing variation of the double burden in the first 1000 days

One of the merits of this study has been to bring forward new perspectives of SES influences on infant growth in nutrition transition context in SSA. While some SES factors are important during pregnancy (maternal education, occupation and household wealth index), others (maternal education and household wealth index) play a significant role in infancy. These factors exert direct and cumulative effects on the double/triple burden of malnutrition and the variability of their effects are explained by variations in cultures, policies and behaviour.

When maternal capital (behaviour, positive information, education, economic power), family support from partner/husband (moral, financial), and the household capital (resources as assets, ownership) are cumulatively improved, infant growth may be optimized by enabling access to basic resources (health, education) (14, 99). The occurrence and intensity of malnutrition is variable throughout the life cycle. It appears that children and women of childbearing age (adolescents and adults) are the most vulnerable to food inaccessibility, infections that depend on the economic capacity of households, family support and the overall socioeconomic and health context of the country. With the persistence of poor SES conditions, undernutrition within the first

1000 days of life exposes the entire life cycle to ripple as well as harmful effects such as non-communicable diseases and adult undernutrition, including maternal malnutrition. In poor conditions, poor nutritional status in adulthood is a factor that determines low birth weight and confirms the heritability of nutritional problems. Thus, access to resources at the household level modulates variability across the life cycle and heritability of the double burden of malnutrition between two or more generations in the context of transition.

Education, occupation, and wealth at the household and maternal levels are based on assessments of the nutritional status of infants made by considering SES clusters. Would clusters be a new approach to investigate SES factors in infant undernutrition in transition contexts? How could this new approach with clusters be developed to better understand the contrast and interpretation of SES factors in the field of undernutrition as part of double/triple burden of malnutrition? These questions raised, put forward the need to address the involvement of vulnerable populations (mother, infant) and three ecological levels (mother, household and country). Our findings suggest that SES factors do not impact human capital in isolation, and the combination of socioeconomic factors may have a significant effect on health, and particularly on infant growth (90, 278). Using a data driven approach, our interaction analyses suggest that, in the South African context, SES factors could be organized into three main clusters potentially associated with infant growth. The first cluster combined HWI and maternal education that could reflect long-term non-financial capital (investments) correspond to Coleman's maternal and human capital (48, 99, 249). The second cluster showed the interrelation between maternal occupation and income, which may encapsulate short-term financial capital (current resources). The last cluster, which only comprises maternal marital status in our analyses, may represent social capital (social support and networks).

7.3 Revision of the Conceptual Framework

The results of this research project inevitably lead to the incorporation of amendments to existing UNICEF conceptual frameworks on child undernutrition (**Figure 24**) focusing on children aged between 0 to 2 years old in relation to the stratification of socioeconomic status according to household and maternal levels. These results confirmed the ecological and UNICEF conceptual frameworks which have pointed out SES factors as basic causes of infant undernutrition and growth at birth and up to two years of age. In addition, the perspective of this research project

brings the link between infant double/triple burden of malnutrition with other SES factors including maternal marital status and maternal occupation; these factors should be added as predictors. Further, early double/triple burden of malnutrition is associated with the SES factors that interact and do not act in isolation within the ecological model on the life course (**Figure 9**) .

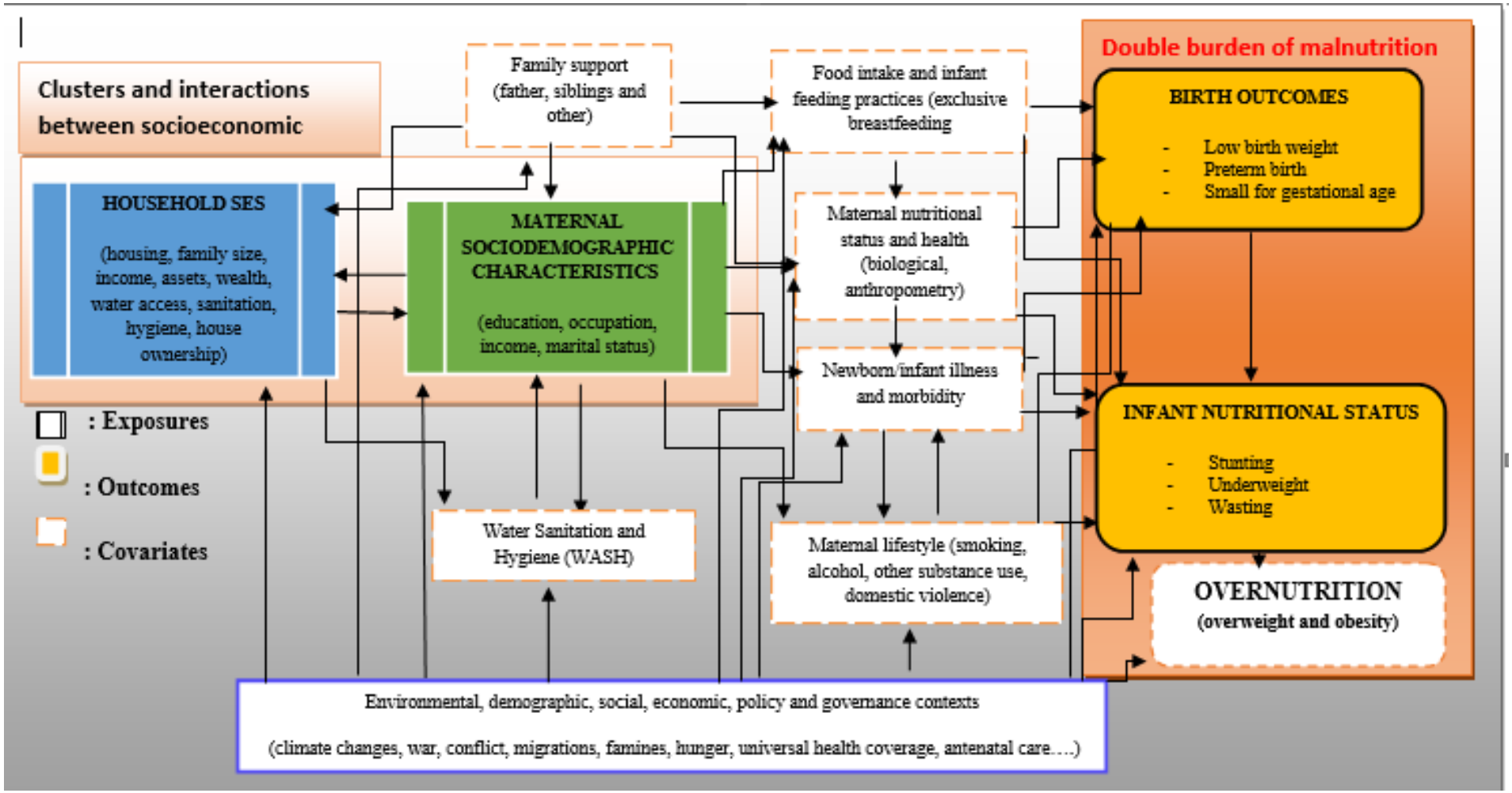


Figure 24: Integrated conceptual framework on the association between the interrelated SES factors with adverse birth outcomes and infant undernutrition outcomes

Moreover, although not explored in this current research project, the global contextual framework of malnutrition should integrate climate change and its effects on hunger and famine as basic contextual factors limiting access to the basic resources and altering the food system in low- and middle-income countries. The negative role of climate change on famine, hunger, and ultimately on the growth and development of infants and next generations cannot be overlooked. Climate change is a global matter in this 21st century playing out in the global socioeconomic context; therefore, it is critical to assess its impact on household and maternal socioeconomic positions. Watts and colleagues (93) drew a conceptual framework where the pathways linking climate changes and human health, food insecurity (terrestrial and marine), poverty, mental disorders and undernutrition. In the framework, amongst the consequences impacting infant growth and nutrition, there was an increased loss of employment for women, particularly in SSA, and poor agricultural production (due to alteration in the bio-ecology of pathogens in plantations) impacting negatively on the food system. Climate change may provide constant negative stimuli to growth and development of individuals throughout their life course, and particularly, during the sensitive and critical period of the first 1000 days.

7.4 Implications for the Different Stakeholders

This research is the first to show the household and maternal SES influence on growth faltering in children between within the first 1000 days of life in SSA. The implications of the findings could broadly be effective in different fields:

1. The findings contribute to knowledge about which stakeholders should be involved when questioning SES factors of infant undernutrition and their interactions. The ecological levels have clearly highlighted maternal, household, and country levels as the most important levels of stakeholders.

1. When addressing infant growth concerns (in research or intervention) it is relevant to cluster based on maternal education, occupation and household wealth characteristics. Using a combined model of SES construct should give a reliable understanding of SES to hierarchically disentangle (dis)similarities between SES variables, which are not interchangeable, in respect for tackling their effects on infant growth in future research.

2. Taking infant growth faltering into consideration as a part of the double/triple burden of malnutrition should be more comprehensive through interventions and researches because of the constant interrelation between forms of malnutrition, and to benefit the global and effective nutrition response.

3. It is important and rational to socially and economically protect girls, adolescents and women of childbearing age against deprivations that may affect their health and well-being throughout their life course. Social policies makers should target women socio-demographic and SES factors, particularly during pregnancy and postnatal periods, to stop infant undernutrition effects and avoid a perpetuation of the cycle of double/triple burden of malnutrition.

4. Intervention for girls and women, such as access to education beyond the secondary level; avoiding physically strenuous work during pregnancy and facilitating longer maternity leave; promoting social support (through partners, families, and governmental programs); and supporting better household living conditions, can prevent the harmful effects of context based socioeconomic deprivation on infant growth.

5. Maternity leave could help women improve breastfeeding practice as well as their children's health care and growth in children younger than two years of life; however, this is not common for women doing informal jobs. Policy makers should, therefore, consider enabling mothers to take care of their children.

7.5 Future Researches

1. For addressing double/triple burden of malnutrition, qualitative investigations of the SES factors on infant growth faltering to understand the perception of key stakeholders at the three levels of the sociological structure (infant and maternal level, household level, and community level) should be conducted. Also, longitudinal and ecological studies of the effects of SES factors on infant growth over generations should be carried out to understand the cumulative effects of SES factors in households, countries, and across the life course.

2. Because the SES factors have been shown to cluster and have combined effect on infant growth, a comparative study of the effects of clustered SES factors on infant growth could bring new and dynamic perspectives to inform the to inform the mechanisms through

which SES factors interact and impact the double/triple burden of infant undernutrition, and therefore to amend appropriately existing theorical and conceptual frameworks.

7.6 Limitations of the thesis

1. The options and measurements of SES factors were one of the major limitations of the research due to the source of the data in the systematic review, their complexity and some variation according to the perception of the interviewee in the observational studies.

2. This research project was hospital-based; hence, limitations which have been noted in the methodological section of this chapter (Chapter 7) are recognised. Population-based studies may be needed for more accuracy and statistical power in the future.

7.7 Conclusion

In conclusion, it is apparent that there is a dearth of evidence for the effects of maternal education, occupation, and household wealth index on growth in children younger than two years of age and at birth in SSA. Household access to socioeconomic resources and maternal education remain the factors that incessantly contribute to infant growth in nutrition transition contexts in SSA. Maternal occupation contributes inconsistently to improve birth outcomes and infant growth.

Contextual setting matters when assessing the association between maternal and household SES factors and birth outcomes between two contrasting countries, the DRC (low-income country) and SA (middle-income country). Living in SA as compared to the DRC was associated with reduced risk of adverse birth outcomes; while, a household, higher social and economic positions (high education, adequate housing, marriage) reduced the likelihood of having LBW and PTB in the DRC. Furthermore, findings from the pooled analyses support that maternal education is a critical determinant of birth outcomes, and biological characteristics (maternal and infant) remain stronger confounding factors of infant growth.

Unfortunately, more ‘working mothers and those living in wealthier households’ emerge as the source of some problems which put their children at risk for higher weight gain at one year of age. Socioeconomic factors exert dynamic interrelationships among themselves with a combined effect on the growth of children at one year old in wealthier households of nutrition transition countries in LMICs. Efforts should be directed towards improving the growth and development of children

in the first 1000 days by socially and economically empowering women, breastfeeding, as well as social support.

REFERENCES

1. Gluckman PD, Hanson MA. Developmental plasticity and human disease: research directions. Journal of Internal Medicine. 2007;261(5):461-71.
2. de Onis M, Blossner M. The world health organization global database on child growth and malnutrition: methodology and applications. International Journal of Epidemiology. 2003;32:5-12.
3. de Onis M, Branca F. Childhood stunting: a global perspective. Maternal Child Nutrition. 2016;12 Suppl 1:12-26.
4. Black RE, Victora CG, Walker SP, *et al.* Maternal and child undernutrition and overweight in low-income and middle-income countries. The Lancet Global Health. 2013;382(9890):427-51.
5. Wedderburn CJ, Evans C, Yeung S, *et al.* Growth and neurodevelopment of HIV-exposed uninfected children: a conceptual framework. Current HIV/AIDS Reports. 2019.1-13.
6. Black RE. Global prevalence of small for gestational age births. Nestle Nutrition Institute Workshop Series. 2015;81:1-7.
7. UNICEF. Improving child nutrition: the achievable for global progress: New York: UNICEF; 2013 [cited 2019 25/2]. Available from: Retrieved from: https://data.unicef.org/resources/improving-child-nutrition-the-achievable-imperative-for-global-progress/.2013.
8. Perumal N, Bassani DG, Roth DE. Use and misuse of stunting as a measure of Child Health. The Journal of Nutrition. 2018;148(3):311-5.
9. Victora CG, Adair L, Fall C, *et al.* Maternal and child undernutrition: consequences for adult health and human capital. The Lancet. 2008;371(9609):340-57.
10. Black RE, Allen LH, Bhutta ZA, *et al.* Maternal and child undernutrition: global and regional exposures and health consequences. The Lancet. 2008;371(9608):243-60.
11. Victora CG, de Onis M, Hallal PC, Blossner M, Shrimpton R. Wolrdwide timing of growth faltering: revisiting implications for interventions. Pediatrics. 2010;125(e473):1.
12. Bhutta ZA, Ahmed T, Black RE, *et al.* What works? Interventions for maternal and child undernutrition and survival. The Lancet. 2008;371:41-95.

13. Cusick SE, Georgieff MK. The role of nutrition in brain development: the golden opportunity of the '1000 first days'. The Journal of Pediatrics. 2016;175:16-21.
14. Wells JC. Worldwide variability in growth and its association with health: incorporating body composition, developmental plasticity, and intergenerational effects. American Journal of Human Biology. 2017;29(2). 32472-9.
15. Said-Mohamed R, Pettifor JM. Life History theory hypotheses on child growth: potential implications for short and long-term child growth, development and health. American Journal of Physical Anthropology. 2018;165(1):4-19.
16. Stearns SC. The evolution of life histories. Journal of Evolutionary Biology. 1992(1):264; Roff DA. Life history evolution: Sinauer, 2002; 2002. 1-256.
17. UNICEF, WHO. UNICEF-WHO."Low birthweight estimates: levels and trends 2000-2015." Geneva: WHO. 2019:1-36.
18. UNICEF, WHO, WBG IBRaDT. "Levels and trends in child malnutrition. Key findings of the 2019 edition of the Joint Child Malnutrition Estimates." Retrieved from: . https://wwwwhoint/nutgrowthdb/estimates2018/en/. 2019(19):1-16.
19. Hales CN, Barker DJ. The thrifty phenotype hypothesis: type 2 diabetes. British Medical Bulletin. 2001;60(1):1-16.
20. Vaag AA, Grunnet LG, Arora GP, Brøns C. The thrifty phenotype hypothesis revisited. Diabetologia. 2012;55(8):2085-8.
21. Zverev Y. Prediction of peak expiratory flow rates in stunted children. The Central African Journal of Medicine. 2001;47(3):74-8.
22. WHO. "Stunting in a nutshell." Retrieved from: https://wwwwhoint/nutrition/healthygrowthproj_stunted_videos/en/. 2019.
23. Blencowe H, Krasevec J, de Onis M, *et al.* National, regional, and worldwide estimates of low birthweight in 2015, with trends from 2000: a systematic analysis. The Lancet Global Health. 2019;7(7):e849-e60.
24. Chirande L, Charwe D, Mbwana H, *et al.* Determinants of stunting and severe stunting among under-fives in Tanzania: evidence from the 2010 cross-sectional household survey. BioMed Central Pediatrics. 2015;15:1-165.

25. Lee Anne CC., Katz Joanne, Blencowe Hannah, *et al.* National and regional estimates of term and preterm babies born small for gestational age in 138 low-income and middle-income countries in 2010. The Lancet Global Health. 2013;1(1):e26-e36.
26. UNICEF, WHO. "Low birthweight: country, regional and global estimates."Retrieved from: https://wwwuniceforg/publications/index_24840html. 2004.1-36.
27. WHO, Global affairs of Canada."Accelering nutrition improvements in sub-Saharan Africa: scaling up nutrition interventions." Final report 2012-2016. Geneva WHO https://appswhoint/iris/handle/10665/43120. 2017:1-66.
28. Black RE. Global prevalence of small for gestational age births. Nestle Nutrition Institute workshop series. 2015;81:1-7.
29. Wang H, Naghavi M, Allen C, *et al.* Global, regional, and national life expectancy, all-cause mortality, and cause-specific mortality for 249 causes of death, 1980–2015: a systematic analysis for the Global Burden of Disease Study 2015. The Lancet.388(10053):1459-544.
30. Lee Anne CC, Kozuki N, Cousens S, *et al.* Estimates of burden and consequences of infants born small for gestational age in low and middle income countries with INTERGROWTH-21st standard: analysis of CHERG datasets. British Medical Journal. 2017;358.
31. Akombi BJ, Agho KE, Merom D, Renzaho AM, Hall JJ. Child malnutrition in sub-Saharan Africa: a meta-analysis of demographic and health surveys (2006-2016). PLoS ONE. 2017;12(5):e0177338-e.
32. UNICEF. "2018 Global Nutrition Report." Retrieved from: https://globalnutritionreportorg/reports/global-nutrition-report-2018/. 2019.
33. Akombi BJ, Agho KE, Hall JJ, *et al.* Stunting, wasting and underweight in sub-Saharan Africa: a systematic review. International Journal of Environmental Research and Public Health. 2017;14(8).1-11.
34. Kassie GW, Workie DL. Exploring the association of anthropometric indicators for under-five children in Ethiopia. BioMed Central Public Health. 2019;19(1):7-64.
35. Wojcicki JM. The double burden household in sub-Saharan Africa: maternal overweight and obesity and childhood undernutrition from the year 2000: results from World Health Organization Data (WHO) and Demographic Health Surveys (DHS). BioMed Central Public Health. 2014;14:1-124.

36. Wells JC, Sawaya AL, Wibaek R, *et al.* The double burden of malnutrition: aetiological pathways and consequences for health. The Lancet. 2018. 32742-9.
37. Kruger S. The double burden of underweight and overweight in south african adolescents: a challenge and an opportunity for nutritionists and dietitians. South African Journal of Clinical Nutrition. 2014;27(1):5-6.;
38. Arthur SS, Nyide B, Soura AB, *et al.* Tackling malnutrition: a systematic review of 15-year research evidence from INDEPTH health and demographic surveillance systems. Global Health Action. 2015;8:282-98.
39. UNICEF. "The State of the world's children 2019. Children, food and nutrition: Growing well in a changing world." Retrieved from: https://www.unicef.org/reports/state-of-worlds-children-2019. 2019.
40. WHO. "Malnutrition." Retrieved from: https://wwwwhoint/news-room/fact-sheets/detail/malnutrition. 2018.
41. Chopra M, Galbraith S, Darnton-Hill I. A global response to a global problem: the epidemic of overnutrition. Bulletin of the World Health Organization. 2002;80(12):952-8.
42. Cutland CL, Lackritz EM, Mallett-Moore T, *et al.* Low birth weight: Case definition and guidelines for data collection, analysis, and presentation of maternal immunization safety data. Vaccine. 2017;35(48 Pt A):6492-500.
43. Kramer MS. The epidemiology of adverse pregnancy outcomes: an overview. The Journal of Nutrition. 2003;133(5 Suppl 2):1592s-6s.
44. von Ehrenstein OS, Wilhelm M, Ritz B. Maternal occupation and term low birth weight in a predominantly latina population in los angeles, california. Journal of Occupational and Environmental Medicine. 2013;55(9):1046-51; Mousa A, Naqash A, Lim S. Macronutrient and micronutrient intake during pregnancy: an overview of recent evidence. Nutrients. 2019;11(2):443.1-15.
45. Patwardhan B, Mutalik G, Tillu G. Chapter 3 - Concepts of health and disease. In: Patwardhan B, Mutalik G, Tillu G, editors. Integrative Approaches for Health. Boston: Academic Press; 2015. 53-78.
46. Adair LS, Fall CH, Osmond C, *et al.* Associations of linear growth and relative weight gain during early life with adult health and human capital in countries of low and middle income: findings from five birth cohort studies. The Lancet Global Health. 2013;382(9891):525-34.

47. WHO, UNICEF. "Survive and thrive. Transforming care for every small and sick newborn." Retrieved from: https://www.who.int/maternal_child_adolescent/documents/care-small-sick-newborns-survive-thrive/en/. 2019:1-162.
48. Lee ACC, Katz J, Blencowe H, *et al.* National and regional estimates of term and preterm babies born small for gestational age in 138 low-income and middle-income countries in 2010. The Lancet Global Health. 2013;1(1):e26-e36.
49. Lawn JE, Cousens S, Zupan J. 4 million neonatal deaths: When? Where? Why? The Lancet. 365(9462):891-900.
50. Max Roser, Hannah Ritchie, Dadonaite B. Child and infant mortality. retrieved from: https://ourworldindataorg/child-mortality#citation. 2019.
51. Martorell R, Horta BL, Adair LS, *et al.* Weight gain in the first two years of life is an important predictor of schooling outcomes in pooled analyses from five birth cohorts from low- and middle-income countries. The Journal of Nutrition. 2010;140(2):348-54.
52. Kremer M, Glennerster R. Chapter Four - Improving health in developing countries: evidence from randomized evaluations1. In: Mark V. Pauly TGM, Pedro PB, editors. Handbook of Health Economics. Volume 2: Elsevier; 2011. 201-315.
53. African Development Bank. "Human capital strategy 2014-2018." Retrieved from; https://wwwtralacorg/images/docs/7035/afdb-human-capital-strategy-for-africa-2014-2018. 2014.
54. Durlauf SN, Fafchamps M. Chapter 26 - Social capital. In: Philippe A, Steven ND, editors. Handbook of Economic Growth. Volume 1, Part B: Elsevier; 2005.1639-99.
55. McGovern ME, Krishna A, Aguayo VM, Subramanian SV. A review of the evidence linking child stunting to economic outcomes. International Journal of Epidemiology. 2017.
56. Vollmer S, Harttgen K, Subramanyam MA, *et al.* Association between economic growth and early childhood nutrition – Authors' reply. The Lancet Global Health. 2015;3(2):e81.
57. Bradley RH, Corwyn RF. Socioeconomic status and child development. Annual Review of Psychology. 2002;53(1):371-99.
58. Madeline. Bronfenbrenner's bioecological model of development (Bronfenbrenner). Retrieved from: https://wwwlearning-theoriescom/bronfenbrenners-bioecological-model-bronfenbrennerhtml#references. 2017

59. Urie. B, Morris. PA. The bioecological model of human development. In handbook of child psychology. (eds W. Damon, R.M. Lerner and R.M. Lerner). Doi:10.1002/9780470147658.chpsy0114. Book. 2007.
60. Browne AW, Barett HR. Female education in sub-Saharan Africa: the key to development? Comparative Education. 1991;27(3):275-85.
61. UNICEF. Strategy for improved nutrition of children and women in developing countries. The Indian Journal of Pediatrics. 1991;58(1):13-24.
62. UNICEF. Improving child nutrition: the achievable for global progress: New York: UNICEF; 2013 [cited 2019 25/2]. Available from: Retrieved from: https://data.unicef.org/resources/improving-child-nutrition-the-achievable-imperative-for-global-progress/.2013.
63. Fraser D, Abu-Saad K. Maternal nutrition and birth outcomes. Epidemiologic Reviews. 2010;32(1):5-25.
64. Stewart CP, Iannotti L, Dewey KG, Michaelsen KF, Onyango AW. Contextualising complementary feeding in a broader framework for stunting prevention. Maternal and Child Nutrition. 2013;9(S2):27-45.
65. Watts N, Amann M, Arnell N, *et al.* The 2019 report of The Lancet countdown on health and climate change: ensuring that the health of a child born today is not defined by a changing climate. The Lancet. 2019;394(10211):1836-78.
66. Patz. JA, Campbell-Lendrum. D, Holloway. T, Foley. JA. Impact of regional climate change on human health. Reviews. 2005;438:8.
67. Crimmins A, j. , Balbus JL, Gamble CB, *et al.* The impacts of climate change on human health in the United States: a scientific assessment. Retrieved from: https://dxdoiorg/107930/J0R49NQX. 2016:1-322.
68. Worldbank. "Worldbank development indicators. South Africa and the Democratic Republic of Congo databases." Retrieved from: https://databankworldbankorg/source/world-development-indicators. 2019.
69. Joe Hasell, Max Roser. Famines. Retrieved from: https://ourworldindataorg/famines#citation. 2019.
70. Max Roser, Hannah Ritchie. Hunger and Undernourishment. Retrieved from: https://ourworldindataorg/hunger-and-undernourishment. 2019.

71. Corruccini RS, Kaul SS. Part 3: The epidemiological transition and anthropology of minor chronic non-infectious diseases. Medical Anthropology. 1983;7(3):36-50.
72. Popkin BM. Nutrition Transition and the Global Diabetes Epidemic. Current Diabetes Reports. 2015;15(9):1-14.
73. Goldstein JA, Norris SA, Aronoff DM. DOHaD at the intersection of maternal immune activation and maternal metabolic stress: a scoping review. Journal of Developmental Origins of Health and Disease. 2017;8(3):273-83.
74. Vogel JP, Lee AC, Souza JP. Maternal morbidity and preterm birth in 22 low- and middle-income countries: a secondary analysis of the WHO Global Survey dataset. BioMed Central Pregnancy and Childbirth. 2014;14:1-14.
75. Aislinn Delany, Selwyn Jehoma, Lori Lake. South African Child Gauge. Review. 2016:1-136.
76. McCuskee S, Brickley EB, Wood A, Mossialos E. Malaria and macronutrient deficiency as correlates of anemia in young children: a systematic review of observational studies. Annals of Global Health. 2014;80(6):458-65.
77. Said-Mohamed R, Stein AD, Pettifor JM, Norris SA. Sanitation and diarrhoea in infancy and CRP level at 18 years: the birth-to-twenty plus cohort. Annals of Human Biology. 2019;46(5):415-24.
78. International Food Policy Research Institute." Global nutrition report: actions and accountability to accelerate the world's progress on nutrition." Washington DC. Report. 2014.
79. Bornstein MH, Bradley RH. Socioeconomic status, parenting, and child development. Routledge. 2003. 29-83.80. Osgood-Zimmerman A, Millear AI, Stubbs RW, *et al.* Mapping child growth failure in Africa between 2000 and 2015. Nature. 2018;555(7694):41-7.
81. FAO, IFAD, UNICEF, WFP, WHO. "The state of food security and nutrition in the world 2019." Retrieved from: https://creativecommons.org/licenses/by-nc-sa/3.0/igo. 2019.
82. Said-Mohamed R, Micklesfield LK, Pettifor JM, Norris SA. Has the prevalence of stunting in South African children changed in 40 years? A systematic review. BioMed Central Public Health. 2015;15:534.1-10.
83. Varela-Silva MI, Azcorra H, Dickinson F, Bogin B, Frisancho AR. Influence of maternal stature, pregnancy age, and infant birth weight on growth during childhood in Yucatan, Mexico:

a test of the intergenerational effects hypothesis. American Journal of Human Biology. 2009;21(5):9. 657-63.

84. Martorell R, Zongrone A. Intergenerational influences on child growth and undernutrition. Paediatric and Perinatal Epidemiology. 2012;26 Suppl 1:302-14.

85. Razanadrakato HR, Randriamanambintsoa M, Barry M, *et al.* [Coexistence of maternal overweight or obesity and stunted children in south-western Benin households]. Global Health Action. 2018;30(1):115-24;

86. Keats EC, Haider BA, Tam E, Bhutta ZA. Multiple-micronutrient supplementation for women during pregnancy. The Cochrane Database of Systematic Reviews. 2019;3:Cd004905.1-132.

87. Kandala NB, Emina JB. The dual burden of nutrition transition among women in sub-Saharan Africa: a case study of underweight in Nigeria. Journal of Biosocial Science. 2016;48(4):486-501.

88. Kramer MS. Determinants of low birth weight: methodological assessment and meta-analysis. Bulletin of the World Health Organization. 1987;65(5):663-737.

89. Arlinghaus KR, Truong C, Johnston CA, Hernandez DC. An Intergenerational approach to break the cycle of malnutrition. Current Nutrition Reports. 2018;7(4):259-67.

90. Lowensohn RI, Stadler DD, Naze C. Current concepts of maternal nutrition. Obstetrical and Gynecological Survey. 2016;71(7):413-26.

91. Alexander Vaiserman, Oleh Lushchak. Prenatal malnutrition-induced epigenetic dysregulation as a risk factor for type 2 diabetes. International Journal of Genomics. 2019;2019:1-11.

92. Ahmed T, Haque R, Shamsir Ahmed AM, Petri WA, Jr., Cravioto A. Use of metagenomics to understand the genetic basis of malnutrition. Nutrition Reviews. 2009;67 Suppl 2:201-6.

93. Zelko IN, Zhu J, Roman J. Maternal undernutrition during pregnancy alters the epigenetic landscape and the expression of endothelial function genes in male progeny. Nutrition Research. 2019.

94. Bhutta ZA, Das JK, Rizvi A, *et al.* Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost? The Lancet. 2013;382(9890):452-77.

95. Blumenshine P, Egerter S, Barclay CJ, Cubbin C, Braveman PA. Socioeconomic disparities in adverse birth outcomes: a Systematic Review. American Journal of Preventive Medicine. 2010;39(3):263-72.
96. Hargreaves JR, Morison LA, Gear JSS, *et al.* Assessing household wealth in health studies in developing countries: a comparison of participatory wealth ranking and survey techniques from rural South Africa. Emerging Themes in Epidemiology. 2007;4:153-157.
97. Ijarotimi OS. Determinants of childhood malnutrition and consequences in developing countries. Current Nutrition Reports. 2013;2(3):129-33.
98. UNICEF." Improving child nutrition: the achievable for global progress." New York: UNICEF; 2013 [cited 2018 25/2/2019]. Available from: https://data.unicef.org/resources/improving-child-nutrition-the-achievable-imperative-for-global-progress/.
99. Black RE, Victora CG, Walker SP, *et al.* Maternal and child undernutrition and overweight in low-income and middle-income countries. The Lancet. 2013;382(9890):427-51.
100. Steyn NP, Walker AR. Nutritional status and food security in Sub-Saharan Africa: Predictions for 2020. Asia Pacific Journal of Clinical Nutrition. 2000;9(1):1-6.
101. Chawanpaiboon S, Vogel JP, Moller AB, *et al.* Global, regional, and national estimates of levels of preterm birth in 2014: a systematic review and modelling analysis The Lancet. 2018;7(1):1-10.
102. UNICEF, WHO. "Low birthweight estimations: levels and trends 2000-2015." Retrieved from: https://wwwwhoint/nutrition/publications/UNICEF-WHO-lowbirthweight-estimates-2019/en/. 2019:1-36.
103. Fouché LC, Kritzinger A, Le Roux T. Gestational age and birth weight variations in young children with language impairment at an early communication intervention clinic. The South African Journal of Communication disorders. 2018;65(1):e1-e9.
104. National Department of Health, Statistics South Africa, South African Medical Research Council, International Classification of Functioning. South Africa Demographic and Health Survey 2016 Report. 2019:1-627.
105. Minister of Public Health, ICF International. "Second Demographic and Health Surveys (DHS II 2013-2014)." Preliminary reports. Retrieved from:http://microdataworldbankorg/indexphp/catalog/2173. 2014 39.

106. Blakely T, Hales S, Pruss-Ustun A, *et al.* Poverty: assessing the distribution of health risks by socioeconomic position at national and local levels. World Health Organization. 2004((WHO Environmental Burden of Diseases Series 10)):32.
107. Adler NE, Newman K. Socioeconomic disparities in health. Pathways And Policies. Health Affairs. 2002;21(2):60-76.
108. Broer M, Bai Y, Fonseca F. A review of the literature on socioeconomic status and educational achievement. Socioeconomic inequality and educational outcomes: evidence from twenty years of TIMSS. Cham: Springer International Publishing; 2019. 7-17.
109. Coleman JS. Social capital in the creation of human capital. American Journal of Sociology. 1988;94:95-120.
110. Vyas S, Kumaranayake L. Constructing socio-economic status indices: how to use principal components analysis. Health Policy and Planning. 2006;21(6):459-68.
111. Smith JP. The impact of Socioeconomic status on health over the life course. The Journal of Human Resources. 2007;42(4):739-64.
112. Kaplan GA. Socioeconomic status and health. In: Smelser NJ, Baltes PB, editors. International Encyclopedia of the Social and Behavioral Sciences. Oxford: Pergamon; 2001. 14554-8.
113. African Bank of Development. "Human capital strategy 2014-2018."Retrievd from: https://www.tralac.org/images/docs/7035/afdb-human-capital-strategy-for-africa-2014-2018.pdf2014.
114. OCDE. "Economis well-being in OECD Framework for statistics on the distribution of household income, consumption, and wealth." Retrieved from: https://doiorg/101787/9789264194830-en. 2013:15.
115. Shavers VL. Measurement of socioeconomic status in health disparities research. Journal of the National Medical Association. 2007;99(9):1013-23.
116. Rustein S, Johnson K. The DHS wealth index. DHS Comparative Report No. 6. 2004:77.
117. Wells JCK, Wibaek R, Poullas M. The dual burden of malnutrition increases the risk of cesarean delivery: evidence from India. Frontiers in Public Health. 2018;6:292-.
118. Silvestrin S, Silva CH, Hirakata VN, *et al.* Maternal education level and low birth weight: a meta-analysis. Journal of Pediatrics. 2013;89(4):339-45.

119. Campbell., Jason G, Paula DN D, *et al.* Socioeconomic status and adverse birth outcomes: a population-based Canadian sample. Journal of Biosocial Science. 2018;50(1):102-13.
120. Wilding S, Ziauddeen N, Roderick P, *et al.* Are socioeconomic inequalities in the incidence of small-for-gestational-age birth narrowing? Findings from a population-based cohort in the South of England. British Medical Journal Open. 2019;9(7):e026998-e.
121. Shah PS, Zao J, Ali S. Maternal marital status and birth outcomes: a systematic review and meta-analyses. Maternal and Child Health Journal. 2011;15(7):1097-109.
122. Andersen A-MN, Mortensen LH. Socioeconomic inequality in birth outcomes: what do the indicators tell us, and where do we find the data? Canadian Medical Association Journal 2006;174(10):1429-30.
123. Luo Z-C, Wilkins R, Kramer MS. Effect of neighbourhood income and maternal education on birth outcomes: a population-based study. Canadian Medical Association Journal [online]. 2006;174(10):1415-22.
124. Aguayo VM, Nair R, Badgaiyan N, Krishna V. Determinants of stunting and poor linear growth in children under 2 years of age in India: an in-depth analysis of Maharashtra's comprehensive nutrition survey. Maternal and Child Nutrition. 2016;12 Suppl 1:121-40.
125. McDonald SD, Han Z, Mulla S, *et al.* High gestational weight gain and the risk of preterm birth and low birth weight: a systematic review and meta-analysis. Journal of Obstetrics and Gynaecology Canada.. 2011;33(12):1223-33.
126. Wamani H, Astrom AN, Peterson S, Tumwine JK, Tylleskar T. Boys are more stunted than girls in sub-Saharan Africa: a meta-analysis of 16 demographic and health surveys. BioMed Central Pediatrics. 2007;7:17.
127. Gronvik T, Fossgard Sandoy I. Complications associated with adolescent childbearing in Sub-Saharan Africa: a systematic literature review and meta-analysis. PLoS ONE. 2018;13(9):e0204327.
128. Mombo-Ngoma G, Mackanga JR, Gonzalez R, *et al.* Young adolescent girls are at high risk for adverse pregnancy outcomes in sub-Saharan Africa: an observational multicountry study. British Medical Journal Open. 2016;6(6):e011783.
129. Cameron N. Human growth, nutrition, and health status in Sub-Saharan Africa. Yearbook of Physical Anthropology. 1991;34:211-50.

130. Khan MN, Rahman MM, Shariff AA, *et al.* Maternal undernutrition and excessive body weight and risk of birth and health outcomes. Archives of Public Health.. 2017;75:1-10.
131. Wumba RD, Zanga J, Aloni MN, *et al.* Interactions between malaria and HIV infections in pregnant women: a first report of the magnitude, clinical and laboratory features, and predictive factors in Kinshasa, the Democratic Republic of Congo. Malaria Journal. 2015;14(1); 1-10.
132. Han Z, Mulla S, Beyene J, Liao G, McDonald SD. Maternal underweight and the risk of preterm birth and low birth weight: a systematic review and meta-analyses. International Journal of Epidemiology. 2011;40(1):65-101.
133. Venkatachalam PS. Maternal nutritional status and its effect on the newborn. Bulletin of the WHO. 1962;26(2):193-201.
134. Tshotetsi L, Dzikiti L, Hajison P, Feresu S. Maternal factors contributing to low birth weight deliveries in Tshwane District, South Africa. PLoS ONE. 2019;14(3):e0213058-e.
135. Aliyu MH, Jolly PE, Ehiri JE, Salihu HM. High parity and adverse birth outcomes: exploring the maze. Birth Issues in Perinatal Care. 2005;32(1):5.
136. Faisal-Cury A, Menezes PR, Quayle J, Santiago K, Matijasevich A. The relationship between indicators of socioeconomic status and cesarean section in public hospitals. Revista de Saude Publica. 2017;51(0):1-14.
137. Lim SS, Vos T, Flaxman AD, *et al.* A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. The Lancet. 2012;380(9859):2224-60.
138. Adeyemi RA, Zewotir T, Ramroop S. Semiparametric multinomial ordinal model to analyze spatial patterns of child birth weight in Nigeria. International Journal of Environmental Research and Public Health. 2016;13(11).1-22.
139. Jackson DJ, Batiste E, Rendall-Mkosi K. Effect of smoking and alcohol use during pregnancy on the occurrence of low birthweight in a farming region in South Africa. Paediatric and Perinatal Epidemiology. 2007;21(5):432-40.
140. Semakula HM, Haq SM. Potential health effects of tobacco smoking in Uganda and how to overcome them through an appropraite communication strategy. East African Journal of Public Health. 2010;7(2):131-9.

141. London L, Nell V, Thompson ML, Myers JF. Health status among farm workers in the Western Cape--collateral evidence from a study of occupational hazards. South African Medical Journal. 1998;88(9):1096-101.
142. London school of hygiene and tropical medicine. The use of epidemiological tools in the conflict-affected populations: open-acces educational resources for policy-markers. Retrieved from: http://conflictlshtmacuk/page_115htm. 2009.
143. Wedi CO, Kirtley S, Hopewell S, *et al.* Perinatal outcomes associated with maternal HIV infection: a systematic review and meta-analysis. The lancet HIV. 2016;3(1):e33-48.
144. UNICEF. "For every child, end AIDS-seventh stockataking report." Retrieved from:https://wwwunscnorg/en/resource-center/global-trends-and-emerging-issues. 2016:1-92.
145. le Roux SM, Abrams EJ, Nguyen K, Myer L. Clinical outcomes of HIV-exposed, HIV-uninfected children in sub-Saharan Africa. Tropical Medicine and International Health. 2016;21(7):829-45.
146. Filteau S, Rowland-Jones S. Cytomegalovirus infection may contribute to the reduced immune function, growth, development, and health of HIV-exposed, uninfected african children. Frontiers in Immunology. 2016;7:1-6.
147. Slogrove AL, Becquet R, Chadwick EG, *et al.* Surviving and thriving-shifting the public health response to HIV-exposed uninfected children: report of the 3rd HIV-exposed uninfected child workshop. Frontiers Pediatriatrics. 2018;6:157.1-5.
148. Genowska A, Fryc J, Szpak A, Tyszko P. Is socioeconomic status associated with adverse birth outcomes in Poland? Annals of Agricultural and Environmental Medicine. 2019;26(2):369-74.
149. Wagura P, Wasunna A, Laving A, Wamalwa D, Ng'ang'a P. Prevalence and factors associated with preterm birth at kenyatta national hospital. BioMed Central Pregnancy and Childbirth. 2018;18(1):1-7.
150. Campbell EE, Gilliland J, Dworatzek PDN, *et al.* Socioeconomic status and adverse birth outcomes: a population-based Canadian sample. Journal of Biosocial Science. 2018;50(1):102-13.
151. Heaton TB, Crookston B, Pierce H, Amoateng AY. Social inequality and children's health in Africa: a cross sectional study. International Journal for Equity in Health. 2016;15:92. 1-14.

152. Moher D, Tetzlaff J, Tricco AC, Sampson M, Altman DG. Epidemiology and reporting characteristics of systematic reviews. PLoS ONE Medicine. 2007;4(3):e78.
153. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Medicine. 2009;6(7):e1000097.
154. Liberati A, Altman DG, Tetzlaff J, *et al.* The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. British Medical Journal. 2009;339:b2700.
155. Balshem H, Helfand M, Schunemann HJ, *et al.* GRADE guidelines: 3. Rating the quality of evidence. Journal of Clinical Epidemiology. 2011;64(4):401-6.
156. Guyatt G, Oxman AD, Akl EA, *et al.* GRADE guidelines: 1. Introduction-GRADE evidence profiles and summary of findings tables. Journal of Clinical Epidemiology. 2011;64(4):383-94.
157. Nritish Medical Journal. What is GRADE? Retrieved from: https://bestpracticebmjcom/info/toolkit/learn-ebm/what-is-grade/. 2019.
158. Atkins D, Best D, Briss PA, *et al.* Grading quality of evidence and strength of recommendations. British Medical Journal (Clinical research edition). 2004;328(7454):1490-.
159. Dijkers M. Introduccing GRADE: a systematic approach to ratingevidence in systematic reviews and to guideline development KT update (1)5. Center on Knowledge Translation for Disability and Rehabilitation Research. 2013;1(5):1-9.
160. Lee-Ann. An overview of SowetoRetrieved from: http://wwwsowetocoza/html/i_overviewhtm. 2019.
161. Map of Africa. Sub-Saharan map of Africa. Retrieved from: http://mapofafricanewblogspotcom/2017/07/sub-saharan-africa-maphtml. 2019.
162. Oakes JM, Rossi PH. The measurement of SES in health research: current practice and steps toward a new approach. Social Science and Medicine (1982). 2003;56(4):769-84.
163. Howe LD, Hargreaves JR, Huttly SR. Issues in the construction of wealth indices for the measurement of socioeconomic position in low-income countries. BioMed Central Journal. 2008;5:3.1-14.
164. Stephanie R Psaki, Jessica C Seidman, Mark Miller, *et al.* Measuring socioeconomic status in multicountry studies: results from the eight-country MAL-ED study. BioMed Central Population Health Metrics. 2014. 1-11.

165. Lee Anne C, Kozuki N, Cousens S, *et al.* Estimates of burden and consequences of infants born small for gestational age in low and middle income countries with INTERGROWTH-21st standard: analysis of CHERG datasets. British Medical Journal. 2017;358.1-11.
166. Victora CG, Villar J, Barros FC, *et al.* Anthropometric characterization of impaired fetal growth: risk factors for and prognosis of newborns with stunting or wasting. The Journal of American Medical Association pediatrics. 2015;169(7):e151431.
167. Nohr EA, Liew Z. How to investigate and adjust for selection bias in cohort studies. Acta Obstetricia et Gynecologica Scandinavica. 2018;97(4):407-16.
168. Ayad M, Barrere B, Otto J. Demographic and socioeconomic characteristics of households. Calverton, Maryland, USA: Macro International, 1997.
169. South Africa Labour and Development Research Unit - University of Cape Town. South Africa National Income Dynamic Surveys (NIDS) 2017, wave 5. Retrieved from: https://wwwdatafirstuctacza/dataportal/indexphp/catalog/712. 2017.
170. Statistics South Africa. Living conditions survey 2014-2015 (dataset). Version1.1. Pretoria: Statistica South Africa (producer). Cape town: Datafirst. 2017.
171. Blossner M, de Onis M, Ustun A. Malnutrition: quantifying the health impact at national and local levels/Monika Blossner, Mercedes de Onis. WHO. Retrieved from: https://appswhoint/iris/handle/10665/43120. 2005.
172. Bhutta ZA, Berkley JA, Bandsma RHJ, *et al.* Severe childhood malnutrition. Nature Reviews Disease Primers. 2017;3:1-44.

173. Review Manager (RevMan). [Computer program]. Version 5.3. . Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration. Retrieved from: https://communitycochraneorg/help/tools-and-software/revman-5. 2014.
174. WHO. "WHO AnthroPlus for personal computers manual: Software for assessing growth of the world's children and adolescents." Geneva: WHO, 2009 Retrieved from:http://wwwwhoint/growthref/tools/en/. 2020.
175. Umeta M, West CE, Verhoef F, *et al.* Factors associated with stunting in infants aged 5-11 months in the Dodota-Sire district, rural Ethiopia. Journal of Nutrition. 2003;133.1064-70.

176. Bouvier P, Papart JP, Wanner P, Picquet M, Rougemont A. Malnutrition of children in Sikasso (Mali): prevalence and socioeconomic determinants. Sozial- und Präventivmedizin. 1995;40(1):27-34.
177. Victora CG, Adair L, Fall C, *et al.* Maternal and child undernutrition: consequences for adult health and human capital. The Lancet. 2008;371(9609):340-57.
178. Richter LM, Orkin FM, Roman GD, *et al.* Comparative models of biological and social pthways to predict child growth through age 2 years from birth cohorts in Brazil, India, the Philippines, and South Africa. The Journal of Nutrition. 2018;148(8):1364-71.
179. Wrottesley SV, Lamper C, Pisa PT. Review of the importance of nutrition during the first 1000 days: maternal nutritional status and its associations with fetal growth and birth, neonatal and infant outcomes among African women. Journal of Developmental Origins of Health and Disease. 2016;7(2):144-62.
180. Lee AC, Katz J, Blencowe H, *et al.* National and regional estimates of term and preterm babies born small for gestational age in 138 low-income and middle-income countries in 2010. The Lancet Global Health. 2013;1(1):e26-36.
181. Black RE. Global prevalence of small for gestational age births. Nestle Nutrition Institute workshop series2015. 1-7.
182. Budree S, Goddard E, Brittain K, *et al.* Infant feeding practices in a South African birth cohort-A longitudinal study. Maternal Children Nutrition. 2017;13(3).1793-1801.
183. Medhin G, Hanlon C, Dewey M, *et al.* The effect of maternal common mental disorders on infant undernutrition in Butajira, Ethiopia: the P-MaMiE study. BioMed Central Psychiatry. 2010;10:32.1-15.
184. Letourneau N, McCaffrey G, Nyanza EC, *et al.* Somatic growth from birth to 6 months in low birth weight, in Bukavu, South Kivu, Democratic Republic of the Congo. British Medical Journal Open. 2018;66(4):245-53.
185. WHO. "Equiy, social determinants and public health programmes." Retrieved from: https://apps.who.int/iris/handle/10665/44289. Book. 2010:1-303.
186. Efevbera Y, Bhabha J, Farmer PE, Fink G. Girl child marriage as a risk factor for early childhood development and stunting. Social Science and Medicine. 2017;185:91-101.
187. Debela BL, Demmler KM, Rischke R, Qaim M. Maternal nutrition knowledge and child nutritional outcomes in urban Kenya. Appetite. 2017;116:518-26.

188. Nguyen Ngoc Hien, Nguyen Ngoc Hoa. Nutritional status and determinants of malnutrition in children under three years of age in Nghean, Vietnam. Pakistan Journal of Nutrition. 2009;8(7):958-64.
189. Engle PL. Influences of mothers' and fathers' income on children's nutritional status in Guatemala. Social Science & Medicine. 1993;37(11):1303-12.
190. Efevbera Y, Bhabha J, Farmer PE, Fink G. Girl child marriage as a risk factor for early childhood development and stunting. Social Science and Medicine. 91-101.
191. Liberati A, Altman DG, Tetzlaff J, *et al.* The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. British Medical Journal. 2009;339:b2700. 1-27.
192. Howe LD, Galobardes B, Matijasevich A, *et al.* Measuring socioeconomic position for epidemiological studies in low- and middle-income countries: a methods of measurement in epidemiology paper. International journal of epidemiology. 2012;41(3):871-86.
193. Nations U. "Handbook of vital statistics systems and methods.": Volume 1, Legal, Organisational and Technical Aspects1991 1991. 1-30.
194. van den Broek N, Ntonya C, Kayira E, White S, Neilson JP. Preterm birth in rural Malawi: high incidence in ultrasound-dated population. Human Reproduction. 2005;20(11):3235-7.
195. Katz J, Lee ACC, Kozuki N, *et al.* Mortality risk in preterm and small-for-gestational-age infants in low-income and middle-income countries: A pooled country analysis. The Lancet. 2013;382(9890):417-25.
196. WHO. "WHO Child Growth Standards length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age Methods and development. " Retrieved from: [http://www.who.int/childgrowth/publications/ca_symposium_fieldtesting/en/index.html]. 2016.
197. Assefa N, Berhane Y, Worku A. Wealth status, mid upper arm circumference (MUAC) and antenatal care (ANC) are determinants for low birth weight in Kersa, Ethiopia. PLoS ONE. 2012;7(6):e39957.
198. Ickes SB, Hurst TE, Flax VL. Maternal literacy, facility birth, and education are positively associated with better infant and young child feeding practices and nutritional status among Ugandan children. The Journal of Nutrition. 2015;145(11):2578-86.

199. Medhin G, Hanlon C, Dewey M, *et al.* Prevalence and predictors of undernutrition among infants aged six and twelve months in Butajira, Ethiopia: The P-MaMiE Birth Cohort. BioMed Central Public Health. 2010;10(1):27.
200. Ndirangu J, Newell ML, Bland RM, Thorne C. Maternal HIV infection associated with small-for-gestational age infants but not preterm births: evidence from rural South Africa. Human reproduction. 2012;27(6):1846-56.
201. Watson-Jones D, Weiss HA, Changalucha JM, *et al.* Adverse birth outcomes in United Republic of Tanzania--impact and prevention of maternal risk factors. Bulletin of the WHO. 2007;85(1):9-18.
202. Engebretsen IMS, Tylleskär T, Wamani H, Karamagi C, Tumwine JK. Determinants of infant growth in Eastern Uganda: a community-based cross-sectional study. BioMed Central Public Health. 2008;8(1):1-12.
203. Mamabolo RL, Alberts M, Mbenyane GX, *et al.* Feeding practices and growth of infants from birth to 12 months in the central region of the Limpopo Province of South Africa. Nutrition . 2004;20(3):327-33.
204. Muhihi A, Sudfeld CR, Smith ER, *et al.* Risk factors for small-for-gestational-age and preterm births among 19,269 Tanzanian newborns. BioMed Central Pregnancy and Childbirth. 2016;16:110.1-12.
205. Ukwuani FA, Suchindran CM. Implications of women's work for child nutritional status in sub-Saharan Africa: a case study of Nigeria. Social Science and Medicine (1982). 2003;56(10):2109-21.
206. Wamani H, Tylleskär T, Åstrøm AN, Tumwine JK, Peterson S. Mothers' education but not fathers' education, household assets or land ownership is the best predictor of child health inequalities in rural Uganda. International Journal for Equity in Health. 2004;3(1):1-9.
207. Wamani H, Astrom AN, Peterson S, Tumwine JK, Tylleskar T. Predictors of poor anthropometric status among children under 2 years of age in rural Uganda. Public Health Nutrition. 2006;9(3):320-6.
208. .NdiranguMN, Gatimu SM, Mwinyi HM, Kibiwott DC. Trends and factors associated with early initiation of breasfeeding in Namibia: analysis of the Demographic and Health Surveys 2000-2013. BioMed Central Pregnancy and Childbirth. 2018; 18(1):171.1-10.

209. Ukwauni FA, Suchindran CM. Implications of women's work for child nutritional status in sub-Sharan Africa: a case study of Nigeria. Social Science and Medicine. 2003;56(10):2019-21.
210. Martineau R. Women and education in South Africa: factors influencing women's educational progress and their entry into traditionally male-dominated fields. The Journal of Negro Education. 1997;66(4):383-95.
211. Zambonato AMK, Pinheiro RT, Horta BL, Tomasi E. Fatores de risco para nascimento de criancas pequenas para idade gestationa. Revista de Saude Publica. 2004;38:24-9.
212. Fujiwara T, Ito j, Kawachi I. Income inequality parental socioeconomic status, and birth outcomes in Japan. American Journal of Epidemiology. 2013;177(10):1042-52.
213. Ghouse G, Zaid M. Determinants of low birth weight a cross sectional study: in case of PakistanMunich Personal RePEc Archive 2016.; Retrieved from: https://mpra.ub.uni-muenchen.de/70660/:26.
214. Setswe G. Prevalence and risk factors for malnutrition among children aged 5 years and less in the Lefaragatlha village of Bophuthatswana. Currationis. 1994;17(3):33-5.
215. Leslie TF, Pawloski LR. Sociodemographic determinants of growth among Malian adolescent females. American Journal of Human Biology. 2010;22(3):285-90.
216. Stylianou-Riga P, Kouis P, Kinni P, *et al.* Maternal socioeconomic factors and the risk of premature birth and low birth weight in Cyprus: a case-control study. Reproductive Health. 2018;15(1):157.1-7.
217. Christian P, Lee SE, Donahue Angel M, *et al.* Risk of childhood undernutrition related to small-for-gestational age and preterm birth in low- and middle-income countries. International Journal of Epidemiology. 2013;42(5):1340-55.
218. Yount KM, DiGirolamo AM, Ramakrishnan U. Impacts of domestic violence on child growth and nutrition: A conceptual review of the pathways of influence. Social Science & Medicine. 2011;72(9):1534-54.
219. Egger M, Smith GD, Altman DG. Systematic reviews in health care. Meta-analysis in context. Book. 2007;6:285-347.
220. Bui K, Nguyen L, TT. P. 240 Risk factors associated with term and pre term low birth weight in Thai, Nguyen, Vietnam. Journal of Investigative Medicine. 2006;54(1).70-78.

221. Khan JR, Islam MM, Awan N, Muurlink O. Analysis of low birth weight and its co-variants in Bangladesh based on a sub-sample from nationally representative survey. BioMed Central Paediatrics. 2018. 2-9.
222. Barankanira E, Molinari N, Msellati P, Laurent C, Bork KA. Stunting among children under 3 years of age in Cote d'Ivoire: spatial and temporal variations between 1994 and 2011. Public Health Nutrition. 2017;20(9):1627-39.
223. Raihan MJ, Farzana FD, Sultana S, *et al.* Examining the relationship between socioeconomic status, WASH practices and wasting. PLoS ONE. 2017;12(3):e0172134.
224. Mya KS, Kyaw AT, Tun T. Feeding practices and nutritional status of children age 6-23 months in Myanmar: Further analysis of the 2015-16 Demographic and Health Survey. Rockville, Maryland, USA: ICF, 2018.1-13.
225. Bhutta ZA, Ahmed T, Black RE, *et al.* What works? Interventions for maternal and child undernutrition and survival. The Lancet. 2008;371.
226. Black RE, Victora CG, Walker SP, *et al.* Maternal and child undernutrition and overweight in low-income and middle-income countries. The Lancet. 2013;382(9890):427-51.
227. Mutisya M, Kandala NB, Ngware MW, Kabiru CW. Household food (in)security and nutritional status of urban poor children aged 6 to 23 months in Kenya. BioMed Central Public Health. 2015;15(1052). 1-10.
228. Murayama N. Effects of socioeconomic status on nutrition in Asia and future nutrition policy studies. Journal of Nutritional Science and Vitaminology. 2015;61 Suppl:S66-8.
229. UNICEF." The state of the world's children 2017." UNICEF. Retrieved from: https://www.unicef.org/sowc2017/. 2017.
230. Ackerson LK, Subramanian SV. Domestic violence and chronic malnutrition among women and children in India. American Journal of Epidemiology. 2008;167(10):1188-96.;
231. Teixeira MPC, Queiroga TPR, Mesquita MDA. Frequency and risk factors for the birth of small-for-gestational-age newborns in a public maternity hospital. Einstein (Sao Paulo, Brazil). 2016;14(3):317-23.
232. Campbell M, Cartier S, Xie B, *et al.* Determinants of small for gestational age birth at term. Paediatric and perinatal epidemiology. 2012;26(6):525-33.

233. Chia A, Chen L, Lai J, *et al.* Maternal dietary patterns and birth outcomes: a systematic review and meta-Analysis. Advances in nutrition (Bethesda, Md). 2019;10(4):685-95.
234. Muula A, Siziya S, Rudatsikira E. Parity and maternal education are associated with low birth weight in Malawi. African Health Science 2011;11:65–71.
235. Chen J-H. Maternal alcohol use during pregnancy, birth weight and early behavioral outcomes. Alcohol and Alcoholism. 2012;47(6):649-56.
236. WHO. "WHO recommendations on antenatal care for a positive pregnancy experience." WHO edition. Retrieved from: https://wwwncbinlmnihgov/books/NBK409110/. 2016.
237. UNICEF, WHO, WBG. "Levels and trends in child malnutrition.Key findings of the 2019 edition. WHO edition. 2019(19):16.
238. Goldstein R, Abell S, Ranasinha S, *et al.* Association of gestational weight gain with maternal and infant outcomes: a systematic review and meta-analysis. The Journal of the American Medical Association. 2017;317(21):2207-25.
239. World Bank. Human development index. World Development Indicators. South Africa and Democratic Republic of Congo databases. The World Bank Group. Retrieved from: http://worldpopulationreviewcom/countries/hdi-by-country/. 2019.
240. Wrottesley SV, Pisa PT, Norris SA. The influence of maternal dietary patterns on body mass index and gestational weight gain in urban black South African women. Nutrients. 2017;9(7):732. 1-14.
241. Macaulay S, Munthali RJ, Dunger DB, Norris SA. The effects of gestational diabetes mellitus on fetal growth and neonatal birth measures in an African cohort. Diabetic Medicine. 2018;35(10):1425-33.
242. Ayad M, Piani AL, Barrere B, Ekouevi K, Otto J. Demographic characteristics of households. Calverton, Maryland, USA: Macro International, 1994.
243. WHO. Training course on child growth assessment. WHO child growth standards. Measuring a child's growth. Retrieved from: https://wwwwhoint/nutrition/publications/childgrowthstandards_trainingcourse/en/. 2008.
244. Kimani-Murage EW. Exploring the paradox: double burden of malnutrition in rural South Africa. Global Health Action. 2013;6:19249.192-206.245. Lekea-Karanika V, Tzoumaka-

Bakoula C, Matsaniotis NS. Sociodemographic determinants of low birthweight in Greece: a population study. Paediatric and Perinatal Epidemiology. 1999;13(1):65-77.
246. Shah P, Shah J. Maternal exposure to domestic violence and pregnancy and birth outcomes: a systematic review and meta-analyses. Journal of Women's Health (2002). 2010;19(11):2017-31.
247. Vatten LJ, Skjaerven R. Effects on pregnancy outcome of changing partner between first two births: prospective population study. British Medical Journal. 2003;327(7424):1138.1-4.
248. Cantarutti A, Franchi M, Monzio CM, Merlino L, Corrao G. Mother's education and the risk of several neonatal outcomes: an evidence from an Italian population-based study. BioMed Central Pregnancy and Childbirth. 2017;17(1):221.1-10.
249. El-Sayed AM, Galea S. Temporal changes in socioeconomic influences on health: maternal education and preterm birth. American Journal of Public Health. 2012;102(9):1715-21.
250. Faucher M, Hastings-Tolsma M, Song J, Willoughby D, Bader S. Gestational weight gain and preterm birth in obese women: a systematic review and meta-analysis. Journal of Obstetrics and Gynaecology. 2016;123(2):199-206.
251. Momplaisir F, Brady K, Fekete T, *et al.* Time of HIV diagnosis and engagement in prenatal care impact virologic outcomes of pregnant women with HIV. PLoS ONE. 2015;10(7):e0132262-e.
252. Raatikainen K, Heiskanen N, Heinonen S. Under-attending free antenatal care is associated with adverse pregnancy outcomes. BioMed Central Public Health. 2007;7(1):268.1-8.
253. Hoffman CS, Messer LC, Mendola P, *et al.* Comparison of gestational age at birth based on last menstrual period and ultrasound during the first trimester. Paediatric and perinatal epidemiology. 2008;22(6):587-96.
254. WHO. "World Health Organization housing and health Guidelines." WHO edition. Retrieved from: https://wwwwhoint/sustainable-development/publications/housing-health-guidelines/en/. 2018.
255. Budree S, Stein DJ, Brittain K, *et al.* Maternal and infant factors had a significant impact on birthweight and longitudinal growth in a South African birth cohort. Acta Paediatrica. 2017;106(11):1793-801.

256. Farah AM, Endris BS, Gebreyesus SH. Maternal undernutrition as proxy indicators of their offspring's undernutrition: evidence from 2011 Ethiopia demographic and health survey. BioMed Central Nutrition. 2019;5(1):17.1-12.
257. Aryastami NK, Shankar A, Kusumawardani N, *et al.* Low birth weight was the most dominant predictor associated with stunting among children aged 12–23 months in Indonesia. BioMed Central Nutrition. 2017;3(1):16.1-6.
258. Schwinger C, Fadnes LT, Shrestha SK, *et al.* Predicting undernutrition at Age 2 years with early attained weight and length compared with weight and length velocity. The Journal of Pediatrics. 2017;182:127-32.e1.
259. Fikadu T, Assegid S, Dube L. Factors associated with stunting among children of age 24 to 59 months in Meskan district, Gurage zone, South Ethiopia: a case-control study. BioMed Central Public Health. 2014;14:800.1-7.
260. Liberatos P, Link BG, Kelsey JL. The measurement of social class in epidemiology. Epidemiology Review. 1988;10:87-121.1-17.
261. Krieger N, Williams DR, Moss NE. Measuring social class in US public health research: concepts, methodologies, and guidelines. Annual Review of Public Health. 1997;18:341-78.
262. Karen Dynan, Douglas Elmendorf, Daniel Sichel. The evolution of household income volatility. The BE Journal of Economic Analysis and Policy: Advances, 122. 2012:41.1-41.
263. WHO. "Indicators for assessing infant and young child feeding practices: Part 2 Measurement." [Internet]. Available from: http://scholargooglecom/scholar?hl=en&btnG=Search&q=intitle:Indicators+for+assessing+infant+and+young+child+feeding+practices#0. 2010.
264. Vollmer S, Harttgen K, Kupka R, Subramanian SV. Levels and trends of childhood undernutrition by wealth and education according to a Composite Index of Anthropometric Failure: evidence from 146 Demographic and Health Surveys from 39 countries. British Medical Journal global health. 2017;2(2):e000206.
265. Guyatt H, Muiruri F, Mburu P, Robins A. Prevalence and predictors of underweight and stunting among children under 2 years of age in Eastern Kenya. Public Health Nutrition. 2020:1-10.
266. Dadi AF, Desyibelew HD. Undernutrition and its associated factors among pregnant mothers in Gondar town, Northwest Ethiopia. PLoS ONE. 2019;14(4):e0215305.

267. Casas M, Cordier S, Martinez D, *et al.* Maternal occupation during pregnancy, birth weight, and length of gestation: combined analysis of 13 European birth cohorts. Scandinavian Journal of Work, Environment and Health. 2015;41(4):384-96.
268. Ohonba A, Ngepah N, Simo-Kengne B. Maternal education and child health outcomes in South Africa: A panel data analysis. Development Southern Africa. 2019;36(1):33-49.
269. National Department of Health (NDoH), Statistics South Africa (Stats SA), South African Medical Research Counsel (SAMRC), ICF. South Africa Demographic and Health Survey 2016, . Report. 2019:1-627.
270. WHO, UN-Water. "UN-Water global analysis and assessment of sanitation and drinking-water (glaas) 2019 report. National systems to support drinking-water, sanitation and hygiene-Global status report 2019." Retrieved from: https://wwwwhoint/water_sanitation_health/publications/glaas-report-2019/en/. 2019:1-144.
271. WHO. "Indicators for assessing infant and young child feeding practices: Part 1 Definitions." Available from: http://scholargooglecom/scholar?hl=en&btnG=Search&q=intitle:Indicators+for+assessing+infant+and+young+child+feeding+practices#0. 2008.
272. de Onis M, Garza C, Victora CG, *et al.* The WHO Multicentre Growth Reference Study: planning, study design, and methodology. Food and nutrition bulletin. 2004;25(1 Suppl):S15-26.
273. WHO." WHO Global Database on Child Growth and Malnutrition." Retrieved From: https://wwwwhoint/nutgrowthdb/en/. 2019.
274. Katherine Hall, Richter LM. Introduction: children, families and the States. South African Child Gauge. 2018:1-10.
275. Caruana EJ, Roman M, Hernández-Sánchez J, Solli P. Longitudinal studies. Journal of Thoracic Disease. 2015;7(11):E537-E40.
276. Setia MS. Methodology series module 1: cohort studies. Indian Journal of Dermatology. 2016;61(1):21-5.
277. Harris P, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap) – A metadata-driven methodology and workflow process for providing translational research informatics support. Journal of Biomedical Information. 2009;42(2):377-81.

278. Chasekwa B, Maluccio JA, Ntozini R, *et al.* Measuring wealth in rural communities: Lessons from the Sanitation, Hygiene, Infant Nutrition Efficacy (SHINE) trial. PLoS ONE. 2018;13(6):e0199393-e.
279. Reyes H, Pérez-Cuevas R, Sandoval A, *et al.* The family as a determinant of stunting in children living in conditions of extreme poverty: a case-control study. BioMed Central Public Health. 2004;4(1):57.1-10.
280. WHO." Clinical, behavioural and socioeconomic factors related to severe malaria. A multicentre study in the Africa region." Retrieved from: https://wwwwhoint/malaria/publications/atoz/multicenter/en/. 2002.
281. Senekal M, Nel JH, Malczyk S, *et al.* Provincial Dietary Intake Study (PDIS): Prevalence and sociodemographic determinants of the double burden of malnutrition in a representative sample of 1 to under 10-year-old children from two urbanized and economically active provinces in South Africa. International Journal of Environmental Research and Public Health. 2019;16(18):3334.1-27.
282. Norris SA, Wrottesley S, Mohamed RS, Micklesfield LK. Africa in transition: growth trends in children and implications for nutrition. Annals of Nutrition and Metabolism. 2014;64(suppl 2)(Suppl. 2):8-13.
283. Nieuwoudt SJ, Ngandu CB, Manderson L, Norris SA. Exclusive breastfeeding policy, practice and influences in South Africa, 1980 to 2018: a mixed-methods systematic review. PLoS ONE. 2019;14(10):e0224029.
284. Barker M, Dombrowski SU, Colbourn T, *et al.* Intervention strategies to improve nutrition and health behaviours before conception. The Lancet. 2018;391(10132):1853-64.
285. Slemming W, Kagura J, Saloojee H, Richter LM. Early life risk exposure and stunting in urban South African 2-year old children. Journal of Developmental Origins of Health and Disease. 2017;8(3):301-10.
286. Caputo A, Foraita R, Klasen S, Pigeot I. Undernutrition in Benin - an analysis based on graphical models. Social Science and Medicine. 2003;56(8):1677-91.
287. Carren Ginsburg, Shane Norris, Linda M Richter, David B Coplan. Patterns of residential mobility amongst children in greater Johannesburg-Soweto, South Africa: observations from the Birth to Twenty cohort. Urban forum. 2009:17.

288. Svefors P, Rahman A, Ekström E-C, *et al.* Stunted at 10 years. linear growth trajectories and stunting from birth to pre-adolescence in a rural Bangladeshi cohort. PLoS ONE. 2016;11(3):e0149700. 1-18.
289. Grossman M. The human capital model of the demand for health. Rerieved from: https://ssrncom/abstract=206128. 1999.
290. Wagstaff A, Watanabe N. What difference does the choice of SES make in health inequality measurement? Health Economics. 2003;12(10):885-90.
291. Howe LD, Hargreaves JR, Gabrysch S, Huttly SR. Is the wealth index a proxy for consumption expenditure? a systematic review. Journal of Epidemiol Community Health. 2009;63(11):871-7.
292. Kaplan GA. Socioeconomic considerations in the health of urban areas. Journal of Urban Health : Bulletin of the New York Academy of Medicine. 1998;75(2):228-35.

APPENDICES

Appendix 1: Change of title of research

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Private Bag 3 Wits, 2050
Fax: 027117172119
Tel: 02711 7172076

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

12 February 2020
Person No: 1297539
TAA

Dr CB Ngandu
Unit 16, The Oval, 274 West Street, Centurion, Pretoria
0157
South Africa

Dear Dr Christian Ngandu

Doctor of Philosophy: Change of title of research

I am pleased to inform you that the following change in the title of your Thesis for the degree of **Doctor of Philosophy** has been approved:

From:	**Association between socioeconomic status with birth outcomes and infant growth in the first year of life. Case study in South Africa and Democratic Republic of Congo**
To:	**Association between socioeconomic status with birth outcomes and infant under nutrition in the first two years of life. Case studies in South Africa and the Democratic Republic of Congo**

Yours sincerely

Mrs Sandra Benn
Faculty Registrar
Faculty of Health Sciences

Appendix 2: Ethics clearance for the research project protocol

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

Office of the Deputy Vice-Chancellor (Research & Post Graduate Affairs)

TO: Dr BC Ngandu
School of Clinical Medicine
Developmental Pathways for Health Research Unit
Medical School

E-mail: 1297539@students.wits.ac.za

CC: Supervisor: Drs RM Said & L Chola; Professor SA Norris
<Rihlat.SaidMohamed@wits.ac.za>

FROM: Iain Burns
Human Research Ethics Committee (Medical)
Tel: 011 717 1252

E-mail: Iain.Burns@wits.ac.za

DATE: 16/01/2018

REF: *R14/49*

PROTOCOL NO: **M170955** *(This is your ethics application study reference number. Please quote this reference number in all correspondence relating to this study)*

PROJECT TITLE: *Association between socioeconomic status and birth outcomes and infant growth in the first year of life: case studies in South Africa and the DR Congo*

Please find attached the Clearance Certificate for the above project. I hope it goes well and that an article in a recognized publication comes out of it. This will reflect well on your professional standing and contribute to the Government funding of the University.

MSWorks2000/Iain0007/Clearscan.wps

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

R14/49 Dr BC Ngandu

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
CLEARANCE CERTIFICATE NO. M170955

NAME: (Principal Investigator)	Dr BC Ngandu
DEPARTMENT:	School of Clinical Medicine Developmental Pathways for Health Research Unit Medical School
PROJECT TITLE:	Association between socioeconomic status and birth outcomes and infant growth in the first year of life: case studies in South Africa and the DR Congo
DATE CONSIDERED:	29/09/2017
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Drs RM Said & L Chola; Professor SA Norris
APPROVED BY:	Professor CB Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	16 /01/2018

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 on 3rd floor, Phillip V Tobias Building, Parktown, University of the Witwatersrand, Johannesburg.

I/We fully understand 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 reviewed in **September** and will therefore be due in the month of **September** each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature

Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix 3: Permission to conduct study- Chris Hani Baragwanath Academic Hospital

GAUTENG PROVINCE
REPUBLIC OF SOUTH AFRICA

MEDICAL ADVISORY COMMITTEE

CHRIS HANI BARAGWANATH ACADEMIC HOSPITAL

PERMISSION TO CONDUCT RESEARCH

Date: 30th June 2017

TITLE OF PROJECT:

Interaction between nutrition, infection, household environment and care practices and their impact on growth and development in infants between birth and one year of age.

UNIVERSITY: Witwatersrand

Principal Investigator: Dr R S Mohamed

Department: DPHRU

Supervisor : N/A

Permission Head Department (where research conducted): Yes

The Medical Advisory Committee recommends that the said research be conducted at Chris Hani Baragwanath Academic Hospital. The CEO / management of Chris Hani Baragwanath Academic Hospital is accordingly informed and the study is subject to:-

- **Permission having been granted by the Committee for Research on Human Subjects of the University of the Witwatersrand.**
- The Hospital will not incur extra costs as a result of the research being conducted on its patients within the hospital
- The MAC will be informed of any serious adverse events as soon as they occur
- Permission is granted for the duration of the Ethics Committee Approval.

.....
Recommended
(On behalf of the MAC)
Date: 30/06/2017

.....
Approved/Not Approved
Hospital Management
Date: 03/07/17

Appendix 4: Permission from Department of Paediatrics at Chris Hani Baragwanath Academic Hospital

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

Department Of Paediatrics
Metabolic Unit
Chris Hani Baragwanath Academic Hospital
P. O. Bertsham
2013

July 2017

The Research Protocol Review Committee
Chris Hani Baragwanath Academic Hospital
Soweto
Johannesburg

Dear Madam/ Sir

I would like to inform you that Dr Rihlat Said Mahamed has been given a permission to conduct his/her research study in the Department of Paediatrics at Chris Hani Baragwanath Academic Hospital.

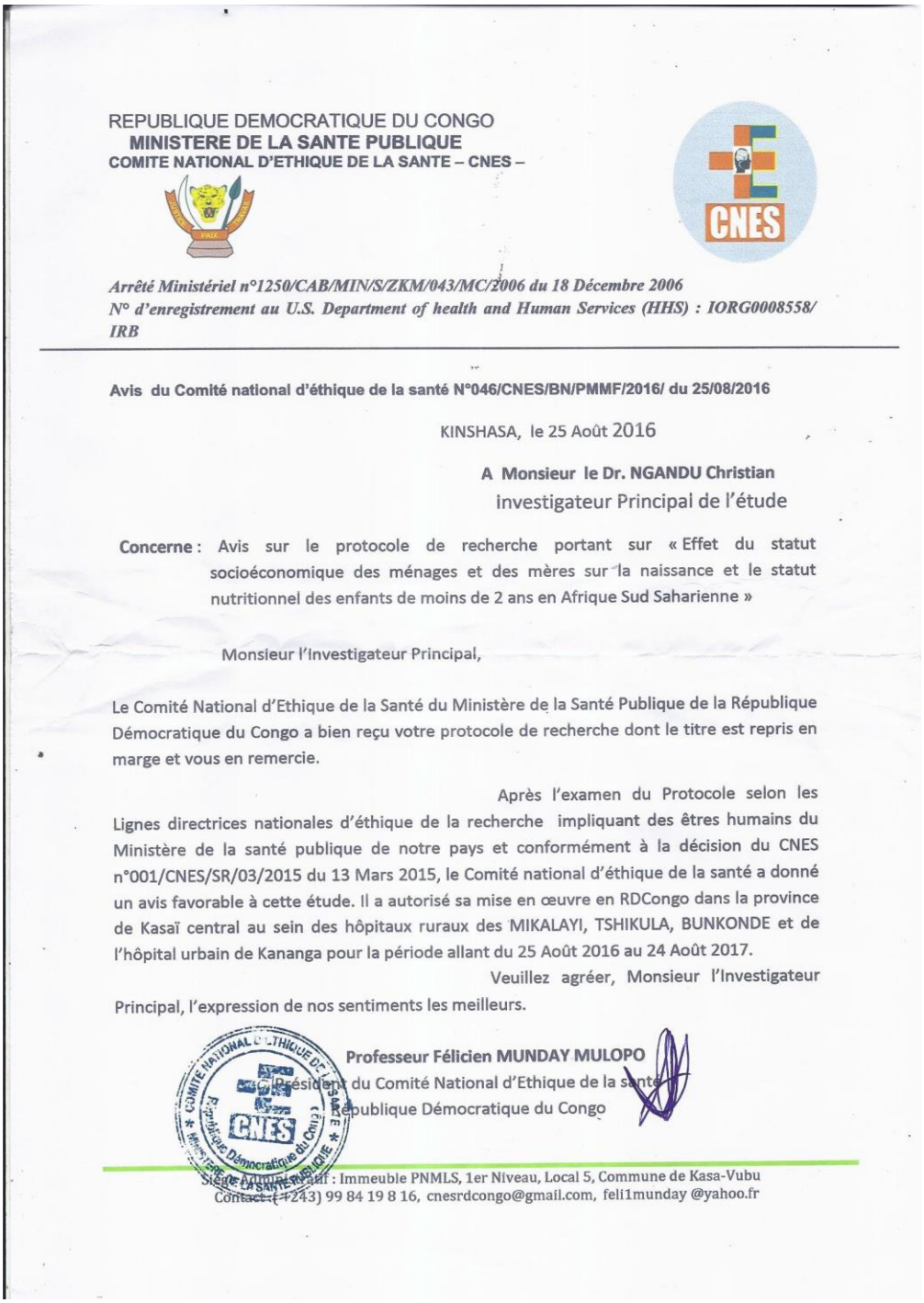
The title of his study is: **"Interaction between nutrition, infection, household environment and care practices and their impact on growth and development in infants between birth and one year of age."**

While he/she has been given permission to conduct this study, he/she cannot start with data collection until he/she has provided the Department with Ethics Committee Clearance Certificate.

Yours Sincerely

Professor Sithembiso Velaphi
Associate Professor and Head of Department of Paediatrics
Chris Hani Baragwanath Academic Hospital

Appendix 5: Ethics clearance from the Democratic Republic of Congo



REPUBLIQUE DEMOCRATIQUE DU CONGO
MINISTERE DE LA SANTE PUBLIQUE
COMITE NATIONAL D'ETHIQUE DE LA SANTE – CNES –

CNES

Arrêté Ministériel n°1250/CAB/MIN/S/ZKM/043/MC/2006 du 18 Décembre 2006
N° d'enregistrement au U.S. Department of health and Human Services (HHS) : IORG0008558/ IRB

Avis du Comité national d'éthique de la santé N°046/CNES/BN/PMMF/2016/ du 25/08/2016

KINSHASA, le 25 Août 2016

A Monsieur le Dr. NGANDU Christian
Investigateur Principal de l'étude

Concerne : Avis sur le protocole de recherche portant sur « Effet du statut socioéconomique des ménages et des mères sur la naissance et le statut nutritionnel des enfants de moins de 2 ans en Afrique Sud Saharienne »

Monsieur l'Investigateur Principal,

Le Comité National d'Ethique de la Santé du Ministère de la Santé Publique de la République Démocratique du Congo a bien reçu votre protocole de recherche dont le titre est repris en marge et vous en remercie.

Après l'examen du Protocole selon les Lignes directrices nationales d'éthique de la recherche impliquant des êtres humains du Ministère de la santé publique de notre pays et conformément à la décision du CNES n°001/CNES/SR/03/2015 du 13 Mars 2015, le Comité national d'éthique de la santé a donné un avis favorable à cette étude. Il a autorisé sa mise en œuvre en RDCongo dans la province de Kasaï central au sein des hôpitaux ruraux des MIKALAYI, TSHIKULA, BUNKONDE et de l'hôpital urbain de Kananga pour la période allant du 25 Août 2016 au 24 Août 2017.

Veuillez agréer, Monsieur l'Investigateur Principal, l'expression de nos sentiments les meilleurs.

Professeur Félicien MUNDAY MULOPO
Président du Comité National d'Ethique de la santé
République Démocratique du Congo

Siège : Adresse e-mail : Immeuble PNMLS, 1er Niveau, Local 5, Commune de Kasa-Vubu
Contact : (+243) 99 84 19 8 16, cnesrdcongo@gmail.com, feli1munday @yahoo.fr

Appendix 6: Permissions from four hospitals (Bunkonde, Kananga, Mikalayi, Tshikula) from the Democratic Republic of Congo

REPUBLIQUE DEMOCRATIQUE DU CONGO

PROVINCE DU KASAI CENTRAL

DIVISION PROVINCIALE DE LA SANTÉ

HOPITAL GENERAL DE REFERENCE DE BUNKONDE

Bunkonde, le 04/07/2017

N° ADM/251/HGR/.24...../BKD/2017

Objet : Autorisation de recherche

Au Directeur du DPHRU/WITSWATERANDS UNIVERSITY
Johannesburg, Afrique du Sud.

Monsieur le Directeur,

Par la présente, j'autorise les chercheurs du DPHRU/WITSWATERANDS UNIVERSITY a procéder dans l'hôpital général de BUNKONDE à la recherche, collecte et utilisation des données en faveur de l'étude en rapport avec les inégalités socio économiques sur la croissance de l'enfant de moins d'un an en Afrique sub Saharienne (« the socioeconomic inequalities with birth out comes and infant growth in sub Saharan Africa »).

Cette étude sera menée pendant la période à convenir. Les données sur le status socio-économique des mères seront collectées par questionnaire ainsi que celles sur l'anthropométrie infantile recueillies par mesurage au niveau dudit hôpital.

En outre, les chercheurs garantiront les principes de confidentialité, discrétion des informations ainsi que le consentement éclairé, la liberté et les droits des enquêtés (couple mère-enfant) selon les normes éthiques universelles en vigueur en République Démocratique du Congo. Et à ce titre, cette étude contribuera à l'amélioration de l'état de santé des populations locales et ne présente pas une nuisance sur le point de vue éthique.

Sentiments patriotiques.

HOPITAL GENERALE DE REFERENCE H G R B.P 70 KANANGA DE BUNKONDE

LE MEDECIN DIRECTEUR DE L'HOPITAL

Dr Huguette WONYA KANGASHE

HP HOPITAL PROVINCIAL GENERAL DE REFERENCE DE KANANGA

REPUBLIQUE DEMOCRATIQUE DU CONGO
MINISTERE DE LA SANTE PUBLIQUE
PROVINCE DU KASAI CENTRAL
HÔPITAL PROVINCIAL GÉNÉRAL DE RÉFÉRENCE
DE KANANGA

Kananga, le

N° ADM/001/HPGR/KGA/....229../2017

Objet : Autorisation de recherche

Au Directeur de DPHRU/WITSWATERANDS UNIVERSITY
Johannesburg, Afrique du Sud.

Monsieur le Directeur,

Par la présente, j'autorise les chercheurs du DPHRU/WITSWATERANDS UNIVERSITY a procéder dans l'hôpital Provincial de référence de Kananga à la recherche, collecte et utilisation des données en faveur de l'étude en rapport avec les inégalités socio économiques sur la croissance de l'enfant de moins d'un an en Afrique sub Saharienne (« the socioeconomic inequalities with birth outcomes and infant growth in sub Saharan Africa »).

Cette étude sera menée pendant la période à convenir. Les données sur le status socio-économique des mères seront collectées par questionnaire ainsi que celles sur l'anthropométrie infantile recueillies par mesurage au niveau dudit hôpital.

En outre, les chercheurs garantiront les principes de confidentialité, discrétion des informations ainsi que le consentement éclairé, la liberté et les droits des enquêtés (couple mère-enfant) selon les normes éthiques universelles en vigueur en République Démocratique du Congo. Et à ce titre, cette étude contribuera à l'amélioration de l'état de santé des populations locales et ne présente pas une nuisance sur le point de vue éthique.

Sentiments patriotiques.

LE MEDECIN DIRECTEUR DE L'HOPITAL

Dr Zed ILUNGA MUTSHIPAYI

117, Noella de Roover, provincialhopital@yahoo.fr, +243997850255, 243812428418

REPUBLIQUE DEMOCRATIQUE DU CONGO

PROVINCE DU KASAI CENTRAL

DIVISION PROVINCIALE DE LA SANTÉ

HOPITAL GENERAL DE REFERENCE

DE MIKALAYI

Mikalayi, le 28/06/2017

N°ADM/Réf/093/HGR MIK/12/2017

Objet : Autorisation de recherche

Au Directeur du DPHRU/WITSWATERANDS UNIVERSITY

Johannesburg, Afrique du Sud.

Monsieur le Directeur,

Par la présente, j'autorise les chercheurs du DPHRU/WITSWATERANDS UNIVERSITY a procéder au sein de l'hôpital général de MIKALAYI à la recherche, collecte et utilisation des données en faveur de l'étude en rapport avec les inégalités socio économiques sur la croissance de l'enfant de moins d'un an en Afrique sub Saharienne (« the socioeconomic inequalities with birth out comes and infant growth in sub Saharan Africa »).

Cette étude sera menée pendant la période à convenir. Les données sur le status socio-économique des mères seront collectées par questionnaire ainsi que celles sur l'anthropométrie infantile recueillies par mesurage au niveau dudit hôpital.

En outre, les chercheurs garantiront les principes de confidentialité, discrétion des informations ainsi que le consentement éclairé, la liberté et les droits des enquêtés (couple mère-enfant) selon les normes éthiques universelles en vigueur en République Démocratique du Congo. Et à ce titre, cette étude contribuera à l'amélioration de l'état de santé des populations locales et ne présente pas une nuisance sur le point de vue éthique.

Sentiments patriotiques.

LE MEDECIN DIRECTEUR DE L'HOPITAL

Dr Serge NDAMAMBA

HOPITAL GENERAL
REFERENCE DE MIKALAYI
70 MIKALAYI/KANANGA
REPUBLIQUE DEMOCRATIQUE DU CONGO

REPUBLIQUE DEMOCRATIQUE DU CONGO

PROVINCE DU KASAI CENTRAL

DIVISION PROVINCIALE DE LA SANTÉ

HOPITAL GENERAL DE REFERENCE DE TSHIKULA

Tshikula, le 1er juillet 2017

N°ADM/.004...../BDOM/HGR/TKLA/2017

Objet : Autorisation de recherche

Au Directeur du DPHRU/WITSWATERANDS UNIVERSITY
Johannesburg, Afrique du Sud.

Monsieur le Directeur,

Par la présente, j'autorise les chercheurs du DPHRU/WITSWATERANDS UNIVERSITY a procéder dans l'hôpital général de Tshikula à la recherche, collecte et utilisation des données en faveur de l'étude en rapport avec les inégalités socio économiques sur la croissance de l'enfant de moins d'un an en Afrique sub Saharienne (« the socioeconomic inequalities with birth outcomes and infant growth in sub Saharan Africa »).

Cette étude sera menée pendant la période à convenir. Les données sur le status socio-économique des mères seront collectées par questionnaire ainsi que celles sur l'anthropométrie infantile recueillies par mesurage au niveau dudit hôpital.

En outre, les chercheurs garantiront les principes de confidentialité, discrétion des informations ainsi que le consentement éclairé, la liberté et les droits des enquêtés (couple mère-enfant) selon les normes éthiques universelles en vigueur en République Démocratique du Congo. Et à ce titre, cette étude contribuera à l'amélioration de l'état de santé des populations locales et ne présente pas une nuisance sur le point de vue éthique.

Sentiments patriotiques.

LE MEDECIN DIRECTEUR DE L'HOPITAL

Dr Matthieu MULUMBA

Appendix 7: Ethics clearance for the Soweto 1000 days study

1. Ethics clearance for the first component: Foetal growth study investigating maternal factors associated with foetal growth and delivery outcomes

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG
Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
R14/49 Professor Shane Norris

CLEARANCE CERTIFICATE	**M120524**
PROJECT	Foetal Growth Study: Investigating Maternal Factors Associated with Foetal Growth and Delivery Outcomes
INVESTIGATORS	Professor Shane Norris
DEPARTMENT	Developmental Pathways Research Unit
DATE CONSIDERED	25/05/2012
DECISION OF THE COMMITTEE*	Approved unconditionally

Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.

DATE 14/07/2013 **CHAIRPERSON** _____
(Professor PE Cleaton-Jones)

*Guidelines for written 'informed consent' attached where applicable
cc: Supervisor :

DECLARATION OF INVESTIGATOR(S)
To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University.
I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to a completion of a yearly progress report.**
PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES.

b) Ethics clearance for the second component: The Soweto baby growth study

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M130905

NAME: (Principal Investigator)	Prof Shane Norris & Shelley Macaulay
DEPARTMENT:	Developmental Pathways for Health Research Unit Chris Hani Baragwanath Academic Hospital
PROJECT TITLE:	The Soweto Baby Growth Study
DATE CONSIDERED:	27/09/2013
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	

APPROVED BY: Professor PE Cleaton-Jones, Chairperson, HREC (Medical)

DATE OF APPROVAL: 25/03/2014

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 Secretary in Room 10004, 10th floor, Senate House, University.

I/we fully understand the conditions under which I am/we are authorized 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 the application to the Committee. **I agree to submit a**

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix 8: Socioeconomic questionnaire used in South Africa

SES (LF)

University of the Witwatersrand, Johannesburg
Developmental Pathways for Health Research Unit
Department of Paediatrics and Child Health

Soweto Baby WASH Study
Socioeconomic Status In Growth (SESGROWTH LF)

SBWID: (Mother)	SBW					
SBWID: (Infant)	SBW					

Timepoint:			Month
Visit Location:	Home	DPHRU	Other:
If other, specify:			

Any other enrolment or ID:	No		Yes		Specify,

Researcher Name:			Researcher Signature:						
Researcher Code:			Date:	D	D	M	M	Y	Y

Comments:

_____

_____

_____

_____

MATERNAL GENERAL INFORMATION							
1. How many people have been living in your home over the past 3 months?				Number			
Can you list the other people who have stayed in your household (on average at least four nights a week over the last four weeks. Do not forget to include babies, the bedridden and elderly people, also include your partner but not yourself)							
Children (≤to 18 years of age)				**Adults (>18 years of age)**			
Age	**Sex**	**Highest level of education**	**Relationship to yourself**	**Age**	**Sex**	**Highest education level**	**Relationship to yourself**
	M/F	CODE; EDUCATION	CODE; RELATIONSHIP		M/F	CODE; EDUCATION	CODE; RELATIONSHIP
	M/F	CODE; EDUCATION	CODE; RELATIONSHIP		M/F	CODE; EDUCATION	CODE; RELATIONSHIP
	M/F	CODE; EDUCATION	CODE; RELATIONSHIP		M/F	CODE; EDUCATION	CODE; RELATIONSHIP
	M/F	CODE; EDUCATION	CODE; RELATIONSHIP		M/F	CODE; EDUCATION	CODE; RELATIONSHIP
	M/F	CODE; EDUCATION	CODE; RELATIONSHIP		M/F	CODE; EDUCATION	CODE; RELATIONSHIP

CODES; EDUCATION	1= No formal schooling 2= Grade R to Grade 3 3= Grade 4 to Grade 7	4= Grade 8 to Grade 12 5= Tertiary/College 6= Undergraduate 7= Postgraduate
CODES; RELATIONSHIP	1= Parent 2= Grandparent 3= Your own child 4= Sibling 5= Other relative (including other children, in laws, etc)	6= Spouse/partner 7= Partner 8= Friend 9= Housemate/flatmate/roommate 10= Other: Specify

Marital Status:			
2. What is your current marital status? (Legal Status)			CODE
CODES	1= Married with certificate (by home affairs) 2= Married traditionally 3= Widowed	4= Divorced or Separated 5= Single 6= Cohabitation	
If the participant is Single, Widowed, Divorced or Separated go to Question 6 *Otherwise go to Question 3*			
3. What has you and your partner's living situation been the past 3 months?			CODE
CODES	1= Living together (at least more than 1 month) 2= Not living together (at least less than 2 months)	3= Not living together (past 3 months) 90= Refused	
4. What is your marital situation regarding the number of spouses?			CODE
CODES	1= Polygamous 2= Monogamous		
5. If polygamous, how many spouses does your partner have?			NUMBER
CODES	99= Don't know Number of co spouses, if known.		
Maternal Occupation			
6. Have you ever had a job? (By job we mean any work done to earn money or to gain skills. This includes casual/informal & volunteer work) *If yes, please go to Question 8* *If no, please go to Question 7*			Yes/No
7. What is the reason why you have never had a job? Go to Question 17			CODE
CODES	1= Family responsibilities 2= Lack of information about job opportunities 3= Lack of job opportunities	4= Not looking or not interested in job 5= Other (Specify)	
8. Did you work in past three months? *If yes, please go to Question 10* *If no, please go to Question 9*			Yes/No
9. Why did you not work in the past three months? If Maternity Leave, go to 16 Otherwise, go to question 15			CODE
CODES	1= Resigned 2= Fired 3= Retrenched 4= Health reasons 5= Maternity leave	6= House wife 8= No transport 9= For studies 10= Other (Specify)	
10. Do you currently work? *If yes, please go to Question 11* *If no, please go to Question 17*			Yes/No
11. What is your current job?			

12. How would you classify your current job?			CODE
CODES	1= Occasional Part time 2= Occasional Fulltime 3= Permanent Fulltime	4= Permanent Part time 99= Don't know	
13. Is your current job contract or casual?			CODE
CODES	1= Contract 2= Casual 99= Don't know		
14. When did you start your current job? (Month & Year)			MM/YY
15. Who is your employer? Go to Question 17			CODE
CODES	1= Self 2= Family 3= Government 4= Non-governmental/community based organisation	5= Private company 6= Private household 7= Other (Specify)	
16. Please provide the date when you will commence or has commenced working again			YY/MM/DD
17. What has been your source(s) of income in the past three months?			CODE
CODES	1= Inheritance 2= Pension 3= Support from family or friend (grandparents, parent, sibling, friend, etc.) 4= Community support (other than family: anonymous donation, church, etc.) 5= Partner	6= Grant (child support, disability) 7= Profit 8= Own loan 9= Other (Specify)	
Maternal Education			
18. What is your highest level of education?			CODE
CODES	1= No formal schooling 2= Grade R to Grade 3 3= Grade 4 to Grade 7 4= Grade 8 to Grade 12	5= Tertiary/College 6= Undergraduate 7= Postgraduate	

19. Have you been at school or studying in the past three months? *If yes, please go to Question 21* *If no, please go to Question 20*				Yes/No
20. If you have stopped schooling/study in the past 3 months, what is the reason?				CODE
CODES	1= Schooling sufficient 2= Lack of books 3= Poor quality of teaching 4= Lack of teachers	5= Facilities in bad condition 6= Fees too high 7= No space available 8= Crime at school	9= Poor discipline 10= Too many learners in class 11= Other (Specify)	

Household and Income Characteristics:

A household is considered as one or more people habitually living in the same dwelling, sharing a meal and having a joint budget.

21. On average, what is your household income, per month, over the past 3 months?					CODE
CODES	1= < 900 2= 900-1 800 3= 1 800-2 700 4= 2 700-3 600	5= 3 600-4 500 6= 4 500-5 400 7= 5 400-6 300 8= 6 300-7 200	9= 7 200-8 100 10= 8 100-9 000 11= 9 000-9 900 12= 10 800-20 700	13= 20 700-30 600 14= >30 600 90= Refused 99= Don't know	

22. What is your home ownership situation?			CODE
CODES	1= Owner 2= Renting 3= Not renting, not owner, but family property	4= Squatting 90= Refused	

23. If (22) is OWNER, where did you find funding for your house?			CODE
CODES	1= Inheritance 2= Mortgage from bank	3= Own funding 4= Government	5= Other (Specify)

24. What is the total number of rooms used for sleeping in your current home? Include outside rooms if they are used by household members, but not if rented out.		Number
25. Which of the following do you have in your current home (place where you spent most	Electricity	Yes/No
	Bicycle	Yes/No
	Motorcycle/Bike	Yes/No

nights in the past 3 months)? *It does not matter who owns/pays for these things. (answer all questions)*	Motor vehicle/Car	Yes/No
	Fridge	Yes/No
	Microwave oven	Yes/No
	Washing machine	Yes/No
	Landline telephone	Yes/No
	Camera	Yes/No
	Cell phone	Yes/No
	Television	Yes/No
	Video machine/DVD player	Yes/No
	MNet/DSTV/Satellite	Yes/No
	Agricultural land	Yes/No
	Farm animals	Yes/No
	Computer/laptop	Yes/No
	Internet access	Yes/No
26. Do you have any debts?	Money owed to banks or financial institutions (legal and documented loans)	Yes/No
	Money owed to money lenders (loan sharks, community money-lenders)	Yes/No
	Money owed to family or friends	Yes/No
	Money owed to shops/private companies/ municipality/unpaid bills/accounts/store accounts (e.g. Jet or Edgars)	Yes/No
27. Who has usually paid for the following expenses for you during the past 3 months (please *answer all questions*)	Food	CODE
	Transport	CODE
	Housing & utilities	CODE
	Education	CODE
	Clothing	CODE
	Cell phone airtime or contract	CODE
CODES	1= I pay for this with my own funds (Myself)	
	2= Family members pay for this	
	3= Partner pays for this	

	4= Someone else pays for this (Specify)		
28. How would you describe the home you are living in?			CODE
CODES	1= Shack/Zozo 2= Flat/Cottage 3= House 4= Room/Garage	5= Residence (attached to education or employment) 6= Hostel 7= RDP/Government Housing 8= Other (Specify)	
29. What are the main walls in your current home made of?			CODE
CODE	1= No walls 2= Mud 3= Plaster finished 4= Corrugated Zinc	5= Prefab 6= Bare brick or cement block 7= Cement 8= Other, specify	
30. What is the main floor material in your current home?			CODE
CODES	1= Ceramic tiles 2= Cement 3= Carpet	4= Earth/sand/mud 5= Wood planks 6= Vinyl/linoleum	7= Other (Specify)
31. Which of the following types of energy do you use for cooking in your current home?			CODE
CODES	1= Electricity 2= Egoli gas 3= Grass/ Shrubs 4 = Kerosene 5= Charcoal	6= Liquid Propane 7= Wood 8= Animal Dung 9= Paraffin 10= Solar Panel	11= Generator 12= No Cooking facilities 13= Other (Specify)
32. Which of the following types of material do you use for your roofing/ceiling in your current home?			CODE
CODES	1= Poured Concrete 2= Metal 3= Wood 4= Thatch 5= Other (Specify)		

Appendix 9: Original paper 1 for objective 1

Journal of Developmental Origins of Health and Disease

www.cambridge.org/doh

Review

Cite this article: Ngandu CB, Momberg D, Magan A, Chola L, Norris SA, and Said-Mohamed R. The association between household socio-economic status, maternal socio-demographic characteristics and adverse birth and infant growth outcomes in sub-Saharan Africa: a systematic review. *Journal of Developmental Origins of Health and Disease* https://doi.org/10.1017/S2040174419000680

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Keywords:
Socio-economic factors; infant undernutrition; sub-Saharan Africa

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The association between household socio-economic status, maternal socio-demographic characteristics and adverse birth and infant growth outcomes in sub-Saharan Africa: a systematic review

Christian Bwangandu Ngandu[1], Douglas Momberg[1], Ansuyah Magan[2], Lumbwe Chola[2], Shane A. Norris[1,3] and Rihlat Said-Mohamed[1,3,4]

[1]MRC/WITS Developmental Pathways for Health Research Unit, Department of Paediatrics and Child Health, University of the Witwatersrand, Johannesburg, South Africa, [2]School of public Health, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa, [3]DST-NRF Centre of Excellence in Human Development, University of the Witwatersrand, Johannesburg, South Africa, and [4]DST-NRF Centre of Excellence in Food Security, University of the Western Cape, Cape Town, South Africa

Abstract

Adverse birth outcomes and infant undernutrition remain the leading causes of morbidity and mortality in sub-Saharan Africa (SSA). Impaired infant growth and development, which often begins during foetal development, may persist during the first 2 years of life and has been associated with higher risks of cardiometabolic diseases. This systematic review assessed the associations between maternal demographic characteristics and household socio-economic status (SES), and preterm birth (PTB), small for gestational age, low birth weight (LBW), stunting, wasting and underweight in children under 2 years of age in SSA countries. Following the Preferred Reporting Items for Systematic reviews and Meta-Analyses guidelines, we searched for publications in three electronic databases (PubMed, Scopus and ScienceDirect). Eleven studies on children under 2 years of age, in four SSA regions, published in English between 1990 and 2018, were included. All the studies were observational in design (cross-sectional or cohort studies). Maternal education was the most commonly explored exposure. Most studies (63.3%) focused on undernutrition during the first 2 years of life: LBW, PTB and stunting. Lower maternal education, maternal unemployment and lower household wealth index were the SES factors most commonly associated with adverse birth outcomes and infant undernutrition. Maternal marital status was not associated with any infant outcomes. The definitions of the SES varied, which may explain discrepancies between studies. Nutrition intervention programs in SSA need to promote education and poverty alleviation in women at reproductive age, starting from pre-pregnancy, to optimise infant growth and development and prevent the increase in the prevalence of cardiometabolic diseases.

Introduction

Undernutrition in infants under 2 years of age remains a major public health issue, particularly in low- and middle-income countries (LMICs).[1,2] The 2011 United Nation Children's Fund (UNICEF) Global Nutrition report indicated that more than 311 million children (32% of all children) under 5 years of age were undernourished. Globally, more than four million children died within a year of their birth due to inadequate nutrition.[3] In addition, poor infant nutrition has been shown to be responsible for more than 40% of deaths in children younger than 5 years, particularly during their first month of life.[1] The adverse effects of infant undernutrition include physical disabilities,[4] poor school attendance,[1] diabetes,[1] hypertension and cardiovascular disease,[5] which may affect the subsequent generation.[1,6] Therefore, undernutrition may have negative long-term consequences for a country's economic growth and development.[3]

Sixty percent of all undernutrition occurs in sub-Saharan Africa (SSA) and South Asia.[3] The impact of undernutrition on child growth and development starts *in utero*. Maternal undernutrition has been associated with poor foetal growth,[1,7,8] which may result in low birth weight (LBW, weight at birth less than 2500 g),[1] small for gestational age (SGA, newborns weighing less than the 10th percentile of a sex-specific reference population) and preterm birth (PTB, children born before 37 gestational weeks).[3,9] In 2016, UNICEF reported that 15% (20 million) of newborns worldwide had LBW and 10% (15 million) PTB.[3] In 2010, 32.4 million newborns worldwide were SGA.[9] The prevalence of SGA was 27% in LMICs, with SSA having one of the highest prevalence.[9–11] Studies in LMICs have shown that LBW, SGA and PTB are the predictors

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of infant undernutrition in children below the age of 2 years.[12–15] Undernourished infants may present with underweight (weight-for-age (WAZ) less than −2 standard deviation (−2SD) of the median of the World Health Organization (WHO) growth standard) or wasting (weight-for-height (WHZ) less than −2SD of the median of the WHO growth standard) which are sometimes combined with a third form of undernutrition, stunting (height-for-age (HAZ) less than −2SD of the median of the WHO growth standard).[1,3] Globally, among children under 5 years of age in 2011, 25.9% were stunted, 15.7% were underweight and 8% were wasted.[5,15] In 2016, Africa had the second largest prevalence (31.6%) of undernutrition in children under 5 years of age in the world, and the absolute number of affected children is continuing to increase.[3]

To formulate strategies to prevent and reduce maternal and infant undernutrition in SSA, a major public health concern in the region, it is critical to understand the contextual factors associated with LBW, PTB, SGA, stunting, wasting and underweight. The period between conception and 2 years of age, the first thousand days, has been shown to be an opportune time for interventions such as immunisation, deworming, nutrient supplementation (vitamin A, iodine) that optimise child growth and development.[16] However, the prevalence of undernutrition varies between SSA countries, probably due to different factors including socio-economic status (SES), cultural and political landscapes.[3] The UNICEF causal framework for maternal and child undernutrition, the first version of which was described in 1990, outlined that infant undernutrition is associated with basic, underlying and immediate factors.[3,17] Maternal demographic characteristics and socio-economic factors have been identified as basic causes of undernutrition.[3] Empirical studies in LMICs have reported associations between household and maternal demographic characteristics and SES factors with stunting in preschool children (between 2 and 5 years of age).[18] Maternal education,[19,20] maternal occupation,[21] household poverty[7,22,23] and marital status[18] have been shown to be associated with adverse birth outcomes and child undernutrition.[1] However, most studies in SSA report those associations in children under 5 years of age as a group, overshadowing evidence during the first thousand days period. In addition, the directions of the associations between the various SES factors and infant undernutrition are not consistent throughout the studies in SSA. Therefore, we undertook a systematic review of the literature to summarise the findings on the associations between maternal demographics and household SES factors and LBW, PTB, SGA, stunting, wasting and underweight in children under 2 years of age in SSA.

Methods

Protocol and registration

This systematic review followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines.[24,25] The protocol was registered under the International prospective register of systematic reviews (PROSPERO, https://www.crd.york.ac.uk/prospero/#myprospero, number CRD42018076828).

Eligibility criteria

We considered studies published between 1990 and June 2018, which investigated the associations between maternal socio-demographic characteristics and household SES factors with birth outcomes and nutritional status of children under 2 years of age, in 52 SSA countries (Supplementary sheet S1).

Data sources

Studies included in this review were obtained from three databases: PubMed, ScienceDirect and Scopus. For studies that were not sourced through these databases, we contacted the corresponding authors to request a copy of the original publication.

Search strategy and study selection

The following combination of category of keywords was used to search for eligible studies: maternal demographic characteristics and household SES factors (maternal education, maternal occupation, maternal marital status, maternal income and household wealth) and birth outcomes and child undernutrition (LBW or SGA or PTB or stunting or wasting or underweight or undernutrition) and 52 SSA countries. We sequentially screened titles, abstracts and the full text to identify studies that matched our inclusion and exclusion criteria. The study search and selection were performed separately by two co-authors (CBN and DM) and conflicts were resolved by a third co-author (RS-M).

Data

Maternal socio-demographic characteristics and household socio-economic factors

In accordance with the UNICEF conceptual framework,[3] we considered the following maternal socio-demographic characteristics and household SES factors: maternal education, maternal occupation, maternal income, maternal marital status and household wealth. Maternal education was measured as educational milestones, qualifications attained or literacy level.[26] In LMICs, repeating school years is considered the most appropriate measure for education level of individuals.[26] Maternal marital status referred to the civil status of each mother in relation to the marriage laws in the country under consideration.[27] Maternal income and maternal occupation in LMICs are more difficult to measure because of the presence of an informal economy, self-employment and seasonal activity. Similarly, occupation was measured by informal employment and domestic work.[26] Household wealth index (HWI) was based on ownership of a range of durable assets, household measures of SES characteristics or access to basic services such as health or education.[26]

Birth outcomes

The following birth outcomes were considered: LBW, SGA and PTB. PTB or prematurity was defined as a baby born before 37 completed gestational weeks or 259 days of pregnancy.[9,28] LBW was defined as birth weight less than 2500 g regardless of gestational age.[3] Newborns classified as SGA were defined as those whose birth weight was below the 10th percentile when compared to the 1991 US national reference population[29] or the WHO standard curve.[9,30]

Undernutrition in children between birth and 2 years of age

The following categories of undernutrition were considered: stunting, wasting and underweight. Stunting was defined as children with length-for-age/HAZ adjusted for sex, less than

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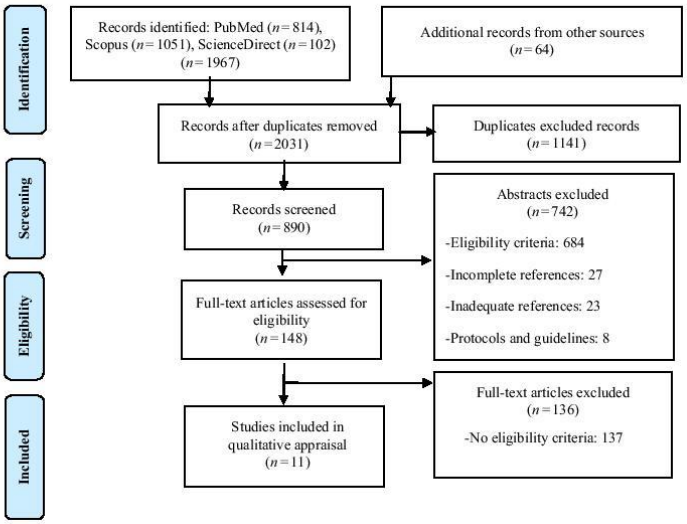

Fig. 1. Flow diagram on the association between demographic, socio-economic factors with birth and infant growth outcomes.

−2SD of the median of the WHO growth standard curve.[31] Wasting and underweight were defined as WHZ and WAZ less than −2SD of the median of the WHO growth standard curve, respectively.[31]

Synthesis of results

We extracted the following data from each study included in this systematic review: author names, year of publication, study aims, country, study design, study setting, participant's age, study sample size, SES factors, growth outcomes and quality of evidence.

Data collection process and summary measures

Data were extracted separately by two co-authors (BN and DM) and conflicts were resolved by a third co-author (RS-M). Data extraction was done independently by the first and second authors. Odds ratios (ORs) and/or adjusted odds ratios (aORs), relative risk and/or adjusted relative risk and related confidence intervals (CIs) were extracted for each association of interest.

Quality appraisal and risk of bias for primary studies

The quality of the studies included in this systematic review was assessed using the GRADE approach by two independent co-authors (BN and DM) with involvement of a third co-author (RS-M) when there was no consensus. Consensus was reached by two co-authors for five (45.4%) studies.[32–36] (Supplementary Table S2). Eight parameters were used to score the quality of each study: study design, risk of bias, inconsistency, indirectness, imprecision, publication bias, magnitude of effect, confounding and dose–response.[37] The quality of the studies was graded as follows: high (four points), moderate (three points), low (one point), and very low (zero points).

Risk of bias

The risk of bias was identified using the GRADE approach.[37,38] Studies were evaluated on three domains: recruitment of the participants (two criteria on randomisation), conduction of the study (one criterion on blinding) and the reporting of the study outcomes (two criteria). For each study, each criterion was rated as high, low or unclear. Studies were then categorised as being high risk (low rate in three or more characteristics), moderate risk (low rate in two characteristics), low risk or very low risk (low rate in less than two characteristics).

Quantitative analysis

A meta-analysis was not conducted in this systematic review as the definitions of SES factors varied across studies. In addition, for studies for which we could harmonise definitions of SES factors (maternal education and marital status), critical data necessary for the meta-analyses were not available in the published manuscript and could not be retrieved by contacting the authors.

Results

Description of studies

The processes of search, selection, inclusion and exclusion of relevant studies for this systematic review are presented in Fig. 1. We identified 2031 studies from the databases. After removing duplicate studies (1141 articles), titles and abstracts of 890 studies were screened and 148 studies were retained for full-text screening. The reasons for exclusion were as follows: duplicated study, publications before 1990, studies conducted in countries outside of SSA, no SES factors included in the study, no outcomes of interest included in the study, conference papers, editorials, newsletters, comments and notes. We included 11 studies in this systematic review.

Table 1 presents the characteristics of each study. All included studies were observational and comprised five cohort studies[32,34,36,39] and six cross-sectional surveys.[33,40–44] There were five (45.4%) high-quality studies,[40–44] five of moderate-quality[32–36] and one low-quality study.[39]

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Table 1. Characteristics and summary of studies included in the systematic review

First author, year (reference)	Aim	Study design	Country	Setting	Participants age	Sample size	Demographic and socio-economic factors	Outcomes	Quality of evidences
Assefa[32]	To measure the incidence and determinants of LBW in a rural population in Ethiopia	Cohort study	Ethiopia	Urban and Rural	0–28 days	956	Maternal education, household wealth index, maternal income	LBW	Moderate
Engebretsen *et al.*[40]	To describe current infant growth patterns and their association with feeding practices in Uganda	Cross-sectional study	Uganda	Rural and Urban	0–11 months	723	Household wealth index, maternal marital status, maternal occupation, maternal education	Stunting Wasting	High
Ickes *et al.*[33]	To assess maternal socio-demographic factors that may constrain women's caring capabilities and child nutrition in Uganda	Cross-sectional study	Uganda	National	0–23 months	1897	Maternal occupation, maternal marital status, maternal education, household wealth index	Stunting Wasting Underweight	Moderate
Mamabolo *et al.*[39]	To evaluate feeding practices and growth patterns in the central region of Limpopo in SA	Cohort study	South Africa	Semi-rural	0–12 months	276	Maternal marital status, maternal occupation, maternal education	Stunting Wasting Underweight	Low
Medhin *et al.*[34]	To assess the predictors of short- and intermediate-term infant health and nutritional outcomes in Ethiopia	Cohort	Ethiopia	Rural	0–12 months	1065	Maternal marital status, maternal occupation, maternal education	Underweight Stunting Wasting	Moderate
Muhihi *et al.*[41]	To determine the risk factors of PTB and SGA in 19629 newborns in Tanzania	Cross-sectional	Tanzania	Urban and rural	0–28 days	19269	Maternal education, household wealth index	Term-AGA, SGA, PTB, SGA-PTB	High
Ndirangu *et al.*[35]	To determine the associations between SGA, PTB, maternal HIV status and infant mortality in South Africa	Cohort	South Africa	Rural	0–24 months	2368	Maternal education	SGA PTB	Moderate
Ukwuani and Suchindran[42]	To examine the relationship between women's work and infant and child nutritional status in Nigeria	Cross-sectional	Nigeria	National	0–12 months (sub group of 0–59 months)	1338	Marital status maternal occupation, maternal education, household wealth index	Stunting, wasting	High

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Wamani *et al.*[43]	To examine the association between four socio-economic indicators (maternal and paternal education, household asset index and land ownership) and stunting in Uganda	Cross-sectional	Uganda	Rural	0–24 months	720	Maternal education, household wealth index	Stunting	High
Wamani *et al.*[44]	To assess the determinants of poor anthropometric status in infants and young children in Uganda	Cross-sectional	Uganda	Rural	0–23 months	698	Maternal education	Stunting Wasting Underweight	High
Watson-Jones *et al.*[36]	To determine the risk factors for poor birth outcomes and their relative contribution on the outcomes in Tanzania	Cohort	Tanzania	Rural	0–28 days	1536	Maternal occupation	PTB, LBW	Moderate

AGA, appropriate gestational age; HIV, human immunodeficiency virus; LBW, low birth weight; PTB, preterm birth; SA, South Africa; SGA, small for gestational age.

Although the studies covered the four regions of SSA, they were conducted in only five countries: four in Uganda,[33,40,43,44] two each in South Africa,[35,39] Ethiopia[32,34] and Tanzania,[36,41] and one study in Nigeria.[42] Most of the studies were conducted exclusively in rural areas,[34–36,39,43,44] five were conducted in both rural and urban areas,[32,33,40–42] and two were national surveys.[33,42]

Only four studies focused on the birth outcomes of interest,[32,36,41,45] while seven studies focused on undernutrition from birth to 2 years of age.[33,34,39,40,42–44] The distribution of studies per outcome of interest was as follows: three for LBW,[32,36,41] four for PTB,[35,36,41,45] two for SGA,[35,41] seven for stunting,[33,34,39,40,42–44] seven for wasting[33,34,39,40,42,44] and four for underweight.[33,34,39,44]

Maternal socio-demographic characteristics and household SES factors investigated in the studies were: maternal education in 11 studies,[32–34,36,39–45] maternal occupation in 5 studies,[33,36,39,40,44] maternal marital status in 5 studies[33,34,39,40,42] and maternal or HWI in 5 studies.[33,34,40,42,43] Maternal education was defined as illiterate or not,[32,33] educated or not,[33,43] student or not,[39] formal or not formal[41] and the level of education (i.e., none, primary and secondary education level).[35,39,41,42] Maternal occupation was measured as follows: staying at home vs. not staying home,[32] working in a skilled job vs. unskilled work such as farming,[36] working vs. not working,[33,42] being a housewife vs. not being a housewife.[39] Ukwuani and Suchindran[42] defined occupation in combination with other variables such as mother earning a cash payment, and taking her child with her to work. Maternal marital status was defined as follows: polygamous vs. non-polygamous marriage,[34,42] or married/living with a partner vs. divorced/widowed/not living together[33] or married vs non married.[40] Lastly, HWI was categorised into three classes (better off, middle or poor)[32] or five quintiles.[33,40,41,44] In some studies, the HWI compared mothers using a 60% cut-off for the HWI[33] or a poverty index from 1 to 12.[34]

Associations between maternal socio-demographic characteristic, household socio-economic factors and birth outcomes (Table 2)

In three studies, maternal level of education was not associated with LBW and PTB.[32,35,41] However, when cut-offs for PTB and SGA were 37th week and 3rd percentile, respectively, Muhihi *et al.*[41] found that having a mother with no formal schooling was associated with simultaneous PTB and SGA compared to having a mother who completed formal schooling. In another study, a maternal education higher than secondary level reduced the odds of SGA by 13% after adjusting for maternal age, residence, parity, maternal height and infant male sex.[41]

There was no significant association between maternal occupation and either SGA or PTB.[36] Stay-at-home mothers had 80% greater odds of having an LBW child compared to those who were working.[32] Another study[36] found that, the odds of having LBW were lower by 72% for those mothers who had skilled work compared to only 55% for those mothers who had unskilled work after adjusting for maternal characteristics (age, anthropometry, fertility desire and parity), paternal support, geographical location (residence), behavioural characteristics (physical violence) and health (access to the antenatal care services).

HWI was not significantly associated with SGA in one study.[41] However, the poorest households had 21% and 49% greater risk of PTB than affluent households in urban and rural settings, respectively.[41] Another study showed that the poorest households had

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Table 2. Associations between demographic and socio-economic factors with LBW, PTB and SGA

Outcomes	Demographic and socio-economic factors	Studies	Demographic and socio-economic variables	Effect size	Effect size estimates (coefficient and CI)	Factors that variables were adjusted for
Low birth weight	Maternal education	Assefa *et al.*[32]	Illiterate (Ref: literate)	OR	1.2 (0.8–1.82)	Maternal age, residence, parity, MUAC, fertility desire, ANC, violence in pregnancy, access to health facility, involvement of the husband.
			Illiterate (Ref: literate)	aOR	0.9 (0.58–1.46)	
			Illiterate (Ref: literate)	aOR	0.9 (0.6–1.47)	
	Household WI	Assefa *et al.*[32]	Poor (Ref: better off)	OR	2.1 (1.46–2.98)	Maternal age, residence, parity, MUAC, fertility desire, ANC, violence in pregnancy, access to health facility, involvement of the husband
			Middle (Ref: better off)		1.3 (0.93–1.92)	
			Poor (Ref: better off)	aOR	1.9 (1.29–2.68)	
			Middle (Ref: better off)		1.2 (1.29–2.68)	
			Poor (Ref: better off)	aOR	2.1 (1.42–3.05)	
			Middle (Ref: better off)		1.0 (0.96–2.10)	
	Maternal occupation	Assefa *et al.*[32]	Staying at home (Ref: having employment)	OR	1.8	Maternal age, residence, parity, MUAC, fertility desire, ANC, violence in pregnancy, access to health facility, involvement of the husband
		Watson-Jones *et al.*[36]	Skilled work (Ref: staying at home)	aOR	0.28 (0.1–0.9)	Benzathine penicillin G treatment, maternal age, ethnicity, maternal sexual debut, smoker mother, maternal anthropometry, gravidity, past stillbirth, child sex, maternal illness, placental malaria
			Manual/Farmer work (Ref: staying at home)	aOR	0.45 (0.2–0.9)	

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Small for gestational age	Maternal education	Muhihi *et al.*[41]	No formal schooling (Ref: completed primary)	aRR	0.88 (0.76–1.02)	Paternal education, maternal anthropometry, maternal age, parity, starting ANC in the third trimester, birth order, child sex
			Some primary (Ref: completed primary)	aRR	1.01 (0.88–1.15)	
			Secondary plus (Ref: completed primary)	aRR	0.87 (0.77–0.98)	
		Ndirangu *et al.*[35]	Some primary (Ref: no education)	RR	1.05 (0.58–1.93)	Child sex, residence, WASH, delivery place, parity, maternal age, maternal anthropometry, HIV status, infant mortality
			Secondary and tertiary (Ref: no education)	RR	1.08 (0.60–1.94)	
	Maternal occupation	Watson-Jones *et al.*[36]	Skilled work (Ref: staying at home)	OR	0.19 (0.1–1.5)	Benzathine penicillin G treatment, maternal age, ethnicity, maternal sexual debut, smoker, maternal anthropometry, gravidity, past stillbirth, child sex, maternal illness, placental malaria
			Manual/Farmer work (Ref: staying at home)	OR	0.5 (0.2–1.4)	
			Maternal occupation (Ref: no occupation)	OR	1.94	
	Household WI	Muhihi *et al.*[41]	Q1 or poorest (Ref: Q5 or richest)	aRR (urban)	1.26 (1.00–1.60)	Paternal education, maternal anthropometry, maternal age, parity, starting ANC in the third trimester, birth order, child sex
			Q2 (Ref: Q5)	aRR (urban)	1.34 (1.08–1.67)	
			Q3 (Ref: Q5)	aRR (urban)	1.18 (0.94–1.49)	
			Q4 (Ref: Q5)	aRR (urban)	1.15 (0.93–1.42)	
			Q1 or poorest (Ref: Q5 or richest)	aRR (rural)	1 (0.90–1.12)	Paternal education, maternal anthropometry, maternal age, parity, starting ANC in the third trimester, birth order, child sex
			Q2 (Ref: Q5)	aRR (rural)	0.95 (0.86–1.06)	
			Q3 (Ref: Q5)	aRR (rural)	1 (0.90–1.11)	
			Q4 (Ref: Q5)	aRR (rural)	0.95 (0.86–1.05)	

(*Continued*)

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Table 2. (*Continued*)

Outcomes	Demographic and socio-economic factors	Studies	Demographic and socio-economic variables	Effect size	Effect size estimates (coefficient and CI)	Factors that variables were adjusted for
Preterm birth	Maternal education	Muhihi *et al.*[41]	No formal schooling (Ref: completed primary)	aRR	1.03 (0.91–1.17)	Paternal education, maternal anthropometry, maternal age, parity, starting ANC in the third trimester, birth order, child sex
			Some primary (Ref: completed primary)	aRR	1.11 (0.98–1.26)	
			Secondary plus (Ref: completed primary)	aRR	0.95 (0.84–1.07)	
		Ndirangu *et al.*[35]	Some primary (Ref: no education)	aRR	1.74 (0.76–3.97)	Child sex, residence, WASH, delivery place, parity, maternal age, maternal anthropometry, HIV status, infant mortality
			Secondary and tertiary (Ref: no education)	aRR	1.72 (0.77–3.85)	
	Maternal occupation	Watson-Jones *et al.*[36]	Skilled work (Ref: staying at home)	OR	0.43 (0.2–1.0)	Benzathine Penicillin G treatment, maternal age, ethnicity, maternal sexual debut, smoker, maternal anthropometry, gravidity, past stillbirth, child sex, maternal illness, placental malaria
			Manual/Farmer work (Ref: staying at home)	OR	0.84 (0.5–1.4)	
			Maternal occupation (Ref: no occupation)	OR	2.95	
	Household WI	Muhihi *et al.*[41]	Q1 or poorest (Ref: Q5 or richest)	aRR (urban)	1.21 (1.001.46)	Paternal education, maternal anthropometry, maternal age, parity, starting ANC in the third trimester, birth order, child sex
			Q2 (Ref: Q5)	aRR	1.10 (0.92–1.32)	
			Q3 (Ref: Q5)	(urban)	1.08 (0.89–1.31)	
			Q4 (Ref: Q5)	aRR	1.08 (0.90–1.29)	
			Q1 or poorest (Ref: Q5 or richest)	aRR (rural)	1.49 (1.32–1.68)	Paternal education, maternal anthropometry, maternal age, parity, starting ANC in the third trimester, birth order, child sex
			Q2 (Ref: Q5)	aRR	1.39 (1.24–1.56)	
			Q3 (Ref: Q5)	(rural)	1.13 (1.00–1.28)	
			Q4 (Ref: Q5)	aRR	1.23 (1.09–1.37)	

A, activity; ANC, antenatal care; aOR, adjusted odds ratio; aRR, adjusted relative risk; C, Cash; CI, confidence interval; HIV, human immunodeficiency virus; LBW, low birth weight; MUAC, mid-upper arm circumference; OR, odds ratio; PTB, preterm birth; Q (1,2,3,4,5), quintile (1,2,3,4,5); RR, relative risk; SGA, small for gestational age; WASH, water sanitation hygiene; WI, wealth index.

110% greater odds of having an LBW child than the richest households after adjusting for maternal mid-upper arm circumference, antenatal care (ANC) attendance, violence during pregnancy and access to a health facility.[32]

Associations between maternal demographic characteristics, household socio-economic factors and stunting (Table 3)

Several studies found that maternal marital status was not significantly associated with stunting.[33,34,39,42] The relationship between maternal level of education and stunting was not consistent across the studies reviewed. Having a mother with either no education or schooling up to primary school level was associated with 110% greater odds of stunting compared to having a mother who had been educated beyond primary school level.[43] Ickes *et al.*[33] found that educated mothers had 57% lower odds of having stunted infants, but there was no significant association between maternal literacy and infant stunting. Two studies did not find an association between maternal education and stunting.[40,42]

Ickes *et al.*[33] found that having a mother with an occupation was positively associated with 54% greater odds of stunting. The association between occupation and stunting was adjusted for child age, breastfeeding, maternal religion, maternal age, maternal education, marital status, decision maker in the family, domestic violence, maternal exposure to media, mothers travelling during pregnancy, delivering in a health facility, water sanitation and hygiene and HWI.[33,42] However, Engebretsen *et al.*[40] did not find any association between maternal occupation and risk of stunting. Studies have defined household wealth using wealth index (terciles[42]), (quintiles[33,40,43,44]), or cut-offs which varied between studies), land ownership[40,43,44] and poverty index.[13] Wamani *et al.*[43] and Engebretsen *et al.*[40] found that the lowest HWIs were associated with higher odds of stunting,[40,44] while other studies reported no significant association between HWI and infant stunting.[33,34,42]

Association between maternal socio-demographic characteristic, household socio-economic factors and wasting (Table 3)

Maternal occupation was associated with 43% lower odds of wasting in the study by Ickes *et al.*[33]; however, in the study by Ukwuani and Suchindran,[42] mothers who were not remunerated in cash and did not take their child to work had 87% greater odds of having a wasted child. Two other studies found no association between maternal occupation and wasting.[39,40] In two of the studies reviewed, there was no significant association between the HWI and wasting.[33,40] Engebertsen *et al.*,[40] Ickes *et al.*[33] and Ukwuani and Suchindran [42] did not find any significant association between wasting and maternal level of education or marital status.[33,40,42]

Associations between maternal socio-demographic characteristic, household socio-economic factors and underweight (Table 3)

The odds of having an underweight child were 40% lower for literate mothers vs illiterate mothers[33]: 35% lower for educated mothers vs non-educated mothers[33]; 76% lower for mothers who had completed primary school compared with those who had completed secondary school.

Discussion

This review has identified a lack of research in SSA (only 11 studies for 52 countries), a region with one of the highest prevalence of child undernutrition, and the role of maternal and household socio-economic determinants of impaired growth and development during the first thousand days. Furthermore, we highlighted interesting methodological challenges when assessing maternal or household socio-economic characteristics as well as important empirical findings pertaining to SSA context. Methodologically, although the definitions of LBW, SGA, PTB, stunting, wasting and underweight were standard, studies used varying definitions of SES factors that made comparison and generalisability of their results challenging. However, overall, lower HWI, maternal unemployment and low maternal education were shown to be important SES predictors of adverse birth outcomes (LBW and SGA) and infant undernutrition (stunting, wasting and underweight) in SSA.

Socio-economic factors and adverse birth outcomes

Evidence gathered in this systematic review has shown that PTB is associated with lower maternal occupation and lower HWI.[36,41] While the risk for a newborn to be SGA was associated with a lower level of maternal education in one out of two studies reviewed,[41] LBW was predicted by living in a household with a lower HWI.[32,41] In addition, having a mother with an occupation, and therefore a source of income, was associated with lower risk of LBW. In a review of studies in 22 LMICs, Watson-Jones *et al.*[36] and Vogel *et al.*[46] found that less-educated mothers had and increased risk of having a newborn that was PTB. However, in a recent study in Kenya, Wagura *et al.*[47] found that maternal level of education had no significant association with PTB but was significantly associated with previous PTB. Furthermore, in Brazil, Zambonato *et al.*[48] found an association between SGA in Brazilian newborns and a lower family income, similar to the study conducted in Tanzania in this review.[41] Similarly, in Japan, mothers living in prefectures with higher socio-economic inequality (measured by the Gini coefficient) had 24% greater risk of having a SGA newborn.[49] In addition, lower parental education and household income was associated with SGA.[49] The protective effect of maternal education, occupation and aggregated SES indices against LBW has been shown in previous studies in other LMICs (South Africa,[12] Pakistan,[50] Vietnam[51] and Bangladesh[52]), as well as in a meta-analysis of studies conducted in middle- and high-income countries.[53] In this systematic review, we did not find any study that investigated the association between maternal marital status and birth outcomes.

Socio-economic factors and infant undernutrition between birth and 2 years of age

Most studies included in this review reported that higher level of maternal education was protective against stunting and underweight, while maternal occupation and low HWI increased the risks for a child to be stunted.[33,40,43,44] The evidence was not consistent for underweight; studies found positive and negative associations with maternal education.[13,33,39] While some studies found that maternal occupation reduced the risks of wasting, others have shown the contrary.[33,42] No study found an association between marital status and stunting[33,34,39,40,42] or wasting,[33,39,40,42] and the association between marital status and underweight had not been explored.

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Table 3. Associations between demographic and socio-economic factors with infant growth outcomes (stunting, wasting and underweight)

Outcomes	Demographic and SES determinant	Studies	SES factors	Effect size	Estimate effect size (value, confidence interval or *p*-value)	Adjusted variables for
Stunting	Maternal education	Ukwuani and Suchindran[42]	Primary (Ref: None)	aOR	0.94 ($p > 0.1$)	Father education, father occupation, religion, child feeding duration, maternal age, sex, birth order, ANC, place delivery, residence, immunisation, child illness, WASH
			Secondary and above (Ref: None)	aOR	1.06 ($p > 0.10$)	
		Wamani *et al.*[43]	None (Ref: above primary)	aOR	2.1 (1.1–3.9)	Child age and sex
			Stopped in primary (Ref: above primary)	aOR	2.1 (1.2–3.8)	
			Completed primary (Ref: above primary)	aOR	1.0 (0.5–2.0)	
			No educated mother (Ref: educated above primary)	aOR	2,5	Child age, child sex, father education
			Literate in 2011 (Ref: illiterate)	OR	0.84 (0.62–1.14)	
			Literate in 2006 (Ref: illiterate)	OR	0.77 (0.58–1.00)	
			Educated mother (Ref: no educated) in 2006	OR	0.72 (0.53–0.99)	
			Maternal educated in 2006 (Ref: illiterate)	OR	0.43 (0.28–0.66)	
		Mamabolo *et al.* (2004)[21]	Primary (Ref: secondary)	aOR	0.438 (0.139–1.382)	Feeding practices, child sex, maternal age at birth, parity
			Student (Ref: no student)	aOR	1.044 (0.523–2.084)	
		Engebretsen *et al.*[40]	Completed lower secondary and more (Ref: full primary and less)	OR	0.78 (052–1.18)	Child sex, child age, country wealth, residence, owning land, maternal age, father education, demography, birth weight

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Maternal occupation	Ukwuani and Suchindran[42]	A/NC/WC (Ref: NA)	aOR	0.97 ($p > 0.10$)	Father education, father occupation, religion, child feeding duration, maternal age, sex, birth order, ANC, place delivery, residence, immunisation, child illness, WASH
		A/C/WC (Ref: NA)	aOR	0.98 ($p > 0.10$)	
		A/NC/NWC (Ref: NA)	aOR	0.66 ($p > 0.10$)	
		A/C/NWC (Ref: NA)	aOR	0.88 ($p > 0.10$)	
	Ickes *et al.*[33]	Employed in 2006 (Ref: Not employed)	aOR	1.01 (0.61–1.68)	Child age, child sex, decision-making in family, maternal age at birth, violence, having travelled away from home or not, feeding practices, access to health facility
		Employed in 2011 (Ref: Not employed)	aOR	1.54 (1.05–2.25)	Child age, child sex, decision-making in family, maternal age at birth, violence, having Travelled away from home or not, feeding practices, access to health facility
	Mamabolo *et al.*[39]	Not being a housewife (Ref: being a housewife)	OR	1.254 (0.518–3.033)	
		Not working (Ref: working)	OR	0.519 (0.178–1.508)	
	Engebretsen *et al.*[40]	Has a job (Ref: Does not have a job)	aOR	0.63 (0.37–1.)	Child sex, child age, country wealth, residence, owning land, maternal age, father education, demography, birth weight
Maternal marital status	Mamabolo *et al.*[39]	Single (Ref: married)	OR	0.749 (0.354–1.583)	Feeding practices, child sex, mother age at birth, parity
	Medhin *et al.*[34]	Polygamous marriage at 6 months of the study (Ref: not polygamous marriage)	aOR	1.06 (0.64–1.74)	Maternal characteristics (religion, ethnicity, age, MUAC), age of husband, father education, WASH, poverty, traditional surgical practices
	Medhin *et al.*[34]	Polygamous marriage at 12 months of the study (Ref: not polygamous marriage)	aOR	1.19 (0.76–1.87)	
	Ukwuani and Suchindran[42]	Two wives polygynous (Ref: one wife)	aOR	1. 2 ($p > 0.10$)	Father education, father occupation, religion, child feeding duration, maternal age, sex, birth order, ANC, place delivery, residence, immunisation, child illness, WASH
		Three wives polygynous (Ref: one wife)	aOR	1.37 ($p < 0.10$)	
	Engebretsen *et al.*[40]	Formal marriage (Ref: traditional)	aOR	1.09 (0.58–2.08)	Child sex, child age, country wealth, residence, owning land, maternal age, father education, demography, birth weight
		Single, separated, divorced, widowed (Ref: traditional)	aOR	1.91 (0.99–3.66)	
	Ickes *et al.*[33]	Married or living with partner in 2006 (Ref: single/separated/ divorced/divorced)	aOR	1.10 (0.73–1.67)	Child age, child sex, decision-making in family, maternal age at birth, violence, having travelled away from home or not, feeding practices, access to health facility
	Ickes *et al.*[33]	Married or living with partner in 2011 (Ref: single/separated/ divorced/divorced)	aOR	0.82 (0.54–1.25)	Child age, child sex, decision-making in family, maternal age at birth, violence, having travelled away from home or not, feeding practices, access to health facility

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Table 3. (*Continued*)

Outcomes	Demographic and SES determinant	Studies	SES factors	Effect size	Estimate effect size (value, confidence interval or *p*-value)	Adjusted variables for
	household wealth	Ukwuani and Suchindran[42]	Medium (Ref: low)	aOR	0.78 ($p > 0.10$)	Father education, father occupation, religion, child feeding duration, maternal age, sex, birth order, ANC, place delivery, residence, immunisation, child illness, WASH
			High (Ref: low)	aOR	0.61 ($p < 0.10$)	
		Wamani *et al.*[43]	Q1 or poorest (Ref: 5 acres or more)	OR	2.1 (1.2–3.7)	Mother education, father education, child sex male, child age between 18 and 23 months
			Q2 (Ref: 5 acres or more)	OR	1.7 (0.9–2.9)	
			Q3 (Ref: 5 acres or more)	OR	1.3 (0.8–2.5)	
			Q4 (Ref: 5 acres or more)	OR	1.1 (0.6–2.0)	
		Wamani *et al.*[43]	None (Ref: 5 acres or more)	aOR	0.9 (0.5–1.8)	Child age, child sex, father education, father education
			1 acre or less (Ref: 5 acres or more)	aOR	0.9 (0.6–1.6)	
			2 acres or less (Ref: 5 acres or more)	aOR	1.2 (0.7–2.1)	
			3 or 4 acres or less (Ref: 5 acres or more)	aOR	1.0 (0.6–1.8)	
			Poorest (Ref: least poor)	OR	2.1	
		Medhin *et al.*[34]	Poverty index at 6 months (range from 0 to11)	aOR	0.94 (0.83–1.06)	Maternal characteristics (religion, ethnicity, age, MUAC), age of husband, father education, WASH, poverty, traditional surgical practices
			Poverty index at 12 months (range from 0 to11)	aOR	0.98 (088–1.09)	
		Engebretsen *et al.*[40]	Mid 40% (Ref: top 20%)	aOR	1.65 (0.74–3.68)	Child sex, child age, country wealth, residence, owning land, maternal age, father education, demography, birth weight
			Lowest 40% (Ref: top 20%)	aOR	3.50 (1.57–7.78)	
		Engebretsen *et al.*[40]	Mid 40% (Ref: top 20%)	aOR	1.71 (0.87–3.36)	Child sex, child age, country wealth, residence, owning land, maternal age, father education, demography, birth weight
			Lowest 40% (Ref: top 20%)	aOR	3.10 (0.56–6.15)	
		Engebretsen *et al.*[40]	Mid 40% (Ref: top 20%)	aOR	1.30 (0.62–2.73)	Child sex, child age, country wealth, residence, owning land, maternal age, father education, demography, birth weight
			Lowest 40% (Ref: top 20%)	aOR	2.7 (1.39–5.28)	
		Ickes *et al.*[33]	Maternal WI upper 60% in 2006 (Ref: less 60%)	aOR	0.82 (0.62–1.06)	Child sex, child age, country wealth, residence, owning land, maternal age, father education, demography, birth weight
			Maternal WI upper 60% in 2011 (Ref: less 60%)	aOR	1.17 (0.87–1.58)	
		Engebretsen *et al.*[40]	Owning land (Ref: no owing land)	aOR	1.45 (0.86–2.45)	Child sex, child age, country wealth, residence, owning land, maternal age, father education, demography, birth weight

Wasting	Maternal education	Ukwuani and Suchindran[42]	Primary (Ref: none)	aOR	1.08 ($p > 0.10$)	Father education, father occupation, religion, child feeding duration, maternal age, sex, birth order, ANC, place delivery, residence, immunisation, child illness, WASH
			Secondary and above (Ref: none)	aOR	0.86 ($p > 0.10$)	
		Engebretsen *et al.*[40]	Completed lower secondary and more (Ref: full primary and less)	OR	0.90 (0.42–1.95)	Child sex, child age, country wealth, residence, owning land, maternal age, father education, demography, birth weight
		Ickes *et al.*[33]	Literate in 2011(Ref: illiterate)	aOR	0.87 (0.54–1.41)	Child age, child sex, decision-making in family, maternal age at birth, violence, having travelled away from home or not, feeding practices, access to health facility
			Literate in 2011 (Ref: illiterate)	aOR	0.87 (0.59–1.29)	
			Educated in 2006 (Ref: not educated)	aOR	0.74 (0.47–1.15)	
			Educated in 2011 (Ref: illiterate)	aOR	0.58 (0.31–1.11)	
		Mamabolo *et al.*[39]	Primary (Ref: secondary)	OR	0.699 (0.141–3.461)	
			Student (Ref: no student)	OR	1.404 (0.508–3.880)	
	Maternal occupation	Ukwuani and Suchindran[42]	No cash/No cash/Work with child (Ref: No activity)	aOR	0.96 ($p > 0.10$)	Father education, father occupation, religion, child feeding duration, maternal age, sex, birth order, ANC, place delivery, residence, immunisation, child illness, WASH
			Activity/Cash/Work with child (Ref: no activity)		1.17 ($p > 0.10$)	
			Activity/No cash/No working with child (Ref: NA)	aOR	1.87 ($p < 0.05$)	
			Activity/Child/No working with child (Ref: no activity)	aOR	1.48 ($p > 0.10$)	
		Engebretsen *et al.*[40]	Has a job (Ref: Does not have a job)	OR	0.50 (0.14–1.76)	Child sex, child age, country wealth, residence, owning land, maternal age, father education, demography, birth weight
		Ickes *et al.*[33]	Employed in 2006 (Ref: not employed)	aOR	1.86 (0.76–4.55)	Child age, child sex, decision-making in family, maternal age at birth, violence, having travelled away from home or not, feeding practices, access to health facility
			Employed in 2011 (Ref: not employed)	aOR	0.57 (0.34–0.95)	
		Mamabolo *et al.*[39]	Not working (Ref: working)	aOR	2.943 (0.916–9.455)	
	Maternal marital status	Engebretsen *et al.*[40]	Formal marriage (Ref: traditional)	OR	0.87 (0.25–2.94)	
			Single, separated, divorced, widowed (Ref: traditional)	OR	0.33 (0.04–2.60)	
		Ukwuani and Suchindran[42]	Two wives (Ref: one wife)	OR	1.26 ($p < 0.10$)	
			Three wives (Ref: one wife)	OR	1.01 ($p < 0.10$)	
		Ickes *et al.*[33]	Married or living with partner in 2006 (Ref: single/separated/divorced/divorced)	aOR	0.97 (0.55–1.71)	Child age, child sex, decision-making in family, maternal age at birth, violence, having travelled away from home or not, feeding practices, access to health facility
			Married or living with partner in 2011 (Ref: single/separated/divorced/divorced)	aOR	1.64 (0.72–3.72)	
		Mamabolo *et al.*[39]	Single (Ref: married)	OR	0.444 (0.121–1.629)	

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Table 3. (*Continued*)

Outcomes	Demographic and SES determinant	Studies	SES factors	Effect size	Estimate effect size (value, confidence interval or *p*-value)	Adjusted variables for
		Engebretsen *et al.*[40]	Mid 40% (Ref: top 20%)	aOR	1.76 (0.54–5.70)	Child sex, child age, country wealth, residence, owning land, maternal age, father education, demography, birth weight
			Lowest 40% (Ref: top 20%)		1.51 (0.48–4.71)	
			Owning land (Ref: do not own land)	aOR	1.06 (0.40–2.81)	
		Ickes *et al.*[33]	Maternal WI upper 60% in 2006 (Ref: less 60%)	aOR	1.00 (0.68–1.49)	Child age, child sex, decision-making in family, maternal age at birth, violence, having travelled away from home or not, feeding practices, access to health facility
			Maternal WI upper 60% in 2011 (Ref: less 60%)	aOR	0.80 (0.50–1.29)	
		Ukwuani and Suchindran[42]	Medium	aOR	0.82 ($p > 0.10$)	
			High	aOR	1.02 ($p > 0.10$)	
Underweight	Maternal education	Mamabolo *et al.*[39]	Primary (Ref: secondary)	OR	0.244 (0.066–0.903)	Feeding practices, child sex, mother age at birth, parity
			No student (Ref: student)		3.199 (1.111–9.208)	
		Ickes *et al.*[33]	Literate in 2011 (Ref: illiterate)	aOR	0.76 (0.53–1.10)	Child age, child sex, decision-making in family, maternal age at birth, violence, having travelled away from home or not, feeding practices, access to health facility
			Literate in 2006 (Ref: illiterate)	aOR	0.60 (0.43–0.82)	
			Educated in 2006 (Ref: no educated)	aOR	0.65 (0.45–0.94)	
			Educated in 2011 (Ref: illiterate)	aOR	0.49 (0.30–0.81)	
	Maternal marital status	Mamabolo *et al.*[39]	Single (Ref: married)	OR	0.660 (0.203–2.150)	Feeding practices, child sex, mother age at birth, parity
		Medhin *et al.*[34]	Polygamous marriage at 6 months (Ref: not polygamous)	aOR	0.89 (0.52–1.54)	Maternal characteristics (religion, ethnicity, age, MUAC), other characteristics in the household (age of husband, father education, WASH), poverty, traditional surgical practices
			Polygamous marriage at 12 months (Ref: not polygamous marriage)	aOR	0.77 (0.45–1.33)	
		Ickes *et al.*[33]	Married or living with partner in 2006 (Ref: single/separated/divorced/)	aOR	1.6 (0.93–2.73)	Child age, child sex, decision-making in family, maternal age at birth, violence, having travelled away from home or not, feeding practices, access to health facility
			Married or living with partner in 2011 (Ref: single/separated/divorced/)	aOR	1.20 (0.68–2.12)	

Maternal occupation	Ickes *et al.*[33]	Maternal employment in 2006 (Ref: no employment)	aOR	1.85 (0.91–3.77)	Child age, child sex, decision-making in family, maternal age at birth, violence, having travelled away from home or not, feeding practices, access to health facility	
		Maternal employment in 2011 (Ref: no employment)	aOR	1.14 (0.72–1.79)		
	Mamabolo *et al.*[39]	Not being a housewife (Ref: being a housewife)	OR	0.614 (0.131–2.874)		
		Not working (Ref: working)	OR	0.341 (0.043–2.715)		
Household WI	Ickes *et al.*[33]	Maternal WI upper 60% in 2006 (Ref: less 60%)	aOR	0.76 (0.55–1.04)	Child age, child sex, decision-making in family, maternal age at birth, violence, having travelled away from home or not, feeding practices, access to health facility	
		Maternal WI upper 60% in 2011(Ref: less 60%)	aOR	0.79 (0.54–1.14)		
	Medhin *et al.*[34]	Poverty index at 12 months (range from 0 to 11)	aOR	0.85 (0.74–0.97)	Maternal age, maternal anthropometry, maternal marital status, autonomy scale, maternal obstetric complication, substance use (Khat or alcohol), residence, number of children, father age, WASH, social support	
		Poverty index at 6 months (range from 0 to 11)	aOR	0.97 (0.85–1.11)		

A, activity; AC, activity with cash; ANC, antenatal care; aOR, adjusted odds ratio; C, cash; HIV, human immunodeficiency virus; MUAC, mid-upper arm circumference; NA, not active; NC, no cash; NWC, no work with child; OR, odds ratio; Q (1,2,3,4,5), quintile; SES, socio-economic status; WASH, wash, sanitation and hygiene; WC, work with child; WI, wealth index.

A review on malnutrition over 15 years in LMICs showed that higher maternal/caregivers' level of education and greater HWI reduced the odds of stunting during infancy.[54] In a pooled analysis of five cohort studies including South Africa,[7] the results showed that low maternal education, low maternal income, low social class (measured by paternal occupation) and low paternal education were predictors of stunting at 2 years of age. However, SES factors (maternal education, maternal income, paternal occupation and paternal education) had less influence on stunting than biological factors (birth weight and maternal height), particularly in South Africa.[7] Similarly, a study in Ivory Coast found that having an educated mother was protective against stunting in 3-year-old children.[55]

In Bangladesh, Raihan *et al.*[56] found that low SES (assets, maternal and household income and maternal education) increased the risk of wasting in children younger than 5 years of age. They also found that water sanitation and hygiene characteristics (e.g., use of soap, use of hygienic latrine and safe drinking water), often used as a composite of HWI and/or as a risk factor of infectious disease, mediated the association between SES factors and wasting.[56]

The outcomes of this review align with the existing findings in children aged between 6 and 23 months in Myanmar[57] and in children under 3 years of age in Vietnam,[21] which reported that children of working mothers had a higher risk of being stunted. Also in Vietnam,[21] maternal occupation was a predictor of all forms of undernutrition (stunting, wasting and underweight), whereas maternal education and income were not. In contrast, *Ukwuani and Suchindran*[42] found that in Nigeria maternal occupation was protective against wasting suggesting that working women have an income that allows for provision of food and better care, and that mothers breastfeed for longer than their non-working peers.

Maternal and household SES factors during the first 1000 days

At the country level, a review of 121 surveys in 36 LMICs[58] found that a 5% increase in per capita gross domestic product decreased the risk of undernutrition in children aged between 0 and 35 months, but this association did not occur in the poorest households, suggesting that poverty and socio-economic inequalities are both vehicles of infant undernutrition. The first thousand days, the period between conception and 2 years after birth,[1] have been acknowledged as a critical period for child growth and development and for adult health outcomes.[58] Evidence from this review highlights that low maternal and household SES are more likely to have a negative effect on growth and development during that period.[59]

The socio-economic environment is both a contributory factor to and a consequence of infant undernutrition.[1] Maternal and household lower SES is an underlying factor of household food insecurity, and therefore of maternal and child health and undernutrition.[60] Children living in households with low SES were found to consume more carbohydrates and less protein and less fat with subsequent undernutrition.[61] Educated mothers have greater knowledge, better job opportunities, higher income, a healthy lifestyle and access to health care, all of which impact infant growth and nutritional status.[53,62] Although the level of education of the general population is improving in SSA countries, education of females is still lower than that of males.[63] McGovern *et al.*,[64] in their systematic review on stunting and economic growth, concluded that education of women is a cost-effective investment that reduces

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poor infant growth and translates into greater future opportunities for children.

One study included in this review found that maternal occupation had a detrimental effect on child growth.[62] Having a job may generate an income for mothers and their households, but it can limit the time spent with their newborn. While having an occupation provides an income that enables greater access to health care, working mothers are not always available to breastfeed their children or to access health care when necessary.[62] Lack of support systems (social support, maternity leave, etc.) may jeopardise mothers' possibilities to provide optimal care for their children (including exclusive breastfeeding), thereby exposing children to the risks associated with early weaning, introduction of solid food and infectious diseases.[4] In this review, we did not find any studies conducted in SSA on the association between maternal marital status and infant undernutrition. Having a partner (married or concubine) may have a positive effect on maternal and child health through the widest network of social support, and additional income that this situation may provide; however, domestic violence may offset those benefits.[65,66]

Based on the studies included in this review, socio-economic factors were generally assessed as contextual variables (HWI) and/or as compositional measurements (education, income, occupation).[62] In addition, we highlighted that across studies, contextual and compositional SES factors were defined using different characteristics.[62] The lack of standardisation and harmonisation of SES measures may explain discrepancies observed between the studies included in this review. For example, whereas a study showed that higher maternal education level was associated with lower risk of stunting,[43] one study found no association between maternal literacy and stunting.[43] It may be that either the influence of education is different depending on the social and economic contexts, or that having a higher level of education, which is indicative of the knowledge acquired, is more important than maternal literacy, which reflects a skill. Wamani *et al.*[44] found that in rural Uganda having a secondary education level was the critical threshold at which maternal level of education was protective against stunting. The use of a variety of SES indicators may also limit comparisons within and between countries, and therefore, the identification of critical maternal and household factors to target in national or regional intervention programs that aim to promote foetal and infant optimal growth.

The majority of studies reviewed did not specifically focus on the assessment of the association between SES factors and birth outcomes or infant undernutrition. Possibly, the choice of SES indices might have been dictated by the main objective of the study. Therefore, another source of discrepancies between studies could be the covariates in the multivariate analyses. The UNICEF causal framework[3] has established that several immediate, underlying and basic causes play a role in infant undernutrition. Various combinations of causal factors were taken into account across the articles reviewed here, including infant gender,[55,60] infant feeding practices,[54,57] maternal age,[55] maternal anthropometry,[53] maternal morbidity (urinary tract infection, hypertensive disorders, malaria, human immunodeficiency virus, infection, gestational diabetes, pre-eclampsia, pregnancy induced hypertension, antepartum haemorrhage, pre-labour rupture of membranes, placental bleeding),[46] maternal obstetrical history (parity, previous PTB, gestation number),[46,48,67] access and usage of antenatal care services, household food insecurity,[55,60] household size and level of urbanisation.[54,60]

Limitations

This review has some limitations. Firstly, studies were selected using English keywords, which given the linguistic diversity in the SSA region, studies written in only other languages may have been missed. Secondly, the various definitions and measurement of SES and the inability to retrieve some key data from publications did not allow us to undertake a meta-analysis. Thirdly, one (9%) study[39] was rated low because of lack of randomisation in recruitment, no blinding in the conduction of the study, lack of adjustment for any variable and no CIs in the results.[37,38] Finally, the accuracy of gestational age may vary across studies depending on the method of assessment. These limitations could lead to a low power of the data included (quality and quantity) in the review.

Conclusion

In conclusion, despite the paucity of studies that have explored the relationship between maternal and household SES and LBW, PTB, SGA, stunting, wasting and underweight in SSA, results from this review emphasise the negative long-term effects of poor maternal and household SES on child growth during the first thousand days. More research, including using a qualitative approach, has to be undertaken to improve our understanding of contextual SES factors that are associated with undernutrition during the first thousand days in the different SSA countries. Furthermore, early intervention from pre-pregnancy through infancy may prevent undernutrition during the first 2 years of life and any irreversible damages caused by undernutrition during infancy. Finally, promoting maternal education and female employment as well as alleviating female poverty and inequality are key interventions to favour optimal maternal and child health.

Supplementary materials. To view supplementary material for this article, please visit https://doi.org/10.1017/S2040174419000680

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Ethical standards. This research did not involve human and/or animal experimentations and therefore does not warrant ethical standards statement.

Authors' contribution. Conceptualisation of the review: CBN, SN, RS-M.
Search, inclusion of studies and data extraction: CBN, DM, RS-M.
Data interpretation: BN, LC, SN, RS-M.
Integrity of data: BN.
Editing manuscript: AM.
Drafting and revising manuscript: BN, DM, LC, AM, SN, RS-M.

References

1. Black RE, Victora CG, Walker SP, *et al.* Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet.* 2013; 382(9890), 427–451.

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2. Umeta M, West CE, Verhoef F, *et al.* Factors associated with stunting in infants aged 5–11 months in the Dodota-Sire district, rural Ethiopia. *J Nutr*. 2003; 133, 1064–1069.
3. UNICEF. Improving child nutrition: the achievable for global progress. 2013. https://data.unicef.org/resources/improving-child-nutrition-the-achievable-imperative-for-global-progress/. Accessed February 25, 2013.
4. Said-Mohamed R, Pettifor JM. Life history theory hypotheses on child growth: potential implications for short and long-term child growth, development and health. *Am J Phys Anthropol*. 2018; 165(1), 4–19.
5. Bouvier P, Papart JP, Wanner P, *et al.* Malnutrition of children in Sikasso (Mali): prevalence and socio-economic determinants. *Sozial- Präventivmedizin SPM*. 1995; 40(1), 27–34.
6. Victora CG, Adair L, Fall C, *et al.* Maternal and child undernutrition: consequences for adult health and human capital. *Lancet (London, England)*. 2008; 371(9609), 340–357.
7. Richter LM, Orkin FM, Roman GD, *et al.* Comparative models of biological and social pthways to predict child growth through age 2 years from birth cohorts in Brazil, India, the Philippines, and South Africa. *J Nutr*. 2018; 148(8), 1364–1371.
8. Wrottesley SV, Lamper C, Pisa PT. Review of the importance of nutrition during the first 1000 days: maternal nutritional status and its associations with fetal growth and birth, neonatal and infant outcomes among African women. *J Dev Orig Health Dis*. 2016; 7(2), 144–162.
9. Lee AC, Katz J, Blencowe H, *et al.* National and regional estimates of term and preterm babies born small for gestational age in 138 low-income and middle-income countries in 2010. *Lancet Glob Health*. 2013; 1(1), e26–e36.
10. Black RE. Global prevalence of small for gestational age births. Nestle Nutr Inst Workshop Ser. 2015; 81, 1–7.
11. Lee AC, Kozuki N, Cousens S, *et al.* Estimates of burden and consequences of infants born small for gestational age in low and middle income countries with INTERGROWTH-21st standard: analysis of CHERG datasets. *BMJ*. 2017; 358, e26–e36.
12. Budree S, Goddard E, Brittain K, *et al.* Infant feeding practices in a South African birth cohort-A longitudinal study. *Matern Child Nutr*. 2017;13(3), e12371.
13. Medhin G, Hanlon C, Dewey M, *et al.* The effect of maternal common mental disorders on infant undernutrition in Butajira, Ethiopia: the P-MaMiE study. *BMC Psychiatry*. 2010; 10, 32.
14. Letourneau N, McCaffrey G, Nyanza EC, *et al.* Somatic growth from birth to 6 months in low birth weight, in Bukavu, South Kivu, Democratic Republic of the Congo. *BMJ Open*. 2018; 66(4), 245–253.
15. Christian P, Lee SE, Donahue Angel M, *et al.* Risk of childhood undernutrition related to small-for-gestational age and preterm birth in low- and middle-income countries. *Int J Epidemiol.* 2013; 42(5), 1340–1355.
16. Bhutta ZA, Das JK, Rizvi A, *et al.* Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost? *Lancet*. 382(9890), 452–477.
17. Fund UNCs. Strategy for improved nutrition of children and women in developing countries. *Indian J Pediatr*. 1991; 58(1), 13–24.
18. Efevbera Y, Bhabha J, Farmer PE, Fink G. Girl child marriage as a risk factor for early childhood development and stunting. *Social Sci Med*. 2017; 185, 91–101.
19. Debela BL, Demmler KM, Rischke R, Qaim M. Maternal nutrition knowledge and child nutritional outcomes in urban Kenya. *Appetite*. 2017; 116, 518–526.
20. Setswe G. Prevalence and risk factors for malnutrition among children aged 5 years and less in the Lefaragatlha village of Bophuthatswana. *Curationis*. 1994; 17(3), 33–35.
21. Hien NN, Hoa NN. Nutritional status and determinants of malnutrition in children under three years of age in Nghean, Vietnam. *Pak J Nutr*. 2009; 8(7), 958–964.
22. Engle PL. Influences of mothers' and fathers' income on children's nutritional status in Guatemala. *Social Sci Med*. 1993; 37(11), 1303–1312.
23. Leslie TF, Pawloski LR. Sociodemographic determinants of growth among Malian adolescent females. *Am J Hum Biol*. 2010; 22(3), 285–290.
24. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med*. 2009; 6(7), e1000097.
25. Liberati A, Altman DG, Tetzlaff J, *et al.* The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *BMJ*. 2009; 339, b2700.
26. Howe LD, Galobardes B, Matijasevich A, *et al.* Measuring socio-economic position for epidemiological studies in low- and middle-income countries: a methods of measurement in epidemiology paper. *Int J Epidemiol*. 2012; 41(3), 871–886.
27. United Nations. *Handbook of Vital Statistics Systems and Methods, Volume 1, Legal, Organisational and Technical Aspects*, 1991. United Nation Publication.
28. van den Broek N, Ntonya C, Kayira E, White S, Neilson JP. Preterm birth in rural Malawi: high incidence in ultrasound-dated population. *Hum Reprod*. 2005; 20(11), 3235–3237.
29. Black RE. Global prevalence of small for gestational age births. *Nestle Nutr Inst Workshop Ser*. 2015; 81, 1–7.
30. Katz J, Lee ACC, Kozuki N, *et al.* Mortality risk in preterm and small-for-gestational-age infants in low-income and middle-income countries: a pooled country analysis. *Lancet*. 2013; 382(9890), 417–425.
31. WHO. WHO Child Growth Standards Length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age Methods and development. http://www.who.int/childgrowth/publications/ca_symposium_fieldtesting/en/index.html (Accessed January 3, 2019).
32. Assefa N, Berhane Y, Worku A. Wealth status, mid upper arm circumference (MUAC) and antenatal care (ANC) are determinants for low birth weight in Kersa, Ethiopia. *PLoS One*. 2012; 7(6), e39957.
33. Ickes SB, Hurst TE, Flax VL. Maternal literacy, facility birth, and education are positively associated with better infant and young child feeding practices and nutritional status among Ugandan children. *J Nutr*. 2015; 145(11), 2578–2586.
34. Medhin G, Hanlon C, Dewey M, *et al.* Prevalence and predictors of undernutrition among infants aged six and twelve months in Butajira, Ethiopia: the P-MaMiE birth cohort. *BMC Public Health*. 2010; 10(1), 27.
35. Ndirangu J, Newell ML, Bland RM, Thorne C. Maternal HIV infection associated with small-for-gestational age infants but not preterm births: evidence from rural South Africa. *Hum Reprod*. 2012; 27(6), 1846–1856.
36. Watson-Jones D, Weiss HA, Changalucha JM, *et al.* Adverse birth outcomes in United Republic of Tanzania – impact and prevention of maternal risk factors. *Bull World Health Organ*. 2007; 85(1), 9–18.
37. Balshem H, Helfand M, Schunemann HJ, *et al.* GRADE guidelines: 3. Rating the quality of evidence. *J Clin Epidemiol*. 2011; 64(4), 401–406.
38. Guyatt G, Oxman AD, Akl EA, *et al.* GRADE guidelines: 1. Introduction-GRADE evidence profiles and summary of findings tables. *J Clin Epidemiol*. 2011; 64(4), 383–394.
39. Mamabolo RL, Alberts M, Mbenyane GX, *et al.* Feeding practices and growth of infants from birth to 12 months in the central region of the Limpopo Province of South Africa. *Nutrition*. 2004; 20(3), 327–333.
40. Engebretsen IMS, Tylleskär T, Wamani H, Karamagi C, Tumwine JK. Determinants of infant growth in Eastern Uganda: a community-based cross-sectional study. *BMC Public Health*. 2008; 8(1), 418.
41. Muhihi A, Sudfeld CR, Smith ER, *et al.* Risk factors for small-for-gestational-age and preterm births among 19,269 Tanzanian newborns. *BMC Pregnancy Childbirth*. 2016; 16, 110.
42. Ukwuani FA, Suchindran CM. Implications of women's work for child nutritional status in sub-Saharan Africa: a case study of Nigeria. *Social Sci Med*. 2003; 56(10), 2109–2121.
43. Wamani H, Tylleskär T, Åstrøm AN, Tumwine JK, Peterson S. Mothers' education but not fathers' education, household assets or land ownership is the best predictor of child health inequalities in rural Uganda. *Int J Equity Health*. 2004; 3(1), 9.
44. Wamani H, Astrom AN, Peterson S, Tumwine JK, Tylleskar T. Predictors of poor anthropometric status among children under 2 years of age in rural Uganda. *Public Health Nutr*. 2006; 9(3), 320–326.
45. Ndirangu MN, Gatimu SM, Mwinyi HM, Kibiwott DC. Trends and factors associated with early initiation of breastfeeding in Namibia: analysis of the Demographic and Health Surveys 2000–2013. *BMC Pregnancy Childbirth*. 2018; 18(1), 171.

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46. Vogel JP, Lee AC, Souza JP. Maternal morbidity and preterm birth in 22 low- and middle-income countries: a secondary analysis of the WHO Global Survey dataset. *BMC Pregnancy Childbirth*. 2014; 14, 56.
47. Wagura P, Wasunna A, Laving A, Wamalwa D, Ng'ang'a P. Prevalence and factors associated with preterm birth at kenyatta national hospital. *BMC Pregnancy and Childbirth*. 2018; 18(1), 107.
48. Zambonato AMK, Pinheiro RT, Horta BL, Tomasi E. Fatores de risco para nascimento de crianças pequenas para idade gestacional. *Rev Saude Publica*. 2004; 38, 24–29.
49. Fujiwara T, Ito J, Kawachi I. Income inequality, parental socioeconomic status, and birth outcomes in Japan. *Am J Epidemiol*. 2013; 177(10), 1042–1052.
50. Ghouse G, Zaid M. Determinants of low birth weight a cross sectional study: In case of Pakistan. Munich Personal RePEc Archive. 2016. https://mpra.ub.uni-muenchen.de/70660/ (Accessed January 8, 2019).
51. Bui K, Nguyen L, Phung TT. 240 Risk factors associated with term and pre term low birth weight in Thai, Nguyen, Vietnam. *J Invest Med*. 2006; 54(1), S121.2-S121.
52. Khan JR, Islam MM, Awan N, Muurlink O. Analysis of low birth weight and its co-variants in Bangladesh based on a sub-sample from nationally representative survey. *BMC Pediatr*. 2018: 18(1), 100.
53. Silvestrin S, Silva CH, Hirakata VN, *et al*. Maternal education level and low birth weight: a meta-analysis. *J Pediatr (Rio J)*. 2013; 89(4), 339–345.
54. Arthur SS, Nyide B, Soura AB, *et al*. Tackling malnutrition: a systematic review of 15-year research evidence from INDEPTH health and demographic surveillance systems. *Glob Health Action*. 2015; 8, 28298.
55. Barankanira E, Molinari N, Msellati P, Laurent C, Bork KA. Stunting among children under 3 years of age in Cote d'Ivoire: spatial and temporal variations between 1994 and 2011. *Public Health Nutr*. 2017; 20(9), 1627–1639.
56. Raihan MJ, Farzana FD, Sultana S, *et al*. Examining the relationship between socio-economic status, WASH practices and wasting. *PLoS One*. 2017; 12(3), e0172134.
57. Mya KS, Kyaw AT, Tun T. *Feeding Practices and Nutritional Status of Children Age 6–23 Months in Myanmar: Further Analysis of the 2015–16 Demographic and Health Survey*, 2018.ICF, Rockville, Maryland, USA.
58. Vollmer S, Harttgen K, Subramanyam MA, *et al*. Association between economic growth and early childhood nutrition – Authors' reply. *Lancet Glob Health*. 2015; 3(2), e81.
59. Bhutta ZA, Ahmed T, Black RE, *et al*. What works? Interventions for maternal and child undernutrition and survival. *Lancet*. 2008; 371, 417–440.
60. Mutisya M, Kandala NB, Ngware MW, Kabiru CW. Household food (in) security and nutritional status of urban poor children aged 6 to 23 months in Kenya. *BMC Public Health*. 2015; 15, 1052.
61. Murayama N. Effects of socioeconomic status on nutrition in Asia and future nutrition policy studies. *J Nutr Sci Vitaminol*. 2015; 61, S66–S68.
62. Shavers VL. Measurement of socioeconomic status in health disparities research. *J Natl Med Assoc*. 2007; 99(9), 1013–1023.
63. UNICEF. *The state of the World's children 2008. Child survival*, 2007. United Nations Children's Fund, New York. p. 154.
64. McGovern ME, Krishna A, Aguayo VM, Subramanian SV. A review of the evidence linking child stunting to economic outcomes. *Int J Epidemiol*. 2017; 46(4), 1171–1191.
65. Ackerson LK, Subramanian SV. Domestic violence and chronic malnutrition among women and children in India. *Am J Epidemiol*. 2008; 167(10), 1188–1196.
66. Yount KM, DiGirolamo AM, Ramakrishnan U. Impacts of domestic violence on child growth and nutrition: a conceptual review of the pathways of influence. *Social Sci Med*. 2011; 72(9), 1534–1554.
67. Teixeira MPC, Queiroga TPR, Mesquita MDA. Frequency and risk factors for the birth of small-for-gestational-age newborns in a public maternity hospital. *Einstein (Sao Paulo)*. 2016; 14(3), 317–323.

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Appendix 10: Original paper for objective 2 (under review)

Maternal and Child Health Journal

Association between household and maternal socioeconomic factors with birth outcomes in the Democratic Republic of Congo and South Africa: a comparative study.

--Manuscript Draft--

Manuscript Number:	
Full Title:	Association between household and maternal socioeconomic factors with birth outcomes in the Democratic Republic of Congo and South Africa: a comparative study.
Article Type:	Original Research
Keywords:	Socioeconomic factors; birth outcomes; Democratic Republic of Congo; South Africa.
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Funding Information:	DST-NRF Centre Of Excellence (SA) (ACC2017007) — Prof Shane Anthony Norris DST - NRF Centre of Excellence in Food Security (SA) (160502) — Dr Rihlat Said-Mohamed
Abstract:	Objective : To assess and compare the associations between household socioeconomic (SES) factors with birth outcomes (low birth weight (LBW), small-for-gestational age (SGA) and preterm birth (PTB)) in the Democratic Republic of Congo (DRC) and South Africa (SA). Methods : Cross-sectional data of mother-newborn pairs collected in 2017 in the DRC were compared with mother-newborn pairs data from the SA Soweto first 1000-days pregnancy cohort study (2013-2016). Country-specific and pooled multivariable logistic regressions analyses assessed the associations between maternal education, marital status, and housing with LBW, SGA, and PTB adjusted for maternal anthropometry and obstetric factors. Results : 1084 mother-newborn pairs were recruited (DRC: 256; SA: 828). The rates of LBW, PTB and SGA were, 11.5%, 17.1% and 32.8% in the DRC and 15.9%, 10.5% and 20.1% in SA. Socioeconomic factors differed between countries and sex. In the DRC, being married decreased the odds of having LBW and PTB children by 86% and 80%, respectively. In SA, being a mother with secondary level of education and above was associated with 86% reduced odds of SGA. In the pooled analyses, women with secondary level of education and above had a 2.2-fold increase in odds of giving birth to a PTB newborn. Country of residence and maternal nutritional status were stronger predictors of birth outcomes than SES factors. Conclusion : In sub-Saharan Africa, policies aiming to alleviate women's education combined with improved social support and household SES prior to and during

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	pregnancy are critical to optimal neonatal outcomes and strategic to achieve the Sustainable Development Goals.

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Title:

Association between household and maternal socioeconomic factors with birth outcomes in the Democratic Republic of Congo and South Africa: a comparative study

Running head: socioeconomic factors and birth outcomes in Africa

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ABSTRACT

Objective: To assess and compare the associations between household socioeconomic (SES) factors with birth outcomes (low birth weight (LBW), small-for-gestational age (SGA) and preterm birth (PTB)) in the Democratic Republic of Congo (DRC) and South Africa (SA).

Methods: Cross-sectional data of mother-newborn pairs collected in 2017 in the DRC were compared with mother-newborn pairs data from the SA Soweto first 1000-days pregnancy cohort study (2013-2016). Country-specific and pooled multivariable logistic regressions analyses assessed the associations between maternal education, marital status, and housing with LBW, SGA, and PTB adjusted for maternal anthropometry and obstetric factors.

Results: 1084 mother-newborn pairs were recruited (DRC: 256; SA: 828). The rates of LBW, PTB and SGA were, 11.5%, 17.1% and 32.8% in the DRC and 15.9%, 10.5% and 20.1% in SA. SES factors differed between countries and sex. In the DRC, being married decreased the odds of having LBW and PTB children by 86% and 80%, respectively. In SA, being a mother with secondary level of education and above was associated with 86% reduced odds of SGA. In the pooled analyses, women with secondary level of education and above had a 2.2-fold increase in odds of giving birth to a PTB newborn. Country of residence and maternal nutritional status were stronger predictors of birth outcomes than SES factors.

Conclusion: In sub-Saharan Africa, policies aiming to alleviate women's education combined with improved social support and household SES prior to and during pregnancy are critical to optimal neonatal outcomes and strategic to achieve the Sustainable Development Goals.

Key words: Socioeconomic factors, birth outcomes, Democratic Republic of Congo, South Africa.

Significance

What is known? In sub-Saharan Africa, lower household and maternal socioeconomic status (SES) (lower level of maternal education level and household poverty) is associated with adverse birth outcomes such as low birth weight, small-for-gestational-age and preterm birth, key predictors of poor population health and human capital. However, disparities in socioeconomic development between countries of the sub-Saharan Africa region may mitigate these associations, and the respective contributions of maternal socioeconomic factors versus biological factors are yet to be disentangled.

What findings does this study add? By comparing data from a low-income country (the Democratic Republic of Congo) with a middle-income country (South Africa) in sub-Saharan Africa, this study brings evidence that maternal marital status and housing may affect differently birth outcomes depending of the country's socioeconomic context, while maternal education remain a strong predictor of birth outcomes. In addition to the country of residence, this study shows that maternal nutritional status prior to and during pregnancy may have a stronger effect than SES factors on birth outcomes and mitigate these relationships.

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INTRODUCTION

Poverty is associated with maternal undernutrition, adverse birth outcomes and poor human capital (Victora et al., 2008). Low birth weight (LBW), small for gestational age (SGA) and preterm birth (PTB) have been shown to be strong predictors of high morbidity and mortality during infancy, and increase risk for chronic diseases in adulthood (Blencowe et al., 2019). Birth outcomes reflect disparities in sociological and economic categories of individuals or groups (Chawanpaiboon et al., 2018). The United International Children's Emergency Fund's (UNICEF) conceptual framework of maternal and child undernutrition identified poor maternal and household socioeconomic factors (SES) as critical determinants of birth outcomes (Black et al., 2013).

Birthweight (BW) is the first postnatal measurement indicating newborn growth and nutritional status, whilst LBW has been used as an indicator of impaired intra-uterine growth (UNICEF & WHO, 2019). Maternal undernutrition contributes to LBW (Fraser & Abu-Saad, 2010), whilst other maternal factors such as age (Campbell et al., 2012), diet (Chia et al., 2019), anthropometry(Black et al., 2013), infection (Victora et al., 2008) and chronic conditions (e.g. hypertension, diabetes) (Victora et al., 2008), obstetrical conditions and parity(Muula et al., 2011), lifestyle (smoking and alcohol use) (Campbell et al., 2012; Chen, 2012) and access to prenatal health care (WHO, 2016) predict BW. Birth weight is closely related to gestational age at birth, which also has been associated with maternal mental and physical health during pregnancy, and foetal distress(Victora et al., 2008).

The association between SES factors and birth outcomes has been widely documented in high-income countries (Campbell et al., 2012; Wilding et al., 2019)) contrasting with sub-Saharan Africa (SSA) where the prevalence of newborns with LBW, PTB and SGA is amongst the highest worldwide at 14.6% (20.5 million) (UNICEF et al., 2019), 10.6% (14.84 million), (Chawanpaiboon et al., 2018) and 19.3 % (23.3 million)(Lee Anne et al., 2017),

respectively. Studies in SSA are scarce and poor birth outcomes have been associated with poor maternal education, unemployment, and household economic deprivation, as highlighted in a recent systematic review (Ngandu et al., 2019). Women with a high level of education are more likely to have better job opportunities and an income than their counterparts with a lower educational level, thus enabling easier and informed access to health information and health care for themselves and their children (Silvestrin et al., 2013). The role of marital status in birth outcomes has not yet been investigated in SSA (Ngandu et al., 2019).

However, it is important to consider that the SSA region comprises low-income (e.g. the Demographic Republic of the Congo, DRC) and middle-income (e.g. South Africa) countries with different social, cultural and political contexts. In 2018, the DRC had a lower human development index (HDI) (0.37) and a weaker gross domestic product (GDP) per capita ($US 808) than SA which had a medium HDI (0.41) and $US 12,215 per capita GDP (World Bank, 2019). The poverty level in the DRC was higher than that of SA with the percentage of the population living on less than US$ 1.90 per day being 73% and 18.8% , respectively (World Bank, 2019). However, social inequality, measured by the Gini coefficient was higher in SA (63%) than in the DRC (42.1%) (World Bank, 2019). The aim of this study was, therefore, to assess and compare the associations between household and maternal demographic and SES factors, and adverse birth outcomes (LBW, PTB and SGA) in two socioeconomically contrasted countries in SSA namely, SA and the DRC.

METHODS

Study design and setting

This study included mother and newborn pairs living in rural and urban areas of the DRC and an urban area of SA. In the DRC, the cross-sectional study was conducted in Kasai central province, in which six out of the 26 health districts are urban. Data were collected from one

urban hospital (Kananga Provincial hospital) and three rural hospitals (Mikalayi, Bunkonde, Tshikula).

For secondary analyses, South African data were collected as part of the Soweto First 1000 Days cohort (S1000) study undertaken at the Chris Hani Baragwanath Academic Hospital (CHBAH) in Soweto, Johannesburg. The S1000 study investigated the associations between maternal factors with foetal and newborn nutritional status and explored the levers of maternal and child health within the first 1000 days of life in Soweto, which is an urban-poor area in South Africa (Wrottesley et al., 2017).

Ethics approval

The DRC study was approved by the Centre National d'Éthique of the DRC (clearance number: 046/CNES/BN/PNMF/2016). The S1000 study was approved by the Human Research Ethics Committee of the University of the Witwatersrand, South Africa (clearance numbers: M120524 and M130905). Written informed consent was obtained from mothers in both studies.

Participants

In the DRC, a two-stage cluster sampling was used. We first selected 4 districts out of 26 in the province in proportion to the number of rural and urban health districts within the province. Mother-newborn pairs were recruited in 4 selected hospitals between August 2016 and January 2017. In each hospital, we included post-partum mothers (72 hours after delivery) with their healthy, singleton child, born after 28 weeks of pregnancy.

In SA, mother-newborn pairs were recruited at the CHBAH between 2013 and 2016. Eligibility criteria included healthy pregnant women older than 18 years, less than 18 weeks of pregnancy, with a singleton newborn, residing in Soweto (Macaulay et al., 2018). Follow up data were collected at participant homes at 6 time points: before 14 weeks, 15-19 weeks, 20-23 weeks, 24-28 weeks, 29-33 weeks and 34-38 weeks (Wrottesley et al., 2017).

Variables

Exposure: household and maternal demographic and socioeconomic factors

Data on maternal education, maternal marital status and the type of house walls within which mothers lived were collected using interviewer-administered questionnaires adapted from the Demographic Health Survey questionnaires (Ayad et al., 1994). Maternal education was the level of education completed by the time of delivery. Maternal education was aggregated into two categories for analyses: none plus primary education vs. secondary education and above. Maternal marital status was defined as the legal marital status (single, married, widowed, divorced) and then aggregated into two categories: married vs. unmarried. The type of house walls was categorised as: walls constructed using durable materials (bare bricks, cement block, plaster finished) vs. walls constructed using non-durable materials (plastic, cardboard, mud, corrugated iron/zinc).

Birth outcomes

Birth weight was measured using digital scales (Salter in DRC; Seca 376 in SA) to the nearest 100 g with babies wearing no clothes(Macaulay et al., 2018). The scales were calibrated daily to ensure the reliability and accuracy of the measurements. Gestational age at birth was measured in weeks of pregnancy between the last menstrual period (LMP) and the date of delivery in the DRC and by dating ultrasound (Philip HD-9, USA) in SA(Macaulay et al., 2018). Classification of newborns was as follows: LBW (BW <2500 g), SGA (BW <10th percentile of the INTERGROWTH 21st standard curve), and PTB (birth before 37 gestational weeks) (Chawanpaiboon et al., 2018; Lee Anne et al., 2017; UNICEF & WHO, 2019).

Covariates

Newborn factors were the child sex (male or female) and birth weight. Maternal factors included age, height and weight according to the WHO guidelines (WHO, 2008). Maternal weight (kilogram) and height (centimetre) were measured using a digital scale to the nearest

100 grams and an adult stadiometer, respectively (Macaulay et al., 2018). Interviewer-administered questionnaires were used in the DRC and in SA to obtain data on gestational age at the first prenatal visit (in weeks of pregnancy), gestational weight gain per week (GWG) (in kilograms per week of pregnancy) and parity (number of previous deliveries), maternal morbidity during pregnancy (including high blood pressure, malaria, anaemia, tuberculosis), smoking status (yes or no) and prenatal alcohol consumption (yes or no). Maternal morbidity was categorised as a binary score (disease vs no disease).

Study sample size

In the DRC, 256 mother-newborn pairs were included in the study after calculating to detect a 10% difference from the baseline LBW prevalence found in the literature (WHO, 2014) with 80% of power ($\alpha < 0.05$ significance). Low birth weight was used for sample size calculation because it includes PTB and SGA (WHO, 2014). In SA, data of 828 mother-newborn pairs were included in the secondary analyses.

Statistical analyses

For each variable, a descriptive analysis was done grouped by sex. Summary statistics included proportions, means and standard deviation, or median and range. Shapiro, Skewness and Kurtosis tests were performed to identify the type of distribution for each variable. Differences by sex and by country were assessed using a Pearson's chi squared test, or an independent Student t-test. Multivariable logistic regression analyses and modelling were done to identify factors associated with birth outcomes. Maternal weight at first prenatal visit was excluded from multivariable regression models due to collinearity with maternal weight at delivery (variation inflation factors, r=0.96). Maternal smoking was excluded from the analyses due to its small rate (<10%) in the DRC.

For each model setting, associations between household and maternal sociodemographic and SES factors with birth outcomes were assessed. Model 1 (M1) investigated the association

between SES factors (maternal education, maternal marital status and type of house walls) and birth outcomes adjusted for newborn sex. In the Model 2 (M2), M1 was adjusted for maternal characteristics (maternal height, maternal age, type of delivery, gestational age at first prenatal visit, GWG, maternal weight at delivery, maternal morbidity score and maternal lifestyle). In Model 3 (M3), M2 was adjusted for the country. Finally, multivariable logistic regression models were performed by pooling the DRC and SA data. This last model consisted of two models adjusted for the country. The significance level was set as p- ≤ 0.05 with 95% confidence intervals. Stata version 13 (StataCorp LP, College station, TX, USA) was used for data management and analyses.

RESULTS

[Insert Table 1]

A total of 1084 women-newborn pairs were included in the study (DRC: 256; SA: 828) (Table 1). In comparison to SA women, a greater number of DRC women had a lower level of education (SA: 2.1%; DRC: 54.6%), were married (SA: 37.7%; DRC: 94.8%) and were living in houses constructed of non-durable materials (SA: 13.2%; DRC: 76.9%). The rates of LBW and SGA were lower in the DRC (LBW: 11.3%; SGA: 10.1%) than in SA (LBW: 17.1%; SGA: 20.2%). The rate of PTB in the DRC (32.8%) was almost double that of SA (15.9%). Child sex-differences were found for maternal education, type of house in the DRC, marital status in SA. With the exception of maternal age at delivery, household, maternal, newborn and lifestyle characteristics differed significantly between the DRC and SA. The DRC women were taller, had higher parity and later first prenatal visit, weighed less at delivery, smoked less and consumed more alcohol during pregnancy, compared to SA women. However, in both countries, the majority of women presented with morbidity conditions during pregnancy (DRC: 78%; SA: 66.3%) and most women had a vaginal delivery (DRC: 89.7%; SA: 58.1%).

Bivariate analyses (Supplementary Table 1) showed that, in the DRC, maternal education and type of house were not associated with birth outcomes. The odds of LBW decreased by 9% for every kilogram increase in maternal weight at first prenatal visit and by 63% for morbidity during pregnancy. The odds of PTB decreased by 72% for married women and by 7% for every week of delay in the first prenatal visit but increased 2.3-fold with smoking during pregnancy. The odds of SGA decreased 7% with every centimetre increase in maternal height but increased by 12% with every week of delay in the first prenatal visit.

Regression analyses adjusted for newborn and maternal characteristics were performed per country (Supplementary Table 3). After adjusting for newborn and maternal characteristics, being married was associated with 83% and 79% decreased odds of LBW and PTB, respectively. Having a secondary level of education or higher decreased the odds of SGA by 86%. In SA, no significant association between household and maternal demographic and SES factors with birth outcomes were found in the bivariate analyses nor in the regression analyses adjusted for newborn and maternal characteristics (Supplementary Tables 1 and 3).

In bivariate analyses (Supplementary Table 1), a kilogram increase in maternal weight at first prenatal visit and a kilogram increase in GWG were associated with a 2% and 87% decrease in the odds of LBW, respectively. The odds of LBW increased by 3%, 27% and 57% with a one-year increase in maternal age, a unit increase in parity and having a vaginal delivery, respectively. For every centimetre increase in maternal height, for every kilogram increase in maternal weight at delivery, the odds of SGA decreased by 4% and 3%, respectively. For every kilogram increase in GWG, the odds of having PTB decreased by 63%. For every unit increase in parity and vaginal delivery there was a 20% and 74% increase in the odds of PTB, respectively. Maternal education was associated with PTB, marital status with LBW and SGA and, type of house walls with PTB and SGA (supplementary Table 2).

[Insert Table 2]

In the pooled analyses adjusted for newborn and maternal characteristics, and country (Table 2), maternal education, marital status and type of house walls were associated with birth outcomes. Having higher than secondary level of education increased the odds of PTB 2.2-fold. Being legally married decreased the odds of LBW and PTB by 45% and 38%, respectively. Living in a house with durable walls decreased the odds of PTB by 39% but increased that of SGA by 92%. After adjusting for country, the odds for women with secondary level of education and above with PTB increased 2.21-fold. Maternal height, gestational age at the first prenatal visit, maternal weight at delivery and GWG confounded the association between SES with LBW. Parity, vaginal delivery, maternal weight at delivery confounded the association between SES and PTB. Child sex, parity, maternal weight at the first prenatal visit and at delivery confounded the association between SES with SGA. Gestational age at the first prenatal visit confounded the association between SES and LBW, PTB and SGA.

DISCUSSION

Main findings

It is clear from the findings of this study that place matters when assessing the association between maternal and household socioeconomic and household factors and birth outcomes in sub-Saharan Africa. Living in SA as compared to DRC was associated with reduced odds of a newborn with LBW, PTB or SGA, which reflects country-specific maternal and household resources and social position differences (education access, housing, marriage). In the DRC, being married decreased the likelihood of having LBW and PTB children while in SA being a mother with secondary level of education and above was associate with lower risks of having a SGA newborn. Furthermore, finding from the pooled analyses of both countries data support that maternal education is a critical determinant of birth outcomes across SSA countries.

Maternal education, maternal marital status and type of house walls, and birth outcomes

To our knowledge, this study is among few that explore the association between marital status and birth outcomes in SSA. Whilst support from biological fathers may contribute to greater household income allowing access to health care and food security which benefit maternal and child health (Lekea-Karanika et al., 1999), these positive influences may be mitigated by factors such as domestic violence (Shah & Shah, 2010) or changing partners between two births which increased the risk of having LBW and PTB newborn in women with more than 14 years of education in Norway (Vatten & Skjaerven, 2003). Collectively, these studies emphasize that cross-country comparisons of associations between marital status and birth outcomes must be interpreted with caution, considering the social structure, performance and quality of pre- and post-natal health care as well as the cultural contexts specific to each country. We used the type of house wall material within which participants resided as a proxy for social position and household wealth, better social position (i.e. living in a house with durable walls) decreased the risk for PTB but increased that of SGA in the pooled dataset.

Our findings also corroborate those of others which found that a lower level of maternal education was associated with LBW in SSA countries (Ngandu et al., 2019) and in Latin America (Silvestrin et al., 2013), and with SGA, PTB and LBW in high-income countries (Campbell. et al., 2018). In the United Kingdom, a poor level of maternal education and unemployment was associated with a higher risk of SGA, which was greater in single compared to married women (Wilding et al., 2019). We found that maternal education had the strongest association with birth outcomes compared to other SES factors. This is consistent with a previous review which found that maternal education rather than maternal income was associated with birth outcomes in high income countries Cantarutti et al.(Cantarutti et al.,

2017), where health systems (with/without universal health care coverage), locality and income (Luo et al., 2006) contrast with LMICs.

Other maternal and child factors with birth outcomes

In our study, maternal and newborn biological factors (child sex, parity, maternal age at delivery, maternal height, gestational age at first prenatal visit, GWG and maternal morbidity during pregnancy) were associated with the birth outcomes of interest independently of demographic and SES factors. Maternal height, parity, weight pre-pregnancy, and GWG decreased negatively the risk of having a LBW, PTB or SGA newborn, reflecting the importance of maternal nutritional status during preconception and pregnancy periods. Gestational weight gain has been associated with dietary intake and physical activity in SA women (Wrottesley et al., 2017). In the S1000, previous analyses have shown that mothers consuming an energy dense diet (sugar and fat foods) during pregnancy was associated with greater GWG while maternal traditional diet (beans, legumes, traditional meats and porridge) was associated with adequate GWG (Wrottesley et al., 2017). A review conducted in London showed that maternal nutritional status and quality of maternal dietary intake in the life course affected the strong association between SES factors with LBW and PTB; maternal nutrition was rather correlated to the quality of diet in the poorest populations in comparison to their richest counterparts (Fraser & Abu-Saad, 2010). A meta-analysis in high-income countries showed that a higher GWG was associated with increased risks of PTB (McDonald et al., 2011) however, two recent reviews (in Peru, Korea, China, Japan, Italy, Denmark and USA) found that women with a higher total GWG (above Institute of Medicine's guidelines) had a lower risk of having a LBW, SGA or PTB newborn(Faucher et al., 2016; Goldstein et al., 2017).

Surprisingly, we found that maternal morbidity during pregnancy was protective against LBW. This may be attributed to women who are aware of their health conditions being more

likely to have their health monitored more closely throughout pregnancy (Momplaisir et al., 2015). Earlier first prenatal visit influenced the association between maternal marital status and PTB. Prenatal alcohol use played a confounding role in our study. Prenatal alcohol exposure was associated with early behavioural birth outcomes (mental disorders) rather than LBW outcomes in China (Chen, 2012). In contrast, fewer prenatal visits (no visit or <5 visits) was associated with 5.4-fold and 9.1-fold increased odds of LBW and PTB, respectively, after adjusting for maternal level of education, younger maternal age, smoking and alcohol use in a study in Finland (Raatikainen et al., 2007).

Our findings show that the effect sizes of maternal biological factors on birth outcomes were larger than those of socioeconomic factor, which is in keeping with other studies that have suggested using maternal undernutrition as a marker of poor birth outcomes (Fraser & Abu-Saad, 2010; Victora et al., 2008) regardless of the type of delivery (Han et al., 2011).

Limitations

The estimate of gestational age using LMP may be less accurate (sensitivity and predilection value) than the ultrasound method in the first trimester compared to the last trimester (Hoffman et al., 2008). Inadequate housing may contribute to poorer child health and nutritional status (WHO, 2018). Other related SES and environmental factors such as water, sanitation and hygiene, should also be investigated in future studies to disentangle their role on birth outcomes.

Implications

Social policies should protect single women socially and economically before, during and after pregnancy to improve birth outcomes and to optimize their intergenerational influences. More context-specific mixed-methods studies in SSA that focus on effectiveness of policies and intervention programs in the field to disentangle the role of proximal factors (maternal and paternal biological factors, maternal and household sociodemographic and socioeconomic

factors) from the role of distal country factors (governance, health policy and system) is needed.

Conclusion

There are disparities in SA and the DRC with respect to the associations between household and maternal SES and birth outcomes. Maternal education and marital status were associated with birth outcomes in SSA while maternal biological and country factors (socioeconomic development, governance and health systems) underpin individual and household capabilities. These are all potential levers to affect positive pregnancy outcomes and address the Sustainable Development Goals.

Competing interests

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Declaration of interests

Authors declare no conflict of interest.

Authors' contribution

Conceptualization of the study: NBC, SAN, RSM;

Data management, analyses and interpretation: NBC, DM, SAN; RSM

Integrity of data: CBN; RSM

Editing manuscript: AM

Writing and updating manuscript: CBN, DM, AM, SAN, RSM

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REFERENCES

Ayad, M., Piani, A. L., Barrere, B., Ekouevi, K., & Otto, J. (1994). Demographic characteristics of households *DHS Comparative Studies No. 14*. Calverton, Maryland, USA: Macro International.

Black, R. E., Victora, C. G., Walker, S. P., Bhutta, Z. A., Christian, P., de Onis, M., *et al.* (2013). Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet, 382*(9890), 427-451. doi: 10.1016/s0140-6736(13)60937-x

Blencowe, H., Krasevec, J., de Onis, M., Black, R. E., An, X., Stevens, G. A., *et al.* (2019). National, regional, and worldwide estimates of low birthweight in 2015, with trends from 2000: a systematic analysis. *The Lancet Global Health, 7*(7), e849-e860. doi: 10.1016/S2214-109X(18)30565-5

Campbell, M., Cartier, S., Xie, B., Kouniakis, G., Huang, W., & Han, V. (2012). Determinants of small for gestational age birth at term. *Paediatr Perinat Epidemiol, 26*(6), 525-533. doi: 10.1111/j.1365-3016.2012.01319.x

Campbell., Jason, G., Paula DN, D., Barbra, D. V., Debbie, P., & Seabrook, J. A. (2018). Socioeconomic status and adverse birth outcomes: a population-based Canadian sample. *J Biosoc Sci, 50*(1), 102-113. doi: 10.1017/s0021932017000062

Cantarutti, A., Franchi M, Monzio CM, Merlino L, & Corrao G. (2017). Mother's education and the risk of several neonatal outcomes: an evidence from an Italian population-based study. *BMC Pregnancy and Childbirth, 17*(1), 221. doi: 10.1186/s12884-017-1418-1

Chawanpaiboon, S., Vogel, J. P., Moller, A. B., Lumbiganon, P., Petzold, M., Hogan, D., *et al.* (2018). Global, regional, and national estimates of levels of preterm birth in 2014: a systematic review and modelling analysis *The Lancet, 7*(1), 10. doi: https://doi.org/10.1016/S2214-109X(18)30451-0

Chen, J.-H. (2012). Maternal alcohol use during pregnancy, birth weight and early behavioral outcomes. *Alcohol and Alcoholism, 47*(6), 649-656. doi: 10.1093/alcalc/ags089

Chia, A., Chen, L., Lai, J., Wong, C., Neelakantan, N., Van Dam, R., *et al.* (2019). Maternal Dietary Patterns and Birth Outcomes: A Systematic Review and Meta-Analysis. *Adv Nutr, 10*(4), 685-695. doi: 10.1093/advances/nmy123

Faucher, M., Hastings-Tolsma, M., Song, J., Willoughby, D., & Bader, S. (2016). Gestational weight gain and preterm birth in obese women: a systematic review and meta-analysis. *Bjog, 123*(2), 199-206. doi: 10.1111/1471-0528.13797

Fraser, D., & Abu-Saad, K. (2010). Maternal Nutrition and Birth Outcomes. *Epidemiologic Reviews, 32*(1), 5-25. doi: 10.1093/epirev/mxq001

Goldstein, R., Abell, S., Ranasinha, S., Misso, M., Boyle, J., Black, M., *et al.* (2017). Association of gestational weight gain with maternal and infant outcomes: a systematic review and meta-analysis. *Jama, 317*(21), 2207-2225. doi: 10.1001/jama.2017.3635

Han, Z., Mulla, S., Beyene, J., Liao, G., & McDonald, S. D. (2011). Maternal underweight and the risk of preterm birth and low birth weight: a systematic review and meta-analyses. *Int J Epidemiol, 40*(1), 65-101. doi: 10.1093/ije/dyq195

Hoffman, C. S., Messer, L. C., Mendola, P., Savitz, D. A., Herring, A. H., & Hartmann, K. E. (2008). Comparison of gestational age at birth based on last menstrual period and ultrasound during the first trimester. *Paediatr Perinat Epidemiol, 22*(6), 587-596. doi: 10.1111/j.1365-3016.2008.00965.x

Lee Anne, C., Kozuki, N., Cousens, S., Stevens, G. A., Blencowe, H., Silveira, M. F., *et al.* (2017). Estimates of burden and consequences of infants born small for gestational age in low and middle income countries with INTERGROWTH-21st standard: analysis of CHERG datasets. *BMJ, 358*. doi: 10.1136/bmj.j3677

Lekea-Karanika, V., Tzoumaka-Bakoula, C., & Matsaniotis, N. S. (1999). Sociodemographic determinants of low birthweight in Greece: a population study. *Paediatr Perinat Epidemiol, 13*(1), 65-77.

Luo, Z.-C., Wilkins, R., & Kramer, M. S. (2006). Effect of neighbourhood income and maternal education on birth outcomes: a population-based study. *Canadian Medical Association Journal, 174*(10), 1415. doi: 10.1503/cmaj.051096

Macaulay, S., Munthali, R. J., Dunger, D. B., & Norris, S. A. (2018). The effects of gestational diabetes mellitus on fetal growth and neonatal birth measures in an African cohort. *Diabetic Medicine, 35*(10), 1425-1433. doi: 10.1111/dme.13668

McDonald, S. D., Han, Z., Mulla, S., Lutsiv, O., Lee, T., Beyene, J., *et al.* (2011). High gestational weight gain and the risk of preterm birth and low birth weight: a systematic review and meta-analysis. *J Obstet Gynaecol Can, 33*(12), 1223-1233. doi: 10.1016/s1701-2163(16)35107-6

Momplaisir, F., Brady, K., Fekete, T., Thompson, D., Diez Roux, A., & Yehia, B. (2015). Time of HIV diagnosis and engagement in prenatal care impact virologic outcomes of pregnant women with HIV. *PloS one, 10*(7), e0132262-e0132262. doi: 10.1371/journal.pone.0132262

Muula, A., Siziya, S., & Rudatsikira, E. (2011). Parity and maternal education are associated with low birth weight in Malawi. *African Health Science 11*, 65–71.

Ngandu, C., Momberg, D., Magan, A., Lumbwe, C., Norris, A. S., & Said-Mohamed, R. (2019). The association between household socioeconomic status, maternal socio-demographic characteristics and adverse birth and infant growth outcomes in sub-Saharan Africa: a systematic review. *Journal of DOHaD*, 18.

Raatikainen, K., Heiskanen, N., & Heinonen, S. (2007). Under-attending free antenatal care is associated with adverse pregnancy outcomes. *BMC Public Health, 7*(1), 268. doi: 10.1186/1471-2458-7-268

Shah, P., & Shah, J. (2010). Maternal exposure to domestic violence and pregnancy and birth outcomes: a systematic review and meta-analyses. *J Womens Health (Larchmt), 19*(11), 2017-2031. doi: 10.1089/jwh.2010.2051

Silvestrin, S., Silva, C. H., Hirakata, V. N., Goldani, A. A., Silveira, P. P., & Goldani, M. Z. (2013). Maternal education level and low birth weight: a meta-analysis. *J Pediatr (Rio J), 89*(4), 339-345. doi: 10.1016/j.jped.2013.01.003

UNICEF, & WHO. (2019). Low birthweight estimations: levels and trends 2000-2015. *https://www.who.int/nutrition/publications/UNICEF-WHO-lowbirthweight-estimates-2019/en/*, 36.

UNICEF, WHO, & WBG. (2019). Levels and trends in child malnutrition.Key findings of the 2019 edition. *WHO edition, https://www.who.int/nutgrowthdb/estimates2018/en/*(19), 16.

Vatten, L. J., & Skjaerven, R. (2003). Effects on pregnancy outcome of changing partner between first two births: prospective population study. *Bmj, 327*(7424), 1138. doi: 10.1136/bmj.327.7424.1138

Victora, C. G., Adair, L., Fall, C., Hallal, P. C., Martorell, R., Richter, L., *et al.* (2008). Maternal and child undernutrition: consequences for adult health and human capital. *The Lancet, 371*(9609), 340-357. doi: https://doi.org/10.1016/S0140-6736(07)61692-4

WHO. (2008). Training course on child growth assessment. WHO child growth standards. Measuring a child's growth. . https://www.who.int/nutrition/publications/childgrowthstandards_trainingcourse/en/.

WHO. (2014). Global nutrition targets 2025: low birth weight policy brief Geneva. World Health Organization. *WHO edition,* https://www.who.int/nutrition/publications/globaltargets2025_policybrief_lbw/en/.

WHO. (2016). WHO recommendations on antenatal care for a positive pregnancy experience. *WHO edition,* https://www.ncbi.nlm.nih.gov/books/NBK409110/.

WHO. (2018). World Health Organization housing and health Guidelines. *WHO edition.* https://www.who.int/sustainable-development/publications/housing-health-guidelines/en/.

Wilding, S., Ziauddeen, N., Roderick, P., Smith, D., Chase, D., Macklon, N., *et al.* (2019). Are socioeconomic inequalities in the incidence of small-for-gestational-age birth narrowing? Findings from a population-based cohort in the South of England. *BMJ open, 9*(7), e026998-e026998. doi: 10.1136/bmjopen-2018-026998

World Bank. (2019). Human development index. World Development Indicators. South Africa and Democratic Republic of Congo databases. The World Bank Group. http://worldpopulationreview.com/countries/hdi-by-country/

Wrottesley, S. V., Pisa, P. T., & Norris, S. A. (2017). The Influence of Maternal Dietary Patterns on Body Mass Index and Gestational Weight Gain in Urban Black South African Women. *Nutrients, 9*(7), 732.

Table

Table 1: **Comparative characteristics of the participants in the Democratic Republic of Congo and in South Africa**

		Democratic Republic of Congo (N=256)							South Africa (N=828)							DRC vs SA (p)
		Male (n=187)		Female (n=69)		P	Total		Male (n=429)		Female (n=397)		p	Total		
		N	%	n	%		n	%	n	%	n	%		n	%	
SES factors																
Maternal education	None + Primary	92	50.5	44	65.7	**0.03**	136	54.6	8	1.9	9	2.3	0.68	17	2.1	**<0.01**
	Secondary+ tertiary	90	49.5	23	34.3		113	45.4	421	98.1	388	97.7		809	97.9	
Maternal marital status	Unmarried (Single/widowed/divorced)	9	4.9	4	6.0	0.75	13	5.2	252	58.7	263	66.3	**0.03**	515	62.3	**<0.01**
	Married	173	95.1	63	94.0		236	94.8	177	41.3	134	33.7		311	37.7	
Type of house	Non-durable materials	130	72.2	60	89.5	**<0.01**	190	76.9	51	13.8	43	12.6	0.63	94	13.2	**<0.01**
	Durable materials	50	27.8	7	10.5		57	23.1	318	86.2	298	87.4		616	96.8	
Birth outcomes																
Birthweight (Mean, SD)	Kilogram	162	3.2 (0.5)	60	3.1 (0.4)	0.90	222	3.20 (0.34)	404	3.0 (0.6)	385	2.9 (0.6)	**0.05**	789	2.97 (0.57)	**<0.01**
GA at delivery (Mean, SD)	Weeks of pregnancy	168	37.0 (3.5)	67	36.2 (3.5)	0.12	235	36.6 (0.3)	415	38.0 (2.5)	397	38.2 (2.3)	**0.05**	826	38.1 (2.5)	**<0.01**
LBW (%)	Yes	20	12.4	5	8.8	0.40	222	11.3	63	15.6	72	18.7	0.25	789	17.1	**0.03**
PTB (%)	Yes	49	29.2	28	41.8	0.06	235	32.8	69	16.6	60	15.1	0.56	812	15.9	**<0.01**
SGA (%)	Yes	20	13.3	23	10.1	0.08	211	10.1	69	17.1	90	23.4	**0.03**	789	20.2	**<0.01**
Maternal and newborn characteristics																
Parity (Median, range)	Number of deliveries	172	3.9 (2-7)	64	3.7 (2-5)	0.95	236	3.0 (0-10)	429	2 (0-7)	397	2 (0-9)	0.99	826	2.0 (0-5)	**<0.01**
Delivery (%)	C-section	19	10.8	6	9.1	0.70	25	10.30	170	41.0	170	42.8	0.59	340	41.9	**<0.01**
	Vaginal	157	89.2	60	90.9		217	89.70	245	59.0	227	57.2		472	58.1	**<0.01**
Maternal age at delivery (Mean, SD)	Years	187	27.8 (7.9)	69	26.5 (6.5)	0.57	256	27.5 (0.5)	429	29.5 (5.8)	397	30.2 (6.0)	0.76	826	29.8 (5.9)	**0.57**
Maternal height (Mean, SD)	Centimetre	185	161.1 (7.5)	68	160.6 (7.6)	0.57	253	160.9 (7.3)	429	158.8 (6.7)	397	158.7 (6.8)	0.62	826	158.8 (6.7)	**<0.01**
GA at the first prenatal visit (Mean, SD)	Weeks of pregnancy	169	18.3 (5.9)	67	16.4 (5.2)	0.12	236	17.8 (0.4)	429	12.4 (2.4)	397	12.4 (2.6)	0.95	826	99.8	**<0.01**
Duration between first prenatal visit and delivery (Mean, SD)	Weeks of pregnancy	165	18.6 (6.1)	67	19.8 (5.9)	0.40	232	18.9 (6.1)	415	25.6 (3.4)	397	25.8 (3.5)	0.36	812	25.0 (6.1)	**<0.01**

Maternal weight at the first prenatal visit (Mean, SD)	Kilogram	170	58.2 (7.2)	65	56.1 (6.2)	0.45	235	57.6 (7.0)	429	70.8 (15.0)	397	71.9 (17.3)	0.99	826	71.3 (16.2)	**<0.01**
Maternal weight at delivery (Mean, SD)	Kilogram	176	62.5 (7.7)	66	60.8 (6.2)	0.45	242	61.8 (0.5)	428	78.8 (14.9)	397	79.7 (16.8)	0.99	825	79.2 (15.8)	**<0.01**
Gestational weight gain per week (Mean, SD)	Kilogram per week	160	0.3 (0.7)	66	0.4 (0.8)	0.20	226	241 (24)	429	0.3 (0.3)	397	0.3 (0.2)	0.98	826	290 (27)	**0.01**
Smoking (%)	Yes	11	6.1	5	7.8	0.64	16	6.6	34	8.6	37	8.6	0.96	71	8.6	**<0.01**
Alcohol use (%)	Yes	49	30.1	22	37.9	0.27	71	32.1	44	12.4	34	10.2	0.37	78	11.3	**<0.01**
Morbidity score (Score)	No morbidity	26	13.9	15	21.7	0.10	41	16.0	139	32.4	139	35.0	0.43	278	33.7	**<0.01**
	Morbidity or co-morbidity	161	86.1	54	78.3		215	84.0	290	67.6	258	65.0		548	66.3	

GA: gestational age: LBW: low birth weight; PTB: preterm birth; SGA: small for gestational age; SD: standard deviation; p= p-value; Significant values $p < 0.05$ highlighted in bold

Table 2: **Multivariable logistic regression analyses of SES factors and birth outcomes (LBW, PTB and SGA) in the pooled dataset from the Democratic Republic of Congo and South Africa.**

		LBW			PTB			SGA		
		M1, n=855, OR (95% CI)	M2, n=817, OR (95% CI)	M3, n=817, OR (95% CI)	M1, n=926, OR (95% CI)	M2, n=850, OR (95% CI)	M3, n=850, OR (95% CI)	M1, n=882, OR (95% CI)	M2, n=817, OR (95% CI)	M3, n=817, OR (95% CI)
SES factors										
Maternal education	None +Primary	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Secondary + tertiary	1.22 (0.62 - 2.38)	2.13 (0.82 - 5.50)	0.74 (0.27 - 1.99)	0.96 (0.58 - 1.57)	3.16 *** (1.60 - 6.27)	2.21 ** (1.07 - 4.59)	0.85 (0.45 - 1.62)	1.01 (0.50 - 2.03)	0.77 (0.36 - 1.65)
Maternal marital status	Unmarried (Single/widowed/divorced)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Married	0.71 * (0.47 - 1.06)	0.55 ** (0.34 - 0.91)	0.75 (0.45 - 1.24)	1.05 (0.73 - 1.51)	0.62 ** (0.39 - 0.98)	0.81 (0.50 - 1.32)	0.83 (0.57 - 1.22)	0.87 (0.58 - 1.29)	0.99 (0.66 - 1.50)
Type of house walls	Non- durable materials	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Durable materials	1.00 (0.61 - 1.65)	1.26 (0.66 - 2.41)	1.07 (0.55 - 2.06)	0.48 *** (0.32 - 0.72)	0.74 (0.44 - 1.24)	0.61 * (0.36 - 1.04)	1.66 * (0.99 - 2.78)	1.92 ** (1.10 - 3.36)	1.48 (0.83 - 2.62)
Maternal and newborns characteristics										
Child sex	Male	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Female	1.16 (0.79 - 1.68)	1.19 (0.76 -1.87)	1.11 (0.71 - 1.74)	1.04 (0.74 - 1.45)	1.36 (0.91 - 2.06)	1.32 (0.87 - 1.99)	1.35 * (0.95 - 1.93)	1.22 (0.77 - 1.07)	1.33 (0.92 - 1.93)
Parity	Number of deliveries		0.89 (0.76 - 1.04)	1.19 ** (1.03 – 1.37)		1.16 ** (1.04 – 1.30)	1.12 * (0.99 – 1.26)		0.87 ** (0.76 – 0.99)	0.92 (0.80 – 1.07)
Type of delivery	C-section		Ref	Ref		Ref	Ref		Ref	Ref
	vaginal		1.46 * (0.95 -2.24)	1.26 (0.76 - 2.07)		1.77 ** (1.11 - 2.82)	1.97 *** (1.22 - 3.15)		0.98 (0.66 - 1.45)	0.98 (0.66 – 1.47)
Maternal age at delivery	Years		1.05 ** (1.01 - 1.09)	1.02 (0.99 - 1.06)		1.02 (0.98 - 1.05)	1.01 (0.98 - 1.05)		1.02 (0.99 - 1.05)	1.02 (0.99 - 1.05)
Maternal Height	Centimetre		0.99 (0.96 – 1.02)	1.01 (0.97 - 1.05)		1.01 (0.98 - 1.04)	1.02 (0.99 - 1.06)		0.96 (0.93 - 0.99)	0.97 ** (0.94 - 0.99)
GA at the first prenatal visit	Weeks of pregnancy		0.63 *** (0.57 - 0.70)	0.65 *** (0.59 - 0.73)		0.95 ** (0.90 – 0.99)	0.93 ** (0.89 – 0.98)		1.14 *** (1.04 -1.26)	1.14 ** (1.03 - 1.26)
Duration between first prenatal visit and delivery	Weeks of pregnancy		0.63 *** (0.58 - 0.69)	0.61 *** (0.56 - 0.67)		0.76 *** (0.71 - 0.79)	0.72 *** (0.68 - 0.77)		1.13 *** (1.04 - 1.23)	1.11 ** (1.01 - 1.21)

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Maternal weight at delivery	Kilogram		0.98 ** (0.96 - 0.99)	0.97 *** (0.95 - 0.99)		0.99 (0.98 - 1.01)	0.99 * (0.97 - 1.00)		0.97 *** (0.96 - 0.99)	0.97 *** (0.95 - 0.98)
Gestational weight gain per week	Kilogram per week		0.55 (0.17 - 1.73)	0.48 (0.15 - 1.52)		0.23 *** (0.08 - 0.65)	0.21 *** (0.07 - 0.61)		1.01 (0.93 – 1.07)	0.91 (0.54 - 1.65)
Alcohol use	Yes		0.79 (0.44 1.43)	0.89 (0.49 1.62)		0.49 ** (0.27 0.91)	0.59 (0.32 1.11)		1.31 (0.71 12.07)	1.35 (0.78 2.32)
Morbidity score	No morbidity		Ref	Ref		Ref	Ref		Ref	Ref
	Morbidity or co-morbidity		0.53 ** (0.34 0.85)	0.53 ** (0.34 0.89)		0.89 (0.57 1.40)	0.94 (0.60 1.49)		0.82 (0.55 1.22)	0.87 (0.58 1.29)
Country										
	DRC			Ref			Ref			Ref
	SA			16.1 *** (4.81 53.88)			3.72 *** (1.51 9.15)			2.41 ** (1.00 5.94)

*: 0.05<p<0.1, **: 0.01<p<0.05, ***: p<0.01; M1= SES factors + child sex, M2= M1 + Newborn and maternal characteristics, M3= M2 + country; OR = Odds Ratio; DRC= Democratic Republic of Congo, GA: gestational age; SA= South Africa

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Supplementary table 1: Bivariate logistic regression analyses of maternal and household SES factors with LBW, PTB and SGA in the Democratic Republic of Congo and South Africa

	The Democratic republic of Congo (n=256)	South Africa (n=828)

		LBW		PTB		SGA		LBW		PTB		SGA	
		N	OR (95% CI)	N	OR (95% CI)	n	OR (95% CI)	n	OR (95% CI)	N	OR (95%CI)	n	OR (95%CI)
SES factors													
Maternal education	None +Primary	220	Ref	234	Ref	210	Ref	789	Ref	789	1.00	789	Ref
	Secondary + tertiary		1.64 (0.44-6.10)		1.45 (0.84-2.51)		0.56 (0.07-4.48)		0.80 (0.51-1.25)		0.71 (0.45-1.13)		0.86 (0.57-1.30)
Maternal marital status	Unmarried (Single/widowed/ divorced)	220	Ref	233	**Ref**	209	Ref	789	Ref	812	Ref	789	Ref
	Married		0.36 (0.09-1.41)		**0.28 ** (0.09-0.89)**		1.38 (0.17-11.23)		0.71 * (0.48-1.06)		0.81 (0.54-1.20)		0.77 (0.53-1.11)
Type of house walls	Non- durable materials	220	Ref	232	Ref	209	Ref	680	Ref	701	Ref	680	Ref
	Durable materials		1.13 (0.44-2.86)		0.98 (0.51-1.90)		1.33 (0.52-3.44)		0.95 (0.52-1.73)		0.62 * (0.36-1.07)		1.27 (0.69-2.33)
Maternal and newborns characteristics													
Child Sex	Male	222	Ref	235	Ref	211	Ref	789	Ref	812	Ref	789	Ref
	Female		0.64 (0.23-1.80)		1.74 * (0.97-3.14)		0.34 (0.10-1.21)		1.24 (0.86-1.80)		0.89 (0.61-1.30)		1.48 ** (1.04-2.10)
Parity	Number of deliveries	209	0.96 (0.80-1.15)	224	1.03 (0.92-1.15)	201	1.01 (0.85-1.20)	789	1.27 *** (1.11-1.45)	812	1.20 *** (1.05-1.38)	789	0.89 (0.77-1.02)
Type of delivery	C-section	219	Ref	229	Ref	209	Ref	789	Ref	812	Ref	789	Ref
	vaginal		0.89 (0.24 - 3.23)		0.91 (0.25-3.33)		1.33 (0.29-6.1)		1.57 ** (1.06-2.32)		1.74 ** (1.16-2.61)		0.96 (0.67-1.36)
Maternal age at delivery	Years	235	1.00 (0.96-1.04)	235	0.98 (0.92-1.04)	211	0.95 (0.88-1.01)	789	1.03 ** (1.00-1.07)	812	1.02 (0.99-1.05)	789	1.02 (0.99-1.05)
Maternal height	Centimetre	233	0.99 (0.93 - 1.04)	233	1.03 (0.99-1.07)	210	0.93 ** (0.87-0.99)	789	0.98 (0.95-1.00)	812	1.00 (0.97-1.03)	789	0.96 ** (0.94-0.99)
GA at first prenatal visit	Weeks of pregnancy	211	1.03 (0.95-1.10)	232	0.93 *** (0.88-0.98)	208	1.12 *** (1.03-1.20)	789	0.93 * (0.86-1.01)	812	0.96 (0.89-1.04)	789	0.97 (0.90-1.04)
Duration between first prenatal visit and delivery	Weeks of pregnancy	208	0.95 (0.88-1.02)	232	0.90 *** (0.86-0.95)	208	0.97 (0.90-1.04)	789	0.72 *** (0.67-0.77)	812	0.62 *** (0.57-0.67)	789	0.99 (0.95-1.05)
Maternal weight at first prenatal visit	Kilogram	213	0.91 ** (0.85-0.98)	224	0.96 * (0.92-1.00)	205	0.97 (0.91-1.04)	789	0.98 ** (0.97-1.00)	812	0.99 (0.99-1.01)	789	0.98 *** (0.96-0.99)
Maternal weight at delivery	Kilogram	220	0.89 *** (0.83-0.96)	229	0.97 (0.93-1.01)	210	0.96 (0.90-1.02)	788	0.97 *** (0.96-0.98)	812	0.99 * (0.98-1.00)	789	0.97 *** (0.95-0.98)
Gestational weight gain per week	Kilogram per week	207	0.89 (0.47-1.68)	226	0.97 (0.66-1.44)	207	0.95 (0.51-1.77)	789	0.13 *** (0.04-0.38)	812	0.37 ** (0.15-0.90)	789	0.48 * (0.22-1.05)
Smoking	Yes	215	2.02 (0.53-7.73)	229	3.36 ** (1.15-9.83)	205	0.59 (0.07-4.74)	788	1.05 (0.55-2.01)	811	1.14 (0.59-2.18)	788	1.25 (0.69-2.26)
Alcohol use	Yes	198	0.72 (0.27-1.95)	208	0.56 * (0.29-1.08)	190	0.49 (0.16-1.55)	660	1.41 (0.78-2.57)	681	1.10 (0.58-2.08)	660	1.48 (0.84-2.59)
Morbidity score	No morbidity	235	Ref	235	Ref	211	Ref	789	Ref	812	Ref	789	Ref
	Morbidity or co-morbidity		0.37 ** (0.15-0.93)		1.70 (0.76-3.79)		0.52 (0.19-1.42)		0.90 (0.61-1.33)		0.89 (0.60-1.31)		1.01 (0.70-1.47)

Supplementary table 2: Adjusted multivariable logistic regression analyses of SES factors and LBW, PTB and SGA in the Democratic Republic of Congo and South Africa.

		LBW				PTB				SGA			
		The DRC		SA		The DRC		SA		The DRC		SA	
		Model 1, n=218	Model 2, n=174	Model 1, n=680	Model 2, n=646	Model 1, n=231	Model 2, n=185	Model 1, n=646	Model 2, n=646	Model 1, n=208	Model 2, n=173	Model 1, n=680	Model 2, n=646
		OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
SES factors													
Maternal education	None +Primary	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	**Ref**	Ref	Ref
	Secondary + tertiary	1.07 (0.43-2.66)	0.56 (0.14-2.24)	1.33 (0.29-5.98)	1.05 (0.11-9.98)	1.56 (0.85-2.88)	1.25 (0.59-2.66)	1.36 (0.30-6.18)	1.36 (0.29-6.48)	0.36 (0.13-1.05)	**0.14 *** (0.26-0.80)**	1.56 (0.35-7.05)	1.31 (0.28-6.19)
Maternal marital status	Unmarried	Ref	**Ref**	Ref	Ref	Ref	**Ref**	Ref	Ref	Ref	Ref	Ref	Ref
	Married	0.34 (0.08-1.38)	**0.17 ** (0.03-1.03)**	0.74 (0.48-1.14)	0.67 (0.35-1.28)	0.31 (0.09-1.04)	**0.21 ** (0.05-0.94)**	0.78 (0.51-1.21)	0.94 (0.61-1.44)	1.30 (0.15-10.93)	0.56 (0.48-6.46)	0.87 (0.58-1.31)	0.95 (0.62-1.47)
Type of house walls	Non- durable materials	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Durable materials	1.08 (0.38-3.03)	1.51 (0.35-6.48)	0.92 (0.51-1.68)	1.60 (0.59-4.34)	1.02 (0.49-2.11)	0.84 (0.36-1.97)	0.61 (0.35-1.05)	1.10 (0.59-2.05)	1.74 (0.58-5.15)	4.85 (0.95-2.65)	1.23 (0.67-2.26)	1.14 (0.61-2.13)
Maternal and newborns characteristics													
Child sex	Male	Ref	Ref	Ref	Ref	**Ref**	Ref	Ref	Ref	Ref	Ref	**Ref**	**Ref**
	Female	0.64 (0.22-1.83)	0.33 (0.07-1.58)	1.18 (0.79-1.77)	1.81 (0.98-3.37)	**2.04 ** (1.10-3.78)**	2.07 (0.97-4.43)	0.85 (0.56-1.28)	1.55 ** (1.04-2.33)	0.33 (0.09-1.19)	0.36 (0.06-1.97)	**1.51 ** (1.03-2.23)**	**1.55 ** (1.04-2.32)**
Parity	Number of deliveries		0.98 (0.73-1.33)		1.05 (0.81-1.37)		1.12 (0.92-1.37)		0.84 ** (0.70-1.00)		1.16 (0.85-1.58)		**0.83 *** (0.69-0.99)**
Type of delivery	C-section		Ref		Ref		Ref		Ref		Ref		Ref
	vaginal		1.00 (.021-4.85)		0.86 (0.45-1.63)		1.20 (0.41-3.57)		0.85 (0.56-1.29)		1.82 (0.30-11.18)		0.83 (0.55-1.27)
Maternal age at delivery	Years		0.96 (0.85-1.07)		1.04 (0.98-1.11)		0.96 (0.89-1.03)		**1.04 ** (1.00-1.08)**		0.92 (0.82-1.04)		**1.04 ** (1.00-1.08)**
Maternal height	Centimetre		0.99 (0.92-1.09)		0.95 * (0.91-1.00)		1.04 * (0.99-1.09)		**0.96 ** (0.93-0.99)**		0.90 * (0.81-1.00)		**0.96 *** (0.92-0.99)**
GA at the first prenatal visit	Weeks of pregnancy		0.93 (0.79-1.09)		**0.27 ** (0.20-0.36)**		**0.93 ** (0.87-0.99)**		0.91 (0.83-1.01)		**1.14 ** (1.03-1.26)**		**0.87 ** (0.77-0.99)**
Gestational weight gain per week	Kilogram per week		0.87 (0.74-1.02)		**0.33 ** (0.26-0.41)**		1.12 (0.70-1.80)		0.52 (0.24-1.15)		0.66 (0.30-1.44)		0.87 ** (0.77-0.99)
Alcohol use	Yes		0.66 (0.14-3.02)		1.17 (0.43-3.16)		**0.40 *** (0.18-0.89)**		1.58 (0.87-2.85)		0.39 (0.08-1.90)		1.61 (0.90-2.91)
Morbidity score	No morbidity		**Ref**		Ref		Ref		Ref		Ref		Ref
	Morbidity or co-morbidity		**0.19 ** (0.05-0.73)**		0.64 (0.33-1.24)		2.05 (0.73-5.75)		0.92 (0.60-1.41)		0.67 (0.13-3.44)		0.93 (0.61-1.42)

Supplementary table 3: Bivariate logistic regression analyses of household and maternal SES factors and birth outcomes (LBW, PTB and SGA) in the pooled dataset from the Democratic Republic of Congo and South Africa

		LBW			PTB			SGA		
		N	OR (95% CI)	P	N	OR (95% CI)	P	n	OR (95% CI)	P
SES factors										
Maternal education	None +Primary	1003	Ref	0.11	1040	Ref	**0.01**	993	Ref	0.24
	Secondary + tertiary		1.55 (0.88 - 2.74)			0.58 ** (0.39 - 0.87)			1.36 (0.81 - 2.27)	
Maternal marital status	Unmarried (Single/widowed/divorced)	1003	Ref	**0.01**	1039	Ref	0.12	992	Ref	**0.02**
	Married		0.64 ** (0.45 - 0.91)			1.28 (0.93 - 1.74)			0.67 ** (0.48 - 0.93)	
Type of house walls	Non- durable materials	894	Ref	0.31	927	Ref	**<0.01**	883	Ref	**0.02**
	Durable materials		1.24 (0.81- 1.91)			0.46 *** (0.33 - 0.65)			1.69 ** (1.09 - 2.61)	
Newborn and maternal characteristics										
Child sex	Male	1005	Ref	0.16	1041	Ref	0.76	994	Ref	**0.04**
	Female		1.28 (0.91- 1.80)			0.95 (0.70 - 1.30)			1.41 ** (1.01 - 1.95)	
Parity	Number of deliveries	992	1.05 (0.95 - 1.14)	0.34	1030	1.17 *** (1.08 - 1.26)	**<0.01**	984	0.89 ** (0.80 - 0.98)	**0.02**
Type of delivery	C-section	1002	Ref	0.13	1035	Ref	**<0.01**	992	Ref	0.23
	vaginal		1.33 (0.92 - 1.95)			2.16 *** (1.50 - 3.11)			0.81 (0.58 - 1.14)	
Maternal age at delivery	Years	1005	1.03 * (0.99 - 1.05)	0.06	1041	0.99 (0.97 - 1.02)	0.88	994	1.01 (0.99 - 1.04)	0.35
Maternal Height	Centimetre	1004	0.98 ** (0.95 - 1.00)	**0.05**	1039	1.02 * (0.99 - 1.04)	0.07	993	0.96 *** (0.93 - 0.98)	**<0.01**
GA at first prenatal visit	Weeks of pregnancy	994	0.96 (0.92 - 1.01)	0.14	1038	1.01 (0.97 - 1.05)	0.59	991	0.99 (0.95 - 1.03)	0.67
Duration between first prenatal visit and delivery	Weeks of pregnancy	991	0.91 *** (0.88 - 0.94)	**<0.01**	1038	0.81 *** (0.78 - 0.84)	**<0.01**	991	1.03 * (0.99 - 1.07)	0.09
Maternal weight at first prenatal visit	Kilogram	996	0.99 * (0.98 - 1.00)	0.07	1030	0.98 *** (0.97 - 0.99)	**<0.01**	988	0.98 *** (0.97 - 0.99)	**<0.01**
Maternal weight at delivery	Kilogram	1002	0.98 *** (0.97 - 0.99)	**<0.01**	1034	0.98 *** (0.96 - 0.99)	**<0.01**	992	0.98 *** (0.97 - 0.99)	**<0.01**
Gestational weight gain per week	Kilogram per week	990	0.19 ** (0.05 - 0.80)	**0.02**	1032	0.48 (0.15 - 1.47)	0.17	990	0.56 (0.18 - 1.72)	0.31
Smoking	Yes	997	1.15 (0.63 - 2.10)	0.65	1034	1.39 (0.82 - 2.36)	0.22	987	1.14 (0.64 - 2.02)	0.66
Alcohol use	Yes	852	0.75 (0.44 - 1.30)	0.31	883	0.99 (0.62 6 1.54)		844	0.86 (0.52 - 1.43)	0.56
Morbidity score	No morbidity	1005	Ref	0.14	1041	Ref	0.30	994	Ref	0.41
	Morbidity or co-morbidity		0.76 (0.52 - 1.09)			1.20 (0.85 - 1.70)			0.86 (0.61 - 1.22)	
Country										
	The DRC	1005	Ref	**0.05**	1041	Ref	**<0.01**	994	Ref	**<0.01**

SA	1.55 ** (0.98 - 2.45)	0.37 *** (0.26 - 0.52)	2.02 *** (1.26 - 3.22)

Appendix 11: the DRC socioeconomic questionnaire (in French).

4. Chaque mois

c. Avez-vous a utilisé un mode de contraception dans votre couple avant la grossesse ?
   i. Non
   ii. Oui
      1. Si oui, lequel? …….
d. Quel comportement adoptez-vous immédiatement après accouchement ?
   i. Separation d'avec le conjoint
   ii. Pas de separation avec le conjoint
e. Quand reprenez-vous les rapports sexuels avant et après accouchement ?
   i. Immédiatement avant l'accouchement
   ii. 1 semaine après accouchement
   iii. 1 mois après l'accouchement
   iv. 6 mois après accouchement
   v. 1 an après accouchement
   vi. Sans réponse

5. FACTEURS EDUCATIONNELS (2)

a. Quel est votre niveau d'études ?
   i. Aucun
   ii. Primaire
   iii. Post primaire
   iv. Secondaire
   v. Universitaire
   vi. Post universitaire

b. Quel est le niveau d'instruction au niveau familial ?

		H	F	Total (H+F)
1	Nombre total d'enfants			
2	Nombre d'enfants scolarisés			
3	Nombre d'enfants déjà mariés			

v. Autres

i. Si Chrétienne, cochez le domaine de culte de l'enquetée :

☐ Pentecôtiste (église de reveil)	☐ Protestant (Mishoni)	☐ Branhamiste
☐ Baba	☐ Néo apostolique	☐ Sankusar
☐ Kimbanguiste	☐ Témoins de Jéhovah	☐ Catholique
☐ Orthodoxe	☐ Malemba	☐ Autres

j. Tout en cochant le type de repas, quel est le nombre de repas journalier habituel dans le foyer de l'enquêtée ? ☐
   i. Petit Déjeuner
   ii. Déjeuner
   iii. Diner
   iv. Souper
   v. Autres

k. Quel est le type de mariage dans lequel vit l'enquetée ?
   i. Monogamique
   ii. Polygamique

l. Si polygamique, combien de co épouses au total ? ☐

m. Cochez l'état civil de l'enquêtée ?

1 Celibataire	☐	3 Divorcée	☐
2 Mariée	☐	4 Veuve	☐

n. Quel est votre type d'habitation actuelle?
   i. Non durable (Case, chaume)
   ii. Semi durable (Brique a dobes)
   iii. Durable
   iv. Autres

4. STYLE ET MODE DE VIE DE L'ENQUETEE (5)

a. Avez-vous fumé la cigarette depuis un an ?
   i. Oui
   ii. Non
   iii. Réservé

b. Avez-vous consommé de l'alcool depuis un mois ?
   i. Réservé
   ii. Non
   iii. Oui
      1. Si oui, quelle est le rythme de consommation ?
         a. Occasionnellement
         b. Régulièrement
            i. Si régulièrement, quelle est le rythme de consommation ?
               1. Chaque jour
               2. Une fois les trois jours
               3. Chaque semaine

☐ 3	☐ 8	☐ 13	☐ 18
☐ 4	☐ 9	☐ 14	☐ 19
☐ 5	☐ 10	☐ 15	☐ Autres

b. Qui est le tuteur de votre famille ?
   i. L'enquêtée elle même
   ii. L'époux
   iii. Autres

c. Quel est la principale profession du tuteur ?

☐ Sans emploi	☐ Commerçant
☐ Cultivateur	☐ Agent de santé
☐ Enseignant	☐ Fonctionnaire
☐ Marchant ambulant (Bayanda)	☐ Autre

d. Cochez la(les) langue (s)parlée (s) par l'enquêtée.

☐ Français	☐ Swahili
☐ Anglais	☐ Kikongo
☐ Tshiluba	☐ Autres
☐ Lingala	

e. Quelle est la langue maternelle de l'enquêtée (la plus parlée) ?

☐ Français	☐ Swahili
☐ Anglais	☐ Kikongo
☐ Tshiluba	☐ Autres
☐ Lingala	

f. Quel est la position sociale qu'occupe l'enquêtée ?
   i. Employé
   ii. Employeur
   iii. Libéral
   iv. Autres

g. Quel est le secteur d'activité de l'emploi de l'enquêtée?
   i. Privé
   ii. Etat
   iii. Confessionnel
   iv. Liberal
   v. Autres

h. Quel est la religion pratiquée par l'enquêtée?
   i. Chrétienne
   ii. Musulmane
   iii. Athée
   iv. Animiste

QUESTIONNAIRE D ENQUETE

Ce questionnaire est adressé aux femmes accouchées dans les maternités. Cette enquête permet de ressortir le style et mode de vie, les conditions socioéconomiques des enquêtés, culturelles et médicales en rapport aussi avec les services de santé offerts en vue d'une amélioration de la qualité. Vous êtes remercié d'avance pour votre acceptation à répondre à ce questionnaire. La confidentialité et la discrétion des données vous sont garanties. Merci de vous prêter à ce questionnaire d'enquête.

1. **IDENTITE DE L ENQUETEE (8Q)**
   a. Nom et Prénom :……
   b. Age (annee) ☐ Poids (Kg) ☐ Taille (Cm) ☐
   c. Date de naissance (YY/MM/DD) : ☐☐☐
   d. Formule obstétricale : PGAD ☐☐☐☐
   e. Adresse de résidence de l'enquêtée (province, Commune/Territoire): ☐☐☐
   f. Lieu (commune/territoire) et date d'enquête :……
   g. Nom de l'Enquêteur :……
   h. Date et heure de l'interrogatoire :……
2. **SYSTEME SANITAIRE (3Q)**
   a. Cochez le type de Structure des soins ou a lieu l'enquête :
      i. Hôpital universitaire
      ii. Hôpital provincial
      iii. Hôpital général
      iv. Centre de santé
      v. Poste de santé :
   b. Nom de la Structure des soins :……
   c. Choisissez la distance, le temps et moyen de locomotion entre le domicile et centre des soins :

Distances (en Km)	**Temps**	**Locomotion**
☐ 0	☐ 0	☐ Pieds
☐ 5	☐ 1h	☐ Vélos
☐ 5 a 10	☐ 2h	☐ Moto
☐ 10 a 15	☐ 12h	☐ Véhicule
☐ 15 a 30	☐ 24h	☐ Autres
☐ Plus de 30	☐ 48h	
☐ Autres	☐ Autres	

3. **SITUATION SOCIO ECONOMIQUE ET CULTURELLE DE L'ENQUETEE (14Q):**
   a. Quelle est la taille de votre ménage ? *(En termes de nombre de personnes)*

☐ 1	☐ 6	☐ 11	☐ 16
☐ 2	☐ 7	☐ 12	☐ 17

v. Autres

i. Si Chrétienne, cochez le domaine de culte de l'enquetée :

☐ Pentecôtiste (église de reveil)	☐ Protestant (Mishoni)	☐ Branhamiste
☐ Baba	☐ Néo apostolique	☐ Sankusar
☐ Kimbanguiste	☐ Témoins de Jéhovah	☐ Catholique
☐ Orthodoxe	☐ Malemba	☐ Autres

j. Tout en cochant le type de repas, quel est le nombre de repas journalier habituel dans le foyer de l'enquêtée ? ☐
   i. Petit Déjeuner
   ii. Déjeuner
   iii. Diner
   iv. Souper
   v. Autres

k. Quel est le type de mariage dans lequel vit l'enquetée ?
   i. Monogamique
   ii. Polygamique

l. Si polygamique, combien de co épouses au total ? ☐

m. Cochez l'état civil de l'enquêtée ?

1 Celibataire	☐	3 Divorcée	☐
2 Mariée	☐	4 Veuve	☐

n. Quel est votre type d'habitation actuelle?
   i. Non durable (Case, chaume)
   ii. Semi durable (Brique a dobes)
   iii. Durable
   iv. Autres

4. STYLE ET MODE DE VIE DE L'ENQUETEE (5)

a. Avez-vous fumé la cigarette depuis un an ?
   i. Oui
   ii. Non
   iii. Réservé

b. Avez-vous consommé de l'alcool depuis un mois ?
   i. Réservé
   ii. Non
   iii. Oui
      1. Si oui, quelle est le rythme de consommation ?
         a. Occasionnellement
         b. Régulièrement
            i. Si régulièrement, quelle est le rythme de consommation ?
               1. Chaque jour
               2. Une fois les trois jours
               3. Chaque semaine

☐ 3	☐ 8	☐ 13	☐ 18
☐ 4	☐ 9	☐ 14	☐ 19
☐ 5	☐ 10	☐ 15	☐ Autres

b. Qui est le tuteur de votre famille ?
   i. L'enquêtée elle même
   ii. L'époux
   iii. Autres

c. Quel est la principale profession du tuteur ?

☐ Sans emploi	☐ Commerçant
☐ Cultivateur	☐ Agent de santé
☐ Enseignant	☐ Fonctionnaire
☐ Marchant ambulant (Bayanda)	☐ Autre

d. Cochez la(les) langue (s)parlée (s) par l'enquêtée.

☐ Français	☐ Swahili
☐ Anglais	☐ Kikongo
☐ Tshiluba	☐ Autres
☐ Lingala	

e. Quelle est la langue maternelle de l'enquêtée (la plus parlée) ?

☐ Français	☐ Swahili
☐ Anglais	☐ Kikongo
☐ Tshiluba	☐ Autres
☐ Lingala	

f. Quel est la position sociale qu'occupe l'enquêtée ?
   i. Employé
   ii. Employeur
   iii. Libéral
   iv. Autres

g. Quel est le secteur d'activité de l'emploi de l'enquêtée?
   i. Privé
   ii. Etat
   iii. Confessionnel
   iv. Liberal
   v. Autres

h. Quel est la religion pratiquée par l'enquêtée?
   i. Chrétienne
   ii. Musulmane
   iii. Athée
   iv. Animiste

QUESTIONNAIRE D ENQUETE

Ce questionnaire est adressé aux femmes accouchées dans les maternités. Cette enquête permet de ressortir le style et mode de vie, les conditions socioéconomiques des enquêtés, culturelles et médicales en rapport aussi avec les services de santé offerts en vue d'une amélioration de la qualité. Vous êtes remercié d'avance pour votre acceptation à répondre à ce questionnaire. La confidentialité et la discrétion des données vous sont garanties. Merci de vous prêter à ce questionnaire d'enquête.

1. **IDENTITE DE L ENQUETEE (8Q)**
   a. Nom et Prénom :……
   b. Age (annee) ☐ Poids (Kg) ☐ Taille (Cm) ☐
   c. Date de naissance (YY/MM/DD) : ☐☐☐
   d. Formule obstétricale : PGAD ☐☐☐☐
   e. Adresse de résidence de l'enquêtée (province, Commune/Territoire): ☐☐☐
   f. Lieu (commune/territoire) et date d'enquête :……
   g. Nom de l'Enquêteur :……
   h. Date et heure de l'interrogatoire :……
2. **SYSTEME SANITAIRE (3Q)**
   a. Cochez le type de Structure des soins ou a lieu l'enquête :
      i. Hôpital universitaire
      ii. Hôpital provincial
      iii. Hôpital général
      iv. Centre de santé
      v. Poste de santé :
   b. Nom de la Structure des soins :……
   c. Choisissez la distance, le temps et moyen de locomotion entre le domicile et centre des soins :

Distances (en Km)	**Temps**	**Locomotion**
☐ 0	☐ 0	☐ Pieds
☐ 5	☐ 1h	☐ Vélos
☐ 5 a 10	☐ 2h	☐ Moto
☐ 10 a 15	☐ 12h	☐ Véhicule
☐ 15 a 30	☐ 24h	☐ Autres
☐ Plus de 30	☐ 48h	
☐ Autres	☐ Autres	

3. **SITUATION SOCIO ECONOMIQUE ET CULTURELLE DE L'ENQUETEE (14Q):**
   a. Quelle est la taille de votre ménage ? *(En termes de nombre de personnes)*

☐ 1	☐ 6	☐ 11	☐ 16
☐ 2	☐ 7	☐ 12	☐ 17

1. Si oui, quelle est le rythme de consommation ?

    1. Occasionnellement
    2. Régulièrement
        1. Si régulièrement, quelle est le rythme de consommation ?
            1. Chaque jour
            2. Une fois les trois jours
            3. Chaque semaine
            4. Chaque mois

2. Avez-vous a utilisé un mode de contraception dans votre couple avant la grossesse ?
    1. Non
    2. Oui
        1. Si oui, lequel? …….
3. Quel comportement adoptez-vous immédiatement après accouchement ?
    1. Separation d'avec le conjoint
    2. Pas de separation avec le conjoint
4. Quand reprenez-vous les rapports sexuels avant et après accouchement ?
    1. Immédiatement avant l'accouchement
    2. 1 semaine après accouchement
    3. 1 mois après l'accouchemen
    4. 6 mois après accouchement
    5. 1 an après accouchement
    6. Sans réponse

2. FACTEURS EDUCATIONNELS (2)

1. Quel est votre niveau d'études ?
    1. Aucun
    2. Primaire
    3. Post primaire
    4. Secondaire
    5. Universitaire
    6. Post universitaire
2. Quel est le niveau d'instruction au niveau familial ?

		H	**F**	**Total (H+F)**
1	Nombre total d'enfants			
2	Nombre d'enfants scolarisés			
3	Nombre d'enfants déjà mariés			

La partie suivante concerne la situation sanitaire des enquêtées. Pour réponse, elle s'adresse au dossier individuel des patients ou parfois l'interview.

3. FACTEURS MEDICAUX ET SANITAIRES DE L'ENQUETE (15Q)

1. L'enquêtée connait elle son groupe sanguin ?
   1. Sans reponse
   2. Non
   3. Oui
      1. Si oui, cochez le groupe sanguin de l'accouchée ?

☐	**A**	☐	**AB**	☐	**Rhésus positif**
☐	**B**	☐	**O**	☐	**Rhésus négatif**

2. L'enquêtée a t elle présenté une maladie ou situation ci-dessous au cours de la grossesse ?

		Oui	Non			Oui	Non
1	Paludisme			6	Tuberculose		
2	HTA			7	VIH		
3	Diabète			8	Ecoulement purulent		
4	Hémorragie génitale			9	Prurit génital		
5	Violence sexuelle			10	Anémie		

3. La sérologie VIH de l'enquêtée a-t-elle été réalisé ?
   1. Pendant la grossesse
   2. Avant la grossesse
      1. Si pendant la grossesse, à quel trimestre de la grossesse ?
         1. Premier trimestre
         2. Deuxieme trimestre
         3. Troisieme trimestre
4. L'enquêtée connait elle son status sérologique VIH ?
   1. Oui
   2. Non
5. Quel est l'état sérologique VIH de l'enquêtée ?
   1. Négatif
   2. Positif
      1. Si positif, l'enquêtée a partagé les résultats sérologiques avec qui ?
         1. Personne
         2. Le conjoint
         3. Les enfants
         4. La famille de l'enquetée
         5. La famille du conjoint
6. L'enquêtée est-elle sous régime d'anti retro viraux ?
   1. Non
   2. Oui
      1. Si oui, depuis quand l'enquêtée est sous régime d'antirétroviraux ?
         1. Premier trimestre
         2. Deuxième trimestre

3. Troisième trimestre
4. Avant la grossesse

7. Quel est l'âge de la grossesse au moment de l'accouchement (en semaines d'aménorrhée) ? ☐
8. Quel a été l'âge de la grossesse lors de la première Consultation Pré Natale (en semaine d'aménorrhée)?
9. Combien de consultation pré natale la femme a-t-elle suivi jusqu'à terme et combien des mois de suivi au total?

Nombre de CPN suivies au cours de la grossesse	
Nombre des mois depuis la première CPN à l'accouchement	

10. Quel est le poids du dernier enfant à la naissance (en gr) ? ☐
11. Quelle est l'évolution du poids de l'enquêtée depuis la première consultation prénatale ?

		Poids (Kg)
1	Poids de l'enquêtée à la première consultation	
2	Poids de l'enquêtée à l'accouchement	

12. Quel est le mode d'accouchement ?
    1. Césarienne
    2. Voie basse
    3. Laparotomie (si grossesse abdominale)
13. Quel est le poids de l'enfant à la naissance (en gr)? ☐
14. Quel situation le nouveau-né a-t-il présenté lors de l'accouchement ?
    1. Nouveau né normal
    2. Prématurité
    3. Détresse respiratoire
    4. Infection néonatale
    5. Anémie
    6. Mort né
15. Si mère avec sérologie positive. Quel régime antirétroviral l'enfant a-t-il connu à la naissance ?

Monothérapie ARV ☐

Trithérapie ARV ☐

Appendix 12: Screening questionnaire

Yes		If Yes, continue to next question.

8.4 Which of these best describes your living conditions: (use flipchart to help indentify type of housing)

Criteria for informal versus formal dwellings	YES	NO
Informal: Make-shift dwelling not erected according to architectural plans with land tenure that is illegal, not officially sanctioned or documented		
Formal: Dwelling erected according to architectural plans with land tenure that is legal, officially sanctioned or documented.		

If the participant has gone through all the questions so far, it means that she and her baby are eligible for the study. You can now proceed with the Information and Consent.

9. Did the participant consent to be part of the study?

No		If No, thank her for her time and move on to the next person.
Yes		If Yes, continue to next section.

10. Complete the contact sheet

Complete		When complete, continue to next section.

11. Book her for her first home visit in 1 Week.

Booking Date:	

When booked, thank her for her time and move on to the next person.

If ≥4000g (above or equal)		Thank her for her time and move on.

7. Has your baby been hospitalised or diagnosed for any disorder at birth? (extract from Maternal Case Records)

1. Hospitalised	YES	NO	11. Gastro-intestinal		
2. Head	YES	NO	12. Bladder/Kidneys	YES	NO
3. Brain	YES	NO	13. Limbs	YES	NO
4. Face	YES	NO	14. Lungs	YES	NO
5. Ear	YES	NO	15. Genitalia	YES	NO
6. Nose	YES	NO	16. Skin	YES	NO
7. Throat	YES	NO	17. Down's Syndrome	YES	NO
8. Neck	YES	NO	18. Foetal Distress	YES	NO
9. Spine	YES	NO	19. Jaundice	YES	NO
10. Heart	YES	NO	20. Other	YES	NO
If Other, Specify:					

If Yes to ANY, thank her for her time and move on.
If No to ALL, continue to next question.

8. Formal / Informal Dwelling:

8.1 Do you live in Soweto?

No		If No, thank her for her time and move on to the next person.
Yes		If Yes, continue to next question.

8.2 In which neighbourhood in Soweto do you live?

_____

8.3 Are you planning on leaving Soweto in the next 12 months?

No		If No, thank her for her time and move on to the next person.

1. Do you verbally consent to us asking you some questions for possible enrolment in a research study?

No		If No, thank her for her time and move on to the next person.
Yes		If Yes, continue to next question.

2. Are you older than 18 years of age?

No		If No, thank her for her time and move on to the next person.
Yes		If Yes, continue to next question.

3. What is your HIV status? (extract from Maternal Case Records)

HIV +		If +, thank her for her time and move on to the next person.
HIV -		If -, continue to next question.

4. Was this a singleton pregnancy?

No		If No, thank her for her time and move on to the next person.
Yes		If Yes, continue to next question.

5. What was your baby's gestational age?__ __ weeks (extract from Maternal Case Records)

If <38 weeks (below)		Thank her for her time and move on to the next person.
If ≥38 weeks (above or equal)		Continue to next question.
If ≥42 weeks (above or equal)		Thank her for her time and move on to the next person.

6. What was your baby's birthweight? _ _ _ _ g (extract from Maternal Case Records)

If <2500g (below)		Thank her for her time and move on.
If ≥2500g (above or equal)		continue to next question.

DPHRU
MRC/Wits Developmental Pathways for Health Research Unit

SQ

University of the Witwatersrand, Johannesburg
Developmental Pathways for Health Research Unit
Department of Paediatrics and Child Health

Soweto Baby WASH Study
Screening Questionnaire (SQ)

Screening ID:	SSBW				

Any other enrolment or ID:	No		Yes		Specify,

Researcher Name:			Researcher Signature:						
Researcher Code:			Date:	D	D	M	M	Y	Y

For Office Use:						
Eligible:	Yes		No		Comment:	
Enrolled:	Yes		No			
SBWID: (Mother)	SBW					
SBWID: (Infant)	SBW					

Project: Soweto Baby WASH Study
Version: V1.5
Date: June 2017

Appendix 13: Maternal anthropometry questionnaire

MA

University of the Witwatersrand, Johannesburg
Developmental Pathways for Health Research Unit
Department of Paediatrics and Child Health

Soweto Baby WASH Study
Maternal Anthropometry (MA)

SBWID: (Mother)	**SBW**					
SBWID: (Infant)	**SBW**					

Timepoint:			**Month**
Visit Location:	Home	DPHRU	Other:
If other, specify:			

Any other enrolment or ID:	**No**		**Yes**		**Specify,**

Researcher Name:				**Researcher Signature:**						
Researcher Code:			**Date:**	D	D	M	M	Y	Y	

Project: Soweto Baby WASH Study
Version: V1.3
Date: April 2017

Maternal Height 1: (Once)				.		**cm**
Maternal Height 2: (Once)				.		**cm**

Maternal Weight 1: (Monthly)				.		**kg**
Maternal Weight 2: (Monthly)				.		**kg**

Maternal Bicep Skinfolds 1: (1, 3, 6, 9 & 12 Months)				**mm**
Maternal Bicep Skinfolds 1: (1, 3, 6, 9 & 12 Months)				**mm**
Maternal Bicep Skinfolds 1: (1, 3, 6, 9 & 12 Months)				**mm**

Maternal Tricep Skinfolds 1: (1, 3, 6, 9 & 12 Months)				**mm**
Maternal Tricep Skinfolds 1: (1, 3, 6, 9 & 12 Months)				**mm**
Maternal Tricep Skinfolds 1: (1, 3, 6, 9 & 12 Months)				**mm**

Maternal Subscapular Skinfolds 1: (1, 3, 6, 9 & 12 Months)				**mm**
Maternal Subscapular Skinfolds 1: (1, 3, 6, 9 & 12 Months)				**mm**
Maternal Subscapular Skinfolds 1: (1, 3, 6, 9 & 12 Months)				**mm**

Comments:

Appendix 14: Infant anthropometry

Infant Weight 1: (Every Visit)					g
Infant Weight 2: (Every Visit)					g

Infant Length 1: (Every Visit)					mm
Infant Length 2: (Every Visit)					mm
Infant Length 3: (Every Visit)					mm

Infant Temperature 1: (Every Visit)			•		° C
Infant Temperature 2: (Every Visit)			•		° C

Mid-Upper Arm Circumference 1: (Every Visit)				mm
Mid-Upper Arm Circumference 2: (Every Visit)				mm
Mid-Upper Arm Circumference 3: (Every Visit)				mm

Head Circumference 1: (Every Visit)				mm
Head Circumference 2: (Every Visit)				mm
Head Circumference 3: (Every Visit)				mm

Infant Road to Health Card: (Every Visit)	YES		NO	

Infection Diary: (Every Visit)	YES		NO	

Infant Bicep Skinfolds 1: (Monthly)				mm
Infant Bicep Skinfolds 2: (Monthly)				mm
Infant Bicep Skinfolds 3: (Monthly)				mm

IA

University of the Witwatersrand, Johannesburg
Developmental Pathways for Health Research Unit
Department of Paediatrics and Child Health

Soweto Baby WASH Study
Infant Anthropometry (IA)

SBWID: (Mother)	**SBW**					
SBWID: (Infant)	**SBW**					

Timepoint:			**Month**
Visit Location:	Home	DPHRU	Other:
If other, specify:			

Any other enrolment or ID:	**No**		**Yes**		**Specify,**

Researcher Name:			**Researcher Signature:**						
Researcher Code:			**Date:**	D	D	M	M	Y	Y

Project: Soweto Baby WASH Study
Version: V1.3
Date: April 2017

Infant Tricep Skinfolds 1: (Monthly)				**mm**
Infant Tricep Skinfolds 2: (Monthly)				**mm**
Infant Tricep Skinfolds 3: (Monthly)				**mm**

Infant Subscapular Skinfolds 1: (Monthly)				**mm**
Infant Subscapular Skinfolds 2: (Monthly)				**mm**
Infant Subscapular Skinfolds 3: (Monthly)				**mm**

Infant DXA: (12 Months)	**YES**		**NO**	

Comments:

Appendix 15: WASH questionnaire

week					
32. How do you heat the water to wash yourself and your baby? Please tick only one response					
Electric Geyser		Boil on Stove, gas or Fire		Use cold water	
Other, specify:					
33. What do you use to wash yourself and your baby? Please tick only one response for you and one response for your baby					
	Mother	Baby		Mother	Baby
Only water			Water and Soap		
Water and Ash			Other, specify:		

SECTION D: Researcher Obervations and General						
34. Where does the baby sleep?						
35. Where does baby spend the majority of its time?						
36. Who looks after the baby most of the time?						
37a. Are there animals in the house?						
37b. Are there kennels/kraal(separate area) for domestic animals and livestock?						
38. General Cleanliness of House	Good		Average		Poor	
Comments:						
39. General Cleanliness of Toilet	Good		Average		Poor	
Comments:						
40. General Cleanliness of Kitchen	Good		Average		Poor	

Project: Soweto Baby WASH Study
Version: V1.4
Date: June 2017

Other, specify:							
25. Do you have problems with any of the following in your house? Multiple responses possible, please tick appropriate answer(s)							
Damp/mold		Cockroaches		Flies		Rodents	
Bed lice		Other, specify:					
26. Do you have any animals on the property? Multiple responses possible, please tick appropriate answer(s)							
Domestic:							
Cats		Dogs		Other, specify:			
Livestock:							
Chickens		Goats		Other, specify:			
Sheep		Cattle					
Personal Hygiene: Handwashing and Ablutions							
27. When do you wash your hands? Multiple responses possible, please tick appropriate answer(s)							
Before and after eating		When hands are dirty		After using toilet			
Before preparing food		Before and after feeding		After changing diaper			
Never/Rarely		Other, specify					
28. Since our last visit, has your baby ingested any stones or soil?							
Yes		No		Don't Know			
29. What do you wash your hands with?							
Only water		Soap and Water		Water and ash			
Other, specify:							
30. How do you wash yourself and your baby? Please tick only one response for you and one response for your baby							
	Mother	Baby		Mother	Baby		
Sink			Shower				
Bath			Basin				
Other							
Specify:							
31. How often do you wash yourself and your baby? Please tick only one response for you and one response for your baby							
	Mother	Baby		Mother	Baby		
Everyday			3-4 Times per Week				
1-2 Times per			Other, specify:				

SECTION C: Hygiene					
Waste Disposal					
18. How is waste stored prior to disposal? Please tick only one response					
Plastic Bags		'Black' bins		Bucket	
Other, specify:					
19. Where is waste stored prior to disposal? Please tick only one response					
Inside the house		Outside the house		Off the property	
Other, specify:					
20. How is waste disposed of? Please tick only one response					
Around or outside the house		Bush/Open plot		Waste pit	
Municipal removal		Burning		Dumping	
Other, specify:					
21. How often is waste disposed of? Multiple responses possible, please tick appropriate answer(s)					
Weekly		Fortnightly		Monthly	
22. How are diapers and infant feces disposed of? Please tick only one response					
Put/Rinsed into Toilet/Latrine		Put/Rinsed into Drain/Ditch		Buried	
Throw into Garbage		Left in the Open		Child used Latrine/Toilet	
Other, specify:					
Personal Hygiene: Household					
23. How often do you clean the house? Please tick only one response					
Everyday		3-4 times per week		1-2 times per week	
Other, specify:					
24. What do you use to clean your house? (detergent)					
Only Water		Multi-purpose Cleaner (Handy Andy)		Bleach (Jik)	

Stand/Settle			

SECTION B: Sanitation					
15. Type of Toilet facilities available Multiple responses possible, please tick appropriate answer(s) Coding: Absolute number of points					
	Household	Communal		Household	Communal
Flush/Pour to piped Sewer System			Ventilated Improved pit latrine		
Flush/Pour to Septic Tank			Pit Latrine with Slab		
Flush/Pour to Pit Latrine			Pit Latrine without Slab (Open Pit)		
Flush/Pour to Elsewhere			Composting Toilet		
Bucket			No facilities (bush or Field)		
Portable Toilet			Other Specify:		
If Portable Toilet, how often are the facilities serviced per week?					
16. If applicable, how many households share the communal toilet facilities?					
17. How often do you have interruptions to your sanitation supply? Please tick only one response					

Daily		Never		Once a Week		Once a Month	

Sink					
Bath					
Shower					
Tub/Bucket					
Toilet					
8. How often do you have interruptions to your water supply? Please tick only one response					
Daily			Rarely/Never		
Once a Week			Don't know		
Once a Month					
9. Do you have enough water for all your needs? Please tick only one response					
Yes			No		
10. Who is your water service provider? Please tick only one response					
Johannesburg Water			Other, specify:		
Private			Don't know		
11. Do you pay for water? Please tick only one response					
Yes		No		Don't know	
12. If yes, who pays? Please tick only one response					
Participant			Home Owner		
Partner			Other, specify:		
13. How much do you spend on average a month for water Please tick only one response					
R0 - R100		R100 - R200		R200 - R300	
R300 - R400		> R400		Don't know	
14. What methods do you use to treat your water? Multiple responses possible, please tick appropriate answer(s)					
None		Add Bleach/Chlorine		Boiling	
Strain it through a cloth		Use a water filter		Solar Disinfection	
Let it		Other,specify:			

SECTION A: Water Supply (Quantity and Quality)							
1. What are the most common (within past 2 weeks) sources of water you have access to and what do you use the water for? Multiple responses possible, please report all appropriate answer(s) Coding: 1 = Yes 0 = No							
	Drinking	Domestic	Cooking		Drinking	Domestic	Cooking
Bottled Water				Public Tap			
Piped into dwelling				Tanker/Cart with small tank			
Piped into yard/plot				Unprotected dug well			
Protected dug well				Surface water			
Rainwater				Unprotected spring			
Protected spring				Borehole			
Other Specify:							

2. How long does it take to go there, get water and come back?			
Water on Premises		Number of Minutes	

3. Who usually goes to collect water for the household?			
Adult Man		Adult Woman	
Male Child (under 15 years)		Female Child (under 15 years)	

4. If water is collected outside the house, what do you use to transport water?							
Bucket		Pot		Bottle		Tub/Basin	
Water Can		Other, Specify					

5. If water is collected outside the house, what do you use to store water?							
Bucket		Pot		Bottle		Tub/Basin	
Water Can		Other, Specify					

6. If water is collected outside the house, how do you take water out of where it stored?							
Cup		Ladle		Bowl			
Tap		Pour		Other, specify			

7. What type of infrastructure do you have access to? incl. Number of points and location of infrastructure Multiple responses possible, please tick appropriate answer(s) Coding: Absolute number of points				
	Wash Room	Kitchen	Communal	Other, specify:
Taps				

Project: Soweto Baby WASH Study
Version: V1.4
Date: June 2017

WASH (LF)

University of the Witwatersrand, Johannesburg
Developmental Pathways for Health Research Unit
Department of Paediatrics and Child Health

Soweto Baby WASH Study
WASH(LF)

SBWID: (Mother)	**SBW**					
SBWID: (Infant)	**SBW**					

Timepoint:			**Month**
Visit Location:	Home	DPHRU	Other:
If other, specify:			

Any other enrolment or ID:	**No**		**Yes**		**Specify,**

Researcher Name:			**Researcher Signature:**						
Researcher Code:			**Date:**	D	D	M	M	Y	Y

Comments:

_____

_____

_____

Project: Soweto Baby WASH Study
Version: V1.4
Date: June 2017

Comments:						
41. General Cleanliness of Baby Area	Good		Average		Poor	
Comments:						
Adapted from UNICEF/Palestinian Hydrology Group (Gaza) & USAID/Mercy Corps (North Kivu -DRC) & DPHRU SES and IA Questionnaires. Core Questions on Drinking-Water and Sanitation for Household Surveys. WHO and UNICEF. 2006.						

Criteria for Researcher Observations	
No dirt/grease/stains	1 - 2 Criteria met (Poor) 3 - 4 Criteria met (Average) 5 - 6 Criteria met (Good)
Furniture, fixtures and surfaces are without dust or grease	
No foul Smell	
Floors are clean and dry	
Waste is separated and stored separately	
Absence of pests (flies, cockroaches, etc)	

Appendix 16: BWP questionnaire

MODULE 4: INFANT SLEEPING, FEEDING AT NIGHT AND MATERNITY LEAVE

We are going to talk about how ***(NAME)*** sleeps at night.

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
22	Does the ***(NAME)*** sleep with you?	Yes _____ 1 No _____ 0	**Ask 23**
23	Are you aware how many times ***(NAME)*** wakes up?	Yes _____ 1 No _____ 0	**Ask 24**
24	Are you being woken-up by ***(NAME)***?	Yes _____ 1 No _____ 0	**Ask 25**
25	Is ***(NAME)*** breastfeeding when he/she wakes?	Yes _____ 1 No _____ 0	**Ask 26**
26	Do you have a job? (by job we mean any activity that you may do on a regular basis and for which you earn money)	Yes _____ 1 No _____ 0	**If response is No, End here the Breastfeeding and weaning practices questionnaire** **Ask 27 if response is Yes**
27	Are you currently working?	Yes _____ 1 No _____ 0	**Ask 28**
28	Are or were you on maternity leave?	Yes _____ 1 No _____ 0	**Ask 29**
29	When are you planning to go back to work?	_ _ / _ _ / _ _ _ _ DD MM YYYY	**End here the Breastfeeding and weaning practices questionnaire**

N0.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
	Circle the response given.	Other _____ 3 Other, specify _____	
J	**How much water do you put in the mix?** *Ask her to show you in the bottle. Report the volume. Circle whether the unit is liter (l) milliliters (ml), cups etc..*	|___|___|___|___|___| **litre(s)/ milliliter(s)/ cups**	**Ask K**
K	**How much powder/concentrated formula do you put in the mix?** *If liquid or concentrated formula ask her to show you with the bottle Circle whether the unit is scoops, liter (l) milliliters (ml), cups etc...*	|___|___|___|___|___| **scoops/ cups/ litre(s)/ milliliter(s)/**	**Please look at response B** **IF the respondent use powder, Ask L** **IF the respondent use concentrated formula, Ask M**
L	**Are the scoops usually:** *Only one possible response Circle the response given*	Rounded (heaped) _____ 1 Flat (leveled) _____ 2 Other _____ 3 Other, specify _____	**Ask M**
M	**Do you add anything else in the formula milk?**	Yes _____ 1 No _____ 0	**IF YES, Ask N** **IF NO, Ask P**
N	**Please describe what is (are) the ingredient(s) you add to the formula.** *Multiple responses possible*	_____ _____ _____	**Ask O**
O	**How many times a day do you add this (these) ingredient(s) to the formula?**	Every time _____ 000 *OR* Number of times _____ |___|___| *OR* Every number of feeds _____ |___|___|	**Ask P**
P	**Before preparing food for *(NAME)*, do you wash your hands?**	Yes _____ 1 No _____ 0	**IF YES, Ask Q** **IF NO, Go to Module 4: INFANT SLEEPING AND FEEDING PRACTICES AT NIGHT**
Q	**How do you usually clean the utensils used for feeding *(NAME)*?** *Including bottles, cups, spoons etc...*	With cold water _____ 1 With cold water and soap _____ 2 With boiled water _____ 3 With boiled water and soap _____ 4 With sterilization solution _____ 5 Other _____ 6 Other, specify _____	**Go to Module 4: INFANT SLEEPING AND FEEDING PRACTICES AT NIGHT**

MODULE 3: INFANT FORMULA

21. We are going to talk about the preparation of ***(NAME)*** formula. **Please show me the container of the formula you currently use to feed *(NAME)*.**

N0.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
A	***Report the brand of the formula you are currently using*** *Brand is the name on package, report that name.*	_____	**Go to B**
B	***Circle in which form is the formula***	Liquid – ready to use? _____ 1 Powder form? _____ 2 Concentrated form? _____ 3 Other _____ 4 Other specify _____	**IF *Liquid, Powder form, Concentrated form* , Go to C** **IF *Other*, Ask M**
C	***Report the size of the container*** *Report the number written in the container.* *Circle whether it is grams (g), kilograms (kg), litre (l), millilitres (ml).*	|___|___|___|___| **gram(s)/ kilogram(s)/ litre(s)/ milliliter(s)**	**Ask D**
D	**For how long does the formula container last?** *Write the number.* *Circle whether it is day(s), week(s) or month(s).*	|___|___| **Day(s) /Week(s) /Month(s)**	**Ask E**
E	**Do you <u>mainly</u> feed *(NAME)* with:** *Only one possible response* *Circle the response given*	Bottle ..... 1 Cup ..... 2 Spoon 3	**IF *Bottle* Ask F** **IF ELSE and the infant has formula in liquid form, Ask M** **IF ELSE and the infant has formula in powder or concentrated form, Ask H**
F	**How many bottles do you own?** *Ask to see the bottles*	|___|___| bottles	**Ask G**
G	**What is the size of the bottle that you <u>MAINLY</u> use CURRENTLY?** *Ask to see the bottle mainly used* *Report the maximum volume of the bottle used in ml.*	|___|___|___| ml	**Please look at response B** **IF the infant has *Liquid formula,* Ask M** **IF the infant has *Powder or Concentrated formula* Ask H**
H	**In which order do you usually incorporate the formula and the water?**	Water then formula _____ 1 Formula then water _____ 2	**Ask I**
I	**What type of water do you <u>mainly</u> use?** *Only one possible response.*	Tap water <u>not</u> boiled _____ 1 Tap water boiled _____ 2 Mineral water (bottled water) <u>not</u> boiled _____ 3 Mineral water (bottled water) boiled _____ 4	**Ask J**

N0.	FOOD ITEMS	YESTERDAY QUESTIONS AND CATEGORIES				PAST 7 DAYS QUESTIONS AND CATEGORIES
		18 I would like to ask you about some solid or semi-solid foods that *(NAME)* may had yesterday during the day or at night.			19 How many times yesterday during the day or at night did *(NAME)* consume any (*ITEM FROM LIST*)? *Record '99' for Don't Know.*	20 During the past 7 days, did *(NAME)* consume any (*READ ONLY ITEMS THAT WERE NOT EATEN YESTERDAY*)?
		YES	NO	DK		
O	honey, jam, marmalade, condensed milk added to tea…)	1	0	99	|___|___| TIMES	No _____ 0 Don't know _____ 99
P	Crisps, savoury snacks	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
Q	Condiments for flavor, such as chilies, spices, herbs, salt, pepper or fish powder	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
R	Insects (Mopani worms, termites, locust, grasshopper…)	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
S	Others items cited: _____	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
T	_____	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99

If the mother reported that she gave infant formula, go to Module 3: INFANT FORMULA
If the mother did not give infant formula, go Module 4: INFANT SLEEPING AND FEEDING PRACTICES AT NIGHT

I would like to ask you about some solid or semi-solid foods that ***(NAME)*** may have had in the last 7 days during the day or at night.

N0.	FOOD ITEMS	YESTERDAY QUESTIONS AND CATEGORIES				PAST 7 DAYS QUESTIONS AND CATEGORIES
		18 I would like to ask you about some solid or semi-solid foods that ***(NAME)*** may had yesterday during the day or at night.			19 How many times yesterday during the day or at night did ***(NAME)*** consume any (***ITEM FROM LIST***)? *Record '99' for Don't Know.*	20 During the past 7 days, did ***(NAME)*** consume any (***READ ONLY ITEMS THAT WERE NOT EATEN YESTERDAY***)?
		YES	NO	DK		
A	Porridge, bread, rice, noodles, or other foods made from grains	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
B	Pumpkin, carrots, Herbert squash, or sweet potatoes that are yellow or orange inside	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
C	Potatoes or sweet potatoes, white yams, cassava, or any other roots that is white	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
D	Any dark green leafy vegetables (spinach, cabbage, broccoli, maroggo…)	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
E	Ripe mangoes, ripe papayas, pineapples, peach (or other local vitamin A-rich fruits)	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
F	Any other fruits or vegetables (bananas, apples, avocado, grape fruit, grape, cucumbers, red tomato, garlic, lettuce light green, baby marrows…)	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
G	Liver, kidney, heart, or other organ meats	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
H	Any meat, such as beef, pork, lamb, goat,	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
I	Eggs	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
J	Poultry (chicken, duck etc..)	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
K	Fresh or dried fish, shellfish, tin fish or seafood	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
L	Any foods made from beans, peas, lentils, nuts, or seeds	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
M	Cheese, yogurt, or other milk products	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
N	Any oil, fats, or butter, or foods made with any of these (margarine/Rama, peanut butter, fish oil, ghee, mayonnaise, sour cream, avocado, olive, coconut…)	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
	High-sugar foods (Biscuits, cakes, candies, chocolates,					Yes _____ 1

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MODULE 2. INFANT FEEDING: 24 HOURS AND 7 DAYS DIETARY RECALL

I would like to ask you about some liquids that ***(NAME)*** may have had in the last 7 days during the day or at night.

N0.	FOOD ITEMS	YESTERDAY QUESTIONS AND CATEGORIES				PAST 7 DAYS QUESTIONS AND CATEGORIES
		15 Yesterday, Did *(NAME)* have any (*ITEM FROM LIST*)?			16 Yesterday, how many times during the day or at night did *(NAME)* consume any (*ITEM FROM LIST*)? *Record '99' for Don't Know.*	17 During the past 7 days, did *(NAME)* consume any *Read **only** item that were not eaten yesterday?*
		YES	NO	DK		
A	Breast milk (own, when applicable)?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
B	Breast milk (other women)?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
C	Plain water (tap water, mineral/bottled water)?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
D	Water with sugar	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
E	ORS (Oral Rehydration Solution)? Like the Sorol etc..	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
F	Infant formula or Soya milk such as Nan, Infacare, Isomil or any other formula milk…?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
G	Infant cereals such as Nestum, Purity, Cerelac…?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
H	Fruit or vegetable juice?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
I	Clear broth (clear salty soup)?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
J	Cow's milk (including powdered milk for adults, liquid milk from shops, fresh milk from cows, long life milk)?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
K	Yogurt (Danone…)?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
L	Thin porridge (Mabele, Ace, Iwisa, Impala…)?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
M	Cold drinks or squash (coke, crème-soda, OROS…)	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
N	Any other water-based liquids such as tea/coffee without milk, traditional herbal drinks, roiboos tea…? Specify _____ _____	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
O	Any other liquids Specify _____ _____	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99

N0.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
		No _____ 3	
9	**How do you clean the breast or nipples?**		Ask 10
10	**Is *(NAME)* fed by** *Food includes breast milk, formula milk, solid food…*	Demand? _____ 1 Schedule? _____ 2	Ask 11
11	**Is *(NAME)* following any special diet?** *Do not read the list* *Multiple responses possible*	Vegetarian _____ 1 Gluten-free _____ 2 Low-lactose _____ 3 Low-phenylalanine _____ 4 Other _____ 5 Other, specify _____ None _____ 6 Don't know _____ 99	Ask 12
12	**Where is most of *(NAME)*'s food prepared?**	No preparation – breastfeeding _____ 1 At home _____ 2 Family/friend _____ 3 Restaurant _____ 4 Shop _____ 5 Crèche _____ 6 Don't know _____ 99	Ask 13
13	**In the last 7 days, were you with *(NAME)*?**	Yes _____ 1 No _____ 0	Ask 14
14	**Yesterday, were you with *(NAME)*?**	Yes _____ 1 No _____ 0	Go to Module 2

MODULE I. GENERAL

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
1	**Do you receive support or advice on how to feed (*NAME*)?** *Food includes anything that the infant eat.*	Yes _____ 1 No _____ 0	If YES, Ask 2 If NO, Ask 3
2	**Who mainly give you support or advice on how to feed *(NAME)*?** *One possible response.* *Food includes anything that the infant eat.*	My spouse/boyfriend _____ 1 My mother, mother-in-law, grandmother _____ 2 My sister or my husband's sister _____ 3 My friend/neighbor _____ 4 Doctor _____ 5 Health workers (other than a doctor) at the Health Centre_____ 6 Community Health Workers _____ 7 Other _____ 8 Other, specify_____ Do not know _____99	Ask 3
3	**Since our last visit, did you ever give *(NAME)* breastmilk, whether it is your own or from another women?**	Yes _____ 1 No _____ 0	If YES, Ask 4 If NO, Ask 8
4	**Are you still giving breastmilk to *(NAME)*?**	Yes _____ 1 No _____ 0	If YES, Ask 7 If NO, Ask 5
5	**How old was *(NAME)* when you stopped giving breast milk?**	|___|___| day(s) |___|___| week(s) |___|___| month(s)	Ask 6
6	**What was the main reason for stopping to give (NAME) your own breast milk?** *Only one response*	Mother ill/Weak _____ 1 Child ill/Weak _____ 2 Nipple/Breast Problem _____ 3 Insufficient Milk_____ 4 Milk not good _____ 5 Mother Working/at School (Or Planning to) _____ 6 Child Refused _____ 7 Worried About HIV and AIDS _____ 8 Chose to formula feed _____ 9 Doctor/health provider's Advice _____ 10 Advice of Family Member/Friend _____ 11 Other _____ 12 Other, specify_____ Do not know/Do not remember _____ 99	Ask 8
7	**In the last 7 days, how did you give breastmilk to (NAME)?** *Multiple responses possible.*	Breast (your own) _____ 1 Breast (from another women) _____ 2 Spoon _____ 3 Cup _____ 4 Bottle _____ 5 Other _____ 6 Other, specify _____ Don't know _____ 99	Ask 8
8	**Do you clean your breast or nipples before feeding *(NAME)*?**	Yes, always _____ 1 Yes, sometimes _____ 2	Ask 9 if the response is Yes Ask 10 if the response in No

Project: Soweto Baby Wash Study, BWP2, Version: V1.0, Date: June2017

DPHRU
MRC/Wits Developmental Pathways for Health Research Unit

BWP2

University of the Witwatersrand, Johannesburg
Developmental Pathways for Health Research Unit
Department of Paediatrics and Child Health

Soweto Baby WASH Study

BREASTFEEDING AND WEANING PRACTICES QUESTIONNAIRE VISIT 2 TO 12 MONTHS OLD

SBWID: (Mother)	**SBW**					
SBWID: (Infant)	**SBW**					

Timepoint:			**Month**
Visit Location:	Home	DPHRU	Other:
If other, specify:			

Any other enrolment or ID:	**No**		**Yes**		**Specify,**

Researcher Name:			**Researcher Signature:**							
Researcher Code:			**Date:**	D	D	M	M	Y	Y	

Comments:

_____
_____

_____
_____

_____
_____

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
	Circle the response given.	Other _____ 3 Other, specify _____	
J	**How much water do you put in the mix?** *Ask her to show you in the bottle. Report the volume. Circle whether the unit is liter (l) milliliters (ml), cups etc..*	|___|___|___|___| **litre(s)/ milliliter(s)/ cups**	**Ask K**
K	**How much powder/concentrated formula do you put in the mix?** *If liquid or concentrated formula ask her to show you with the bottle Circle whether the unit is scoops, liter (l) milliliters (ml), cups etc...*	|___|___|___|___| **scoops/ cups/ litre(s)/ milliliter(s)/**	**Please look at response B** **IF the respondent use powder, Ask L** **IF the respondent use concentrated formula, Ask M**
L	**Are the scoops usually:** *Only one possible response Circle the response given*	Rounded (heaped) _____ 1 Flat (leveled) _____ 2 Other _____ 3 Other, specify _____	**Ask M**
M	**Do you add anything else in the formula milk?**	Yes _____ 1 No _____ 0	**IF YES, Ask N** **IF NO, Ask P**
N	**Please describe what is (are) the ingredient(s) you add to the formula.** *Multiple responses possible*	_____ _____ _____	**Ask O**
O	**How many times <u>a day</u> do you add this (these) ingredient(s) to the formula?**	Every time _____ 000 *OR* Number of times _____ |___|___| *OR* Every number of feeds _____ |___|___|	**Ask P**
P	**Before preparing food for *(NAME)*, do you wash your hands?**	Yes _____ 1 No _____ 0	**IF YES, Ask Q** **IF NO, Go to Module 4: INFANT SLEEPING AND FEEDING PRACTICES AT NIGHT**
Q	**How do you usually clean the utensils used for feeding *(NAME)*?** *Including bottles, cups, spoons etc...*	With cold water _____ 1 With cold water and soap _____ 2 With boiled water _____ 3 With boiled water and soap _____ 4 With sterilization solution _____ 5 Other _____ 6 Other, specify _____	**Go to Module 4: INFANT SLEEPING AND FEEDING PRACTICES AT NIGHT**

MODULE 3: INFANT FORMULA

21. We are going to talk about the preparation of ***(NAME)*** formula. **Please show me the container of the formula you currently use to feed *(NAME)*.**

N0.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
A	***Report the brand of the formula you are currently using*** *Brand is the name on package, report that name.*	_____	**Go to B**
B	***Circle in which form is the formula***	Liquid – ready to use? _____ 1 Powder form? _____ 2 Concentrated form? _____ 3 Other _____ 4 Other specify _____	**IF *Liquid, Powder form, Concentrated form* , Go to C** **IF *Other*, Ask M**
C	***Report the size of the container*** *Report the number written in the container.* *Circle whether it is grams (g), kilograms (kg), litre (l), millilitres (ml).*	|___|___|___|___| **gram(s)/ kilogram(s)/ litre(s)/ milliliter(s)**	**Ask D**
D	**For how long does the formula container last?** *Write the number.* *Circle whether it is day(s), week(s) or month(s).*	|___|___| **Day(s) /Week(s) /Month(s)**	**Ask E**
E	**Do you <u>mainly</u> feed *(NAME)* with:** *Only one possible response* *Circle the response given*	Bottle ..... 1 Cup ..... 2 Spoon 3	**IF *Bottle* Ask F** **IF ELSE and the infant has formula in liquid form, Ask M** **IF ELSE and the infant has formula in powder or concentrated form, Ask H**
F	**How many bottles do you own?** *Ask to see the bottles*	|___|___| bottles	**Ask G**
G	**What is the size of the bottle that you <u>MAINLY</u> use CURRENTLY?** *Ask to see the bottle mainly used* *Report the maximum volume of the bottle used in ml.*	|___|___|___| ml	**Please look at response B** **IF the infant has *Liquid formula,* Ask M** **IF the infant has *Powder or Concentrated formula* Ask H**
H	**In which order do you usually incorporate the formula and the water?**	Water then formula _____ 1 Formula then water _____ 2	**Ask I**
I	**What type of water do you <u>mainly</u> use?** *Only one possible response.*	Tap water <u>not</u> boiled _____ 1 Tap water boiled _____ 2 Mineral water (bottled water) <u>not</u> boiled _____ 3 Mineral water (bottled water) boiled _____ 4	**Ask J**

N0.	FOOD ITEMS	YESTERDAY QUESTIONS AND CATEGORIES				PAST 7 DAYS QUESTIONS AND CATEGORIES
		18 I would like to ask you about some solid or semi-solid foods that *(NAME)* may had yesterday during the day or at night.			19 How many times yesterday during the day or at night did *(NAME)* consume any (*ITEM FROM LIST*)? *Record '99' for Don't Know.*	20 During the past 7 days, did *(NAME)* consume any (*READ ONLY ITEMS THAT WERE NOT EATEN YESTERDAY*)?
		YES	NO	DK		
O	honey, jam, marmalade, condensed milk added to tea…)	1	0	99	|___|___| TIMES	No _____ 0 Don't know _____ 99
P	Crisps, savoury snacks	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
Q	Condiments for flavor, such as chilies, spices, herbs, salt, pepper or fish powder	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
R	Insects (Mopani worms, termites, locust, grasshopper…)	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
S	Others items cited: _____	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
T	_____	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99

If the mother reported that she gave infant formula, go to Module 3: INFANT FORMULA
If the mother did not give infant formula, go Module 4: INFANT SLEEPING AND FEEDING PRACTICES AT NIGHT

I would like to ask you about some solid or semi-solid foods that ***(NAME)*** may have had in the last 7 days during the day or at night.

N0.	FOOD ITEMS	YESTERDAY QUESTIONS AND CATEGORIES				PAST 7 DAYS QUESTIONS AND CATEGORIES
		18 I would like to ask you about some solid or semi-solid foods that ***(NAME)*** may had yesterday during the day or at night.			19 How many times yesterday during the day or at night did ***(NAME)*** consume any (***ITEM FROM LIST***)? *Record '99' for Don't Know.*	20 During the past 7 days, did ***(NAME)*** consume any (***READ ONLY ITEMS THAT WERE NOT EATEN YESTERDAY***)?
		YES	NO	DK		
A	Porridge, bread, rice, noodles, or other foods made from grains	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
B	Pumpkin, carrots, Herbert squash, or sweet potatoes that are yellow or orange inside	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
C	Potatoes or sweet potatoes, white yams, cassava, or any other roots that is white	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
D	Any dark green leafy vegetables (spinach, cabbage, broccoli, maroggo…)	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
E	Ripe mangoes, ripe papayas, pineapples, peach (or other local vitamin A-rich fruits)	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
F	Any other fruits or vegetables (bananas, apples, avocado, grape fruit, grape, cucumbers, red tomato, garlic, lettuce light green, baby marrows…)	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
G	Liver, kidney, heart, or other organ meats	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
H	Any meat, such as beef, pork, lamb, goat,	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
I	Eggs	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
J	Poultry (chicken, duck etc..)	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
K	Fresh or dried fish, shellfish, tin fish or seafood	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
L	Any foods made from beans, peas, lentils, nuts, or seeds	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
M	Cheese, yogurt, or other milk products	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
N	Any oil, fats, or butter, or foods made with any of these (margarine/Rama, peanut butter, fish oil, ghee, mayonnaise, sour cream, avocado, olive, coconut…)	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
	High-sugar foods (Biscuits, cakes, candies, chocolates,					Yes _____ 1

MODULE 2. INFANT FEEDING: 24 HOURS AND 7 DAYS DIETARY RECALL

I would like to ask you about some liquids that ***(NAME)*** may have had in the last 7 days during the day or at night.

N0.	FOOD ITEMS	YESTERDAY QUESTIONS AND CATEGORIES				PAST 7 DAYS QUESTIONS AND CATEGORIES
		15 Yesterday, Did ***(NAME)*** have any (***ITEM FROM LIST***)?			16 Yesterday, how many times during the day or at night did ***(NAME)*** consume any (***ITEM FROM LIST***)? *Record '99' for Don't Know.*	17 During the past 7 days, did ***(NAME)*** consume any *Read **only** item that were not eaten yesterday?*
		YES	NO	DK		
A	Breast milk (own, when applicable)?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
B	Breast milk (other women)?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
C	Plain water (tap water, mineral/bottled water)?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
D	Water with sugar	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
E	ORS (Oral Rehydration Solution)? Like the Sorol etc..	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
F	Infant formula or Soya milk such as Nan, Infacare, Isomil or any other formula milk…?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
G	Infant cereals such as Nestum, Purity, Cerelac…?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
H	Fruit or vegetable juice?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
I	Clear broth (clear salty soup)?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
J	Cow's milk (including powdered milk for adults, liquid milk from shops, fresh milk from cows, long life milk)?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
K	Yogurt (Danone…)?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
L	Thin porridge (Mabele, Ace, Iwisa, Impala…)?	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
M	Cold drinks or squash (coke, crème-soda, OROS…)	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
N	Any other water-based liquids such as tea/coffee without milk, traditional herbal drinks, roiboos tea…? Specify _____	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99
O	Any other liquids Specify _____	1	0	99	|___|___| TIMES	Yes _____ 1 No _____ 0 Don't know _____ 99

N0.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
		No _____ 3	
9	**How do you clean the breast or nipples?**		Ask 10
10	**Is *(NAME)* fed by** *Food includes breast milk, formula milk, solid food…*	Demand? _____ 1 Schedule? _____ 2	Ask 11
11	**Is *(NAME)* following any special diet?** *Do not read the list* *Multiple responses possible*	Vegetarian _____ 1 Gluten-free _____ 2 Low-lactose _____ 3 Low-phenylalanine _____ 4 Other _____ 5 Other, specify _____ None _____ 6 Don't know _____ 99	Ask 12
12	**Where is most of *(NAME)*'s food prepared?**	No preparation – breastfeeding _____ 1 At home _____ 2 Family/friend _____ 3 Restaurant _____ 4 Shop _____ 5 Crèche _____ 6 Don't know _____ 99	Ask 13
13	**In the last 7 days, were you with *(NAME)*?**	Yes _____ 1 No _____ 0	Ask 14
14	**Yesterday, were you with *(NAME)*?**	Yes _____ 1 No _____ 0	Go to Module 2

MODULE I. GENERAL

N0.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
1	**Do you receive support or advice on how to feed (*NAME*)?** *Food includes anything that the infant eat.*	Yes _____ 1 No _____ 0	If YES, Ask 2 If NO, Ask 3
2	**Who mainly give you support or advice on how to feed *(NAME)*?** *One possible response.* *Food includes anything that the infant eat.*	My spouse/boyfriend _____ 1 My mother, mother-in-law, grandmother _____ 2 My sister or my husband's sister _____ 3 My friend/neighbor _____ 4 Doctor _____ 5 Health workers (other than a doctor) at the Health Centre_____ 6 Community Health Workers _____ 7 Other _____ 8 Other, specify_____ Do not know _____99	Ask 3
3	**Since our last visit, did you ever give *(NAME)* breastmilk, whether it is your own or from another women?**	Yes _____ 1 No _____ 0	If YES, Ask 4 If NO, Ask 8
4	**Are you still giving breastmilk to *(NAME)*?**	Yes _____ 1 No _____ 0	If YES, Ask 7 If NO, Ask 5
5	**How old was *(NAME)* when you stopped giving breast milk?**	|___|___| day(s) |___|___| week(s) |___|___| month(s)	Ask 6
6	**What was the main reason for stopping to give (NAME) your own breast milk?** *Only one response*	Mother ill/Weak _____ 1 Child ill/Weak _____ 2 Nipple/Breast Problem _____ 3 Insufficient Milk_____ 4 Milk not good _____ 5 Mother Working/at School (Or Planning to) _____ 6 Child Refused _____ 7 Worried About HIV and AIDS _____ 8 Chose to formula feed _____ 9 Doctor/health provider's Advice _____ 10 Advice of Family Member/Friend _____ 11 Other _____ 12 Other, specify_____ Do not know/Do not remember _____ 99	Ask 8
7	**In the last 7 days, how did you give breastmilk to (NAME)?** *Multiple responses possible.*	Breast (your own) _____ 1 Breast (from another women) _____ 2 Spoon _____ 3 Cup _____ 4 Bottle _____ 5 Other _____ 6 Other, specify _____ Don't know _____ 99	Ask 8
8	**Do you clean your breast or nipples before feeding *(NAME)*?**	Yes, always _____ 1 Yes, sometimes _____ 2	Ask 9 if the response is Yes Ask 10 if the response in No

DPHRU
MRC/Wits Developmental Pathways for Health Research Unit

BWP2

University of the Witwatersrand, Johannesburg
Developmental Pathways for Health Research Unit
Department of Paediatrics and Child Health

Soweto Baby WASH Study

BREASTFEEDING AND WEANING PRACTICES QUESTIONNAIRE VISIT 2 TO 12 MONTHS OLD

SBWID: (Mother)	**SBW**					
SBWID: (Infant)	**SBW**					

Timepoint:			**Month**
Visit Location:	Home	DPHRU	Other:
If other, specify:			

Any other enrolment or ID:	**No**		**Yes**		**Specify,**

Researcher Name:				**Researcher Signature:**							
Researcher Code:			**Date:**	D	D	M	M	Y	Y		

Comments:

_____
_____

_____
_____

_____
_____

MODULE 4: INFANT SLEEPING, FEEDING AT NIGHT AND MATERNITY LEAVE

We are going to talk about how ***(NAME)*** sleeps at night.

N0.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
22	Does the ***(NAME)*** sleep with you?	Yes _____ 1 No _____ 0	**Ask 23**
23	Are you aware how many times ***(NAME)*** wakes up?	Yes _____ 1 No _____ 0	**Ask 24**
24	Are you being woken-up by ***(NAME)***?	Yes _____ 1 No _____ 0	**Ask 25**
25	Is ***(NAME)*** breastfeeding when he/she wakes?	Yes _____ 1 No _____ 0	**Ask 26**
26	Do you have a job? (by job we mean any activity that you may do on a regular basis and for which you earn money)	Yes _____ 1 No _____ 0	**If response is No, End here the Breastfeeding and weaning practices questionnaire** **Ask 27 if response is Yes**
27	Are you currently working?	Yes _____ 1 No _____ 0	**Ask 28**
28	Are or were you on maternity leave?	Yes _____ 1 No _____ 0	**Ask 29**
29	When are you planning to go back to work?	__/__/____ DD MM YYYY	**End here the Breastfeeding and weaning practices questionnaire**

Appendix 17: Agreement of co-authors

Declaration: Student's contribution to article(s) and agreement of co-author(s)

I, **Christian Bwangandu Ngandu, student number 1297539**, declare that this Thesis is my own work and that I contributed adequately towards research findings published in the article(s) stated below which are included in my Thesis.

Signature of Student ... . **Date** 18/04/2020.....

Name of Primary Supervisor: Dr Rihlat Said-Mohamed

Signature of Primary Supervisor..... **Date** 19/03/2020

Agreement by co-authors: By signing this declaration, the co-authors listed below agree to the use of the article(s) by the student as part of his Thesis. In cases where the student is not the 1st author of a published article, the primary supervisor must explain (under comments) why the student is entitled to use the paper for his/her degree purposes.

Article 1: Title: The association between household socioeconomic status, maternal socio-demographic characteristics and adverse birth and infant growth outcomes in sub-Saharan Africa: a systematic review.
Journal name, year: Journal of developmental origins of health and disease, 2019. Published article.

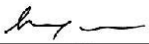
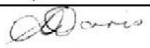
Authors	Name	Signature	Date
1st author	Christian Bwangandu Ngandu		18/04/2020
2nd author	Douglas Momberg		18/04/2020
3rd author	Ansuyah Magan		17/04/2020
4th author	Lumbwe Chola		09/03/2020
5th author	Shane Anthony Norris		19/03/2020
6th author	Rihlat Said-Mohamed		19/03/2020

Article 2: Association between household and maternal socioeconomic factors with birth outcomes in the Democratic Republic of Congo and South Africa: a comparative study.

Journal name, year: Maternal and child health journal, 2020. In review.

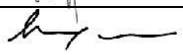
Authors	Name	Signature	Date
1st author	Christian Bwangandu Ngandu		18/04/2020
2nd author	Douglas Momberg		18/04/2020

1

3rd author	Ansuyah Magan		17/04/2020
4th author	Shane Anthony Norris		19/03/2020
5th author	Rihlat Said-Mohamed		19/03/2020

Article 3: Association between maternal demographic characteristics and household socioeconomic factors and infant growth in South Africa: the Soweto Baby WASH study.

Journal name, year: Health and place, 2020. In review.

Authors	Name	Signature	Date
1st author	Christian Bwangandu Ngandu		18/04/2020
2nd author	Innocent Maposa		19/03/2020
3rd author	Douglas Momberg		18/04/2020
4th author	Ansuyah Magan		17/04/2020
5th author	Shane Anthony Norris		19/03/2020
6th author	Rihlat Said-Mohamed		19/03/2020

Comments by primary supervisor/editor:

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Appendix 18: Certificate of Turn it turn

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ORIGINALITY REPORT

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SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

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Appendix 19: Declaration of plagiarism

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

FACULTY OF HEALTH SCIENCES

PLAGIARISM DECLARATION TO BE SIGNED BY ALL HIGHER DEGREE STUDENTS

SENATE PLAGIARISM POLICY: APPENDIX ONE

I Christian Bwanpandy Nganda (Student number: 1297529) am a student registered for the degree of PhD in the academic year 2017

I hereby declare the following:

- I am aware that plagiarism (the use of someone else's work without their permission and/or without acknowledging the original source) is wrong.
- I confirm that the work submitted for assessment for the above degree is my own unaided work except where I have explicitly indicated otherwise.
- I have followed the required conventions in referencing the thoughts and ideas of others.
- I understand that the University of the Witwatersrand may take disciplinary action against me if there is a belief that this is not my own unaided work or that I have failed to acknowledge the source of the ideas or words in my writing.
- I have included as an appendix a report from "Turnitin" (or other approved plagiarism detection) software indicating the level of plagiarism in my research document.

Signature: _____ Date: 18 April 2020

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